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"INTERNATIONAL CONFERENCE ON CURRENT CHALLENGES IN CONSERVATION OF BIODIVERSITY"

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PREAMBLE

The term 'Conservation' came into use in the late 19^{th} century and referred to as an ethic of resources used by humanity for its allocation and protection. The primary aim is to maintain the health of the natural world, its fisheries, habitats, and biological diversity. The two terms 'conservation' and 'preservation' are closely related with a degree of protection. Conservation is generally associated with the protection of natural resources, while preservation is associated with the protection of buildings, objects, and landscapes. Hence, it is perfectly phrased as "*conservation seeks the proper use of nature, while preservation seeks protection of nature from use*". Although the natural resources are fulfilling human needs by providing food, shelter, clothing and energy, human activities, particularly the greedy attitude of man, are the major reasons for the loss of natural resources. At present, the researches indicate that the survival of living organisms are affected by various threats which are associated with one or more aspects of *HIPPO dilemma* which include Habitat loss, Introduced species, Pollution, Population growth, and Over exploitation. To meet these perspectives, therefore, it is decided to have an "International Conference on Current Challenges in Conservation of Biodiversity [In4CB-2017] on 16-18 February, 2017.

The biodiversity is one of the most valuable natural resources which fulfill the human need in variety of ways. The estimated total number of species on Earth is 6.5 million species on land and 2.2 million species (about 25 percent of the total) dwelling in the ocean depths. Furthermore, a study indicates that 86% of all species on land and 91% of those in the seas are yet to be discovered, described and catalogued. The aquatic ecosystems are holding a huge junk of both biological and non-biological natural resources. The slight change due to anthropogenic or natural pressures in the aquatic ecosystems would remove considerable amount of natural resources from the system. After having done intensive research on different aspects of various living organisms, researchers feel that there are several threats which bring conservation issues of living organisms into limelight. For examples there are several expressions about the animal conservation such as 'Hug a Slug - Save a Snail', 'Born captive, Die Freely', etc.,

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We express our gratitude to Chairman, Secretary and members of the college management for their splendid support for organizing this conference. We extend our wholehearted thanks to the Chairperson, Secretary, and authorities of National Biodiversity Authority (NBA), Chennai, for their support and encouragements. We wish to thank the NBA for financial assistance and support. We wish to extend our gratitude to DST- SERB (Department of Science and Technology- Science and Engineering Research Board), New Delhi and TNSCST (Tamil Nadu State Council for Science and Technology), Chennai for the financial assistance extended for this conference.

We are grateful to the members of the International Advisory Committee [Professor Stephen E G Lea, (University of Exeter, UK), Prof. G. Agoramoorthy, (Tajen University, Taiwan), Dr. K. Ramesh, (Adjunct Professor, Canada), Dr. B. Subha, (Pusan National University, South Korea), Dr. Riddhika Kalle, (University of KwaZulu-Natal Scottsville Pietermaritzburg, South Africa), Dr. C. Subramanian, (University of Gondar, Ethiopia), Regina Viduthalai, (Aarhus University), Dr. Arie van der Lugt, (Department of Cognitive Neuroscience, Maastricht University, The Netherland)] and National Advisory Committee [Dr. K. Sankar, (SACON, Anaikatty, Coimbatore), Dr. S. Jayakumar, (School of Life Sciences, Pondicherry University), Dr. V. Vijay Kumar, (Gujarat Institute of Desert Ecology, Gujarat), Dr. Hilloljyoti Singha, (Assam University, Silchar), Dr. C. Venkatraman, (Zoological Survey of India, Kolkata), Dr. Karthikeyan Vasudevan, (LaCONES, CCMB, Hyderabad), Dr. Hema Somanathan, (IISER, CET Campus, TVM), Dr. T.N.C. Vidya, (Jawaharlal Nehru Centre for Advanced Scientific Research, Jakku, Bangalore), Dr. V. Elangovan, (Babasaheb Bhimrao Ambedkar Central University Lucknow), Dr. N. Krishnakumar, IFS, (PCCF -Head of Forest Force, Chennai)] for their kind advice and support towards the grand success of this event. We personally thank Prof. Lea and Madam Bronwen Lea for their presence, support, and kindness throughout the whole programme. We thank all the invited speakers, researchers, scholars, students who made this conference a great successful event by their thought provoking talks.

We gratefully acknowledge the services rendered by Faculties, Non-teaching Staff, Research Scholars and Students of Department of Zoology and Wildlife Biology, A.V.C. College (Autonomous), Mannampandal as members of various organizing committees of In4CB-2017.

R. Nagarajan

December 30, 2018 Organizing Secretary

PLANARY TALK

URBANIZATION, COGNITION AND PERSONALITY IN ANIMALS: A REVIEW OF SOME RECENT EVIDENCE

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ABSTRACT

Urbanization has two contrasting effects on (non-human, vertebrate) animal numbers. On the one hand, it decreases species diversity. But on the other, it may increase biomass. In other words, most species do poorly in the urban environment, many becoming effectively extinct even though they flourished in the rural environments that the towns replaced, and continue to flourish in the rural environments neighbouring those towns. But a few species do very well. What characterises the species that do well around human settlements? Obviously, there are some direct ecological effects: particular food types may become available or unavailable as a result of urbanization, predators may be removed or become prevalent, nest sites may become scarce or abundant. I am concerned, however, with two other factors, which may operate between species but also within them; and in so far as they vary within species, may constitute the raw material for evolution, leading to inherited differences between urban animals and their rural conspecifics. These factors are cognition (my primary concern) and personality. The urban environment is always likely to pose new challenges to a species encountering it for the first time, and furthermore, because of human innovativeness, it is constantly changing. So it seems likely that species, or individuals within species, that are able to learn quickly and change their behaviour flexibly will flourish better within human settlements. It is clear that animals differ in the rate at which they learn any particular task or solve any particular problem, but a crucial subject for current research is whether such individual differences are consistent across time and across different cognitive challenges, allowing us to use a concept of "general intelligence" to describe differences in cognitive capacity between or within species. If that is possible, will more "intelligent" animals do better in the urban environment – or worse? Furthermore, in recent decades, scientists have taken note of something that has always been obvious to those who live or work with animals: individual animals, like individual people, differ in their behaviour, in ways that are relatively stable across time and situations. In a word, they have personalities. And again, we can ask the question, will some personality types (which may be particularly common in particular species) adapt more easily to the urban environment than others? This paper reviews some recent research on these topics.

Keywords: Urbanization, ecological effects, evolution, cognitive challenges, adaptation

The world's cities are growing. Although they only account for about 0.5% of the earth's land surface, that figure is likely to increase to around 2.5% by the middle of the 21st century, with most of the expansion coming at the expense of arable land (Angel, *et al.,* 2011). Consider Figure 1, which shows two maps of London, to the same scale. Near the outer edge of the bigger map (which dates from 2017) runs a red line, the route of the M25 orbital motorway. Pretty much everything within that perimeter is urbanized. The smaller map at the centre is John Rocque's 1743 map of London, with agricultural land at every margin. Angel *et al.* (2011) point out that cities like London are now mature and growing less quickly – but cities in the developing world are growing at the kind of rate that London has shown in the past. The urban environment thus represents a significant, and rapidly growing, area within which species of plants and non-human animals may be able to find, or carve out, an ecological niche. It is therefore no surprise that there is an increasing body of research in urban ecology, investigating which organisms do, or do not, adapt successfully to the urban environment, and what the nature of the adaptation is where it is successful. The present paper focuses on two behavioural factors that may influence the success of adaptation to the urban environment by vertebrate animals, either between species or between individuals within a species, namely personality (individual or species differences in emotional responses and the resultant behaviour) and cognition.

It is worth stressing at the outset that urbanization generally does not bring about a change from a "natural" to an "unnatural" environment. Towns and cities typically develop onto what was previously agricultural land, and agricultural land is as much a human-made environment as a town. Simultaneous with the urbanization of agricultural land, there is of course going on a (quantitatively much larger) process of conversion of wilderness land to agricultural use. That is a major ecological and conservation concern; but it is one that is well recognized and much studied. The ecological and conservation implications of urbanization are less well understood; and in particular the possibility that some species might profit from it has not been widely considered.

At least among birds, the broad population effects of urbanization are clear: there is a reduction in biodiversity compared with either agricultural or wilderness land, but there may be an increase in biomass (Chace and Walsh, 2006). It is highly likely that the same is true of other land vertebrate classes. These twin trends mean that, while many species native to a city's site may suffer extinction as the city develops; a few species are doing very well indeed in the urban environment. A number of studies, reviewed by Chace and Walsh, suggest that among birds, towns favour species that are omnivorous or granivorous, and also cavity nesters, but it is unlikely that these factors are the only ones at play: the urban environment would be much more species-rich if they were, because many species would fit that description. It is clear that there is a minority of species that are in some way well adapted for living alongside humans, and are thus enabled to exploit the resources that humans make available.

Naturalists, biologists, and indeed everyday speech have long acknowledged this obvious fact. Their English common names speak to the longstanding commensality with humans of such species as the House Sparrow (*Passer domesticus*), the House Mouse (*Mus musculus*), the House martins (*Delichon* spp.), the House Crow (*Corvus splendens*),the Garden Lizard (*Calotes versicolor*), and the fence lizards, Eastern and Western (*Sceloporus undulates* and *S. occidentalis*). It is a common joke among Americans to ask what the fence lizards sat on before there were fences, but the answer is probably that there simply weren't as many of them: humans have provided them with resting places that help them survive in greater numbers than before. Relatedly, it is no accident that many of these species have spread well beyond their original ranges, accidentally introduced by travelling humans – the house sparrow, the house mouse and the house crow are among the commonest and most widespread non-human vertebrates on the planet.

However, these longstanding companions of humans are not the only vertebrates that are now at home in our towns. In the past century, Great Britain has seen the emergence of the "urban fox" (the Red Fox, *Vulpes vulpes*). The phenomenon was already well established at the time of the first scientific discussion of it (Teagle, 1967), and urban foxes are now so ubiquitous in Britain that citizen science methods can be used to study their distribution (Scott *et al.,* 2014). More recently, urban fox populations have been rapidly establishing themselves in other countries, for example in Japan and Eastern Europe. In North America, Raccoons are familiar scavengers of the urban environment, and their density increases as areas urbanize (Haverland and Veech, 2017); but other medium-sized predators also flourish in American urban environments, for example, Coyotes (*Canis latrans*), Striped Skunks (*Mephitis mephitis*) and Virginia Opossums (*Didelphis virginiana*) (Greenspan, *et al.,* 2018). Theory Greenspan et al. argue that this is an example of "meso-predator release", due to the absence of larger predators from the urban environment.

It is not just mammalian predators that are at home in towns, however. The Barn Owl (*Tyto alba*) is one of the most widespread of birds in terms of its natural distribution. At least in damp climates, it chooses to nest in human-made structures rather than trees (Taylor, 2004), suggesting that in a human-free environment, its population would be nest-site limited; the Hindu temples of Tamil Nadu, however, provide an abundance of highly suitable nest sites, and with their aid the region supports a substantial Barn Owl population (Nagarajan *et al.,* 2002). Nor is it only predators: as every North American gardener knows, White-tailed Deer (*Odocoileus virginianus*) are comfortably at home in suburban environments, requiring small home ranges and living long lives because of abundant resources and the absence of large predators and human hunting (Crawford *et al.,* 2018).

So there are a good number of species that tolerate the urban environment, and in many cases profit from it. It remains true, however, that they are a small minority of the species native to the regions in which the towns they inhabit have been established. And while we can identify some obvious ecological factors that help urban species to thrive – a preference for food and nest sites that town-dwelling humans make available, a vulnerability to predators that town-dwelling humans remove – there are far more species to which those factors would be relevant than ever find a home in towns. There must be more specific, and much less common, factors at work. Some of these will undoubtedly be behavioural, and I would like to suggest three that we should consider: an ability to tolerate human closeness; a tolerance for new stimuli and stimulus change; and an ability to solve new problems. To put it in everyday terms, successful urbanizers need to be bold (especially around humans) and clever. These factors derive from two obvious characteristics that distinguish the urban environment from both natural and agricultural landscapes: it is full of humans, and it is constantly changing. The rates at which humans are transforming and modifying environments far exceed the rates of any form of historical evolutionary variation (Diffenbaugh and Field, 2013), and this environmental change is at its most marked in towns and cities.

Like the ecological factors we have noted, these more specific factors favouring urbanization vary between species (and this no doubt contributes to the reduced biodiversity of urban landscape). However, they do not have to be present in every member of the species. Indeed, they are likely to vary within species. Tolerance of humans is closely related to what is usually called "boldness" (as distinct from "shyness") in animals, and boldness vs shyness is arguably the best-established dimension in the study of individual differences in animal behaviour (that is, the study of animal personality), going back, albeit with some changes in nomenclature, to the work on sticklebacks of Huntingford (1976); see reviews by Sih *et al.* (2004) and, more recently but unfortunately restricted to fish, the least urbanized of vertebrate classes, Conrad, *et al.* (2011).

Such individual variation provides the raw material for the evolution of an urban population that may behave quite differently from its rural progenitors. There are also other reasons to expect urban and rural populations to diverge. The rapidly changing nature of the urban environment sets a premium on behavioural flexibility: the ability of an animal to change its behaviour within its own lifetime. The capacity to learn always provides a degree of such flexibility, but it is commonly argued that some animals are more behaviourally and/or cognitively flexible than others, and so more able to solve new problems that the environment sets them, whether those problems are physical, social or spatial. It follows that we would expect that more flexible species, or more flexible individuals within a species, will be more likely to thrive in the urban environment. Tree squirrels provide a good example. The Eastern Grey Squirrel (*Sciurus carolinensis*) is frequently found in towns, using both parks and gardens freely,both within its natural range of Eastern North America and in other regions to which it has been introduced such as the British Isles and California,. The same is true of the Fox Squirrel (*S. niger*), though this species has not been so widely introduced. In contrast, the Western Grey Squirrel (*S. griseus*), ecologically similar to the Eastern grey and native to California, is highly wary of humans, and has never been seen as an urban species (Lloro-Bidart, 2017); and though the Eurasian Red Squirrel, again ecologically similar to the grey, does also live in towns, this seems to be a more recent development, and to be restricted to urban parks (Hamalainen, *et al.,* 2018). Consistent with this, Chow, *et al.* (2018) found that on average Eastern Grey Squirrels were typically more successful, behaviourally flexible solversof physical problems than Eurasian Red Squirrels when faced with the same tasks; interestingly, the red squirrels were more variable than the greys, and a minority of them did better than the best of the greys. Fox Squirrels have also proved to be highly persistent, flexible problem solvers (Waismanand and Jacobs, 2008; Delgado and Jacobs, 2016).

It is worth pausing at this point to reflect on what we mean by "problem solving ability". It is not necessarily the case that either species, or individual animals within a species, who do well at physical problems will also do well at spatial or social problems; or indeed that individuals or species that do well at one physical problem will also do well at other physical problems (and the same in the spatial, social and other domains). It is a matter of current controversy whether we can usefully talk about a factor of "general intelligence", or "general problem solving ability" or "general cognitive capacity" that varies between individuals of a species, or between species, as we can within the human species, at least within a single human cultural environment(and subject to some other caveats, too). The value, or otherwise, of postulating such a "*g*" factor as underlying animal problem solving has been discussed extensively, for example by Burkart, *et al.* (2017) and Cauchoix, *et al.* (2018). Obviously, if the usefulness of such a factor is confirmed, and if variations in it have a genetic basis, it is what we would predict to be enhanced by the selective pressures of urbanization. But it may be that all we can look at is the selective advantages of being good at solving particular classes of problems.

To sum up, therefore, we may expect urban and rural animals to differ, whether between or within species. This is hardly a new insight: a fable about a town mouse and a countrymouse is one of the best known of those attributed to the Greek slave Aesop, who is believed to have lived between 620 and 564 BCE (Temple, 1998). Of course, as a fable, it is not a study in animal ethology, but is intended to illuminate the differences between human life in city and country. Nonetheless, Aesop's fables usually rely on a more or less accurate depiction of the animals that are their superficial subjects, indeed they only work as fables because readers can recognize the animals' behaviour as typical, or perhaps stereotypical, of the species concerned.

In the remainder of this paper, I illustrate this general thesis – and note some ways in which it is far from complete – by reference to four case studies. I have drawn most of them from a recent special issue of the journal *Animal Cognition*, edited by Griffin, *et al.* (2017), and many other examples could be found in that journal issue. The first, however, comes from a so-far unpublished PhD thesis. It concerns the Eurasian Magpie, *Pica pica.* Like foxes, magpies are a relatively recent immigrant to towns, at least in Britain; as a London child 60 years ago, I had never seen one, but they are now ubiquitous. Their numbers are currently increasing faster in urban than nearby rural environments (Leszek, 2001), and they have been shown to thrive in towns (Antonov and Antonasova, 2002; Mérő, *et al.,* 2010). They are showy, noisy birds, and one might expect them to be bold and exploratory, and that this would explain their successful colonization of towns. On the contrary, however, Vernelli (2013) showed that urban magpies are highly neophobic, immediately avoiding obvious, familiar food sources if a novel object is placed near them, and taking a long time to habituate to the novel object's presence. This was true both in field situations (on the university campus, and in urban parks), and in an aviary setting.

But if magpies do not fit the picture of the bold urbanizer, they do show evidence of cognitive flexibility. They share the general corvid reputation for high intelligence, and there is some evidence to support this casual inference. Prior, *et.al.* (2008) claimed that they show self-recognition in the mirror test devised by Gallup (1970), a claim that has been made for very few other bird species. Such claims are almost always controversial, but even to give the appearance of self-recognition requires a capacity for rapid and complex learning. In Vernelli's studies, one pair of magpies demonstrated an ingenious strategy for obtaining peanuts despite their fear of the novel object that had been placed near them: they waited until Eastern Grey Squirrels had removed and cached the nuts, and then pilfered the caches.

A second case study also concerns corvids, in this case Hooded and Carrion Crows (both subspecies of *Corvus corone*). Bílá *et al.* (2017) studied crows scavenging at the Vienna zoo in Austria. The crows scavenged in many animals' enclosures, including some that had been seen to kill crows (Polar Bears and wolves) and others that made no attempt to harm them (Eland, cranes and peccaries). In both situations, they played a range of different sounds to scavenging crows: alarm calls of their own species, and also of Jackdaws (*Coloeus monedula*, a corvid not found in Vienna); the song of Great Tits (*Parus major*). They also used a silent control. The crows responded to all corvid alarm calls by taking flight, regardless of whether they were of their own species or of jackdaws, and regardless of whether they were in a safe or a dangerous enclosure. But their response to Great Tit song was context dependent. In a safe enclosure, they ignored it, but in a dangerous one they often flew off. It seems that they recognized the level of danger their immediate environment posed, and, like Vernelli's magpies, they were hypercautious when in a location they recognized as dangerous.

A third case study looked at differences between urban and rural individuals of the same species, but did so across a range of nine species that form an assemblage of opportunistic foragers on the Caribbean island of Barbados, so that both within- and between-species comparisons were possible (Ducatez, *et al.,* 2017). The study took advantage of the major survey of bird species' innovativeness that has been undertaken by Lefebvre and colleagues (Overington, *et al.,* 2009). The species concerned included four that had been classified as innovative foragers, the Shiny Cowbird (*Molothrus bonariensis*), the Carib Grackle (*Quiscalus lugubris*), the Bananaquit (*Coereba flaveola*) and the Grey Kingbird (*Tyrannus dominicensis*); two for which no classification had been made, the Red-necked Pigeon (*Patagioenas squamosus*) and the Black-faced Grassquit (*Tiaris bicolor*), and three that had been classified as non-innovative, the Barbados Bullfinch (*Loxigilla barbadensis*), the Common Ground-dove (*Columbina passerina*), and the Zenaida Dove (*Zenaida aurita*). These species all forage together, taking advantage of anthropogenic food sources in both urban and rural contexts. Ducatez *et al.* (2017) took two measures of behaviour, in both environments. The first was the flight initiation distance (FID) to an approaching human, who walked steadily towards feeding birds. The second, intended as a measure of boldness and neophobia, was the latency to feed from a standard food source (left in place throughout the experiment), in locations that were either near or far from anthropogenic food sources, and with or without a variety of novel objects placed next to the feeder.

The results confirmed a difference between urban and rural birds, regardless of species: although Flight Initiation Distances varied between species, within a species urban birds were always more tolerant of humans (i.e. had a lower FID) than rural birds. The more innovative species also tended to have lower FIDs than the non-innovative ones, but only in the rural environment, and the innovativeness factor entirely explained the species differences. In the tests of boldness and neophobia, not all the species approached the feeders at all, but of those that did, the species classed as innovative (grackles and cowbirds) were quicker to feed than those classified as non-innovative (doves and finches). However, as in Vernelli's (2013) studies of magpies, the innovative species were more sensitive to the presence of a novel object. There was no significant difference between the urban and rural contexts. This study thus suggests that tolerance of humans may be distinct from general boldness, and also gives further evidence that neophobia and boldness may be independent traits rather than polar opposites. But it also tends to confirm that there may be a distinctive, cognitively advanced, way of adapting to the urban environment, which combines boldness with extreme vigilance – echoing the results of Bílá *et al.* (2017), which we considered in our second case study, as well as those of Vernelli (2013).

Our final case study concerns the Great Tit (*Parus major*), a species that has long been at home in urban gardens in parts of Europe, but has recently been extending its range. Like many other garden birds, the Great Tit probably depends on winter feeding by humans for its survival at the highest latitudes in its range (Orell, 1969). Preiszner, *et al.* (2017) studied problem solving success in Great Tits nesting in nesting-boxes in urban and forest environments in Hungary, using both an obstacle-removing task (the nesting-box entrance was blocked with a feather) and a food acquisition task (baits were made available in a familiar food-well, but it was covered with a transparent lid held in place with toothpicks). They also assessed risk-taking, by placing a stuffed model of either a dove or a sparrow hawk on a tripod near the nesting box, and measuring the number of visits the birds made to the nest while the model was present. Since some birds made two breeding attempts in the season, they were able to show that individual differences in success at eachproblem-solving task were consistent across attempts; however, there was no correlation across individuals between levels of success at the two different tasks, so the results do not support the idea of a general trait of problem solving ability, or *g* factor.

As in our previous case studies, there was a difference between urban and forest birds, with the urban birds solving both problems more quickly than their forest-dwelling conspecifics. This effect was not mediated by differences in neophobia. Interestingly, it was sex-specific: considered as units, urban pairs were more successful than forest pairs, but the difference was entirely due to a difference in the behaviour of the females. Preiszner et al. (2017) extended the analysis of our previous case studies in an important way: they assessed the breeding success of their birds, and showed that the birds that solved the feather-removal task more quickly had higher fitness. This is consistent with the idea that the urban environment will exert a greater selective pressure on problem-solving ability.

I started this paper with a simple idea: that the urban environment would favour species, and individuals within species, that were bold and clever. Through this series to case studies (to which many others could of course be added), we have seen that, though that simple summary contains a degree of truth, the situation is considerably more complicated, in a number of ways.

First, the concept of "boldness" is too simple. We need to consider boldness and neophobia not as polar opposites but as independent dimensions of individual difference between animals. It looks as though flourishing in the urban environment is facilitated by being both bold and neophobic: being willing to get close to humans and other dangerous objects, but very aware of changes and the threats they may pose.

Second, it is too simple to describe certain individuals or species as "clever" (or, more technically but amounting to much the same thing, "cognitively flexible"). We always need to ask, "clever at what?" So far we have some evidence that being successful at solving some problems may be correlated with urban residence, and with fitness in the urban environment. Interesting, all the problems that have been tested in this way fall within the physical domain. But we are far from having a general characterisation of the cognitive capacities that may confer selective advantage in the urban environment. Furthermore, some successful urbanizers seem to buck these trends.There is a pigeon strategy as well as a corvid strategy for occupying towns and cities, and anyone who has ever been to London, or Venice, or almost any other major city, knows that it is obviously very successful – to the point where humans are introducing into those cities animals like Harris Hawks, Goshawks or Peregrine Falcons, which (except perhaps for the peregrine) are not spontaneous urbanizers, in an attempt to deter the pigeons – a solution that, though reliably newsworthy, is probably not the most cost-effective (Bishop, *et al.,* 2008).

Finally, we need to return to the evolutionary question. The spectrum of species present isaffected by the urbanization of the environment – but what about the nature of those species? We have no solid evidence yet of distinctive adaptations to urban environments, and certainly no experimental evidence: there is a need for cross-fostering experiments to determine whether the behavioural differences between urban and rural members of a species have a genetic basis. Such experiments are beginning to be done, but so far their focus is on physical rather than behavioural or cognitive differences: Salmon *et al.* (2016) showed that urban Great Tits had lower telomere length (usually taken as a marker for reduced longevity) than rural birds, but cross-fostering experiments showed that this was due to developmental rather than genetic differences. Seress *et al.* (2012) found a similar result when examining why rural House Sparrows produced larger fledglings than urban birds. So while there is circumstantial evidence that urban life should select for individuals with higher cognitive skills, either specific or general, we have no direct evidence.

Similarly, we have no direct evidence that the urban environment selects for greater boldness, or greater neophobia. Boldness is partly a matter of rapid habituation to novel situations, and neophobia is partly a matter of extreme sensitivity to them; how can selection for these apparently contradictory tendencies work, even if we have seen that they are not in fact opposites? Once again, cross-fostering experiments are needed to examine the origins of urban-rural differences, once they are securely established.

And, finally, the rapid pace of change of urban environments constantly sets animals new problems. The evidence is that some species, at least, are able to keep up with these changes, at least in the sense of exploiting the new opportunities that new urban environments present. It seems obvious that this must involve constant learning; but again, we lack experimental evidence of whether, and how this is occurring.

Although much research thus remains to be done, there are no grounds for pessimism. The increasing urbanization of the world constitutes a massive, if accidental, ecological experiment. It creates a huge opportunity for researchers to gather in its results.

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REFERENCES

Angel, S., Parent, J., Civco, D.L. and Blei, A.M. 2011. Making room for a planet of cities, policy focus report.Lincoln Institute of Land Policy, Cambridge, MA.

Antonov, A. and Atanasova, D. 2002. Nest-site selection in the magpie *Pica pica* in a high-density urban population of Sofia (Bulgaria). *Acta Ornithol.,* 37: 55-66. doi:10.3161/068.037.0201.

Bílá, K., Beránková, J., Veselý, P., Bugnyar, T. and Schwab, C. 2017. Responses of urban crows to con- and hetero-specific alarm calls in predator and non-predator zoo enclosures. *Anim. Cogn.,* 20: 43-51. doi:10.1007/s10071-016-1047-5.

Bishop, J., McKay, H., Parrott, D. and Allan, J. 2008. Review of international research literature regarding the effectiveness of auditory bird scaring techniques and potential alternatives.. Unpublished report, UK Department for Environment, Food and Rural Affairs.

Burkart, J.M., Schubiger, M.N. and Van Schaik, C.P. 2017. The evolution of general intelligence. *Behav. Brain Sci.,* 40: e195.doi:10.1017/S0140525X16000959.

Cauchoix, M., Chow, P.K.Y., VanHorik, J.O., Atance, C.M., Barbeau, E.J., Barragan-Jason, G., Bize, P., Boussard, A., Buechel, S.D. and Cabirol, A.M.O.R.E. 2018. The repeatability of cognitive performance: a meta-analysis. *Phil. Trans. Roy. Soc. B,* 373: 20170281. doi:10.1098/rstb.2017.0281.

Chace, J.F. and Walsh, J.J. 2006. Urban effects on native avifauna: a review. *Landsc. Urban Plan.,* 74: 46-69. doi:10.1016/j.landurbplan.2004.08.007.

Chow, P.K.Y., Lurz, P.W.W. and Lea, S.E.G. 2018. A battle of wits? Problem-solving abilities in invasive Eastern grey squirrels and native Eurasian Red squirrels. *Anim. Behav*., 137: 11-20. doi:10.1016/j.anbehav.2017.12.022.

Conrad, J. L., Weinersmith, K. L., Brodin, T., Saltz, J. B. and Sih, A. 2011.Behavioural syndromes in fishes: a review with implications for ecology and fisheries management.*J. Fish Biol.,* 78: 395-435. doi:10.1111/j.1095-8649.2010.02874.x

Crawford, J.C., Quinn, A.D., Williams, D.M., Rudolph, B.A., Scribner, K.T. and Porter, W.F. 2018. Fine-scale spatial genetic structure of deer in a suburban landscape. *J. Wildl. Manage.,* 82: 596-607. doi:10.1002/jwmg.21417.

Delgado, M.M. and Jacobs, L.F. 2016. Inaccessibility of reinforcement increases persistence and signalingbehavior in the fox squirrel (*Sciurus niger*). *J Comp. Psychol.,* 130: 128-137. doi:10.1037/com0000021.

Diffenbaugh, N.S. and Field, C.B. 2013. Changes in ecologically critical terrestrial climate conditions. *Science*, 341: 486-492. doi:10.1126/science.1237123.

Ducatez, S., Audet, J., Rodriguez, J.R., Kayello, L. and Lefebvre, L. 2017. Innovativeness and the effects of urbanization on risk-taking behaviors in wild Barbados birds. *Anim. Cogn.,* 20: 33-42. doi:10.1007/s10071-016-1007-0.

Gallup, G.G. 1970. Chimpanzees: Self-recognition. *Science,* 167: 86-87.

Greenspan, E., Nielsen, C.K. and Cassel, K.W. 2018. Potential distribution of coyotes (*Canis latrans*), Virginia opossums (*Didelphis virginiana*), striped skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*) in the Chicago Metropolitan Area. *Urban Ecosys.,* 21: 983-997. doi:10.1007/s11252-018-0778-2.

Griffin, A.S., Tebbich, S. and Bugnyar, T. 2017. Animal cognition in a human-dominated world. *Anim. Cogn.,* 20: 1-6. doi: 10.1007/s10071-016-1051-9.

Hamalainen, S., Fey, K. and Selonen, V. 2018. Habitat and nest use during natal dispersal of the urban red squirrel (*Sciurus vulgaris*). *Landsc. Urban Plan.,* 169: 269-275. doi:10.1016/j.landurbplan.2017.09.011.

Haverland, M.B. and Veech, J.A. 2017. Examining the occurrence of mammal species in natural areas within a rapidly urbanizing region of Texas, USA. *Landsc. Urban Plan.,* 157: 221-230. doi:10.1016/j.landurbplan.2016.06.001.

Huntingford, F.A. 1976. The relationship between anti-predator behaviour and aggression among conspecifics in the three-spined stickleback. *Anim. Behav.,* 24: 245-260.

Kato, Y., Amaike, Y., Tomioka, T., Oishi, T., Uraguchi, K. and Masuda, R. 2017. Population genetic structure of the urban fox in Sapporo, northern Japan. *J. Zool*., 301: 118-124. doi:10.1111/jzo.12399.

Leszek, J. 2001. Synurbanization of the magpie in the Palearctic. In: Marzluff, J., Bowman, R., and Donnelly, R. (Eds.) (eds.), *Avian ecology and conservation in an urbanizing world*..pp. Kluwer Academic, Boston. pp. 403-425.

Lloro-Bidart, T. 2017. When 'Angelino' squirrels don't eat nuts: a feminist post humanist politics of consumption across southern California. *Gender Place Cult.,* 24: 753-773. doi:10.1080/0966369X.2017.1314949.

Méro, T.O., Zuljevic, A. and Varga, K. 2010. Nest-site characteristics and breeding density of Magpie *Pica pica* in Sombor (NW Serbia). *Acrocephalus,* 31: 93-99.

Nagarajan, R., Thiyagesan, K., Natarajan, R. and Kanakasabai, R. 2002. Patterns of growth in nestling Indian barn-owls. *Condor,* 104: 885-890. doi:10.1650/0010-5422(2002)104[0885:POGINI]2.0.CO;2.

Orell, M. 1989. Population fluctuations and survival of great tits *Parus major* dependent on food supplied by man in winter. *Ibis,* 131: 112-127.

Overington, S.E., Morand-Ferron, J., Boogert, N.J. and Lefebvre, L. 2009. Technical innovations drive the relationship between innovativeness and residual brain size in birds. *Anim. Behav.,* 78: 1001-1010. doi:10.1016/j.anbehav.2009.06.033.

Plumer, L., Davison, J. and Saarma, U. 2014. Rapid urbanization of red foxes in Estonia: Distribution, behaviour, attacks on domestic animals, and health-risks related to zoonotic diseases.*PLoS ONE*, *9*. doi:10.1371/journal.pone.0115124.

Preiszner, B., Papp, S., Pipoly, I., Seress, G., Liker, A. and Bókony, V. 2017. Problem-solving performance and reproductive success of great tits in urban and forest habitats.*Anim. Cogn.,* 20: 53-63. doi:10.1007/s10071-016-1008-z.

Prior, H., Schwarz, A. and Güntürkün, O. 2008.Mirror-induced behavior in the magpie (*Pica pica*): Evidence of self-recognition. *PLoS Biol*., 6, e202. doi:10.1371/journal.pbio.0060202.

Salmon, P., Nilsson, J.F., Nord, A., Bensch, S. and Isaksson, C. 2016. Urban environment shortens telomere length in nestling great tits, *Parus major*. *Biol. Lett.*, *12*. doi:10.1098/rsbl.2016.0155.

Scott, D.M., Berg, M.J., Tolhurst, B.A., Chauvenet, A.L.M., Smith, G.C., Neaves, K., Lochhead, J. and Baker, P.J. 2014. Changes in the distribution of red foxes (*Vulpesvulpes*) in urban areas in Great Britain: Findings and limitations of a media-driven nationwide survey.*PLoS ONE*, *9*. doi:10.1371/journal.pone.0099059.

Seress, G., Bokony, V., Pipoly, I., Szep, T., Nagy, K. and Liker, A. 2012. Urbanization, nestling growth and reproductive success in a moderately declining house sparrow population.*J. Avian Biol.,* 43: 403-414. doi:10.1111/j.1600-048X.2012.05527.x

Sih, A., Bell, A. and Johnson, J.C. 2004. Behavioral syndromes: an ecological and evolutionary overview.*Trends Ecol. Evol.,* 19: 372-378.

Taylor, I. 2004. Barn owls: Predator-prey relationships and conservation. Cambridge University Press, Cambridge.

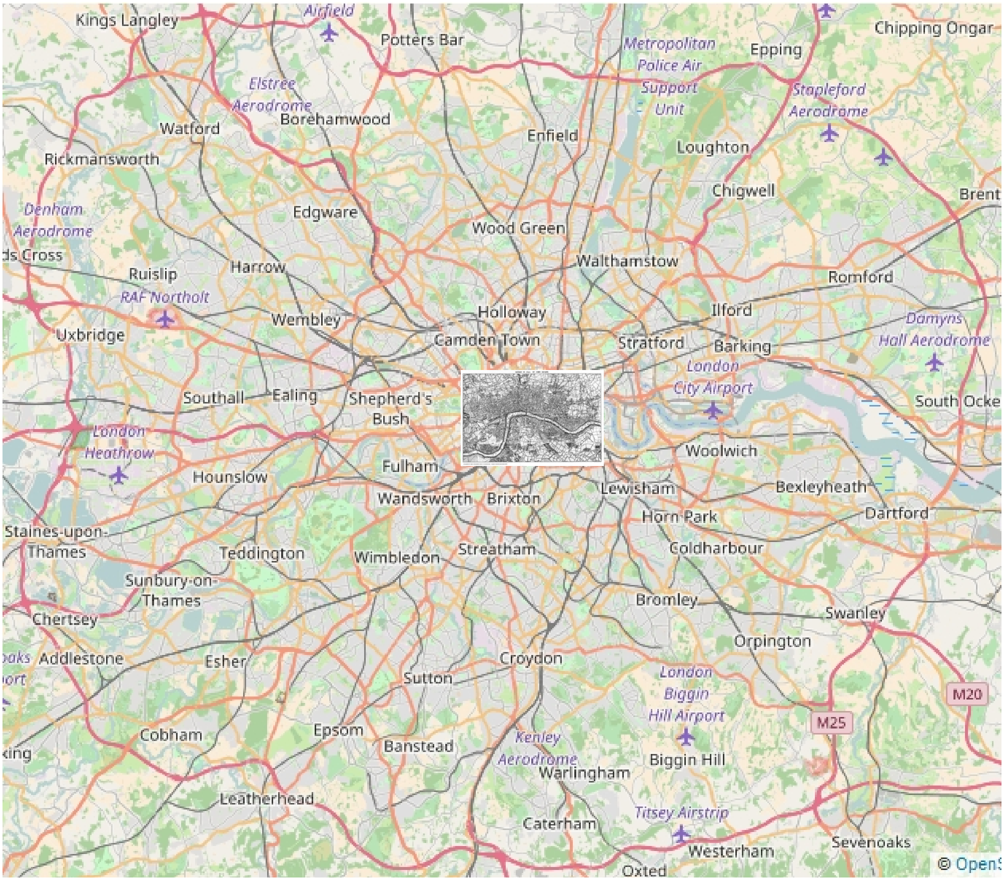
Teagle, W.G. 1967. The fox in the London suburbs. *London Naturalist,* 46: 44-68.

Temple, R. 1998. Aesop: The complete fables. Penguin, London.

Vernelli, T. 2013.The complexity of neophobia in a generalist foraging corvid: the common magpie, *Pica pica*.Unpublished PhD dissertation, University of Exeter.

Waisman, A.S. and Jacobs, L.F. 2008. Flexibility of cue use in the fox squirrel (*Sciurus niger*). *Anim. Cogn.,* 11: 625-636. doi:10.1007/s10071-008-0152-5.

Figure 1: London in 1743 and 2017.The 1743 map was produced by John Rocque; the 2017 map is from the Open Street Map, © Open Street Map Contributors.



CONSERVATION OF WATERBIRDS AND ASSOCIATED THREATS IN INDIAN WETLAND HABITATS

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ABSTRACT

India has a wide variety of wetlands like marshes, swamps, open water bodies, mangroves and tidal flats and salt marshes etc. with a coastline of over 7500km. The coastal lines support large area of coastal wetlands of over 40230 km^2 which consists of near shore Gulfwater, inlets, creeks, tidal deltas, bays, lagoons, coastal lakes, backwater, estuaries, coral reefs, shoals, tidal flats, mudflats, beaches, sand ridges, coastal dunes, mangroves, marsh, algae/sea grass beds, strand features, salt affected lands, reclaimed lands and delta plains. Among the avifaunal community, the second biggest group is wetland birds after passeriformes. India has wide diversity of wetland microhabitats of both inland (mainly freshwater) and coastal (saline water) areas and hence there is a wide variations and diversity of wetland birds. Till recently, 124 Protected Areas were declared exclusively for birds and in which majority (300 winter visitors) of them for migratory birds. Several studies explored the causes for the change and decline of waterbirds in different wetlands of India and mostly based on short term studies. The causes includes: man-made, man induced and natural which include cattle grazing, over-fishing, bird hunting, tourism, recreation and natural disasters (cyclone and tsunami), pollution, anthropogenic pressures, disturbances, changes in the land use patterns and disturbing the natural actions. These impacts induce habitat degradation and fragmentation which affect the diversity of waterbirds and hence some of the important bird habitats and areas become unpopular to birds. The associated threats are eventually, one or more aspects of HIPPO dilemma which include Habitat loss, Introduced species, Pollution, Population growth, and Over exploitation. Our data collection in some of the waterbird areas over the years indicated that the population decline. The long term data indicated the factors associated with them. We assess the factors associated with the changes in waterbird population and also review from other studies for the conservation of waterbirds in the wetland habitats.

Keywords: coastal and inland, wetland, waterbird, population, habitat use, HIPPO dilemma, conservation

1. INTRODUCTION

Totally around 10,000 species were recorded in the class Aves (Birds) around the world. The traditional taxonomy based on the morphometry inferred that there are 29 orders, 187 families, 2050 genera and 9648 species of avifauna (Ali and Ripley, 1983; Grimmett *et al.*, 1999). On the other hand the modern taxonomy purely based on DNA hybridisation identifies 21 orders, 2057 genera and 9672 species. In which the order passeriformes (Passerines=perching or song birds) contained more than 50% of species which consists of 1161 genera and 5712 species. In India, there are 2061 species of birds in which 55% are breeding in India. Totally 141 species of bird are endemic to India. Till recently, 124 Protected Areas were declared exclusively for birds and in which majority (300 winter visitors) of them are migratory birds. In India, around 1193 wetlands covering an area of 3.9 lakh Ha have ornithological importance (Nayak, 1997; Parikh and Parikh, 1999; Prasad *et al.*, 2002).

The attraction of birding areas increase when its avifaunal density, richness and diversity increase and these are the important measures to assess the avian diversity. Furthermore, the density provides the details of the total bird population of an area. The richness indicates the number of bird species, whereas the diversity combines the density and richness of birds i.e. species wise density and therefore shows the pattern of the bird species of an area (Nagarajan and Thiyagesan, 1996; Pandiyan *et al.*, 2006). There are several factors which are influencing the avian population characteristics (density, richness and diversity). The density dependent (such as competition, predation, starvation, food availability, etc.,) and density independent factors (viz., abiotic factors, climatic variations, etc.,) have been influencing the avian population characteristics.

As the human being is evolved at the end of the evolution cycle, they have to rely on the other life forms at every step of his growth and development. They dependent on the other life forms directly or indirectly for food, clothing, shelter, entertainment, recreation, economy and much more. The wetlands are in immediate threat due to pollution, encroachment, patterns of changes in habitat use, etc., which ultimately affect the waterbirds which are in the apex of the ecosystem. Therefore, in this chapter we review the conservation of waterbirds and associated threats in wetland habitats.

2. MATERIALS AND METHODS

The total number of birds present in the Point Calimere was counted using 7'x50" binoculars. Waterbird species were identified with the help of their special features using Ali (1969), Ali and Ripley (1983) and Grimmett *et al.* (1999). The data collections were done by direct count method (Nagarajan and Thiyagesan 1996) during morning hours. The total number of species was also counted to estimate species richness and diversity was calculated using the Shannon-Wiener diversity index (Shannon and Wiener, 1949) by using the following formula

$$H' = -\Sigma\, pi \log_e pi$$

Where *pi* is the proportion of the *i*th species in the sample.

The data on waterbird populations in Point Calimere Sanctuary were also collected from existing research sources viz., research dissertations and forest department reports. Avian nomenclature is based on Grimmett *et al.* (1999) and Ali and Ripley (1983).

3. RESULTS AND DISCUSSION

3.1 Case Study: Changes in Waterbird Population in Point Calimere Sanctuary

It is general concern around the world that the bird population and especially migratory waterbird population has been declining across the years. In India, we do not have long term data for any area especially for birds. East coast of Tamilnadu region has many important bird areas in which Point Calimere is one of the oldest and traditional wintering sites and the only Ramsar site in Tamilnadu. Empirical data collected from Point Calimere Sanctuary in different years across the decades are given in table 1.

The population of different waterbirds across the years in Point Calimere varied widely. The total population of waterbird declined across the years and it was 60075 during 1986 which drastically declined to 3031 during 2006. On the other hand, the species richness and diversity increased across the years which indicated that the number of species visited to Point Calimere increased. This is due remarkable decline in the mass migration of Painted stork *Mycteria leucocephala*, Kentish plover *Charadrius alexandrinus*, Curlew sandpiper *Calidris ferruginea* Little stint *Calidris minuta* and Flamingos *Phoenicopterus* spp. (Table 1).

Table 1: Total counts, species richness and diversity of waterbirds[a] at Point Calimere Wildlife Sanctuary, Tamil Nadu, Southern India in 1986, 1998, 1999 and 2004-2006.

Common Name	Species name	1986[b]	1998[c]	1999[c]	2004[d]	2005[d]	2006[d]
Grey Heron	*Ardea cinerea*	235	64	20	21	19	19
Indian Pond Heron	*Ardeola grayii*	0	0	45	11	5	5
Cattle Egret	*Bubulcus ibis*	0	61	0	0	0	0
Great Egret	*Casmerodius albus*	6	18	299	112	69	41
Little Egret	*Egretta garzetta*	307	0	296	95	63	35
Pacific Reef Egret	*Egretta sacra*	12	0	2	0	2	2
Black-crowned Night Heron	*Nycticorax nycticorax*	0	1	0	0	0	0
Kentish Plover	*Charadrius alexandrinus*	856	0	0	35	40	33
Asian Openbill Stork	*Anastomus oscitans*	0	31	26	0	0	0
Painted Stork	*Mycteria leucocephala*	1017	1018	156	196	250	89
Little Ringed Plover	*Charadrius dubius*	0	31	207	96	350	27
Greater Sand Plover	*Charadrius leschenaultii*	0	2	0	0	0	0
Lesser Sand Plover	*Charadrius mongolus*	394	0	0	42	71	26
Grey Plover	*Pluvialis squatarola*	0	3	2	0	0	0
Pacific Golden Plover	*Pluvialis fulva*	2	7	0	0	0	0
Common Ringed Plover	*Charadrius hiaticula*	0	0	0	12	12	5
Red-wattled Lapwing	*Vanellus indicus*	0	2	14	0	0	0
Ruddy Turnstone	*Arenaria interpres*	92	0	0	9	14	6
Whiskered Tern	*Chlidonias hybridus*	109	0	0	16	35	16
Gull-billed Tern	*Gelochelidon nilotica*	11	0	5	360	73	27
Caspian Tern	*Sterna caspia*	604	8	4	585	139	45
Little Tern	*Sterna albiforns*	643	972	153	485	150	39
River Tern	*Sterna aurantia*	0	34	101	0	0	0
Common Tern	*Sterna hirundo*	330	1363	858	15	15	16
Black-headed Gull	*Larus ridibundus*	0	24	0	21	42	12
Herring Gull	*Larus argentatus*	90	4	0	500	126	76
Brown-headed Gull	*Larus brunnicephalus*	0	525	5	15	12	14
Heuglin's Gull	*Larus heuglini*	0	0	0	7	11	7
Pallas's Gull	*Larus ichthyaetus*	0	0	0	12	0	3
Black-winged Stilt	*Himantopus himantopus*	19	0	92	0	0	0
Pied Avocet	*Recurvirostra avosetta*	2	0	0	0	0	0
Red-necked Phalarope	*Phalaropus lobatus*	0	0	0	15	12	14
Common Sandpiper	*Actitis hypoleucos*	0	199	90	0	0	0
Curlew Sandpiper	*Calidris ferruginea*	4437	0	20	65	450	27

Little Stint	*Calidris minuta*	46666	237	4184	750	2000	256
Temminck's Stint	*Calidris temminckii*	0	0	0	11	12	0
Broad-billed Sandpiper	*Limicola falcinellus*	9	0	0	0	0	0
Black-tailed Godwit	*Limosa limosa*	0	0	0	96	260	226
Bar-tailed Godwit	*Limosa lapponica*	0	0	3	62	210	45
Eurasian Curlew	*Numenius arquata*	1	13	19	3	5	2
Whimbrel	*Numenius phaeopus*	0	0	0	2	0	3
Common Greenshank	*Tringa nebularia*	55	0	57	26	76	62
Marsh Sandpiper	*Tringa stagnatilis*	21	425	3	76	138	19
Common Redshank	*Tringa totanus*	351	51	17	63	42	85
Wood Sandpiper	*Tringo glareola*	0	15	0	0	7	4
Terek Sandpiper	*Xenus cinereus*	2	0	0	12	6	12
Spot-billed Pelican	*Pelecanus philippensis*	89	14	13	73	58	52
Flamingos	*Phoenicopterus spp.*	3351	250	350	0	127	1675
Eurasian Spoonbill	*Platalea leucorodia*	364	46	129	11	69	6
Black-headed Ibis	*Threskiornis melanocephalus*	0	7	0	5	3	0
	Total birds	60075	5425	7170	3915	4973	3031
	Species richness	28	28	28	35	36	36
	Diversity index (H')	0.4946	1.5005	1.0039	2.6287	2.3272	1.6319

[a]Excluding family Arididae; [b]Data from Sankar (1989); [c]Unpublished data from Tamilnadu Forest Department; [d]Unpublished data from Sumathi

Diversity index (H')= Shannon and Wiener (1949)

In addition, Balachandran (2012; Table 1) assessed the population trends of some of the common waders at Point Calimere on different periods from 1980 to 2008 which indicated that the population declined drastically over the period. The Curlew Sandpiper (*Calidris ferruginea*) were more than 1,50,000 individuals in 1980s which declined to less than 25,000 individuals in 2000-2008, Little Stint (*Calidris minuta*) from more than 2,00,000 individuals (in 1980s) to less than 30,000 individuals (in 2000-2008), Lesser Sand Plover (*Charadrius mongolus*) from more than 1,00,000 individuals (in 1980s) to less than 40,000 individuals (in 2000-2008), Ruff (*Philomachus pugnax*) from more than 1,00,000 individuals (in 1980s) to less than 10,000 individuals (in 2000-2008), Black-tailed Godwit (*Limosa limosa*) from more than 50,000 individuals (in 1980s) to less than 15,000 individuals (in 2000-2008), Black-winged Stilt (*Himantopus himantopus*) from more than 15,000 individuals (in 1980s) to less than 1000 individuals (in 2000-2008), and Pied Avocet (*Recurvirostra avosetta*) from more than 7000 individuals (in 1980s) to less than 100 individuals (in 2000-2008). Further, Balachandran (2012; Table 3) narrated that the population of waterbirds (shorebirds, ducks, gulls, terns, flamingos, storks, egrets, herons, ibises, spoonbill) 10,00,000 individuals during 1980s declined to 4,50,000 individuals during 2011-12.

3.2 Changes in the Waterbird Population Dynamics and the Causing Factors

Several factors were identified as potential factors for causing the changes in the avifaunal diversity. The factors can be grouped into three different categories viz., Man-made factors, Man induced factors and Natural factors.

Man-made factors: The factors that are directly made by human which causes problems to avifaunal diversity and survival. The factors are bird hunting and poaching, pollution of all kinds (water, air, soil, thermal, pesticide and ocean), accumulation of plastics and e-waste, cattle grazing, over-fishing, tourism and recreation, unsustainable development activities.

Man-induced factors: The factors which are being activated due to indirect effects of human activities such as habitat degradation, habitat loss, habitat alteration, conversion of land and changing land use pattern.

Natural factors: Factors which are naturally happen and affect the avifaunal diversity and survival which include natural disasters i.e. cyclone, storm, drought, acid rain, tsunami, etc.,

Among these, one of the major factors is water scarcity and changes in the water quality of wetlands.

Availability Freshwater Discharge

All the wetlands are affected due to scarcity of water and alteration of watershed conditions. In addition, the changes occurred in the precipitation and restriction of spreading of rainfall across the season to few days. Hence, large quantity of water is being wasted to mix with sea, instead of the groundwater recharge. Furthermore, draining of wetlands and pumping of groundwater has depleted the ground water recharge and storage.

Reduction in Freshwater Discharge and its Impacts

The shortage of freshwater alters the quality of existing water bodies. The significant change is in the levels of ions and salinity. Salinity rise was noticed by many researchers in various wetlands. Most of the reports concluded that the freshwater recharge was considerably deprived which intern increase the salinity level in most of the wetlands. For example, salinity in the Pichavaram mangroves of Tamilnadu, Southern India ranges between 0.6 and 36.2‰ while in Muthupet mangroves (Tamilnadu) the ranges are from 5 to 47‰. In Sundarbans mangroves of West Bengal, salinity ranges from 0.4‰ to 27.5‰ and in west coast of India, the range is between 7‰ and 22‰. Even within, the mangrove different regions and microhabitats show variations in salinity. In addition, significant salinity fluctuations in adjourning habitats of Pichavaram mangroves were also reported (cited in Sandilyan *et al.*, 2010b). Selvam (2003) reported that, freshwater recharge was considerably deprived in many of the Indian mangroves. Prior to 1980s the Pichavaram mangroves received 73 TMC (thousand million cubic feet) of fresh water form River Coleroon. By late eighties, it had decreased to 31 TMC, with a further depletion and reached to 3-5 TMC. Our long term study focused on the avifaunal composition of Pichavaram mangrove wetlands indicated that within last two decades (i.e. from 1984-1988; and from 2004 to 2007) 40% of waterbird species richness declined in the area (Sandilyan *et al.*, 2010a). Furthermore, the waterbirds showed preference for different microhabitats for various activities. For example they preferred the agricultural lands for foraging and mangroves for roosting (Nagarajan and Thiyagesan, 1998) and also in Vedanthangal Bird Sanctuary (Venkatraman *et al.*, 2008).

3.3 Uses of Waterbirds

The birds are economically important which provide both direct and indirect uses. The direct uses include from morning to night (Amulet to Sleeping beds & Pillows containing bird feathers) for food, clothing, utilitarian use, recreational hunting and bird watching. Many bird species have spiritual significance in different cultures around the world, and they and their products may be used as sacred objects in religious rituals. For example Grey Heron as holy bird, peacock feathers in Hinduism as religious objects etc., Waterbirds perform functions which are enhancing the survival of other organisms of aquatic ecosystems. The processes like scavenging (by Adjutant Stork, Gulls), biological control agents (insectivore cattle egret), indicator of environmental changes (by shore and sea birds), etc., are some of the classical examples for the beneficial role played by birds. The indirect benefits are ecological and evolutionary role, environmental services, as biological indicators, and for scientific study. The environmental services, which the waterbirds offer to this earth is innumerable. Green and Elmberg (2014; Table 1) reviewed the ecosystem services (natural processes that benefit humans) provided by waterbirds including ‘Cultural services’ such as value for human recreation, and ‘provisioning services’ such as harvest for meat or feathers and regulating services such as pest control, and ‘supporting services’ such as maintaining connectivity for plants and invertebrates in isolated wetlands by acting as vectors for dispersal. Further, waterbirds can provide clear indirect benefits for human populations by consuming invertebrate pests. Waterbirds have positive effect on biodiversity by regulating competition through grazing, by controlling fish populations, by acting as hosts for unique parasites, by cycling nutrients, and by dispersing seeds, invertebrates and microbes. Recent ecosystem services by birds become apparent for example disease surveillance and reduced production of the greenhouse gas methane when swans feed on submerged plants. Economic valuation of ecosystem services by birds income associated with the hunting of ducks and geese, recreational value of these groups extent to which ducks remove weed seeds and invertebrate pests, and accelerate the breakdown of straw in ricefields, etc. (Green and Elmberg, 2014). The Oystercatchers are extreme top level predators in estuarine and coastal environment. They are capable of discriminating the minute differences in the prey and their environment (Nagarajan *et al.* 2002a,b,c,; 2006, 2008). Therefore, they are capable indicating the minute difference in the environment. In addition, they are used as best model species to study the ecological, evolutionary and behavioural theories (Goss-Custard 1996, Goss-Custard and Sutherland, 1997).

3.4 Threats to Avifauna

Due to increase in human population, globalization and urbanization activities, we lose the conscious of protecting the environment. In addition, humans do induce both directly and indirectly many impacts on the natural ecosystems (Thiyagesan and Nagarajan, 1995). The ways in which the humans predominantly inflict the impacts are: man-made, man induced and natural which include cattle grazing, over-fishing, bird hunting, tourism, recreation and natural disasters (cyclone and tsunami), pollution, anthropogenic pressures, disturbances, changes in the land use patterns and disturbing the natural actions (Nagarajan and Thiyagesan, 1995, 2006; Thiyagesan and Nagarajan 1997). These impacts induce habitat degradation and fragmentation which affect the diversity of avian species. Such activities eventually make some of the important waterbird habitats and areas unpopular to birds and thus by the areas lose its attraction. Also these changes affect the ecosystem services provided through the birds for that particular area.

The species richness (i.e. number of species present) of 50 species was recorded in 1987, which increased to a maximum of 63 in 1990 and then declined rapidly to a low of 23 in 2001 in Pichavaram Mangrove areas (Nagarajan and Thiyagesan 2006). Nagarajan and Thiyagesan (1998) found that adjoining croplands played an important role in attracting the birds to the Pichavaram mangroves. In addition the cyclone, developmental activities such as ecotourism, climate change affected the avian diversity in Pichavaram mangroves (Thiyagesan and Nagarajan, 1995, 1997; Nagarajan and Thiyagesan, 2006; Sandilyan *et al.*, 2008; Nagarajan, 2014).

3.5 Waterbirds and their Losing Battle Against Mankind: Is Man Kind?

In addition to the above factors, some of the common threats for waterbird species are as follows. The main reasons that lead to the destruction of the birdlife are:

Poaching and Hunting: Indiscriminate hunting of birds for its meat, feathers, claws, beaks etc. is one of the major causes for the destruction of birds (Sandilyan *et al.* 2010a).

Habitat Fragmentation and Destruction: Wetlands are perceived as wastelands and tons of hectares of wetland are converted into real estates, industrial development, city expansion, agricultural lands, etc., The valuable wetlands are damaged daily due to people greediness which are vital habitats for many species of migratory waterbirds (Nagarajan and Thiyagesan, 2006; 2014).

Impact of Weed Species: *Eichhornia crassipes* (Water hyacinth), *Pistia stratiotes* (Water lettuce), *Lemna minor* (Duck weed), *Azolla imbricata waxai* (Water velvet), *Zannichellia palustris* (Horned pond weed), and *Hydrilla verticillata* (Hydrilla) are examples of species that have become invasive threats to waterbird habitats in various parts of the world. Several ponds in our nearby localities can be seen fully covered by Water Hyacinth, Hydrilla, Water lettuce, etc., which prevents the foraging of many waterbird species.

Climate Change: Changes in the water quality due to climate change changed the waterbird population dynamics (Nagarajan, 2014) and population of shorebirds (Pandiyan *et al.*, 2014). Human activities such as the burning of fossil fuels have altered the Earth's atmosphere and have resulted in global climate changes. The loss of 5 islands which are potential bird habitats of Gulf of Mannar out of 21 islands due to sea-level rise is an example for habitat loss due to climate change.

Pollution: Pollutants (pesticides, herbicides, etc.) released into the environment. The oil spills in various seas and oceans which threatens the sea birdlife such cormorants, pelicans, etc, due oil contamination (Nagarajan and Thiyagesan, 2006).

Over-Exploitation of Resources: Exploitation of wild populations such as over fishing, indiscriminate killing of wildlife, etc., for food has resulted population crashes of wildlife. For examples, indiscriminate harvesting fishes and over-harvesting of nests of edible swiftlefts of Andaman Nicobar Islands (Nagarajan and Thiyagesan 2006; Sandilyan, 2010).

Accidental Deaths: Car hits (a major cause for road kills such as night jar), electric collisions (geese, ducks), collisions with ships (sea birds) and air strikes (raptors and some of waterbirds) are the major causes.

3.6 HIPPO Dilemma

There are several studies on the population assessment of individual species of waterbirds or group of waterbirds or waterbirds of different habitats in different coastal and inland wetland areas. Such studies identified different types of threats such as human disturbance, encroachment, conversion of habitats, shrinkage of wetlands, cattle grazing, over-fishing, bird hunting, poaching, tourism, recreation, climate change, global warming, windmills, high electric power lines, cell phone towers, natural disasters (cyclone, storm & tsunami), changes in water quality, scarcity of water or water flow, impact of introduced species, weed invasion, pesticides, water pollution, soil pollution, ocean pollution, oil spills, air pollution, noise pollution, plastics, e-wastes solid waste pollution, thermal pollution, etc., However, these threats are eventually associated with one or more aspects of HIPPO dilemma which include Habitat loss, Introduced species, Pollution, Population growth, and Over exploitation.

3.7 Conservation of Birdlife

There are two main ways generally were used in conservation of the birdlife: *In-situ* and *ex-situ* conservation.

In-situ conservation:

It involves the conservation of habitats, ecosystems and species in their natural environment which is also called "on-site conservation". It is the process of protecting an endangered plant or animal species in its natural habitat. Example: Sanctuary, National Parks, Biosphere Reserves, etc.

Ex-situ conservation:

It is the process of protecting an endangered species of plant or animal outside of its natural habitat which is also called "off-site conservation"; for example, by removing part of the population from a threatened habitat and placing it in a new location, which may be a wild area or within the care of humans. Example: Zoos, Botanical Gardens, etc.,

3.8 Conservation through Legal Protection

Wildlife Protection Act, 1972

The Wildlife Protection Act was formulated in the year 1972 to protect India's wildlife more effectively. It controls poaching, smuggling and illegal trade in wildlife and its derivatives. It also protects ecologically important Protected Areas.

Animals and plants are listed in different schedules based on their density, rarity, endemism, ecosystem function, etc. There are six schedules which give varying degrees of protection. Schedule I and part I of Schedule II provide absolute protection - offences under these are prescribed the highest penalties. Species listed in Schedule IV are also protected, but the penalties are much lower.

Biological Diversity Act, 2002

This act was formulated to fulfill the objectives devised in the United Nations Convention on Biological Diversity (CBD) 1992. The Act aims at the conservation of biological resources through its sustainable use. To effectively meet the goals, National Biodiversity Authority (NBA) is established in Chennai. NBA acts as a facilitating, regulating and advisory body to the Government of India on issues of conservation, sustainable use of biological resources and fair and equitable sharing of benefits arising out of the use of biological resources. Additionally, it advises State Governments in identifying the areas of biodiversity importance (biodiversity hotspots) as heritage sites.

Protected Areas

The term ***Protected Area*** (PA) describes a wide array of land and water designations, of which some of the best known are National Park, Nature Reserve, Wilderness Area, Wildlife Management Area, Wildlife Sanctuary, Biosphere Reserve and Landscape Protected Area but can also include such approaches as Community Conserved Areas.

The first National Park in India was declared in 1935, now famous as the Corbett National Park and Vedanthangal Bird Sanctuary was first sanctuary declared during 1942. Since Independence, there has been a steady rise in the number of Protected Areas (PAs), especially after the enactment of the Wildlife Protection Act in 1972. In 1988, there were 54 National Parks and 372 Wildlife Sanctuaries covering a total area of 109,652km^2. By the year 2000, this number had increased to 566, covering 1,53,000km^2, or 4.66% of India's geographical area. There are currently about 597 National Parks and Wildlife Sanctuaries in India, encompassing 1,54,572km^2 or 4.74% of the country's geographical area. Along with over 500 wildlife sanctuaries in India now hosts 14 Biosphere Reserves, four of which are part of the World Network of Biosphere Reserves; 25 wetlands are registered under the Ramsar Convention (Nayak, 1997; Parikh and Parikh, 1999; Prasad *et al.*, 2002).

Besides the official PAs, there are numerous Sacred Groves, scattered all over the country, that are important for biodiversity conservation. Some Sacred Groves represent forest types that have disappeared from the area. Besides Sacred Groves, there are many small community conserved areas. Many villagers do not allow hunting in their village ponds and lakes. These areas serve as excellent habitats for waterfowl. Similarly, the tribal reserves of Andaman and Nicobar are perhaps the best protected forests left in these emerald islands.

3.9 Awareness

Various measures to bring about awareness have greatly enhanced the knowledge of common man about wildlife. Inclusions of conservation education at school and college levels, media coverage and eco-tourism have brought the names of many endangered birds and animals in focus which will help in conserving the avifauna. Eco-tourism industry is becoming one of the highest income-generating industries which will help the biodiversity-rich Under Developed Nations to protect their birdlife.

Many NGOs, Governmental Organizations as well as private institutions are now actively taking part to spread the awareness to protect our fast depleting birdlife. One such example is the "Save Vultures" campaign.

International Conservation Agencies

One of the most widely recognized agencies all over the world for conservation of the nature is the IUCN (International Union for Conservation of the Nature and Natural Resources). The IUCN Red List is the best known conservation status listing.

Internationally, 199 countries have signed an accord agreeing to create Biodiversity Action Plans to protect endangered and other threatened species. In the United States this plan is usually called as Species Recovery Plan.

IUCN Red List Categories

IUCN Red List refers to a specific category of threatened species, and may include critically endangered species. IUCN Red List of Threatened Species uses the term *endangered species* as a specific category of imperilment, rather than as a general term. Under the IUCN Categories and Criteria, *endangered species* is between *critically endangered* and *vulnerable*. Also *critically endangered* species may also be counted as *endangered species* and fill all the criteria

The more general term used by the IUCN for species at risk of extinction is *threatened species*, which also includes the less-at-risk category of vulnerable species together with endangered and critically endangered. IUCN categories include:

- **Extinct**: The last remaining member of the species has died, or is presumed beyond reasonable doubt to have died. Example: Labrador Duck (*Camptorhynchus labradorius*)
- **Extinct in the wild**: Captive individuals survive, but there is no free-living, natural population. Example: Guam Kingfisher (*Todiramphus cinnamominus*)
- **Critically endangered**: Faces an extremely high risk of extinction in the immediate future. Example: Spoon-billed Sandpiper (*Calidris pygmaea*), Siberian Crane (*Leucogeranus leucogeranus*)
- **Endangered**: Faces a very high risk of extinction in the near future. Example: Great Knot (*Calidris tenuirostris*)
- **Vulnerable**: Faces a high risk of extinction in the medium-term. Example: Wood Snipe (*Gallinago nemoricola*)
- **Conservation dependent**: Birds that are not severely threatened, but must depend on conservation programs. Example: River Lapwing (*Vanellus duvaucelii*)
- **Near threatened**: May be considered threatened in the near future. Example: Asian Dowitcher (*Limnodromus semipalmatus*)
- **Least concern**: No immediate threat to the survival of the species. Example: Little Stint (*Calidris minuta*)

Major International Organizations Involved in Conservation

The major international organizations working for the conservation of the bird life include the WWF (World Wide Fund for Nature), RSPB (Royal Society for the Protection of Birds), CI (Conservation International), WCS (Wildlife Conservation Society), IUCN (International Union for Conservation of Nature and Natural Resources), etc..

3.10. Limitations and Suggestions for Future Research

Nagarajan (2011) reviewed the research on waterbirds and wetlands of India and indicated the limitations and made suggestions for the future research which reiterated again for the future research.

- Studies undertaken on waterbirds in different wetlands were mostly survey in nature. Regular census of waterbirds were undertaken in different years but the accessibility of data is difficult. The area covered across the years and estimator errors were not uniform and hence temporal comparison using those data is cynical. No wetland has long term data on waterbird population. The regular census programmes needs to be conducted atleast in some of the ornithologically important wetlands and the accessibility of data should be easy to anybody by proving the information in the internet.
- In some areas, wide amount of research have been undertaken on birds and other associated fauna and flora. But most of the research outcomes are in the form of reports, dissertation and published in local journals. Hence, they were not accessed by researchers. Hence, duplication of researches have been undertaken in some of the aspects. Therefore, it is essential to compile the annotated bibliography for different areas as has been done for Point Calimere (Balachandran *et al.*, 2010).
- Some of the studies did not include the data collection of all associated factors. The speculative discussions were made and the validity were not confirmed. So it is essential to conduct research integrating all factors associated with the birds.
- Waterbirds are the top level predators and respond immediately for the environmental changes (Nagarajan *et al.* 2006, 2008; Sumathi *et al.*, 2008). Therefore, the waterbirds can be used as indicator species to assess the habitat quality by studying behaviour ecology of birds.

- The hot core behavioural ecological studies and its applications are in primitive stage in India. Behavioural ecology could have an important role to play in predicting the effect on populations of habitat loss because it provides a means of predicting how animals will respond to the changes in their environment brought about by habitat loss. Predicting the effects on populations of habitat loss by using behavioural ecology will show what will happen to populations when conditions change and individuals vary their behaviour. By close interaction between theoreticians and empiricists, and between population and behavioural ecologists, it may be possible in the future to proceed with commercial and recreational developments in the coastal zone in ways that minimise, even eradicate, many conservation problems. Birds which are specialist in their food and feeding and breeding behaviours are used as model systems for these kinds of studies. Animals generally use the optimisation strategies for their survival. Optimisation is the processes of minimising costs or maximising benefits, or both, obtaining the best possible compromise between the two. Therefore, optimisation theory is used as common platform for these kinds of research.
- Making the pure science into applied science would provide an opportunity to solve many natural problems and certainly attract more funds for research. In this context, one of the most classical examples is Goss-Custard's Behaviour based model (Goss-Custard and Sutherland, 1997).
- Goss-Custard and his colleagues developed a Behaviour-based model using their long term data on non-breeding wader populations and how they have been used to predict the consequence of environmental change in terms of the mortality rate and body condition of waders. They have narrow down the variables which needs to be collected for these models.
- Hence, parameterising the model to our wetland conditions would provide an opportunity for easy assessment of wetlands. It is essential to conduct long term studies including the behavioural ecological component is essential. Furthermore, these kinds of studies would be successful when inter disciplinary approaches are attempted. Hence, it is essential to include interdisciplinary approached in our research.

4. CONCLUSION

Every passing minute, three species of plants and animals become extinct, vanish forever from this earth. Already, we lost the Passenger Pigeon or Wild Pigeon (*Ectopistes migratorius*) and Dodo (*Raphus cucullatus*) and no information on the survival of Crested Shelduck (*Tadorna cristata*), Pink-headed duck (*Rhodonessa caryophyllacea*) in India. At present we do have countable number of individuals of few bird species namely Spoon-billed sandpiper (*Calidris pygmaea*), Sarus Crane (*Antigone antigone*), etc., which are in a position to become extinct. Birds form the intricate part of our environment and culture. It is our moral duty to save them. Further, it is most essential to save and protect their habitats i.e. all wetlands and water bodies. At this juncture, it is very vital to remember Mahatma Gandhi's words i.e. **"*The Earth provides enough to satisfy every man's needs but not anybody's greed*".**

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REFERENCES

Ali, S. 1969. *The book of Indian birds* (8th ed.) Bombay Natural History Society, Bombay.

Ali, S. and Ripley, S.D. 1983. *Handbook of the Birds of India and Pakistan*. Compact Edition. Oxford: Oxford University Press.

Balachandran, S. 2012. Avian diversity in coastal wetlands of India and their conservation needs. International Day for Biological Diversity: Marine Biodiversity on 22 May 2012. Uttar Pradesh State Biodiversity Board. Pp. 155-163.

Balachandran, S., Thirunavukarasu, V. and Sathiyaselvam, P. 2010. *Annotated bibliography of Point Calimere*. BNHS Bird Migration Study Centre and Tamilnadu Forest

Department. Nagapattinam Wildlife Division, Nagapattinam.

Goss-Custard, J.D. (Ed.). 1996. *The Oystercatcher: from individuals to populations*. Oxford University Press, Oxford.

Goss-Custard, J.D. and Sutherland, W.J. 1997. Individual behaviour, populations and conservation. In: *Behavioural ecology: an evolutionary approach* (4th edition) (eds. J.R. Krebs and Davies, N.B.), pp. 373– 395. Blackwell Science, Oxford.

Green, A.J. and Elmberg, J. 2014. Ecosystem services provided by waterbirds. Biological Reviews 89: 105-122. https://doi.org/10.1111/brv.12045

Grimmett, R., Inskipp, C. and Inskipp, T. 1999. *Birds of India, Pakistan, Nepal, Bangladesh, Bhutan, Sri Lanka, and the Maldives*. Princeton University Press, Princeton, New Jersey

Nagarajan, R. 2011. Coastal wetlands and waterbirds of Tamilnadu-A review. Pages 117-121. In: *Status of Indian Birds and their Conservation* (Eds. Bhupathy, S., Prusty B.A.K., Kumara, H.N. Jayaraj, R.S.C. Quadros, G. and Pramod, P). Salim Ali Centre for Ornithology & Natural History, Coimbatore.

Nagarajan, R. 2014. Climate change: Bird diversity and conservation issues. Pages 1-12. In: *Proceedings of National Seminar on Impact of Global Climate Change on Environment & Ecological Conservation'.* (Ed. Udawant, S.) Mahatma Phule Arts, Science & Commerce College, Panvel.

Nagarajan, R., Goss-Custard, J.D. and Lea, S.E.G. 2002a. Oystercatchers use colour preference to achieve longer-term optimality. *Proceedings of the Royal Society of London - B - Biological Sciences* 269: 523-528.

Nagarajan, R., Lea, S.E.G. and Goss-Custard, J.D. 2002b. Re-evaluation of patterns of mussel (*Mytilus edulis*) selection by European Oystercatchers (*Haematopus ostralegus*). *Canadian Journal of Zoology* 80: 846-853.

Nagarajan, R., Lea, S.E.G. and Goss-Custard, J.D. 2002c. Mussel valve discrimination and strategies used in valve discrimination by the Oystercatcher *Haematopus ostralegus*. *Functional Ecology* 16: 339-345.

Nagarajan, R., Lea, S.E.G. and Goss-Custard, J.D. 2006. Seasonal variations in mussel, *Mytilus edulis* L. shell thickness and strength and their ecological implications. *Journal of Experimental Marine Biology and Ecology* 339:241-250.

Nagarajan, R., Lea, S.E.G. and Goss-Custard, J.D. 2008. Relation between water quality and dorsal thickness of mussel (*Mytilus edulis*) and its ecological implications for wintering Oystercatchers (*Haematopus ostralegus*). *Acta Zoologica Academiae Scientiarum Hungaricae* 54 (Suppl.1): 225–238.

Nagarajan, R. and Thiyagesan, K. 1995. Avian mortality caused by a cyclone at the Pichavaram mangroves, southern India. *PAVO* 33: 117-121.

Nagarajan, R. and Thiyagesan, K. 1996. Waterbird population and substrate quality of the Pichavaram wetlands, southern India. *Ibis* 138: 710-721.

Nagarajan, R. and Thiyagesan, K. 1998. Significance of adjacent croplands in attracting waterbirds to the Pichavaram mangrove forests. *In:* 172-181; Dhinsa, M.S., Rao, P.S. and Parasharya, B.M. (Eds.) *Birds in Agricultural Ecosystem*. Society for Applied Ornithology (India).

Nagarajan, R. and Thiyagesan, K. 2006. The effects of coastal shrimp farming on birds in Indian mangrove forests and tidal flats. *Acta Zoologica Sinica*: 52(Supplement): 541–548.

Nagarajan, R. and Thiyagesan, K. 2014. Ecology and conservation of waterbirds of Pichavaram mangrove, Tamil Nadu. Pages 100-111. In: *Waterbirds of India. ENVIS Bulletin: Wildlife and Protected Areas. Vol. 16* (Eds. Gopi, G.V. and Hussian, S.A.) Wildlife Institute of India, Dehradun.

Nayak, S. 1997. Information needs of Integrated Coastal Zone Management. Role of remote sensing and geomorphic information system. *Proc. Workshop on Integrated Coastal Zone Management.* Space Application Centre (ISRO), Ahmedabad, 6-25: 166pp.

Pandian, J., Asokan, S., Thiyagesan, K. and Nagarajan, R. 2006. Use of tidal flats in the Cauvery Delta region of SE India by shorebirds, gulls and terns. *Wader Study Group Bulletin* 109: 95-101.

Pandiyan, J., Nagarajan, R., Asokan, S., Srinivasan, S., Naresh, B., Karthick, R., Amutha, J. and Balasubramanian, R. 2014. Does climate change affect the shorebird population? A case study from Southern India. Pages 13-25. In: *Proceedings of National Seminar on Impact of Global Climate Change on Environment & Ecological Conservation'.* (Ed. Udawant, S.) Mahatma Phule Arts, Science & Commerce College, Panvel.

Parikh, J. and Parikh, K. 1999. *Sustainable Wetland.* Environmental Governance-2, Indira Gandhi Institute of Development Research, Mumbai.

Prasad, S.N., Ramachandra, T.V., Ahalya, N., Sengupta, T., Alokkumar, Tiwari, A.K., Vijayan, V.S. and Lalitha Vijayan. 2002. Conservation of wetlands of India – a review. *Tropical Ecology* 43: 173-186.

Sandilyan, S., Thiyagesan, K. and Nagarajan, R. 2008. Ecotourism in wetlands causes loss of biodiversity. *Current Science* 95: 1511.

Sandilyan, S., Thiyagesan, K. and Nagarajan, R. 2010a. Major decline in species richness of waterbirds in the Pichavaram mangrove wetlands, Southern India. *Wader Study Group Bulletin* 117: 91-98.

Sandilyan, S., Thiyagesan, K., Nagarajan, R. and Vencatesan, J. 2010b. Salinity rise in Indian mangroves – a looming danger for coastal biodiversity. *Current Science* 98:754-756.

Sankar, K. 1987. Habitat utilization of some wintering shorebirds in Point Calimere Sanctuary. M.Phil. Dissertation, Bharathidasan University, Trichirappalli.

Selvam, V. 2003. Environmental classification of mangrove wetlands of India. *Current Science* 84: 757-765

Shannon, C.E. and Wiener, W. 1949. *The Mathematical Theory of Communication*. Illinois University Press, Urbana, Ill.

Sumathi, T., Nagarajan, R. and Thiyagesan, K. 2008. Effect of water depth and salinity on the population of Greater Flamingo (*Phoenicopterus ruber*) in Point Calimere Wildlife and Bird Sanctuary, Tamilnadu, Southern India. *Scientific Transactions in Environment and Technovation* 2: 9-17.

Thiyagesan, K. and Nagarajan, R. 1995. Impacts of developmental projects on the wetlands in two coastal districts of Tamilnadu, Southern India. *Asian Wetland News* 8:8.

Thiyagesan, K. and Nagarajan, R. 1997. Effects of a cyclone on waterbird populations at the Pichavaram mangroves, Southern India. *Wader Study Group Bulletin* 80:47-51.

Venkatraman, C., Thiyagesan, K., Nagarajan, R. 2008. Factors influencing waterbird populations Vedandhangal Bird Sanctuary, Tamilnadu, India. In (Ed: Reddy, M.V.) *Wildlife Biodiversity and Conservation*. Pages 92-103. Daya Publishers, Delhi.

OVERVIEW OF INDIAN BIODIVERSITY, BIOLOGICAL DIVERSITY ACT AND RULES

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INTRODUCTION

Biodiversity refers to varieties of life on the Earth including animals, plants, microbes and genes within them, their habitats and ecosystems and all variations within a given ecosystem, biome or entire planet. The term was coined by W.G. Rosen in 1985. First it was published in 1988 by E. O. Wilson, a sociologist. Life on Earth has many levels of diversity, from DNA and genes to species, populations, ecosystems and communities. Biodiversity is the basis of life on Earth, important for the functioning of ecosystems, provides us with products and services without which we cannot live. Consider our food range in India. It ranges from Indian bread (chapatti), rice and rice products and related curries and other varieties made out of different vegetables. These food items are made of wheat, paddy, maize, bajra, ragi, potato, tapioca, sweet potato, yams and corms, pulses like pigeon pea, green and black gram, Bengal gram, soya bean, vegetables like tomato, brinjal, cucumber, pumpkin, drum stick, bitter gourd, snake gourd, bottle gourd and various gourds, French bean, amaranth and so many leafy vegetables, spices and condiments like chilly, cardamom, ginger, turmeric, pepper, nutmeg, clove, cinnamon, cumin, coriander, fenugreek etc. This is the diversity of food we have in India. Similarly, all other groups such as herbal medicine, ornamentals, timber and non-timber species are also very diverse. Conservation and sustainable use of this biodiversity is fundamental to sustainable development. Similarly, biodiversity is extremely complex, dynamic and supports many ecosystem services that are often not easily visible and plays an important role in regulating the atmospheric conditions, hydrological cycle and recycling the nutrients. The importance of biodiversity can be understood, but not easily be valued and very often difficult to estimate it (Sullivan 1997).

Biodiversity Scenario

To date, 1.8 million species have been *described*, whereas the number of living species is estimated to be anywhere between 5 million and 30 million, possibly even higher. The majority of species not yet described is made up of insects (between 4 million and 10 million or more of *un-described* species, many of which are thought to be concentrated in the canopies of tropical forests). Different estimates are available recently on the total number of plants excluding fungi, lichens and microbes. One estimate gives a total number of vascular plants as 3,91,000 and including 3,69,000 flowering plants (Kew, 2016). The other estimate account for various plant groups in following table 1 totalling to 3,74,000 (Christenhusz and Byng, 2016).

Table 1. Total number of plant species in World

Groups	No of species recorded in the world
Angiosperms	295383
Gymnosperms	1079
Pteridophytes	11850
Bryophytes	21925
Algae	44000

Biodiversity hotspots

Biodiversity hotspot is a biogeographic region that is both a significant reservoir of biodiversity and is threatened with destruction. To qualify as a biodiversity hotspot, a region must meet two strict criteria: it must contain at least 0.5% or 1,500 species of vascular plants as endemics, and it has to have lost at least 70% of its primary vegetation. Around the world, 35 areas have qualified under this definition. Now 36th (North American Coastal Plain (NACP) is under declaration (CEPF, 2018). These sites support nearly 60% of the world's floral and faunal species, with a very high share of endemic species (Myers *et al.,* 2000). The floral diversity in India is mainly concentrated in the 4 biodiversity hotspots, namely Himalayas, Western Ghats (and Sri Lanka), Northeast India and Andaman Islands (Indo-Burma) and Nicobar Island (Sundaland), out of 36 biodiversity hotspots (Table 2) recognised in the world. These floristically significant areas exhibit exceptional concentration of endemic species and are also experiencing loss of habitat with higher occurrence of threatened plant species. There are eight hottest hotspots are also recognised (Table 4).

Table 2. Biodiversity Hotspots in world.

	AFRICA		ASIA-PACIFIC
1	Cape floristic region	19	East Melanesian Islands
2	Coastal forests of eastern Africa	20	Forests Of East Australia
3	Eastern afromontane	21	Himalaya * **#**
4	Guinean forests of western Africa	22	Indo-burma * **#**
5	Horn of Africa	23	Japan
6	Madagascar & the Indian ocean island_	24	Mountains of Southwest China
7	Maputaland-pondoland-albany	25	New Caledonia
8	Succulent karoo	26	New Zealand
	NORTH AND CENTRAL AMERICA	27	Philippines **#**
9	California Floristic Province	28	Polynesia-Micronesia
10	Caribbean Islands	29	Southwest Australia **#**
11	Madrean Pine-oak Woodlands	30	Sundaland * **#**
12	Mesoamerica	31	Wallacea **#**
13	North American Coastal Plain	32	Western Ghats & Sri Lanka * **#**
	SOUTH AMERICA		**EUROPE AND CENTRAL ASIA**
14	Atlantic Forest **#**	33	Caucasus
15	Cerrado	34	Irano-Anatolian
16	Chilean Winter Rainfall-Valdivian Forest	35	Mediterranean Basin
17	Tropical Andes	36	Mountains of Central Asia
18	Tumbes-chocó-magdalena		

*Hotspots sharing Indian land areas; # Hottest hotspots
(Source: www.conservationinternational.org)

Biodiversity in India

The vast geographical variations, diverse climatic and topographical realms of India have culminated in enormous ecological diversity supporting about 8% of the world's biological diversity. Adding to this, there is a very high diversity of human influenced ecosystems including agricultural and pasture lands and impressive range of domestic aided plants and animals (Sanjappa, 2014). Forests, grasslands, wetlands, estuarine coastal and marine and desert are the major ecosystems in India. The forest cover of the country constitutes about 21.54% (7,08,278 km^2) of India's total geographical area (FSI, 2017). Champion and Seth (1968) have recognised 16 major forest types comprising 220 subtypes in the country. It has about 4.1 million hectares of wetlands (excluding paddy fields and mangroves). Mangroves in India cover an area of about 4,921 km^2 constituting 3.3% of the world's mangroves and represent one of the best swamps in the world. Coral reef, the other unique shallow coastal marine ecosystem in the country occurs in Andaman & Nicobar Islands, Lakshadweep Islands, Gulf of Kutch and Gulf of Mannar. The desert ecosystem covers about 2% of the total landmass (spreads over states of Rajasthan, Gujarat, Punjab and Haryana) in India, and is characterised by low precipitation and largely barren arid lands with only sparse or seasonal plant cover. The cold desert lies in Ladakh (Jammu & Kashmir) and in Lahaul-Spiti of Himachal Pradesh that covers an area of about 1,09,990 km^2.

Though the geographical area of the country represents about 2.4% of the world's total landmass, it harbours a total number of 48650 plant species (BSI, 2018) out of about 0.4 million hitherto known species in the world, representing as much as 11.4% of world flora. Nearly 28 % of these plant species are endemic to India with main centres of endemism in the Himalayas, Northeast, Western Ghats and Andaman & Nicobar Islands. The Northeast with about 130 species of primitive flowering plants is considered as cradle of Indian flowering plants (Sanjappa, 2014). The table 3 provides number of plant species in India and approximate number of species endemic to India.

Table 3. Total number of plant species (including virus, bacteria, algae, fungi and lichens) in India

Groups	No. of species recorded in India	Percentage share of Indian species	Endemic species	Threatened species
Flowering plants				
Angiosperms	18386	6.84	4303	1700
Gymnosperms	79	7.73	12	7
Non flowering plants				
Pteridophytes	1289	10.74	66	414
Bryophytes	2743	16.92	629	80
Others				
Algae	7357	18.39	1924	0
Lichens	2511	14.77	520	0
Fungi	15115	15.26	4100	580
Bacteria & Viruses	1170	9.90	0	0
Total	**48650**	**100**	**11554**	**2781**

(Source: BSI, 2018).

India is also has very rich diverse fauna. The total number of animal species reported from India is 1,01,167 (6.45%of the world fauna). There are 427 species of mammals, 1,340 birds, 584 reptiles, 407 amphibians and 3,364 fishes (ZSI, 2018). The mammalian fauna include the Tiger, Asiatic lion, Snow leopard, Clouded leopard, Common leopard and a number of lesser cats, the wolves, wild dogs and jackal, yak, cheeru, hangul, deers, tahrs, Indian gazelle, wild ass as well as dolphin and whales in marine habitats. India is also rich in endemic fauna, which include 230 species of amphibians, 214 reptiles, 81 birds, 46 mammals. About 13% of birds in India are globally threatened (Venkataraman et al., 2013). Nearly 140 breeds of domestic animals like cattle, sheep, goat, horse, dog and camel etc. are also found in the country. It has a rich and diverse invertebrate fauna, represented by 65222 species of insects, 5205 molluscs, 1029 annelids, 5953 arachnids (spiders, mites etc.) 3825 species of crustaceans (Prawns, crabs etc.) 2949 nematodes, 1760 flat worms as well as several species under other smaller groups of animals.

Agro-biodiversity is also very rich with 166 crop species and 320 wild relatives of crops along with numerous wild relatives of domesticated animals. These plant and animal resources are mostly distributed in four biodiversity hot spot region falls in India such as Himalayas, Indo-Burma, Western Ghats and Sri Lanka and Sundaland. Comparative account of the biodiversity of different hot spots of Indian region is given in Table 4.

Table 4. Account of biodiversity in different hot spots of Indian region

	Himalaya	Indo-Burma	Western Ghats and Sri Lanka	Sundaland
Hotspot Original Extent (km²)	741706	2373057	189611	1501063
Hotspot Vegetation Remaining (km²)	185427	118653	43611	100571
Endemic Plant Species	3160	7000	3049	15000
Endemic Threatened Birds	8	18	10	43
Endemic Threatened Mammals	4	25	14	60
Endemic Threatened Amphibians	4	35	87	59
Extinct Species†	0	1	20	4
Human Population Density (people/km²)	123	134	261	153
Area Protected (km²)	112578	235758	26130	179723
Area Protected (km²) in Categories I-IV*	77739	132283	21259	77408

†Recorded extinctions since 1500. *Categories I-IV affords higher levels of protection.

Source: http://www.conservation.org

Legislations for Biodiversity Conservation

Every citizen has the fundamental duty to protect and improve the natural environment including forests, lakes, rivers and wildlife, and to have compassion for living creatures under Article 51A of the Constitution of India. According to Article 48A, the State shall attempt to protect and improve the environment and to safeguard the forests and wildlife of the country. Both the central and the state governments to make legislation on issues related to the protection of forests, wild animals and birds. The customs and beliefs of Indian society are deeply rooted in the conservation of environment and its natural resources. However, over the period these customs and beliefs are being eroded and along with other detrimental factors our environment and biodiversity face great threat of destruction. National and International bodies have formulated different legislations for conservation of biodiversity both pre and post independent period. But more thrust to conservation was found in the later part of the 20th century. India is party to the following major international conventions and all such conventions, protocols and treaties had its impact on different conservation actions and strategies in India.

Following international legislations related to Forest, Environment and Biodiversity were announced and signed by various world partner countries which have influenced the legislation in our country also.

- The International Convention for the Regulation of Whaling, 1946 (IWC, 1946)
- Ramsar Convention, 1971(IUCN, 1989)
- The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 1973 (CITES, 2013)
- The Convention on Migratory Species, 1979 (CMS Bonn Convention) 1983 (UNEP, 2011)

- Man and Biosphere Programme (MAB, 1986)
- The Convention on Biological Diversity (CBD, 1992)
- The Cartagena Protocol on Bio-safety (CBD, 2012)
- The Nagoya Protocol (CBD, 2010)
- Strategic Plan for Biodiversity 2011-2020 and Aichi Biodiversity Targets (CBD, 2011).

Among them, the Convention on Biological Diversity (CBD) is very important and far-reaching and legally binding treaty with three main goals: (1) conservation of biological diversity (2) sustainable use of its components; and (3) fair and equitable sharing of benefits arising from biological resources, enacted during Earth Summit at Rio de Janeiro in 1992. To achieve these goals of the convention, India has enacted Biological Diversity Act, 2002 followed by Biological Diversity Rules-2004 to implement the Act. The salient features of Act are: (i) To regulate access to biological resources of the country with the purpose of securing equitable share in benefits arising out of use of biological resources and associated knowledge relating to biological resources (ii) To conserve and sustainably use biological diversity (iii) To respect and protect knowledge of local communities relating to biodiversity (iv) To secure sharing of benefits with local people as conservers of biological resources and holders of knowledge and information relating to the use of biological resources (v) Conservation and development of areas of importance from the stand-point of biological diversity by declaring them as biological diversity heritage sites (vi) Protection and rehabilitation of threatened species and (vii) Involvement of institutions of State Governments in the broad scheme of implementation of the Biological Diversity Act through constitution of committees. The BD Act (MoEF, 2002) consists of 12 Chapters, 65 Sections, Many subsections, Regulations (agreements, guidelines) and 24 rules (MoEF, 2004).

Definitions:

Biological resources: means plants, animals, microorganisms, genetic material and by products of value but excluding human genetic material.

Bio-survey and bio-utilization: means survey or collection of species, sub-species, genes, components and extracts of biological resources for any purpose including for characterisation, inventories and bioassay.

Benefit claimers: means conservers of biological resources and their by-products and creators and holders of knowledge relating to the use of such biological resources.

Commercial utilization: means using biological resources as drugs, industrial enzymes, food flavours, fragrances, cosmetics, emulsifiers, oleoresins, colours, extracts and genes used for improving crops and livestock through genetic intervention.

The Act covers conservation, use of biological resources and associated knowledge occurring in India for commercial or research purposes or for the purposes of bio-survey and bio-utilisation. It provides a framework for access to biological resources and sharing the benefits arising out of such access and use. The Act also includes in its ambit the transfer of research results and application for intellectual property rights (IPRs) relating to Indian biological resources.

The Act covers foreigners, non-resident Indians, body corporate, association or organization that is either not incorporated in India or incorporated in India with non-Indian participation in its share capital or management. These individuals or entities require the approval of the National Biodiversity Authority when they use biological resources and associated knowledge occurring in India for commercial or research purposes or for the purposes of bio-survey or bio-utilisation.

Indians and Indian institutions do not require the approval of the National Biodiversity Authority when they engage in the above mentioned activities. However they would need to inform the State Biodiversity Boards prior to undertaking such activities. However, any commercial application related to use of biological resources should be approved by the Authority.

The Act excludes Indian biological resources that are normally traded as commodities. Such exemption holds only so far the biological resources are used as commodities and for no other purpose. The Act also excludes traditional uses of Indian biological resources and associated knowledge and when they are used in collaborative research projects between Indian and foreign institutions with the approval of the central government.

National Biodiversity Authority (NBA)

It was established in 2003 at the national level with headquarters at Chennai, following the enactment, for regulating activities as provided in the Biodiversity Act, for issuing guidelines and advising the Central and State Governments. Subsequently, the State Biodiversity Boards (SBB) have also been established by many State Governments as provided in section 22 of the Act to advise them subject to any guidelines issued by the Central Government on matters relating to the conservation of biodiversity and their sustainable use.

The National Biodiversity Authority with Dr. B. Meenakumari as its Chairperson from February 2016 and Shri. T. Rabikumar as its Secretary supported by Technical, administrative and finance teams, shall give approval, based on agreement with State Biodiversity Boards (SBBs), only after establishing mutually agreed terms and an equitable benefit sharing agreement between the users of the biological resources and associated knowledge and concerned local bodies and benefit claimers. Different expert committees are constituted as advisory bodies for different aspects like implementing access and benefit sharing mechanism, notification of biological resources as Normally Traded as Commodity etc.

The Act under section 41 has also made provision for constitution of Biodiversity Management Committees (BMC) by every local body for the implementation of the act. A decentralized regulation has been made through BMCs, SBBs and NBA each with well defined function within their respective jurisdiction. Accordingly, it is operated at local, state and national levels as a 3 tier system. NBA and SBB provide guidance and technical support to BMC for preparing People's Biodiversity Register (PBR). The BD Act provides legal mechanism for establishing sovereign rights over the Indian biodiversity and its conservation, protection against misappropriation, regulation of access and sustainable use of biodiversity. The act covers foreigners, non-resident Indians, body corporate, association or organization that is either not incorporated in India or incorporated in India with non-Indian participation in its share capital or management. These individuals or entities require the approval of the National Biodiversity Authority when they use biological resources and associated knowledge occurring in India for commercial or research purposes or for the purposes of bio-survey or bio-utilisation. Biological Diversity Rules were formulated during 2004 for operationalising the Biological Diversity Act, 2002. The act also covers the intellectual property right related to traditional knowledge. Traditional knowledge (TK) is a collectively owned property and is integral to the cultural or spiritual identity of the social group in which it operates and is preserved. Traditional knowledge is now at the centre of the discussions on intellectual property rights and has assumed immense significance. India does not have any specific legislation for protecting traditional knowledge. The concept of benefit sharing, which is an integral part of protecting traditional knowledge, has been covered in Biological Diversity Act 2002 and Plant Variety Protection and Farmers Rights Act, 2001.

People's Biodiversity Register (PBR)

The present guidelines have drafted taking into consideration different ecosystems and include the rural, urban and protected areas. The guidelines may be customized and further information may be added to enrich the effort. It is important to keep in mind some of the issues related to PBRs:

- It is to be undertaken in a participatory mode involving varying sections of village society.
- While documenting, the knowledge and views of both genders are to be recorded.
- Information provided by people need to be collated, analysed and crosschecked by the members of the Technical Support Group (TSG) before documentation.
- The PBR is important base document in the legal arena as evidence of prior knowledge and hence careful documentation is necessary.
- The document should be endorsed by the BMC and later publicized in the Gram Sabha / Gram

Panchayat / Panchayat Samiti. The document can be a very useful tool in the management and sustainable use of bioresources. The document can also be a very useful teaching tool for teaching environmental studies at schools, colleges and university level

- The document should be periodically updated with additional and new information as and when generated.

The preparation of People's Biodiversity Registers (PBRs) involves the active support and cooperation of a large number of people who need to share their common as well as specialized knowledge. One of the first steps for preparing a PBR is to organize a group meeting to explain the objectives and purpose of the exercise. Different social groups in the village need to be identified for purpose of data collection from those groups. In an urban situation, spots where biodiversity are important need to be identified for the purpose of the study and documentation. The documentation process includes information gathered from individuals through detailed questionnaire, focused group discussion with persons having knowledge and published secondary information.

Documentation of Traditional Knowledge (TK) related to biodiversity Documentation of knowledge of individuals with regard to biodiversity and its uses is an important part of PBR. Every effort should be made to identify the persons with proven knowledge of local biodiversity; special attention should be given to the elderly persons who can also provide informations on the biodiversity which was available in the past but no longer seen at present. In some cases focus group discussion may be held for the purpose of documentation.

The PBR is a participatory process requiring intensive and extensive consultation with the people. The objectives and purpose is to be explained in a group meeting in the presence of all sections of people in the Panchayat, members of the BMC, students, knowledgeable individuals and all those interested in the effort. Documentation includes photographs (including digital images), drawings, audio and video recordings and other records like printed material.

PBR Preparation Step

1. Formation of Biodiversity Management Committee (BMC)
2. Sensitization of the public about the study, survey and possible management
3. Training of members in identification and collection of data on biological resources and traditional knowledge
4. Collection of data. *Data collections* includes review of literature on the natural resources of the districts, Participatory Rural Appraisal (PRAs) at village level, house hold interviews, individual interviews with village leaders and knowledgeable individuals, household heads, key actors of the panchayat raj institutions and NGOs and direct field observations
5. Analysis and validation of data in consultation with technical support group and BMC
6. Preparation of People's Biodiversity Register (PBR)
7. Computerization of information and resources.

Present status of PBR in India

Several State Biodiversity Board and Biodiversity Management Committee has taken at most importance to prepare the People biodiversity registers. However, some states have not initiated the work. Details of present status of the PBR is given below (Table 5)

Table 5. Present status of PBR in India

1.	Andhra Pradesh	25
2.	Arunachal Pradesh	43
3.	Assam	25
4.	Bihar	--
5.	Chhattisgarh	--
6.	Goa	--
7..	Gujarat	1164
8..	Himachal Pradesh	122
9.	Haryana	--
10	Jharkhand	14
11.	Jammu & Kashmir	--
12.	Karnataka	1777
13.	Kerala	892

14.	Madhya Pradesh	890
15.	Maharashtra	01
16.	Manipur	22
17.	Meghalaya	15
18.	Mizoram	5
19.	Nagaland	--
20.	Odisha	87
21.	Rajasthan	--
22.	Punjab	11
23.	Sikkim	4
24.	Tamil Nadu	--
25.	Telangana	67
26.	Tripura	431
27.	Uttar Pradesh	256
28.	Uttarakhand	124
29.	West Bengal	121
	Total	**6096**

Important sections of the Act

Sections	Activity covered	Purpose covered	Persons covered	Application form and fee
Section 3: Regulation of access to biological diversity	Obtaining any biological resource occurring in India or knowledge associated thereto.	Research, Commercial utilization, Bio-survey and Bio-utilization	Foreign citizens, NRIs, body corporate, associations or organizations not incorporated or registered in India or incorporated or registered in India which has any non-Indian participation in share capital or management (*Indians and Indian institutions do not require the approval of NBA when they engage in the above mentioned activities for said purpose*).	*Form I* Rs. 10000/-
Section 4: Transfer the results	Transfer of results of any research relating to biological resource occurring in India or obtained from India to any person covered under Section 3.	Transfer of research results for monitory considerations or otherwise.	Indian citizens, foreign citizens, NRIs, body corporate, associations or organizations incorporated or registered in India with or without any non-Indian participation in share capital or management and body corporate, associations or organizations not incorporated or registered in India	*Form II* Rs. 5,000/

Section 5: Collaborative research **#**	Transfer or exchange of biological resources or information relating thereto between the collaborating institutions. No IPR exemption is provided.	**#** Exemption Criteria: *The collaborative research project must be between institutions including government sponsored institutions and such institutions in other countries and to be approved by Central Government. The collaborative research project must conform with the Central Government guidelines* (Submit all relevant details to NBA as per guidelines).		
Section 6: Application for IPR *(If the IPR is a patent, application may be made to NBA after acceptance of patent application but before sealing the patent)*	Application of any IPR in or outside India for any invention based on any research or information on a biological resource obtained from India.	Obtaining IPR by whatever name called, in or outside India.	Indian citizens, foreign citizens, NRIs, body corporate, associations or organizations incorporated or registered in India with or without any non-Indian participation in share capital or management and body corporate, associations or organizations not incorporated or registered in India.	Form III Rs. 500/-
Section 7: exemption for local people/ hakims etc**.**	Obtaining any biological resource	Commercial utilization, Bio-survey and Bio-utilization for commercial utilization.	Indian citizens, body corporate, associations or organizations which are incorporated or registered in India and *not covered under Section 3* (*Local people/ communities practicing indigenous medicine including Vaidyas and Hakims, and growers and cultivators of biological diversity of local area are exempted from this provision*). *	
Section 21: Determination of equitable sharing of benefits	Rule 20 of the Biological Diversity Rules, 2004, deals with the procedural provisions for determining benefit sharing component of ABS agreements. It will be decided on case to case basis. NBA may decide whether the benefits could be in monitory or non monitory terms.			
Section 40: Exemption – Notification of biological resources as normally traded commodity (NTC).	Section 40 of the Act empowers the Central Government to exempt from its purview, any items including biological resources normally traded as commodities (NTACs), in consultation with NBA. The Ministry of Environment, Forest & Climate Change (MOEF&CC) had accordingly issued a notification under Section 40 dated October 26th, 2009 listing 190 biological resources to be exempted from the purview of the Act 2002 provided they are traded as commodities. A notification issued on 7th April, 2015 in supersession of the earlier one made it more comprehensive in terms of crop plants with information like trade/common name; part used, and sources procurement as cultivated or mixed (cultivated plus wild) and increased to 385 species, and inclusion of products derived from these as common practice being exempted from this Act through issue of this Notification is a major step towards a more rational implementation of the Act at the national level.			

Section 55: Penalties	Contravention or abatement of Contravention of provisions of section 3, 4, 6, 7 and 24 of the Act amounts to cognizable non-bailable offence. Penalties extend up to five years of imprisonment and ten lakhs rupees for offences under section 3, 4 and 6. Penalties extend up to 3 years of imprisonment and five lakh rupees for offences under section 7 and 24. In cases where the State Biodiversity Board needs to be intimated about the use of Indian biological resources and associated knowledge and this is not done, the punishment can extent to three years imprisonment or a fine of five lakh rupees or both. Any offence under the Act is cognizable and non-bailable.

* Submit prior information to the concerned state Biodiversity Board. Obtain relevant permits/ letters of no objection from the concerned SBB prior to commencement of activity.

CONCLUSION

National Biodiversity Authority implementing the act and rules with help of SBB, BMCs and other agencies, there were some instances of hurdles. NBA is solving such issues by bringing up several guidelines and clarifications. Implementation of the Act now started bringing benefits to the people who protect the biological resources or keeping the knowledge on biological resources. NBA also brought out norms for sharing the benefits to concerned people or communities.

When we realise different conditions and regulations within each act/ policy/ action plan it is easy to approach and formulate strategies and actions to resolve issues related to utilisation of different biological resources either for research, commercial or personal use. Whatever acts, rules and guidelines are available, people should learn to abide the rules and act accordingly. Otherwise biodiversity will continue to disappear from the world. Already so many species have disappeared from the earth and certain species yet to be discovered. If this trend continues, such species also disappear before its discovery.

REFERENCES

BSI, 2017. Floral Statistics of India 2017 http:// www. bsienvis.nic.in/ Database/ Floral_ Statistics_ of_ India_ 2017_26352.aspx visited on 10.09.18.

BSI, 2018. *Plant Discoveries 2017- New Genera, Species and New records.* Botanical Survey of India, Kolkata.

CBD, 1992. *Convention on Biological Diversity*, Secretariat of the Convention on Biological Diversity. Canada.

CBD, 2010. *Nagoya Protocol on access to genetic resources and the fair and equitable Sharing of benefits arising from their utilization*, The Convention on Biological Diversity, Secretariat of the Convention on Biological Diversity, Montreal.

CBD, 2011. Strategic Plan for Biodiversity-2011–2020, Secretariat of the Convention on Biological Diversity, Canada.

CBD, 2012. *Biosafety-Tools to advance implementation*, Secretariat of the Convention on Biological Diversity, Montreal.

CEPF, 2018. Announcing the World's 36th Biodiversity Hotspot (https://www.cepf.net/ stories/ announcing-worlds-36th-biodiversity-hotspot-north-american-coastal-plain)

Champion, H. G. and Seth, S. K. 1968. *A Revised Survey of Forest types of India*. Govt. of India, New Delhi.

Christenhusz and Byng, 2016. The number of known plant species in the world and its annual increase, *Phytotaxa* 261 (3):201-217.

CITES, 2013. Appendices I, II and III, Convention on International Trade in Endangered Species of Wild Fauna and Flora. www.cites.org

FSI. 2017. *India State of Forest Report*. Forest Survey of India, Dehradun.

IUCN, 1989. *The Ramsar Convention on the Conservation of Wetlands*, Environmental Policy and Law Paper, No. 23.International Union for Conservation of Nature and Natural Resources, Switzerland.

IWC, 1946. The International Convention for the Regulation of Whaling, 1946. The International Whaling Commission. Cambridge.

MAB, 1986. *Man and Biosphere Programme* 1986, http://www.unesco.org/ new/ en/ natural-sciences/environment/ecological-sciences/man-and-biosphere-programme visited on 09.08.2013.

MoEF, 2002. *The Biological Diversity Act*, 2002, Ministry of Environment & Forest, New Delhi, Government of India

MoEF, 2004. *Biological Diversity Rules*, 2004, Ministry of Environment & Forest, New Delhi, Government of India

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca and J. Kent. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.

Kew, R.B.G. 2016. The State of the World's Plants Report – 2016. Royal Botanic Gardens, Kew

Sanjappa, M. 2014. Floristic Diversity in India. Presented in 24th *Annual Conference of Indian Association for Angiosperm Taxonomy (IAAT) and International Conference on Trends in Plant Systematics (TIPS)* held at Tiruchirapalli, Tamil Nadu from 31st October to 2nd November, 2014.

UNEP, 2011.*Convention on the Conservation of Migratory Species of Wild Animals*. Vol. I, CMS Text, The Federal Ministry for the Environment, Germany

Venkataraman. K., Chattopadhyay, A. And Subramanian, K.A. 2013. *Endemic Animals of India (Vertebrates)*. Zoological Survey of India, Kolkatta.

ZSI, 2018. *Animal discoveries 2017: New Species and New records*. Zoological Survey of India, Kolkatta.

REINTRODUCTION OF RED-BILLED OXPECKER: MACROECOLOGICAL NICHE MODELS PREDICT SUITABLE HABITATS FOR THE CONSERVATION OF AN AVIAN MUTUALIST

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ABSTRACT

Distribution of mutualists is affected by changes in host-parasite densities and environmental conditions over time. The range contraction of Red-billed Oxpecker (*Buphagus erythrorhynchus*) in South Africa is a result of the widespread use of acaracides, toxic to both ticks and oxpeckers. We aimed at predicting suitable habitats, country-wide, for the threatened Red-billed Oxpecker using niche models to assist the ongoing reintroduction efforts and to identify new reintroduction sites for population recovery. We used biotic factors, climate, vegetation, topography, water and proximity to protected areas in our predictions and evaluated the predictive performance of all models using test data by applying generalized linear models, generalized additive models, boosted regression trees and ensemble models. Abiotic–biotic models described the current range of Red-billed Oxpecker in South Africa and outperformed the climate-only, veg-only, biotic-only, and climate-biotic models. The distribution of Red-billed Oxpeckers was influenced by moderate to high tree cover, woodlands, and starling density (a proxy for cavity-nesting birds) with regard to nest-site characteristics. Consumable resources (host and tick density), bioclimate, surface water body density, and proximity to protected areas were other influential predictors. Niche models reliably predicted suitable habitat in 40-61% of the reintroduction sites where breeding is currently successful. Our study highlights the need to involve biotic interactions within co-dependent species and its interactions with climate as key limiting factors when modelling the distribution of obligatory mutualists. Niche models serve as promising decision support tools for guiding reintroduction programs at macroscales. Active reintroductions, the use of oxpecker-compatible agrochemicals and installation of adequate nest boxes by farmers can facilitate population recovery of the species, in transformed landscapes. Prior to embarking on a reintroduction program, the effect of anthropogenic threats on habitat distributions must be investigated as the habitat in the historical range may no longer be viable for current bird populations.

Keywords: *Buphagus erythrorhynchus*, lethal agrochemicals, mutualistic interactions, oxpecker, reintroduction success, South Africa, species distribution model

1. INTRODUCTION

Complex networks (i.e food webs) of biotic interactions such as mutualisms are structured in ways that promote community and ecosystem stability (Neutel *et al.,* 2002; Rooney *et al.,* 2006; Ives and Carpenter, 2007). Keystone mutualists have tightly coevolved direct interactions among multiple species that jointly benefit from these interactions (Bezuidenhout and Stutterheim, 1980). Globally many mutualists have become extinct due to imminent host extinction (Koh *et al.,* 2004; Douda *et al.,* 2013), obligatory mutualists, in particular, suffer the most (Dunn *et al.,* 2009; Mellanby *et al.,* 2009). The disruption of biotic interactions (host-parasite complex, trophic relationships, plant-pollinator relationships), through direct/indirect human interventions within the mutualistic network and across multiple trophic levels has caused range declines of mutualists (Chacoff and Aizen, 2006; Traveset and Richardson, 2006; Ives and Carpenter, 2007) and species coextinctions (Aslan *et al.,* 2013).

In South Africa, anthropogenic pressures rather than climate-mediated habitat modification appears to be driving range contraction in many bird species (Okes *et al.,* 2008). Many wild vertebrate host species are endangered and as part of conservation efforts for threatened large mammals, a common practice is the removal of ectoparasites through chemical treatment, with devastating impact on hard-tick populations (Ixodides, *Hyalomma spp.* and *Amblyomma spp.*) (Mihalca *et al.,* 2011) and, in turn, leading to the population decline of avian consumers of ectoparasites (Bezuidenhout and Stutterheim, 1980). Habitat suitability modelling is being actively applied to conservation planning and reintroduction programs to recover populations of species with contracted ranges (Olsson and Roger, 2009; Chauvenet *et al.,* 2012; Cook *et al.,* 2016). However, predictions through distribution models must be realistic enough to accurately identify suitable and unsuitable habitats across vast geographical space.

The Red-billed Oxpecker *Buphagus erythrorhynchus* and Yellow-billed Oxpecker *B. africanus* are the world's only obligate mammal gleaners, endemic to the African continent. As keystone obligatory mutualists they have symbiotic relationships with mammalian hosts by emitting anti-predator warning calls and feeding on hard ticks to reduce the tick load (Bezuidenhout and Stutterheim, 1980). The Red-billed Oxpecker (hereafter called RBOs) has suffered a significant population decline throughout most of its global range and in South Africa (Feare and Craig, 1998), primarily as a result of the elimination of many wild host species (large game) and from the indiscriminate dipping of cattle. For example, the white rhinoceros *Ceratotherium simum*, a species which was recently driven nearly to extinction in much of Africa, is a preferred host for oxpeckers. The major factor influencing the decline of RBOs was the increasing use of acaracides (mainly arsenical compounds) in cattle dips from 1902 onwards (Bezuidenhout and Sttuterheim, 1980). With the advent of new dipping compounds, lethal to ticks, and the birds, the concept of re-establishing RBOs within their historic range became a viable option for increasing their distribution. Currently, dips containing organophosphates or home brews (where farmers mix chemicals to make their own homemade dips) are the main threat to populations of RBO in certain parts of South Africa. It is expected that the decline in host-parasite densities due to the aforementioned threats has caused range contractions of the RBO (Fig. 1).

Re-introductions and translocations have long been used as a tool for the population recovery and conservation of many wildlife species. In South Africa, translocations of RBOs have been implemented for a period of 22 years. The Endangered Wildlife Trust (EWT) has been capturing and relocating RBOs from areas of abundance to areas within their historical range from which they have been eliminated by inappropriate livestock dipping practices and oxpecker-incompatible pesticides since 2002. The receiving areas are sensitized by farmer awareness programs. Although reintroductions are the fastest way of expanding a species' range it is essential that the receiving areas are suitable' to ensure that the new founder population will establish and thrive. For this reason, identifying the suitable release areas through niche models for species persistence or identifying potential release sites for future oxpecker translocations are of utmost importance.

Quantitative information on the ecological niche of the species across vast geographic space could help restore locally-extinct populations, and prioritize regions for efficient management. In order to effectively direct conservation efforts for RBO in South Africa and to assess the success of reintroductions it is important to make realistic predictions in our niche models. Thus, the suitable habitat of RBO includes abiotic data (climate, topography and habitat) that include high resolution remote-sensing data, biotic consumable resources (i.e animal prey), and other biotic interactions (i.e co-occurring species, and host distributions). With the development of ecological theory and advanced niche modelling approaches, the role of interaction strength within mutualistic species (such as biotic predictors) and bio-physical interactions must be reflected in the distribution models for mutualists to make realistic predictions at large spatial scales. We applied predictive distribution modeling techniques; Generalized Linear Models (GLM), Generalized Additive Models (GAM), Boosted Regression Trees (BRT) and Ensemble models using long-term RBO occurrence data to develop habitat suitability maps to aid the ongoing reintroduction/translocation program and to develop recovery strategies for the RBO in South Africa. We tested the model's ability to reliably predict suitable habitat at the reintroduction sites.

2. MATERIALS AND METHODS

2.1 Presence/absence records of RBO

Several sources of occurrence records were considered: field data, citizen science data, and past and present literature collections from published papers. Field data included the ongoing capture and translocation programme by the EWT (2002-2014); translocations conducted by the South African National Parks (SANParks) (1988-1998) and bird ringing operations by the South African Bird Ringing Unit (SAFRING). Other presence-absence records were obtained from citizen science data of the South African Bird Atlas Project (SABAP1 and 2, http://sabap2.adu.org.za/). From the SABAP1 and 2 data the pentad centroids were considered as presence/absence records. All the records were pooled together and plotted using ArcMap 10. All the duplicate presence/absence records were removed. By using the "Selection by location" tool in ArcMap 10 we ensured only the spatially unique records of RBO such that every ~5 km^2 grid would contain only one record. This gave us 773 spatially unique records of RBO presence for our modelling (Appendix A).

2.2 Biotic and abiotic predictors

A systematic literature search based on ISI web of knowledge using the keywords "Red-billed Oxpecker and ecology" and "Red-billed Oxpecker" aided in gathering information on ecological predictors. We synthesized, and related relevant life history information on RBO from available literature, as a basis for designing and interpreting habitat models. Variables that are either known or suspected to correlate with RBO occurrence were considered (Appendix B). Some of the key requirements for successful reintroductions of RBO would be a fairly high density of host species (wild or domestic), along with suitable nesting sites, open habitat, high tick densities (as adequate food supply), and proximity to protected areas, water sources and land-use type. We compiled recent occurrence records on 20 symbiotic mammal species and six tick species from various sources. Occurrence records on mammal symbionts/wild host species were obtained from Mammal Map group (University of Cape Town), Ezemvelo KwaZulu-Natal Wildlife (http://www.kznwildlife.com/database.html), Durban Natural Science Museum and MANIS (http://www.manisnet.org). We also used the "spocc" package to download data from GBIF, and inat (http://www.inaturalist.org/) in R 3.11 (R Core Team, 2013). All wild host species records were pooled and duplicate records were discarded. An index of wild host density was calculated as a spatial layer based on spatially unique occurrence records, using the 'Kernel density' tool of the Spatial Analyst extension in ArcMap 10, for each ~5 km^2 grid, giving us the smooth surface raster as an index of abundance. *Amblyomma hebraeum* is the most numerous tick species on cattle, and *Rhipicephalus* (*Boophilus*) *microplus* and *B. decoloratus* are also abundant on wild host species, mainly the large mammals. *R.* (*B.) microplus* feeds more efficiently on cattle. Bont Tick, *A. hebraeum*, Blue Tick, *B. decoloratus*, Brown Ear-tick, *R. appendiculatus*, and Red-legged Tick, *R. evertsi evertsi* (Bezuidenhout and Stutterheim, 1980; Stutterheim *et al.,* 1988; Plantan, 2009) are preferred by RBO. Presence records of six major tick species were obtained from various sources including published literature and online sources (Appendix B). We calculated tick density following the same approach used to calculate wild host density. These indices provide a measure of the host and tick population and are most appropriate to model RBO distribution as RBOs generally thrive in areas with high tick density and large herds of wild game. Presence/absence records of six species of starlings were obtained from SABAP 1 and 2. We considered six widely distributed starlings as a proxy for suitable nesting sites because RBOs are secondary cavity nesters. RBOs naturally feed on ticks over cattle therefore we obtained domestic livestock density data from Food and Agriculture Organisation of the United Nations (FAO). We used 19 bioclimatic variables from WorldClim 1.4 (Hijmans *et al.,* 2005). Digital elevation data at 90 m resolution was aggregated to 5 km to quantify mean elevation. Elevation, top of the canopy reflectance (Copernicus data portal) and aspect were topographical variables. RBOs follow the movement of their mammal symbionts when surface water availability fluctuates seasonally causing a shift in local movements and when water supply decreases. RBOs frequently visit large rivers, often where large game congregate. Therefore, artificial surface water, surface water body density and distance to river were used as potential variables of water sources. Euclidean distance to rivers and protected areas were calculated using the "Euclidean distance tool" to create a raster "distance to" (km) layer, respectively. Vegetation variables included land cover, biomes, tree cover, leaf area index, and canopy height (Appendix B). Disturbance factors included human footprint index, burnt areas, and urbanization (Appendix B). All explanatory variables were clipped to South Africa. Individual raster layers of ~5 km^2 grids were created for each variable using the Zonal statistics tool in Spatial Analyst, ArcMap 10. All layers were resampled to ~5 km for consistency. We used the ellipse-shaped glyphs and Pearson correlation coefficients using the package "ellipse" (Murdoch and Chow, 2007) to remove variables with a correlation ≥0.7 (Appendix C).

2.3 Species distribution modeling

The relationship between abiotic-biotic variables and presence/absence of RBO was analyzed using various techniques. We included various combinations of predictors picked randomly in our models. To avoid over fitting in parametric models, we reduced complexity in GLM (McCullagh and Nelder, 1989) and GAM (Wood and Augustin, 2002) models by serially removing variables from a full model until a minimum Akaike information criterion (AIC) was achieved. In GAM, we used the automatic term selection procedure that enforces a penalty to smooth functions and efficiently eliminates terms from the model (Wood and Augustin, 2002). In GAM, the dimension of the basis used to represent the smooth term (k) was set to 5. Models were constructed in R 3.11 with packages 'mgcv' (Wood, 2011), 'gbm' (Ridgeway, 2013), and 'dismo' (Hijmans *et al.,* 2011). The "MuMIn" package (Barton, 2012) was used for model selection of GLM and GAM, providing AICc values and a ranked selection table for all possible combinations of variables (i.e. candidate models). Candidate models with ≤ΔAICc 2 were regarded as the best models (Burnham *et al.,* 2011). The relative importance of the predictors in GLMs and GAMs was calculated as the sum of the AIC weights over all models including the top models. We used the "effects" package in R to the fitted GLM models (Fox *et al.,* 2014) to display relationships between predicted probabilities and predictor sets.

BRT models followed scripts available in Elith *et al.* (2008). Models were constructed in R 3.11 with packages, 'gbm' (Ridgeway, 2013), and 'dismo' (Hijmans *et al.,* 2011). To increase the interpretability of the models, predictor sets were reduced using the 'gbm.simplify' function (Elith *et al.,* 2008). Using the reduced sets of variables, we fitted BRT models with a learning rate of 0.005, a tree complexity of 5 (the number of splits in each tree, also called the interaction depth), a bag fraction of 0.5 (the default setting of the fraction of the training set observations randomly selected to propose the next tree in the expansion, as suggested by (Elith *et al.,* 2008). We performed cross-validation optimization using a family of Bernoulli. This created 10 initial models of 50 trees. All other parameters were left at default settings. We applied BRT models to explore important interactions of predictors. The BRT analysis provided the relative contribution of each predictor. The relative influence of each variable was normalized to 100, with higher numbers indicating stronger influence on the response. We used the partial response plots to visualize the relative importance of the predictors to interpret the fitted functions in BRT and GAM. Categorical variables included land cover and biome in all our models.

We used an "ensemble" approach (Araújo and New, 2007) to combine predictions from multiple top performing models that varied in structure and parameterization as this is often more robust than predictions from a single model. Ensemble predictions were calculated with weights assigned to each modelling technique based on its discriminatory power, as measured by the area under the receiver-operated characteristic curve (Araújo and New, 2007). The data set was randomly divided into training (75%) and test set for model evaluation (25%). We constructed habitat suitability models for RBO at ~5 km x 5 km pixel resolution. We looked for agreement and disagreement among models to reliably predict suitability at the reintroduction sites.

2.4 Model evaluation and calibration

We assessed model performance based on the accuracy of predictions for both the training and the independent test data, and reported the area under the receiver-operating characteristic curve (AUC) as discrimination performance criteria. AUC values range from 0 to 1, where the value of 0.5 indicates that a model performs the same as a random assignment, and that values above 0.5 indicate increasing model discrimination between presences and absences; values below 0.5 indicate a reversed favouring of observations, with presences receiving lower fitted values than absences. We assessed model discrimination based on how well they predicted the training and test dataset according to the value of kappa. We reported kappa because it corrects for prediction success by chance and is considered a robust index (Manel and Williams, 2001). We calculated the Youden index, called the true skill statistic, as criteria for selecting the optimal cut-off value (i.e. the optimal threshold criteria called "Max sens + spec" in (Freeman and Moison, 2008). This index identifies the threshold that maximizes the sum of sensitivity and specificity and thereby enhances the possibility to differentiate between presence and absence of a condition when equal weight is given to sensitivity and specificity. All model evaluation statistics and calibration plots were calculated and developed using the package 'PresenceAbsence' in R 3.11 (Freeman and Moison, 2008).

3. RESULTS

3.1 Variable importance and response curves

Models with greater complexity (a higher number of predictor variables) in GAM and GLM tended to rank higher than simpler models, suggesting that the chosen variables were complementary to each other and that each explains unique amounts of variation in the data. Abiotic-biotic variables were present in the top ranked models (GLM $\sum w = 0.87$, GAM w = 0.51; Appendix D) and had a substantial contribution across all modelling methods. The general patterns showed that tree cover had the highest relative contribution followed by host density, bio8, land cover type, proximity to protected areas and livestock density. Woodland, forest, bushland, and built-on were predicted suitable habitats. Host density had a positive relationship with predicted occurrence of RBO (Appendix E: Fig. E1- E3). Temperature seasonality (bio8 = 20-25ºC) was predicted suitable while bio9 showed a bimodal response in GAM and BRT (Fig. E1 and Fig. E3). Areas receiving high summer rainfall (bio18 = 400-700 mm), and with south and west facing slopes were predicted suitable. There was a strong interaction strength between wild host density and distance to protected areas (0.88), between bio8 and distance to protected areas (0.76) and between wild host density and bio8 (0.7) while there was moderate strength between host and tick density (0.51, Fig. 2). Suitable sites were identified close to protected areas. Domestic livestock density had variable responses. Cattle density had a skewed response in BRT and GLM. Occurrence of Violet Backed Starling *Cinnyricinclus leucogaster* influenced the distribution of RBO however Wattled Starling *Creatophora cinerea* had a lower influence in BRT and was therefore dropped in the model. Tick density had hump shaped responses in GAM and BRT while it had a positive relationship in GLM. The top of the canopy reflectance showed bimodal patterns while the leaf area index had negative associations indicating that moderate vegetative cover was predicted suitable for RBO (Appendix E).

3.2 Model validation and extent of suitable habitat

High AUC values (>0.9) for all four models indicated that occupied sites were highly likely to be assigned a higher probability of presence than background sites irrespective of method. The calibration plots indicated that each of the tested models for RBO performed well (Appendix F: Fig. F1). All models had good accuracy (kappa > 0.5) with the test data. Cut-off values at 0.5 resulted in 42-57% of the test data being correctly classified (Table F1).

The present IUCN range of RBO (BirdLife International 2012) totally encompasses 2,22,885.15 km^2 (extent of occurrence) covering Gauteng (1313.07 km^2), KwaZulu-Natal (KZN) (36,515.46 km^2), Limpopo (1,23,312.87 km^2), Mpumalanga (34,963.97

km^2), North West (26,156.27 km^2), Northern Cape (619.37 km^2) and Free State (3.07 km^2). However, our predictions estimated the total suitable area (0.5-1) ranging from 45,903.72- 54,009.86 km^2 (Fig. 3) across all methods covering the majority of Limpopo, North West and Mpumalanga provinces, a substantial portion of northern KZN and few areas south in the Northern Cape that fall outside the historic range. The Limpopo province and northern KZN were predicted to have grids with higher suitability for RBO. Our models did not predict suitable areas in the Eastern Cape and areas inland from the coast and predicted fewer suitable sites south of KZN that included the historic range while some sites were identified in the Northern Cape which were outside the historic range. This suggests that there is a wide variation in the climatic suitability, distribution of wild hosts and tick species and threat levels between the Northern Provinces (Limpopo, North West, Northern Cape, Mpumalanga and north of KZN) and Southern Provinces (southern KZN and Eastern Cape, Fig. 3).

3.3 Ensemble models and model agreement

Differences in models were apparent, however, mainly in areas of the environmental space in the southern portion of South Africa that had lower data coverage. Ensemble models nearly appeared to match the "real world scenario" by adequately predicting suitable and unsuitable oxpecker habitat, especially when locations of reintroduction sites were compared to the predicted suitability values expected from each model. According to the ensemble models eleven out of 23 reintroduction sites (47%) in the bird's native range accurately predicted moderate to high suitable (i.e. 0.4-0.9) areas where the birds are successfully breeding. The remaining 12 sites were predicted with low and unsuitable habitats (≤ 0.3) in the Eastern Cape and southern KZN. Particularly in the Eastern Cape the breeding success and abundance has been lower compared to the Northern Provinces. On the contrary, the less conservative models; GLM, GAM and BRT predicted suitable sites in the Eastern Cape and southern KZN (93-560 km^2) suggesting that these models predicted spatially more suitable areas with potential for future reintroductions. BRT predicted spatially more number of sites with high suitability, indicating its higher predictive power than the other methods.

4. DISCUSSION

Distribution of RBO was best explained by a combination of environmental and biotic variables. Although ensemble models are criticized for being conservative they fairly matched the real world scenario. On the contrary the less conservative models like BRT and GAM aid in identifying potentially new release sites for future reintroductions. Most of the suitable sites predicted were in close proximity to conservation areas, provincial nature reserves, game reserves and national parks that are largely concentrated in the Northern Provinces where RBO populations have fairly recovered. These areas have adequate open savannas, woodlands, tree cover, and host-tick densities. However RBO conservation remains to be challenging at the wildlife/cattle interface outside of protected areas and inside a few protected areas subject to high levels of poaching for large game. The predicted suitability of RBO in the Northern Cape outside the historic range is linked to the increasing artificial woodlands (i.e *Prosopsis spp.*) with the spreading human habitats in the west of South Africa. This northward shift has been reported in many other bushveld species in South Africa (Hockey *et al.,* 2011). Assisted colonization of RBOs in the southern parts of the Northern Cape took operation in 2012 and these birds continue to persist suggesting that assisted colonization could help in the population recovery of species outside its historical range when sites in the native range are unsuitable provided these areas are monitored regularly (Chauvenet *et al.,* 2013). Particularly in the Eastern Cape the breeding success and abundance has been low in comparison to the Northern Provinces, which nearly matched our expectations from the suitability maps. BRT interaction plots showed that host-tick densities have increased in the warmer parts of South Africa and tick densities had no linear relationship with host densities suggesting that despite areas having high wild host densities; mainly in the Northern Provinces the tick densities are reported to be low and therefore not directly proportional. Although the Northern Provinces were predicted with highly suitable habitats, the excessive arsenic use in farmlands remains to be a major threat throughout its range (Ramudzuli and Horn, 2014) and particularly in the Northern Provinces; this being the main reason for low tick densities. Land transformation through subsistence and commercial agriculture has increased in the northeast parts of South Africa (Okes *et al.,* 2008).

Our maps showed that particularly, small game reserves and farmlands with urban surrounds, bushland, and adequate domestic host densities could also be considered as suitable release sites in landscapes that have lost its savanna/open woodland habitat. We attribute this to the changing tick and host community structure and densities due to the diverse land management systems such as cattle ranches, wildlife-cattle ranches and private game reserves (Smith and Parker, 2010). The agricultural industry has grown in the Eastern Cape and in the KwaZulu-Natal Provinces. However there is a possibility that the proliferation of game farming could facilitate the expansion of RBO distributions with the help of farmers, as they are effective biological controllers of ticks and the species could switch to domestic hosts in the long-term. In the Eastern Cape specifically, farm owners will need to maintain high densities of blue ticks and brown ear ticks to support RBO populations. In transformed landscapes sufficient tree cover would be scarce as most of the savanna habitat has been converted to croplands to boost agricultural development. In these areas strategic placement of nest boxes would ease the pressure on natural nest holes in trees to facilitate breeding by RBOs as artificial nest cavities are readily accepted by the birds. This is a prerequisite for receiving sites in the ongoing translocations by the EWT. This strategy would help restore populations in the Eastern Cape and southern KwaZulu-Natal although these provinces have comparatively less tree cover. Species with dissimilar niches can coexist (Krebs, 2009), however, Morelli and Tryjanowski (2015) pointed out that this relationship may rather function at a local scale. Compared with the Wattled Starling, the Violet Backed Starling is spatially correlated with the RBO's present range in South Africa, based on the reporting rates by SABAP2. Therefore it is possible that RBO can co-occur with both of these starling species as their niches are not identical to that of the RBO in terms of foraging habits and habitat preferences. This minimizes the chance of competition for space and resources. Our models did not predict suitable areas in the Eastern Cape and Free State provinces and many areas inland which were part of the historic range of RBO, primarily due to the loss of tree cover as a result of heavy land transformation for farming.

Our correlates of long-term distribution (last 10 years) showed that the range of RBO still remains contracted in comparison to its historic range despite several long-term efforts invested in the translocation and reintroduction of the species. Although RBO may sparsely occur in a few historic sites despite the loss of natural prey and host species, they could exhibit parasitic feeding behavior on domestic livestock where tick densities are low. If environmental conditions in historic sites are suitable currently, RBOs would have naturally dispersed to these areas unless we assume that mutualists have low dispersal abilities (Yamamura *et al.,* 2004). The ongoing capture-release programmes in their historic sites which also include farmlands facilitate the formation of new biotic interactions (RBO-domestic host interactions) with both positive and potential negative effects, considering their sometimes parasitic feeding behaviour. Although farmlands have high livestock densities, in areas where RBOs have been sighted by bird-ringing groups, it is unclear whether these areas are suitable in terms of breeding and if populations will be viable. In such areas we might expect RBOs to exhibit parasitic behavior by feeding on blood, saliva and open wounds of domestic livestock primarily due to the reduction in tick densities (Nunn *et al.,* 2011) as a result of the excessive use of cattle dips. Such forms of parasitic behavior lead to conflicts between farmers and RBOs, hampering capture-release operations especially in farmlands in semi-urban areas, when farmers do not welcome the presence of RBO. To further elucidate these patterns in feeding behavior along their historic and current range, we need more experimental studies specifically to determine if RBO-mammal interactions in farmlands are mutual or parasitic (Plantan, 2009) and whether this can be attributed to low tick densities.

4.1 Conservation implications

Our models that explicitly incorporated biotic relationships (trophic relationships and host affiliations) and biotic interactions with environmental factors aid in realistic species distribution patterns of RBO. Models had good predictions of suitability at reintroduction sites even at the nation-wide scale; however for improved accuracy models must be refined with the updated spatial layers of livestock density estimates and many others in order to reflect the ground reality. This paves new directions to conservation efforts that make use of niche models with high predictive power. This countrywide approach to suitability mapping helps delineate recommendations for future capture-relocation activities aimed at spatially integrating the major components of their distribution. In the future, post-release monitoring is needed to determine the RBO's breeding status and survival rates in human-modified areas. Till today 23 translocations of a total of 598 birds have been successful and reintroductions of RBOs have occurred country-wide. Many landowners have since switched to using oxpecker-compatible tick control products are keen to have them on their farmlands. The conservation status of the Red-billed Oxpeckers has thus improved in South Africa. Their national conservation status has recently been changed to Least Concern from previously being listed as Near Threatened. On the other hand many commercial and some rural subsistence farmer's use dips i.e acaricides at short intervals to keep their cattle virtually tick-free. With the use of oxpecker-compatible dips in conjunction with the active reintroductions, the RBO has started to recover in some areas, although its range still remains contracted. Such management strategy with the help of local farmer's support will continue to restore RBO populations in a few areas within their historic range. Arsenic and organophosphate based compounds should be avoided if communities wish to collectively increase RBO populations in their region. Conservation measures should make use of improved niche models that explicitly focus on abiotic-biotic factors incorporating the complete ecology of the species in predicting habitat suitability of other threatened mutualists that are declining globally (Dunn *et al.,* 2009). Our model can primarily be tested as released RBOs disperse from the reintroduced. In principle, the model could best be tested by releasing RBOs both in areas predicted to be good RBO habitats and in those not predicted to be so, for further validation. Our results highlight the areas within the country that are currently suitable for RBO with no or little interventions needed. However, in terms of possible sites for future reintroductions, areas such as the Eastern Cape and southern KwaZulu-Natal could be considered provided there is some woody cover and sufficient nest boxes are made available to the birds. Interfaces between protected and private lands constitute sharp transitions between areas occupied by host communities that are extremely contrasted in terms of composition, diversity and density and this makes RBO conservation challenging. Our models also predicted suitable areas outside protected areas suggesting that RBO conservation should focus on areas not formally protected under conservation laws. If private areas are well managed, with the cooperation of landowners regarding the use of oxpecker-compatible agrochemicals, the long-term survival of RBO in South Africa seems promising. Ultimately, whether RBOs persist on new hosts/livestock will depend on how quickly they are able to evolve to increase their fitness. Our results provide a scientifically-based platform for highlighting suitable habitat for RBOs, to ensure long-term survival. We recommend that any capture-release programme first assesses the potential habitat currently available to the species in question, as our findings show that not all areas within the species' historic range have suitable habitats for reintroductions.

Conflict of Interest

The funding bodies played no role in the study design, data collection, analysis, and interpretation of data, report writing and decision to submit the article for publication. Authors have no conflict of interest.

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REFERENCES

Araújo, M.B. and New, M. 2007. Ensemble forecasting of species distributions. *Trends. Ecol. Evol.* 22: 42–47.

Aslan, C.E., Zavaleta, E.S., Tershy, B. and Croll. D. 2013. Mutualism disruption threatens global plant biodiversity: a systematic review. *PLoS One* 8: e66993.

Barton, K. 2012. MuMIn: Multi-model inference. R package version 1.7.7. http://CRAN.R-project.org/package = MuMIn.

Bezuidenhout, J.D. and Stutterheim, C.J. 1980. A critical evaluation of the role played by the red-billed oxpecker *Buphagus erythrorhynchus* in the biological control of ticks. *Onderstepoort. J. Vet. Res.* 47: 51-75.

Burnham, K.P., Anderson, D.R. and Huyvaert, K. 2011. AIC model selection and multimodel inference in behavioral ecology: some background, observations, and comparisons. *Behav. Ecol. Socio.*, 65:23–35.

BirdLife International. 2012. *Buphagus erythrorhynchus*. The IUCN Red List of Threatened Species 2012: e.T22711009A39697998.

Chacoff, N. P. and Aizen, M. A. 2006. Edge effects on flower-visiting insects in grapefruit plantations bordering premontane subtropical forest. *J. Appl. Ecol.* 43, 18–27.

Chauvenet, A.L.M., Ewen, J.G., Armstrong, D.P., Blackburn, T.M. and Pettorelli, N. 2013. Maximizing the success of assisted colonizations. *Anim. Conserv.* 16: 161–169.

Cook, C.N., Morgan, D.G. and Marshall, D.J. 2010. Reevaluating suitable habitat for reintroductions: lessons learnt from the eastern barred bandicoot recovery program. *Anim. Conserv.* 13: 184–195.

Douda, K., Lopes-Lima, M., Hinzmann, M., Machado, J., Varandas, S., Teixeira, A., Sousa and R. 2013. Biotic homogenization as a threat to native affiliate species: fish introductions dilute freshwater mussel's host resources. *Divers. Distrib.* 19: 933–942.

Dunn, R.R., Harris, N.C., Colwell, R.K., Koh, L.P. and Sodhi, N.S. 2009. The sixth mass coextinction: are most endangered species parasites and mutualists? *Proc. R. Soc. Lon., B* 276: 3037-3045.

Elith, J., Leathwick, J.R., Hastie, T. 2008. A working guide to boosted regression trees. *J. Anim. Ecol.* 77: 802–813.

Feare, C. and Craig, A. 1998. Starlings and Mynas. Helm, London.

Fox, J., Weisberg, S., Friendly, M. and Hong, J. 2014. effects: Effect Displays for Linear, Generalized Linear, Multinomial-Logit, Proportional-Odds Logit Models and Mixed-Effects Models. R package version 3.0-0.

Freeman, E.A. and Moison, G.G. 2008. PresenceAbsence: An R package for presence - absence model analysis. *J. Stat. Soft.* 23: 1-31.

<http://www.jstatsoft.org/v23/i11> Accessed January 9, 2014.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G. and Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. *Int. J. Climatol.* 25:1965-1978.

Hijmans, R. J., Phillips, S., Leathwick, J. and Elith, J. 2011. Dismo: Species distribution modeling. - R package version 0.7-11. http://CRAN.R-project.org/package= dismo.

Hockey, P. A. R., Sirami, C., Ridley, A. R., Midgley, G. F. and Babiker, H. A. 2011. Interrogating recent range change in South African birds: confounding signals from land use and climate change present a challenge for attribution. *Divers. Distrib.* 17: 254–61.

Ives, A. R. and Carpenter, S. R. 2007. Stability and diversity of ecosystems. *Science* 317: 58–62.

Kiers, E. T., Palmer, T. D., Ives, A. R., Bruno, J. F. and Bronstein, J. L. 2010. Mutualisms in a changing world: an evolutionary perspective. *Ecol. Lett.* 13: 1459–1474.

Koh, L. P., Sodhi, N. S. and Brook, B. W. 2004. Co-extinctions of tropical butterflies and their hostplants. *Biotropica* 36: 272–274.

Krebs, C. J. 2009. Ecology, 6th edn. Benjamin Cummings, San Francisco.

Manel, S. and Williams, H. C. 2001. Evaluating presence–absence models in ecology: the need to account for prevalence. *J. Appl. Ecol.* 38: 921–931.

McCullagh, P. and Nelder, J. A. 1989. Generalized Linear Models. Chapman and Hall, Washington, DC, USA.

Mellanby, R. J., Broadhurst, C., Wondafrash, M., Ewnetu, M., Watt, S., Critchlow, R., Dadesa, A., Deasa, T., Enawgaw, C., Gebremedhin, B., Graham, E., MacLean, S. and Ross, B. 2009. A perceived local extinction of red-billed oxpeckers in the Yabelo region, southern Ethiopia. *Ostrich* 80: 197-199.

Mihalca, A. D., Gherman, C. M. and Cozma, V., 2011. Coendangered hard-ticks: threatened or threatening. *Parasit. Vectors.* 4: 71.

Morelli, F. and Tryjanowski, P. 2015. No species is an island: testing the effects of biotic interactions on models of avian niche occupation. *Ecol. Evol.* 5: 759-768.

Murdoch, D. and Chow, E. D. 2007. Ellipse: functions for drawing ellipses and ellipse-like confidence regions. R Package Version 0.3 – 5.

Neutel, A. M., Heesterbeek, J. A. P. and de Ruiter, P. C. 2002. Stability in real food webs: weak links in long loops. *Science* 296:1120–1123.

Nunn, C. L., Ezenwa, V. O., Arnold, C. and Koenig, W. D. 2011. Mutualism or parasitism? Using a phylogenetic approach to characterize the oxpecker‐ungulate relationship. *Evolution* 65: 1297-1304.

Okes, N. C., Hockey, P. A. R. and Cumming, G. S. 2008. Habitat use and life history as predictors of bird responses to habitat change. *Conserv. Biol.* 22: 151–162.

Olsson, O. and Rogers, D. J. 2009. Predicting the distribution of a suitable habitat for the white stork in Southern Sweden: identifying priority areas for reintroduction and habitat restoration. *Anim. Conserv.* 12: 62–70.

Plantan, T. B. 2009. Feeding behavior of wild and captive oxpeckers (*Buphagus spp.*): A case of conditional mutualism. PhD Thesis, University of Miami, Coral Gables, FL.

Ramudzuli, M. R. and Horn, A. C. 2014. Arsenic residues in soil at cattle dip tanks in the Vhembe district, Limpopo Province, South Africa. *South. Afr. J. Sc.* 110, 1-7.

R Core Team, 2013. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Ridgeway, G., 2013. Gbm: generalized boosted regression models. R package version 2.1. Available from <http://cran.r-project.org/web/packages/gbm/> (accessed June 2013).

Rooney, N., McCann, K., Gellner, G. and Moore, J. C. 2006. Structural asymmetry and the stability of diverse food webs. *Nature* 442: 265–269.

Smith, E. R. and Parker, D. M. 2010. Tick communities at the expanding wildlife/cattle interface in the Eastern Cape Province, South Africa: implications for Corridor disease. *J. South. Afr. Veter. Assoc.* 81: 237-240.

Stutterheim, C. J. 1982. Past and present ecological distribution of the red-billed oxpecker (*Buphagus erythrorhynchus*) in South Africa. *South. Afri. J. Zool.* 17: 190–196.

Stutterheim, I. M., Bezuidenhout, J. D. and Elliott, E. G. 1988. Comparative feeding behaviour and food preferences of oxpeckers (*Buphagus erythrorhynchus* and *B. africanus*) in captivity. *Onderstepoort. J. Vet.,* 55:173-179.

Traveset, A., Richardson, D.M., 2006. Biological invasions as disruptors of plant reproductive mutualisms. *Trends. Ecol. Evolut.* 21: 208–216.

Wood, S.N., Augustin, N.H., 2002. GAMs with integrated model selection using penalized regression splines and applications to environmental modelling. *Ecol. Model.* 157: 157–177.

Wood, S. N. 2011. Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. *J. R. Stat. Soc. B.* 73: 3–36.

Yamamura, N., Higashi, M., Behera, N., Wakano, J.Y., 2004. Evolution of mutualism through spatial effects. *J. Theor. Biol.* 226: 421-428.

Figure 1. Theoretical expectations about the underlying mechanisms of range changes in obligatory mutualists. a) Typically host and tick densities are directly proportional positively where we expect RBO to occupy its full range, b) In the presence of human interventions, in this case excessive use of invasive agrochemicals we expected a negative relationship where the decrease in host and tick densities results in population decline and consequently range contractions of the RBO.

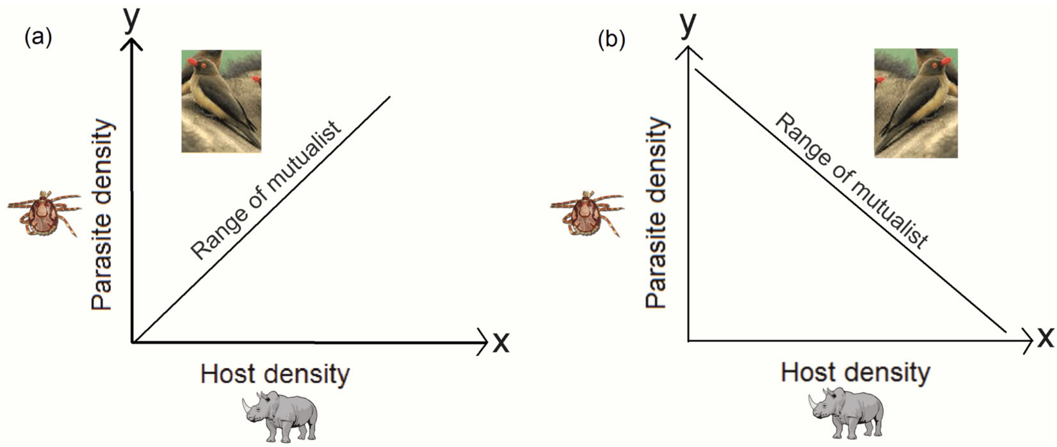


Figure 2. 3-D plots depicting interaction strength between influential predictors from BRT model. For explanations on abbreviations please refer to Appendix B.

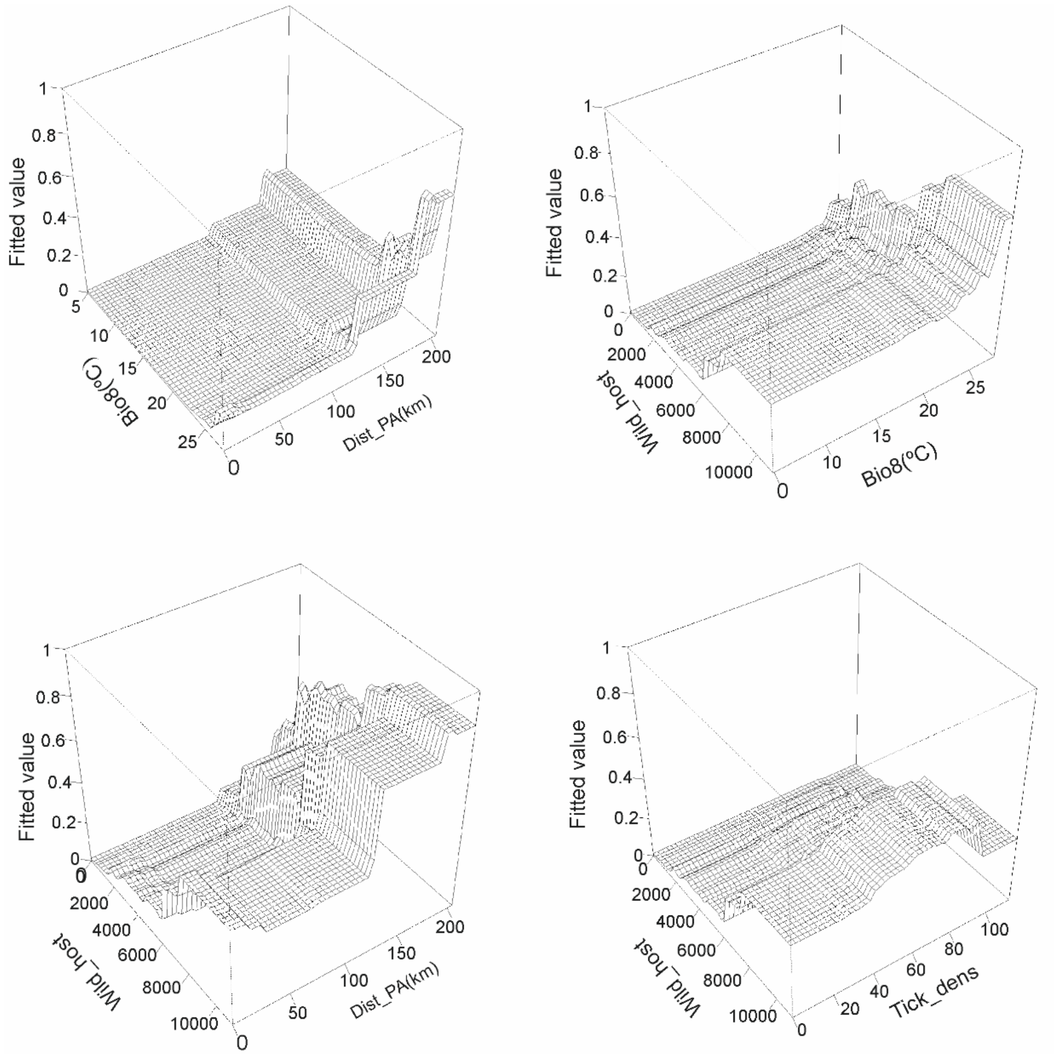
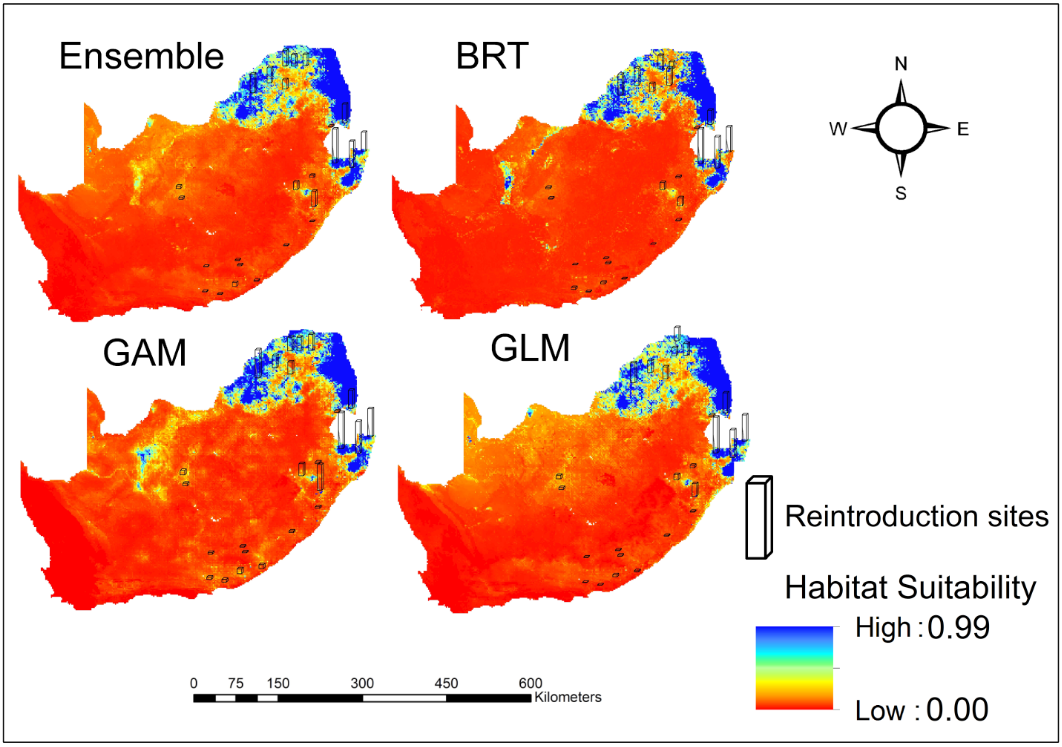
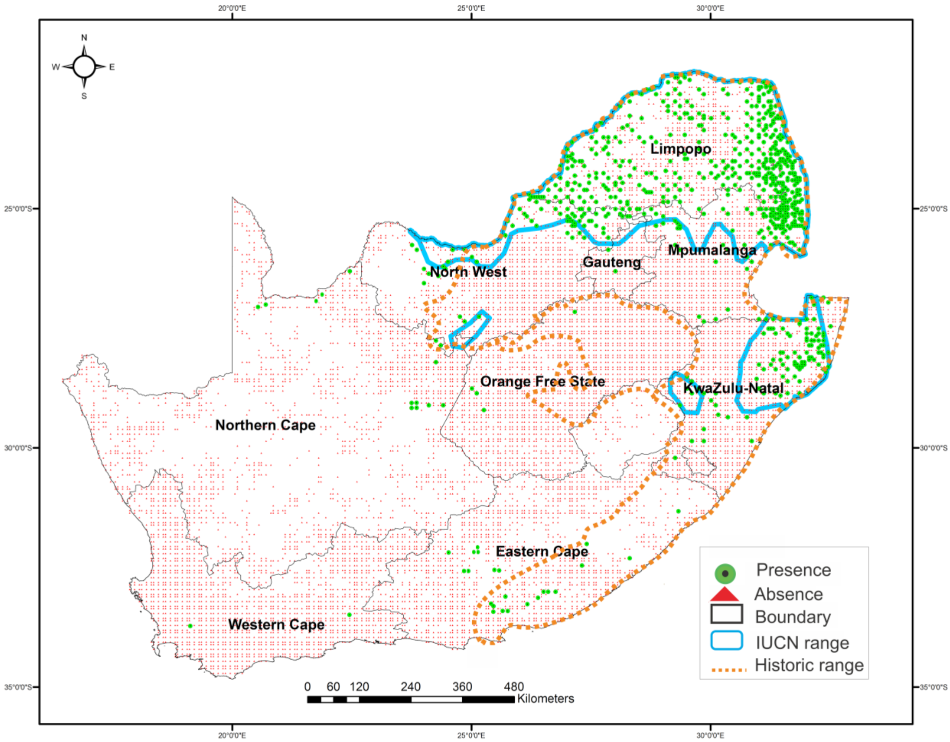


Figure 3. Habitat suitability map from ensemble models, BRT, GAM and GLM for predicting the distribution of RBO in South Africa. The rectangular bars are the quantitative representation of the predicted suitability values from each model at the reintroduction site. The taller the bar, the higher is the predicted suitability value.



APPENDIX A. Spatially unique presence-absence records of RBO in South Africa. The map shows the historic range from Stutterheim (1982) and the current IUCN range (BirdLife International, 2012). Absence records were taken from SABAP 1 and 2.



APPENDIX B. Abiotic and biotic predictors considered in the distribution models for the Red-billed Oxpecker

Variables	Justification and methodology	**Type and *code***	**Source/Reference**
Biotic variables			
Wild host species density (African Buffaloe *Syncerus caffer*, White Rhino *Ceratotherium simum*, Black Rhino *Diceros bicornis*, Giraffe *Giraffa camelopardalis*, Plains Zebra *Equus quagga*, Mountain Zebra *E. zebra*, Eland *Tragelaphus oryx*, Impala *Aepyceros melampus*, Kudu *Tragelaphus strepsiceros*, Warthog *Phacochoerus africanus*, Nyala *Tragelaphus angasii*, Bushbuck *T. scriptus*, Sable *Hippotragus niger*, Blue Wildebeest *Connochaetes taurinus*, Black Wildebeest *C. gnou*, Waterbuck *Kobus ellipsiprymnus*, Roan Antelope *Hippotragus equinus*, Heartbeest *Alcelaphus buselaphus*, Hippopotamus *Hippopotamus amphibius*, African Elephant *Loxodonta africana*)	Mammal host species are useful perches for oxpeckers to feed on ticks, flies and other ectoparasites. The presence of a host animal is imperative for successful breeding (Plantan *et al.,* 2014). Although many studies have reported preference for some host species, we did not limit our data to this as in recent times it has been reported that they have to rely on multiple host species (both large game and domestic livestock) for survival due to the decline in wild game populations. We browsed through Google Scholar literature that recorded any oxpecker interactions or associations with host species eg. feeding, scissoring, perching, pecking etc) based on which we considered 20 host species as potential wild symbionts. Multiple data sources for occurrence records were considered All were pooled and plotted in ArcMap 10. Duplicate/overlapping records were removed. Kernel density was calculated to represent an index of host density.	Continuous *wild_host*	Past published papers documenting any host-oxpecker interactions. Occurrence records were obtained from the "spocc" package (GBIF, inat) in R (Chamberlain *et al.,* 2014). Additional data was taken from the Ezemvelo KwaZulu-Natal Widlife, Mammal map (University of Cape Town), Manis and Durban Museum.
Domestic livestock density (cattle , goat, sheep)	A large portion of natural habitat has been lost from excessive farming in South Africa. But these farmlands have high domestic livestock densities which can still support RBO populations due to the high tick load.	Continuous cattle, goat, sheep	Global Gridded Livestock data Food and Agriculture Organisation of the United Nations (FAO) (http://www.fao.org/ag/againfo/resources/en/glw/GLW_dens.html)

Starling occurrence (Black-bellied Starling *Lamprotornis corruscus*, Cape Glossy Starling *L. nitens*, Red-Winged Starling *Onychognathus morio*, Violet-backed Starling *Cinnyricinclus leucogaster*, Wattled Starling *Creatophora cinerea* and Pied Starling *Spreo bicolor*)	RBOs are secondary cavity-nesters, and need available cavities that occur naturally in the environment. Presence/absence of other starlings indicates potential nesting sites suitable for Sturnidae species which would be helpful in spatial predictions of RBOs. Using associated species in distribution models for a target species improves the predictive performance of the modelled species (Morelli and Tryjanowski, 2015) Presence/absence records of starlings were obtained from pentad centroids in SABAP 1 and 2.	Presence/absence blackbell_star, capeglossy_star, red-winged_star, violback_star, wattled_star and piedstar	South African Bird Atlas Project 1 and 2 (http://sabap2.adu.org.za/)
Tick density (*Rhipicephalus appendiculatus*, *Amblyomma hebraeum*, *R.* (*B.*) *decoloratus*, *R.* (*B.*) *microplus*, *R. evertsi evertsi*, *Hyalomma truncatum*	Selected tick species were identified from literature. Only six tick species records were considered since these were preferred by RBOs (Bezuidenhout and Stutterheim, 1980; Weeks, 2000; Plantan *et al.,* 2014). We pooled all the records and removed the spatially overlapping records. Kernel density was calculated to represent an index of tick density.	Presence tick_dens	Data by Cumming (2002) accessed from http://www.vectormap.org/, Dr. Arthur Spickett provided the updated additional data and other records were procured using the "spocc" package in R.
Climate			
Worldclim data (19 bioclimatic variables)	Temperature and rainfall are factors determining the distribution of ticks (Howell *et al.,* 1978). Across its range oxpeckers tend to be found in slightly wetter areas of savanna.	Continuous Codes follow the source link	Hijmans *et al.,* 2005 (http://www.worldclim.org/bioclim)
Topography			
Aspect (East, West, North, South, Undefined)	North: 0˚< aspect ≤45˚ or 315˚< aspect ≤360˚ East: 45˚ < aspect ≤ 135˚ South: 135˚ < aspect ≤ 225˚ West: 225˚ < aspect ≤ 315˚ Undefined: Slope aspect undefined; this value is used for grids where slope gradient is undefined or slope gradient is less than 2%.	Continuous aspect_E, aspect_W, aspect_N, aspect_S, aspect_U	Fischer *et al.,* 2008 http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/global-terrain-slope-download.html?sb=7

Elevation (m)	Digital elevation data at 90 m resolution was aggregated to 5 km resolution to quantify mean elevation using the Zonal statistics tool in Arcmap 10.	Continuous elevation	Digital Elevation Model (http://data.fao.org/map?entryId=5c439c10-e77b-11db-a939-000d939bc5d8&tab=metadata)
Top of the canopy reflectance	This is a biophysical component that captures the canopy structure that could have an effect on oxpecker distribution.	Continuous tocr	Copernicus data portal (http://land.copernicus.eu/global/products/toc-r)
Vegetation			
Land cover		Categorical land cover	Southern Africa Development Community (SADC) from CSIR
Biomes	Red-billed Oxpeckers of South Africa, favour the savanna and bushveld vegetation types (Feare and Craig, 1998).	Categorical biome	2009 National Land Cover (SANBI, 2009)
Leaf area index	As a measure of vegetation density	Continuous lai	Copernicus data portal (http://land.copernicus.eu/global/products/lai)
Tree cover	Oxpeckers are strictly secondary cavity nesters relying on tree holes for breeding therefore adequate tree cover is an important element in a suitable site.	Continuous tree cover	Global Land Cover 2014 (http://www.glcn.org/databases/lc_glcshare_en.jsp)
Canopy height	Oxpeckers often nest in tall trees for protection against predators.	Continuous canopy_ht	Simard *et al.*, 2011. (http://lidarradar.jpl.nasa.gov/)
Cropland	Croplands indirectly represent areas with livestock mainly cattle, sheep and goat. Oxpeckers are being sighted in farmlands of South Africa.	Continuous cropland	Global Land Cover 2014 (http://www.glcn.org/databases/lc_glcshare_en.jsp)
Grassland	The habitat preference of hosts influences the rate at which ticks are consumed by oxpeckers. Hosts are more likely to be selected when in habitat types that increase the visibility of hosts to oxpeckers, such as in open grassland versus closed woodland (Mooring and Mundy, 1996).	Continuous grassland	Global Land Cover 2014 (http://www.glcn.org/databases/lc_glcshare_en.jsp)
Water			

Distance to river	Oxpeckers have been frequently sighted close to large rivers often where large game congregate. Polyline feature was used to calculate Euclidean distance to river (km) using the Spatial Analyst Tool in ArcMap 10.	Continuous distance to river	Rivers of Africa derived from World Wildlife Fund's (WWF) HydroSHEDS (http://data.fao.org/map?entryId=b891ca64-4cd4-4efd-a7ca-b386e98d52e8&tab=metadata)
Surface water body density	The presence and abundance of tick species varies locally according to many factors, including host availability. Surface water availability fluctuates seasonally causing a shift in local movements of large mammal symbionts and in areas where locally seasonal migration occurs where water supply decreases we would expect oxpeckers to survive only by following the movement of their symbionts. Oxpeckers often perch on their host species close to water bodies. They are often observed drinking from the same waterhole and simply fly down from the host to the water; and back again once they have quenched their thirst.	Continuous surface water	GEOnet Gazetteer and Southern Africa Development Community (SADC)-WRD Surface (http://data.fao.org/map?entryId=76d117a0-b06d-11db-8922-000d939bc5d8&tab=about and http://data.fao.org/map?entryId=eb0d2910-e362-11db-a939-000d939bc5d8, respectively)
Artificial surface water		Continuous artif_surfw	Global Land Cover 2014 (http://www.glcn.org/databases/lc_glcshare_en.jsp)
Proximity			
Distance to protected areas	Their dependence on game animals means they are naturally common in protected parks and reserves, where large herds are found. Euclidean distance to protected areas (km) was calculated using the "Euclidean distance tool" in Spatial Analyst, ArcMap 10.	Continuous dist_PA	UNEP-WCMC (2012). Data Standards for the World Database on Protected Areas. UNEP-WCMC: Cambridge, UK. (http://www.protectedplanet.net/)
Disturbance			
Urbanization	Urbanisation could impose a negative effect on oxpecker distribution.	Continuous urbanisation	Seto *et al.*, 2012
Human footprint Index		Continuous hfp	Last of the Wild Data Version 2, (2005) http://sedac.ciesin.columbia.edu/data/collection/wildareas-v2
Burnt areas	Veld burning is likely to have a major impact on vegetation structure and cover and thus on tick survival at different life-stages.	Presence/absence burnt	SAFARI (2000) Global Burned Area Map, 1-km, Southern Africa, (http://daac.ornl.gov/cgi-bin/dataset_lister.pl?p=18#vegetation_wetlands)

REFERENCES

Chamberlain, S., Ram, K. and Hart, T. 2014. spocc: R interface to many species occurrence data sources. R package version 0.1.0. https://github.com/ropensci/spocc.

Cumming, G. S. 2002. Comparing climate and vegetation as limiting factors for species ranges of African ticks. *Ecology* 83:255-268.

Fischer, G., Nachtergaele, F. O., Prieler, S., van Velthuizen, H. T., Verelst, L. and Wiberg, D. 2008. Global Agro-Ecological Zones Assessment for Agriculture (GAEZ 2008) - IIASA, Laxenburg, Austria.

Howell, C. J., Walker, J. B. and Nevill, E. M. 1978. Ticks, mites and insects infesting domestic animals in South Africa. Part 1. Descriptions and biology. Department of Agricultural Technical Services, Republic of South Africa. (Science Bulletin no. 393).

Last of the Wild Data Version 2, 2005. (LTW-2) Global Human Footprint Dataset (Geographic). Wildlife Conservation (WCS) and Center for International Earth Science Information Network (CIESIN).

Mooring, M. S. and Mundy, P. J. 1996. Factors influencing host selection by yellowbilled oxpeckers at Matobo National Park, Zimbabwe. *Afr. J. Ecol.* 34:177-188.

Plantan, T. B., Howitt, M. J., Kotzé, A. and Gaines, M. S., 2014. Breeding biology of Redbilled oxpeckers *Buphagus erythrorhynchus* at the National Zoological Gardens of South Africa. *Int. Zoo. Yearb.* 48: 92-100.

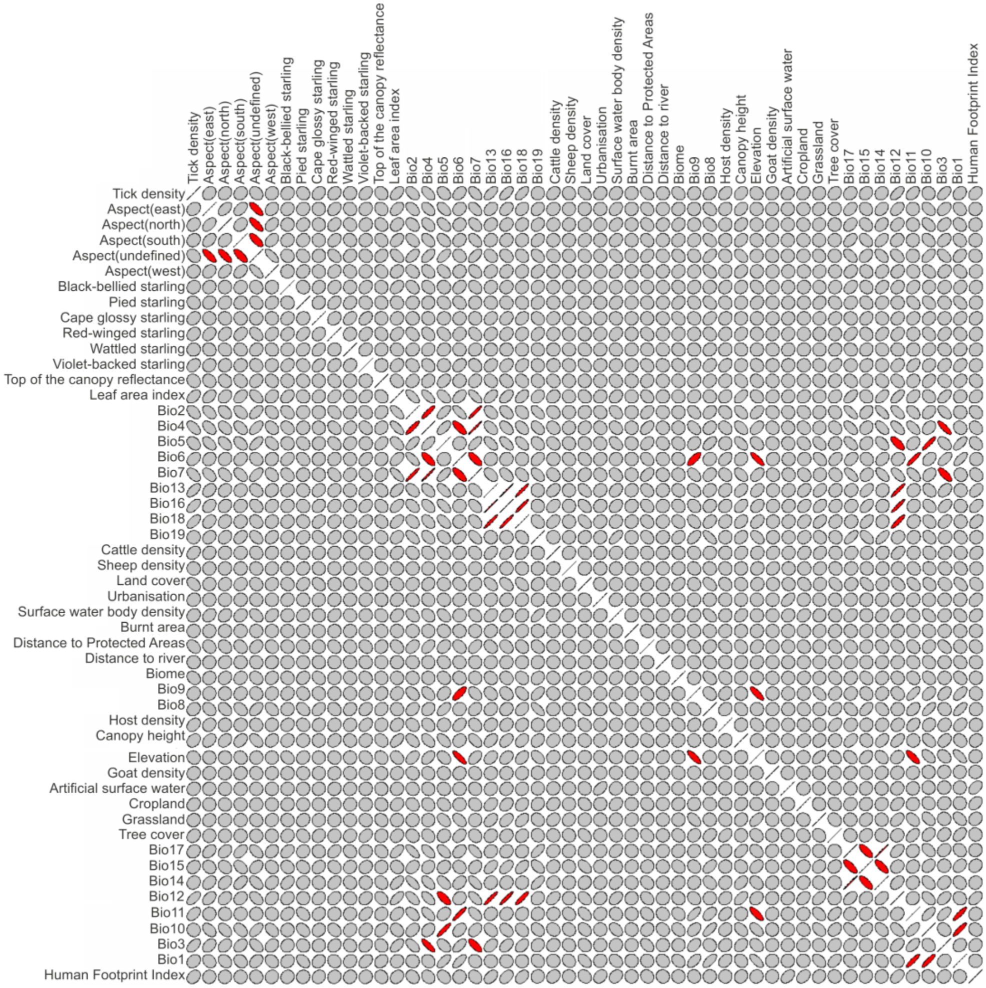
SANBI 2009. Updating national landcover. South African National Biodiversity Institute, Pretoria. Unpublished report. Available at http://bgis.sanbi.org/landcover/project.asp

Seto, K. C., Güneralp, B. and Hutyra, L. R. 2012. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proc. Natl. Acad. Sci. USA.* 109:16083-16088.

Simard, M., Pinto, N., Fisher, J. B. and Baccini, A. 2011. Mapping Forest Canopy Height Globally with Spaceborne Lidar. *J. Geophys. Res. Biogeosci.* 116: G04021.

Weeks, P., 2000. Red-billed oxpeckers: vampires or tickbirds?. *Behav. Ecol.* 11:154-160.

APPENDIX C. Correlation plot of predictor variables at occurrence points of the Red-billed Oxpecker in South Africa. Red ellipses indicate correlated predictors (≥ 0.7). Grey ellipses are uncorrelated variables.



APPENDIX D. Distribution models for RBO in South Africa using GAM and GLM.

Category	GAM Model	df	logLik	AICc	ΔAICc	AICc weight
abiotic + biotic (GAM_top)	aspect_W + bio18 + bio19 + bio7 + bio8 + bio9 + cattle + dist_PA + goat + wild_host + lai + tick_dens + tocr + tree cover + land cover + violback_star + wattled_star	33.12	-1170.29	2407.09	0.00	0.51
abiotic + biotic	aspect_W + bio18 + bio19 + bio7 + bio8 + bio9 + cattle + dist_PA + goat + wild_host + lai + sheep + surface water + tick_dens + tocr + tree cover + land cover + violback_star + wattled_star	31.00	-1173.49	2409.20	2.11	0.18
abiotic + biotic	aspect_W + bio18 + bio19 + bio5 + bio7 + bio8 + bio9 + cattle + dist_PA + goat + wild_host + lai + tick_dens + tocr + tree cover + land cover + violback_star + wattled_star	30.13	-1174.41	2409. 30	2.21	0.17
abiotic + biotic	aspect_W + bio18 + bio19 + bio8 + bio9 + cattle + dist_PA + goat + wild_host + lai + tick_dens + tocr + tree cover + land cover + biome + violback_star + wattled_star	30.61	-1174.43	2410.32	3.23	0.10
abiotic + biotic	aspect_W + bio18 + bio8 + bio9 + cattle + dist_PA + wild_host + lai + tick_dens + tocr + tree cover + violback_star + wattled_star	27.26	-1178.94	2412.57	5.47	0.03
abiotic + biotic	aspect_N + aspect_S + aspect_W + aspect_E + bio18 + bio8 + bio9 + cattle + dist_PA + goat + wild_host + lai + sheep + tick_dens + tocr + tree cover + land cover + biome + violback_star	31.15	-1183.36	2429.25	22.15	0.00
abiotic + biotic	aspect_W + bio17 + bio18 + bio7 + bio8 + bio9 + cattle + cropland + dist_PA + goat + wild_host + lai + sheep + tick_dens + tocr + tree cover + land cover + biome + violback_star	29.75	-1184.85	2429.41	22.31	0.00
abiotic + biotic	aspect_N + aspect_S + aspect_W + aspect_E + bio18 + bio19 + bio7 + bio8 + bio9 + cattle + goat + wild_host + lai + sheep + tick_dens + tocr + tree cover + land cover + biome + violback_star + wattled_star	32.86	-1191.72	2449.43	42.34	0.00

abiotic + biotic	blackbell _star + piedstar + redwinged_star + bio18 + bio19 + bio5 + bio7 + bio8 + bio9 + cattle + dist_PA + distance to river + wild_host + sheep + tick_dens + violback_star + wattled_star	29.22	-1213.37	2485.38	78.29	0.00
abiotic + biotic	aspect_W + bio18 + bio19 + bio7 + bio8 + bio9 + cattle + cropland + goat + lai + tick_dens + tocr + tree cover + land cover + biome + violback_star + wattled_star	33.22	-1216.66	2500.02	92.93	0.00
climate + biotic	blackbell_star + piedstar + redwinged_star + bio18 + bio19 + bio5 + bio7 + bio8 + bio9 + cattle + wild_host + sheep + tick_dens + violback_star + wattled_star	24.71	-1240.48	2530.53	123.44	0.00
climate	bio18 + bio19 + bio5 + bio7 + bio8 + bio9	15.85	-1377.70	2787.16	380.07	0.00
climate	bio17 + bio18 + bio19 + bio5 + bio7 + bio8 + bio9	13.68	-1391.44	2810.28	403.19	0.00
vegetation	cropland + grassland + lai + tocr + tree cover + land cover + biome	18.15	-1447.59	2931.55	524.46	0.00
biotic	blackbell_star + piedstar + redwinged_star + cattle + wild_host + sheep + tick_dens + violback_star + wattled_star	17.54	-1467.09	2969.35	562.25	0.00
biotic	blackbell_star + capeglossy_star + piedstar + redwinged_star + cattle + goat + wild_host + sheep + tick_dens + violback_star + wattled_star	18.54	-1467.03	2971.22	564.13	0.00
urban	artif_surfw + cropland + hfp + urbanisation + land cover	7.90	-1746.12	3508.06	1100.96	0.00
topography + water	artif_surfw + aspect_N + aspect_S + aspect_W + aspect_E + distance to river + surface water	14.37	-2123.05	4274.88	1867.79	0.00
topography + water	aspect_S + aspect_W + aspect_E + distance to river + surface water	10.84	-2126.83	4275.36	1868.27	0.00
Category	GLM Model	df	logLik	AICc	ΔAICc	AICc weight
abiotic + biotic (GLM1)	aspect_W + bio18 + bio19 + bio7 + bio8 + bio9 + cattle + dist_PA + goat + wild_host + lai + land cover + tick_dens + tocr + tree cover +violback_star + wattled_star	18	-1254.87	2545.83	0.00	0.40

abiotic + biotic (GLM2)	aspect_W + bio17+ bio18 + bio7 + bio8 + bio9 + cattle + cropland + dist_PA + goat + wild_host + lai + land cover + sheep + tick_dens + tocr + tree cover + violback_star	20	-1253.30	2546.69	0.86	0.26
abiotic + biotic (GLM3)	aspect_W + bio18+ bio19+ goat + bio7+ bio8+ bio9 + cattle + dist_PA + goat + wild_host + lai + land cover + tick_dens + tocr + tree cover + violback_star + wattled_star	19	-1254.51	2547.11	1.28	0.21
abiotic + biotic	aspect_W + bio18 + bio19 + bio7 + bio8 + bio9 + cattle + dist_PA + goat + wild_host + lai + land cover + sheep + surface water + tick_dens + tocr + tree cover + violback_star + wattled_star	20	-1254.81	2549.72	3.89	0.06
abiotic + biotic	aspect_W + bio18 + bio19 + bio8 + bio9 + cattle + dist_PA + goat + wild_host + lai + land cover + tick_dens + tocr + tree cover + biome + violback_star + wattled_star	18	-1257.15	2550.37	4.55	0.04
abiotic + biotic	aspect_N + aspect_S + aspect_W + aspect_E + bio18 + bio19 + bio7 + bio8 + bio9 + cattle + goat + wild_host + lai + land cover + sheep + tick_dens + tocr + tree cover + biome + violback_star + wattled_star	22	-1253.31	2550.75	4.92	0.03
abiotic + biotic	aspect_W + bio18 + bio8 + bio9 + cattle + dist_PA + wild_host + lai + tick_dens + tocr + tree cover + violback_star + wattled_star	14	-1263.61	2555.28	9.45	0.00
abiotic + biotic	aspect_N + aspect_S + aspect_W + aspect_E + bio18 + bio8 + bio9 + cattle + dist_PA + goat + wild_host + lai + land cover + sheep + tick_dens + tocr + tree cover + biome + violback_star	20	-1269.45	2578.99	33.16	0.00
abiotic + biotic	aspect_W + bio18 + bio19 + bio7 + bio8 + bio9 + cattle + cropland + goat + lai + land cover + tick_dens + tocr + tree cover + biome + violback_star + wattled_star	18	-1283.64	2603.35	57.53	0.00
abiotic + biotic	bio18 + bio19 + goat + bio7 + bio8 + bio9 + blackbell_star + cattle + dist_PA+ distance to river + wild_host + piedstar + redwinged_star + sheep + tick_dens + violback_star + wattled_star	18	-1287.03	2610.13	64.31	0.00
climate + biotic	bio18 + bio19 + bio5 + bio7 + bio8 + bio9 + blackbell_star + cattle + wild_host + piedstar + redwinged_star + sheep + tick_dens + violback_star + wattled_star	16	-1289.87	2611.81	65.98	0.00

climate	bio17 + bio18 + bio19 + bio5 + bio7 + bio8 + bio9	8	-1442.57	2901.15	355.33	0.00
climate	bio18 + bio19 + bio5 + bio7 + bio8 + bio9	7	-1446.15	2906.32	360.49	0.00
vegetation	cropland + hfp + lai + land cover + tocr + tree cover + biome	9	-1514.03	3046.08	500.26	0.00
biotic	blackbell_star + cattle + wild_host + piedstar + redwinged_star + sheep + tick_dens + violback_star + wattled_star	10	-1525.53	3071.08	525.25	0.00
biotic	blackbell_star + capeglossy_star + cattle + goat + wild_host + piedstar + redwinged_star + sheep + tick_dens + violback_star + wattled_star	12	-1525.45	3074.95	529.12	0.00
urban	artif_surfw + cropland + hfp + land cover + urbanisation	6	-1751.77	3515.55	969.73	0.00
topography + water	artif_surfw + aspect_N + aspect_S + aspect_W + aspect_E + distance to river + surface water	8	-2147.71	4311.44	1765.62	0.00
topography + water	aspect_S + aspect_W + aspect_E + distance to river + surface water	6	-2148.66	4309.34	1763.51	0.00

In bold are the best models. Parameters included are the model's degrees of freedom (df) and Loglikelihood value (logLik).
For explanation of variable codes refer to Appendix B

APPENDIX E. Figures showing the response plots from BRT, and from the top models in GAM and GLM for predicting the distribution of RBO.

Figure E1. Smoothed partial dependence plots for the top generalized additive model. For each plot, there is a greater chance of occurrence of the RBO than absence where y > 0 and a greater chance of absence than presence when y < 0 holding all other variables at their mean values.

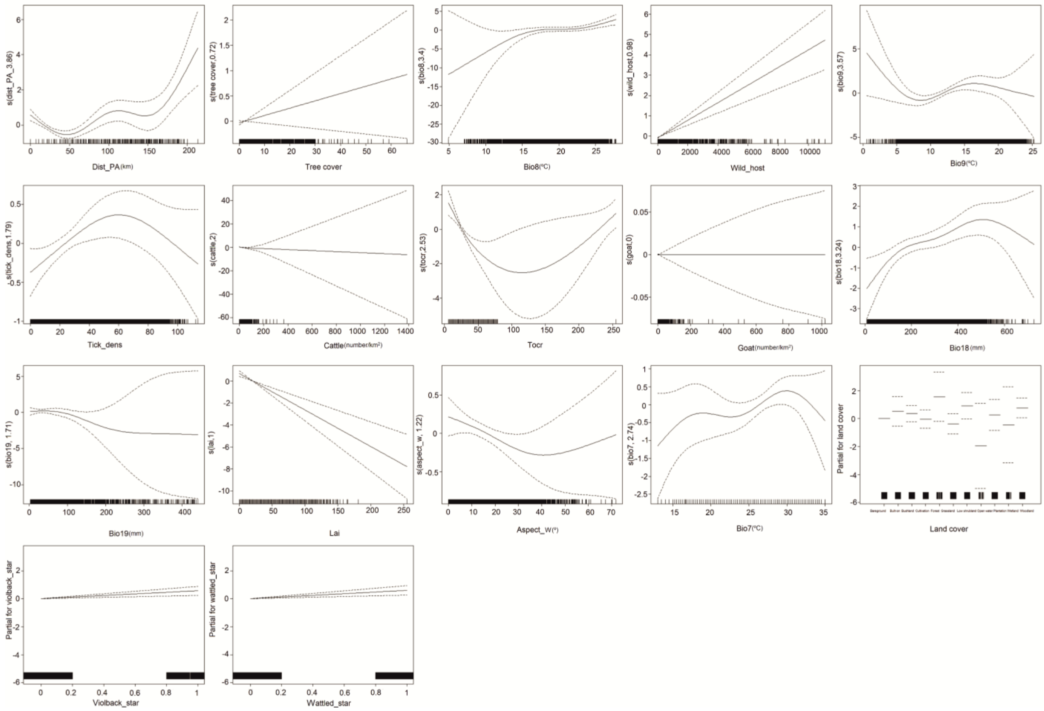


Figure. E2. Effects plots for the top three generalized linear models showing predicted probabilities of RBO occurrence against predictors.

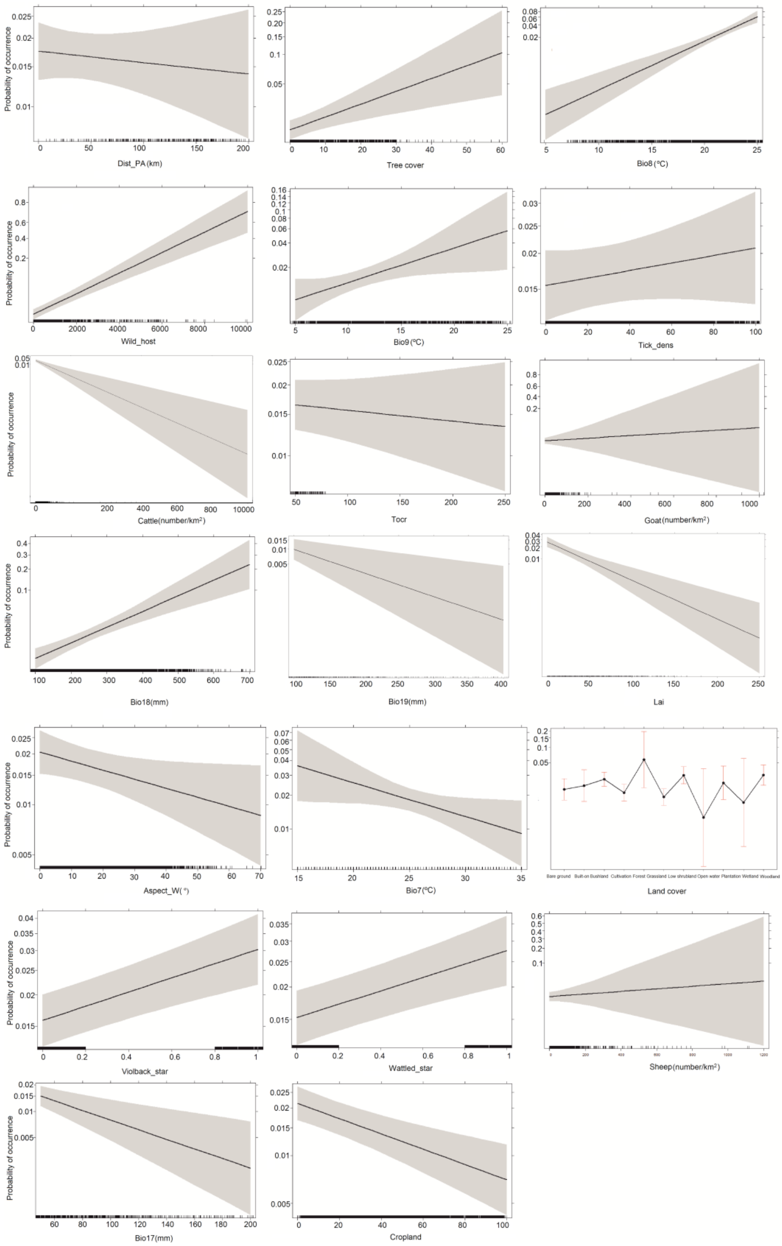
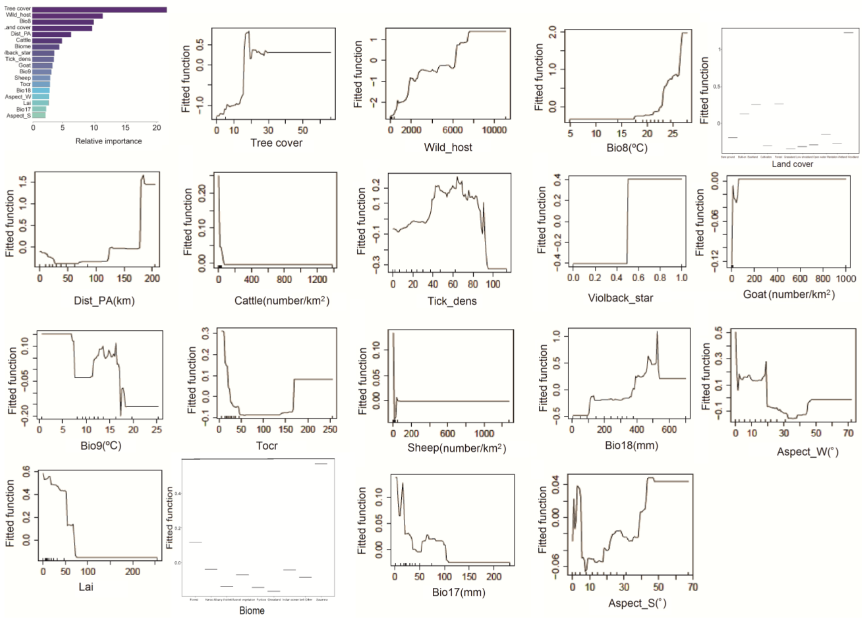


Figure E3. Partial response plots for the most influential variables in the boosted regression tree model of the RBO. Variables are ordered by increasing model contribution. Y-axes are changes in the log odds of presence of RBO and are centered to have zero mean over the data distribution. For each plot, there is a greater chance of species presence than absence where y > 0 and a greater chance of species absence than presence when y < 0 holding all other variables at their mean values.



APPENDIX F. Figures and table show the performance and evaluation of species distribution models for RBO

Figure F1. Calibration plots from boosted regression tree (BRT), generalized additive model (GAM), generalized linear model (GLM) and ensemble models fitted for predicting RBO distribution. Points falling along the diagonal line indicate that models predicted the probability of RBO occurrence adequately.

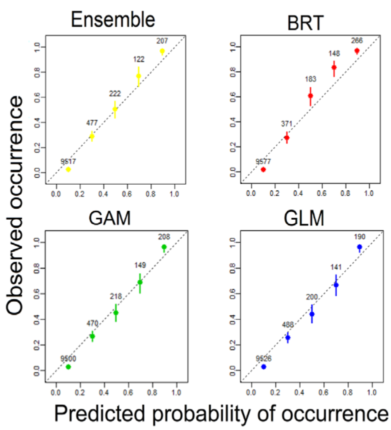


Table F1. Evaluation metrics for the best models from generalized additive model (GAM), generalized linear model (GLM), boosted regression tree (BRT) and ensemble models. PCC, proportion of presences and absences correctly classified; sensitivity, proportion of presences correctly classified; specificity, proportion of absences correctly classified; AUC, area under the curve

Model	Threshold	PCC	Sensitivity	Specificity	Kappa	AUC	PCC.sd	Sensitivity.sd	Specificity.sd	Kappa.sd	AUC.sd
Ensemble	0.5	0.95	0.45	0.99	0.56	0.93	0.002	0.018	0.00085	0.018	0.0053
BRT	0.5	0.96	0.57	0.99	0.68	0.96	0.0018	0.018	0.00079	0.015	0.004
GAM	0.5	0.95	0.47	0.99	0.56	0.92	0.0021	0.018	0.001	0.017	0.0059
GLM	0.5	0.95	0.42	0.99	0.52	0.9	0.0021	0.018	0.001	0.018	0.0068

SEAWEEDS IN A CLIMATE CHANGE PERSPECTIVE

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INTRODUCTION

Global climate change is predicted to cause environmental variables which are of great importance to the structure and function of the coastal and marine ecosystems (Gamal, 2010). Evidence is emerging that marine organisms may be responding faster to the climate change than the land-based plants and animals such as seaweed beds, coral reefs and other coastal ecosystems that provide with trillions of dollars of ecosystem goods and services every year, and the degradation of these systems will have far-reaching consequences for human societies (Sivakumar, 2016).

Seaweeds and Coral Reefs

Seaweeds are the important primary producers, competitors and ecosystem engineers that play a key role in the ecology of coastal habitats, ranging from kelp forests to coral reefs and the consequences of ocean acidification on the seaweed-based coastal ecosystems vary from organismal to community levels of biological organization. Organismal responses can be species specific, depending on their carbon physiology, mode of calcification, and morphology (functional form) (Roleda *et al.,* 2012). At the community level, changes in the community structure and function can cause severe impacts on the trophic dynamics. In this context, researchers have studied the coral-seaweed battle in miniature, setting up bits of each *Acropora intermedia*, the most common hard coral in the Great Barrier Reef and *Lobophora papenfussii*, an abundant reef seaweed, in the laboratory tanks. Results have suggested that the coral reefs may become increasingly susceptible to seaweed proliferation under ocean acidification (Diaz-Pulido *et al.,* 2011).

Sargassum mats

Marine algae are a heterogeneous group of plants with a long fossil history. Marine macroalgae (seaweeds) are found in the littoral habitats. Among them, many *Sargassum* species generally grow on the rocky surfaces of the intertidal regions and their thalli float due to the presence of air vesicles on the lateral branches. Recently, frequent occurrence of *Sargassum* mats was observed from Chatam to NorthBay, Andaman and Nicobar Islands, India and the exact reason for this is not known (Sivakumar and Anantharaman, 2017). Across the Caribbean, mysterious invasion of *Sargassum* had disruptive impacts on both fisheries and tourism for the past four years. But this phenomenon which was first seen as a bane because of its adverse impacts has conversely fueled a boon for enterprising persons who have found innovative ways to exploit the explosion of this weed for use as biofertilizers, making compressed wood etc. Since 2011, the small South Pacific atoll nation of Tuvalu has been affected by *Sargassum* blooms, the most recent being a large growth of *Sargassum* in the main atoll of Funafuti; a total of 19 species of macroalgae were found here, the dominant one being *Sargassum polycystum*. A correlation was noticed between the density of human population on the shore and the algal biomass. Higher amount of *Sargassum* biomass made it a good candidate for use as a fertilizer additive for agricultural practices in Tuvalu. Additionally, such *Sargassum* biomass could be converted into biogas using the process of anaerobic digestion in simple household digesters, to meet the renewable energy need (De Ramon *et al.,* 2015).

The Sargasso Sea is a vast patch of ocean named for a genus of free-floating seaweed called *Sargassum*. While all other seas in the world are defined at least in part by land boundaries, the Sargasso Sea is defined only by ocean currents. It lies within the Northern Atlantic Subtropical Gyre. The Gulf Stream establishes the Sargasso Sea's western boundary, while the Sea is further defined to the north by the North Atlantic Current, to the east by the Canary Current, and to the south by the North Atlantic Equatorial Current. Sargassum provides a home to an amazing variety of marine species. Turtles use sargassum mats as nurseries where hatchlings have food and shelter. Sargassum also provides essential habitat for shrimp, crab, fish, and other marine species that have adapted specifically to this floating algae. The Sargasso Sea is a spawning site for threatened and endangered eels, as well as white marlin, porbeagle shark, and dolphinfish. Humpback whales annually migrate through the Sargasso Sea. Commercial fish, such as tuna, and birds also migrate through the Sargasso Sea and depend on it for food (NOAA).

The "whole-genome shotgun sequencing" of microbial populations collected from the Sargasso Sea near Bermuda shows that these data are estimated to have been derived from at least 1800 genomic species based on sequence relatedness, including 148 previously unknown bacterial phylotypes (Venter *et.al.,* 2004). Therefore, Sargassum mats are a boon rather than a bane (Sivakumar and Anantharaman, 2017).

Padina as Bio-indicator

Rising carbon dioxide concentrations in the atmosphere and in the oceans are driving a number of important physical and chemical changes. Seaweeds grow close to their thermal limits and for the species to survive; they will have to up-regulate stress-response systems to tolerate more frequent and longer sub-lethal and lethal temperature exposures. It directly affects seaweeds in terms of their physiology, growth, reproduction and survival. Given the fan-like calcified fronds of the brown weed, *Padina pavonica,* Gil-Dı´az *et al.* (2014) evaluated the acute (short term) effects of a sudden pH drop due to a submarine volcanic eruption, affecting the offshore waters around El Hierro Island (Canary Islands, Spain). They further studied the chronic (long-term) effects of the continuous decrease in pH in the last decades around the Canarian waters. In both the observational and retrospective studies (using herbarium collections of *P. pavonica* thalli, from the overall Canarian Archipelago), percent surface calcium carbonate coverage of *P. pavonica* was in contrast with the oceanographic data collected either *in situ* (volcanic eruption event) or from the ESTOC marine observatory data series (herbarium study). Results showed that this calcified alga was sensitive to acute and chronic environmental pH changes. In both the cases, pH changes predicted a progressive decalcification in the frond's surface over a period of three decades. This result concurs with the previous studies where calcareous organisms were found to decalcify under more acidic conditions.

Johnson *et al.* (2012) compared the ecological shifts in the sub-tidal rocky shore systems along CO_2 gradients, created by volcanic seeps in the Mediterranean and Papua New Guinea, focussing on abundant macroalgae and grazing sea urchins. In both the temperate and tropical systems, abundances of the grazing sea urchins declined dramatically along the CO_2 gradients. Temperate and tropical species of the calcifying macroalgal genus *Padina* showed reductions in $CaCO_3$ content with CO_2 enrichment. In contrast to the other studies on the calcified macroalgae, Johnson *et al.* (2012) observed an increase in the abundance of *Padina* spp. in acidified conditions. Reduced sea urchin grazing pressure and significant increases in photosynthetic rates might explain the unexpected success of the decalcified *Padina* spp. at elevated levels of CO_2. Similarities found in the responses of *Padina* spp. and sea urchin abundance, at several vent systems, have increased the confidence in the predictions of the ecological impacts of ocean acidification over a large geographical range. We have also observed good growth of *Padina sp.* on the coral rubbles and platforms in the inter-tidal regions of the Neil, Ross & Smith islands and Limoy Bay of the Andamans.

Hence, *Padina* may be considered as a bio-indicator of ocean acidification for the monitoring purposes, over wide geographic ranges, as this macroalga is affected but thrives well (unlike strict calcifiers) under more acidic conditions. Further indepth studies on *Padina* species, in relation to ocean acidification, will help estabilish seaweed bio-indicators.

Climate Mitigation

Present-day energy scenario around the globe is heading towards the search of alternatives to fossil fuels. Increasing energy consumption creates unbalanced energy management and requires power sources that are able to sustain for longer periods.

In this regard, Microbial Fuel Cell (MFC) technology represents a new form of renewable energy by generating electricity. The technology can use the microbes as a catalyst to generate electricity. MFCs can be best defined as fuel cells where microbes act as catalysts in degrading the organic content to generate electricity (Sivakumar *et al.,* 2015). Coastal ecosystems of mangroves, tidal marshes and seagrass meadows sequester and store significant amounts of carbon from the atmosphere and oceans and hence they are now recognized for their very important role in mitigating the climate change. Algae and aquatic biomass have the potential to provide a new range of “third generation” biofuels, including jet fuels. Their high oil and biomass yields, widespread availability, very reduced competition with agricultural land, high quality and versatility of the by-products, their efficient use as a means to capture CO_2 and their suitability for wastewater treatments make algae and aquatic biomass as the most promising renewable sources for a fully sustainable and low-carbon economy portfolio.

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REFERENCES

Diaz-Pulido, G., Gouezo, M., Tilbrook, B., Dove, S. and Anthony, K.R. 2011. High CO_2 enhances the competitive strength of seaweeds over corals. *Ecol Lett*. 14(2):156-62.

De Ramon N’Yeurt, Antoine, and Viliamu Iese, 2015. The Proliferating Brown Alga Sargassum Polycystum in Tuvalu, South Pacific: Assessment of the Bloom and Applications to Local Agriculture and Sustainable Energy. *Journal of Applied Phycology* 27(5): 2047–2047.

Gamal, A.E. 2010. Biological importance of marine algae. *Saudi Pharm J.,* 18(1):1–25.

Gil-Díaz, T., Haroun, R., Tuya, F., Betancor, S. and Viera-Rodríguez, M. A. 2014. Effects of ocean acidification on the brown alga *Padina pavonica*: Decalcification due to acute and chronic events. *PLoS ONE* 9:e108630. doi: 10.1371/journal.pone.0108630

Johnson, V.R., Russell, B.D., Fabricius, K.E., Brownlee, C. and Hall‐Spencer, J.M. 2012. Temperate and tropical brown macroalgae thrive, despite decalcification, along natural CO_2 gradients. *Global Change Biology*, 18, 2792–2803.

Roleda, M.Y. and Hurd, C.L. 2012. Seaweed Responses to Ocean Acidification, Seaweed Biology, Springer, C. Wiencke and K. Bischof (ed), Berlin, pp. unknown. ISBN 978-3-642-28450-2.

Sivakumar, K. 2016. Climate change impacts on seaweeds and mitigation strategies (abstract). In: CD of the ‘National Conference on Advances in Algal biotechnology’, VIT University and Seaweed Research and Utilization Association during 10th to 12th August 2016, Vellore, TN,

Sivakumar, K. and Anantharaman, P. 2017. Frequent occurrence of Sargassum Mats in South Andamans. *Seshaiyana,* 24 (4): 1 -2.

Sivakumar, K., Ann Suji, H. and Kannan, L. 2015. Bioelectricity Production by Marine Bacteria, Actinobacteria, and Fungi. Marine Bioenergy, *edition. CRC Press, Taylor & Francis Group, 2015. 515 -526pp,* print.

Venter, J.C., Karin, R., Heidelberg, F.J., Halpern, L.A., Doug, R., Jonathan, J., Wu, D., Paulsen, I., Karen, E.N., Nelson, W., Derrick, E.F., Samuel, L., Anthony, K., Michael, L., Kenneth, N., Owen, W., Jeremy, P., Jeff, H., Rachel, P. and Hamilton, O.S. 2004. Environmental Genome Shotgun Sequencing of the Sargasso Sea. Science (New York, N.Y.). 304. 66-74.

RESEARCH ARTCIES

EVALUATION OF PREY SELECTION OF BARN OWL (*TYTO ALBA*) IN VARIOUS DISTRICTS OF TAMIL NADU, SOUTHERN INDIA

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Abstract

Barn owl is nocturnal raptor which is one of the major biological control agents against rodents pests in agricultural ecosystems. The major rodent species were the lesser bandicoot rat *Bandicota bengalensis*, the soft-furred field rat *Millardia meltada*, the Indian field mouse *Mus booduga*, the Indian gerbil *Tatera indica*, the house rat *Rattus rattus*, and the field mouse *Mus booduga* from different districts. The Barn Owl found to consume these rodent pests and also the grey musk shrew *Suncus murinus* to a greater extent. We evaluated the prey selection of Barn Owl in different districts of Tamil Nadu where the agricultural operations were intense. *Suncus murinus* was the dominant prey species in all districts except Nagapattinam. In Kanchipuram and Thirvannamalai districts, the percentage of *Suncus murinus* was more than 60%. In Thanjavaur and Thiruvarur districts, the percentage of *Suncus murinus* was almost similar to *Bandicota bengalensis* and *Millardia meltada* respectively. The rodent pest species composition was highest in the districts of Nagapattinam (55.4%), followed by Trichy (49.8%), Thruvarur (42.6%), Thanjavur (41.9%), Kanchipuram (24.5%), Thiruvannamalai (24.2%) and Vilupuram (23.3%). Apart from these species, frog was recorded in Kanchipuram districts, birds were seen in all the districts except Kanchipuram and Vilupuram. Bat was recorded in all the districts except Nagapattinam and Vilupuram. Insects were reported in Thanjavur and Thiruvannamalai. The Vilupuram district had highest percentage of unidentified prey species (32.6%) which indicated that there is a possibility for identifying new prey species. Among these rodent pests, the diversity measures indicated that the rodent species diversity in the diet of Barn Owl showed variations. The overall prey species diversity was highest in Nagapattinam (H'=0.5813), followed by Thiruvarur (H'=0.5367), Trichy (H'=0.5231), Thiruvannamalai (H'=0.4211), Thanjavur (H'=0.4102) and Kanchipuram (H'=0.3654). The diversity was lowest in Vilupuram (H'=0.1406). This result indicated that the Barn Owl was extreme specialist in Vilupuram when compared to other districts. The Barn Owl consistently selected uniform number of prey species in Nagapattinam and Thiruvarur and Thanjavur districts. Although the Barn Owl acts as major biological control agent, the changing agricultural practices can cause potential threat to the population of Barn Owl.

Keywords: *Bandicota bengalensis*, *Millardia meltada*, *Mus booduga*, *Tatera indica*, *Rattus rattus*, *Mus booduga, Suncus murinus*, *Tyto alba*, Barn Owl, Prey Selection, Agricultural fields

1. INTRODUCTION

Common Barn Owl (*Tyto alba*) is a nocturnal bird which mainly forages on the small mammals such as rats, mice and gerbils (Ali and Ripley, 1967). It hunts the live prey and consumes the whole body and regurgitates the undigested items such as bones and fur in a solid form of pellets through mouth. It uses a wide variety of nesting sites including natural cavities in trees and cliffs and man-made structures such as barns, silos, church steeples, water towers, buildings, bridges, airport hangers, farm buildings, granaries and nest boxes. In southern India the Barn Owl *T. a. stertens* (Hartert, 1929) commonly uses the No Common Barn Owl Hindu temples because of their suitable structural features as nesting sites and forage on the rodent pests of the surrounding agricultural lands. Because of their dependence on field rodents for food, they have also been regarded as potential bio-control agents for rodent pests that harm agricultural crops and stored products. Many success stories are known of their role in bio-control. Therefore, Barn Owl holds a special fascination for people because of their power and majesty. Taylor (1994) has narrated; "When seen hunting over a meadow Barn Owls have an ethereal grace and beauty that can be matched by no other bird". Further, because of its position at the top of the food chain this bird of prey can as well be our natural warning system of environmental quality.

Ever since man started to cultivate crops on this planet, he has been losing significant quantities of grains by the vermin, rats and mice. Three pairs of rodents cause ten times greater damage through their excreta. It has been estimated that in India, we lose 7 to 8 million tonnes of food grains every year due to rodents and the loss is seven thousand million rupees (Neelanarayanan *et al*., 1995a). The problem of rodents is intense in the Granary of Tamil Nadu (Nagarajan, 1997). Furthermore earlier studies indicated that the Barn Owl feeds extensively on the small mammals and in which 85% of the diet constitute the agricultural rodent pests (Nagarajan *et al*., 1999). In addition, the Barn Owl pellets indicated the distribution of different rodent species of this area. The species include the lesser bandicoot rat *Bandicota bengalensis*, the soft-furred field rat *Millardia meltada*, the Indian field mouse *Mus booduga*, the Indian gerbil *Tatera indica*, the house rat *Rattus rattus*, the house mouse *Mus musculus*, and the grey musk shrew *Suncus murinus* (Neelanarayanan *et al.,* 1994; Nagarajan *et al.,* 1999). These results suggest that the Barn Owl would be used to assess the small mammal diversity especially agricultural rodent pests of different parts of Tamilnadu. However, totally 128 species of rodents were reported in India and in which at least 18 species of rodents causing damage to agricultural crops (Aplin *et al.,* 2003). Therefore, assessing the pellets of Barn Owl from different districts of Tamil Nadu would provide an opportunity to assess the rodent species diversity and enlist the rodent pests of agricultural importance. Hence, in this chapter we assess the prey selection and diversity of Barn Owl in different districts of Tamil Nadu.

2. METHODOLOGY

The Barn Owl pellets were collected from the nesting sites. Earlier studies indicated that more than 90% of the nests of Barn Owl were located in the temple towers, other associated structures and dilapidated building as nesting sites and roosting sites (Nagarajan, 1998; Nagarajan *et al.,* 1999). The potential nesting and roosting sites of Barn Owl were chambers in different tiers of the entrance towers (gopuram), sanctum sanctorium, temple walls, unused rooms, ventilator shafts and dilapidated vahanas (large animal statues used for carrying the idols of Gods and Goddesses). The Barn Owls occasionally do use the gaps behind statues in the temple towers, sanctum sanctorium and walls, as nesting sites (Nagarajan *et al*., 1999). Furthermore the rural temples with adjoining agricultural habitats were the most preferred nesting sites for Barn Owls (Nagarajan, 1998). Hence, the temples of different districts were searched for nesting sites. Nests were located from the signs diagnostic of Barn Owl nest site viz: the presence of pellets, and bones or the prey remains under the nesting sites, the white markings of its droppings spread on the wall or floor near the nest, and the nestling's continuous food begging call soon after sunset and various calls of adult birds (Neelanarayanan *et al*., 1993). The collected pellets were labelled with the details of period of collection and locality of collection. The pellets were brought to the laboratory and were placed in an oven at 70ºC for 24 hrs to dry the pellets and to kill associated parasites. The pellets were placed in hot 3% of sodium hydroxide (NaOH) for dissolving the fur and debris leaving the osteous remains alone (Schueler, 1972). The mandibles of different rodent species is species specific (Sivaprakasam, 1988) which was used to identify the rodent species diversity. The other prey items were identified using the osteous remains or using other body parts of the prey.

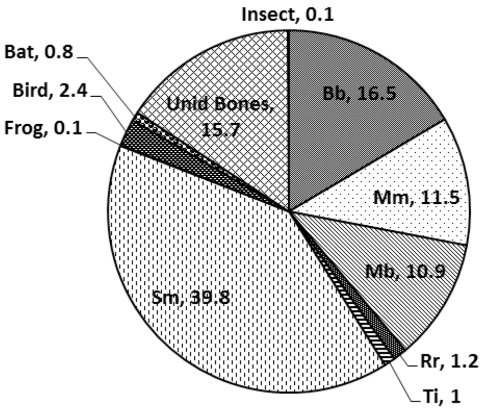
2.1 Study Area and Study Period

The pellets of Barn Owls were collected from Kanchipuram, Nagapattinam (Nagai), Thiruvarur, Thanjavur, Vilupuram, Thiruvannamalai (TV Malai), and Trichy districts of Tamilnadu, Southern India. The pellets were collected from June 2012 to January 2014.

3. RESULTS

The rodent species diversity was assessed using the pellets of Barn Owl and the rodent species identified included were the lesser bandicoot rat *Bandicota bengalensis* (Bb), the soft-furred field rat *Millardia meltada* (Mm), the Indian field mouse *Mus* *booduga* (Mb), the Indian gerbil *Tatera indica* (Ti), the house rat *Rattus rattus* (Rr), and the field mouse *Mus booduga* (Mb) from different districts. In addition, the grey musk shrew *Suncus murinus* (Sm) was also identified from the pellets of Barn Owl. Apart from these species, the bones of frog (Frog), birds (Bird), and bats (Bat) were also collected from the pellet and also the insect remains (Insect) such as electra of beetles were also found in the pellets. Also some bones and prey remains were recovered from the pellets which were not identified and given as unidentified prey items (Unid Bones) (Fig. 1).

Figure 1. Percentage of prey items in the diet of Barn Owl in various districts of Tamil Nadu.



The shrew *Suncus murinus* was the dominant prey species with almost 40% and the all the rodent species collectively contributed more than 40% and the rodent species included were the lesser bandicoot rat *Bandicota bengalensis*, the soft-furred field rat *Millardia meltada*, the Indian field mouse *Mus booduga*. These prey items contributed equally to the prey spectrum of the Barn Owl. The overall diversity of the prey species in the pellet was H'=1.6862 and among the rodent species the diversity was H'=1.2644.

The number of prey items per pellet ranged from one to seven. Totally, 79.6% of the pellets contained one prey item and 15.2% of the pellets had two prey items and 3.4% of the pellets had three prey items. Only one occasion, a total of seven prey items were recorded from a single pellet.

Among the seven districts the prey selection varied noticeably. In all the districts, *Suncus murinus* was the dominant prey species except Nagapattinam. In Kanchipuram and Thirvannamalai districts, the percentage of *Suncus murinus* was more than 60%. In Thanjavaur and Thiruvarur districts, the percentage of *Suncus murinus* was almost similar to *Bandicota bengalensis* and *Millardia meltada* respectively. The rodent pest species composition was highest in the districts of Nagapattinam (55.4%), followed by Trichy (49.8%), Thruvarur (42.6%), Thanjavur (41.9%), Kanchipuram (24.5%), Thiruvannamalai (24.2%) and Vilupuram (23.3%). Apart from these species, frog was recorded in Kanchipuram districts, birds were seen in all the districts except Kanchipuram and Vilupuram. Bat was recorded in all the districts except Nagapattinam and Vilupuram. Insects were reported in Thanjavur and Thiruvannamalai. The Vilupuram district had highest percentage of unidentified prey species (32.6%) (Table 1).

Table 1: Percentage of prey items in the diet of Barn Owl, prey diversity (H') and richness in various districts of Tamil Nadu. The percentage of Rodents & Gerbil, *Suncus murinus* and other prey items are given as sub-total in bold numbers.

Prey Species	Districts						
	Kanchipuram	Nagai	Thiruvarur	Thanjavur	Vilupuram	TV Malai	Trichy
Tatera indica	4.9	0.0	0.0	0.6	4.7	1.4	0.3
Bandicota bengalensis	6.3	33.1	18.1	22.5	11.6	8.8	9.4
Millardia meltada	3.5	13.5	22.2	16.3	0.0	4.2	9.4
Mus booduga	9.8	8.8	2.1	2.5	7.0	9.8	25.9
Rattus rattus	0.0	0.0	0.0	0.0	0.0	0.0	4.9
Sub-total (%)	**24.5**	**55.4**	**42.4**	**41.9**	**23.3**	**24.2**	**49.9**
Suncus murinus	66.4	19.1	31.0	26.1	44.1	61.3	42.3
Frog sp.	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Bird sp.	0.0	2.4	6.2	1.3	0.0	1.9	1.9
Bat	2.1	0.0	0.4	1.3	0.0	0.9	1.0
Insects	0.0	0.0	0.0	0.6	0.0	0.5	0.0
Unidentified Preys	6.3	23.1	19.8	28.8	32.6	11.2	4.9
Sub-total (%)	**9.1**	25.5	26.4	32	32.6	14.5	7.8
Overall Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Overall (H')	0.3654	0.5813	0.5367	0.4102	0.1406	0.4211	0.5231
Rodent & Gerbil (H')	0.2555	0.5802	0.4675	0.3542	0.0702	0.2379	0.4313
Prey Species Richness (out of 11 preys)	**8**	**6**	**7**	**9**	**5**	**8**	**9**

Out of the 11 prey items the highest numbers of nine prey species were identified from Thanjavur and Trichy districts and a lowest number of five prey species found in Vilupuram district. The overall prey species diversity was highest in Nagapattinam (H'=0.5813), followed by Thiruvarur (H'=0.5367), Trichy (H'=0.5231), Thiruvannamalai (H'=0.4211), Thanjavur (H'=0.4102) and Kanchipuram (H'=0.3654). The diversity was lowest in Vilupuram (H'=0.1406). This result indicated that the Barn Owl was extreme specialist in Vilupuram when compared to other districts. The Barn Owl consistently selected uniform number of prey species in Nagapattinam and Thiruvarur and Thanjavur districts (Table 1).

The overall rodent prey species diversity was highest in Nagapattinam (H'=0.5802), followed by Thiruvarur (H'=0.4675), Trichy (H'=0.4313), Thanjavur (H'=0.3542), Kanchipuram (H'=0.2555) and Thiruvannamalai (H'=0.2379). The diversity was lowest in Vilupuram (H'=0.0702). This result indicated that the Barn Owl was extreme specialist in Vilupuram when compared to other districts. The Barn Owl consistently selected uniform number of rodent prey species in Nagapattinam, Thiruvarur and Thanjavur districts (Table 1).

4. DISCUSSION

In the present study Barn Owl pellets were recovered from different districts and recorded almost 10 different prey items and in which the small mammal including rodents, gerbils and shrew were the major preys. Barn Owl has an almost global distribution (Taylor, 1994). It is well established that in different parts of world that Barn Owl feed on field rodents for food (Wallace, 1948; Lenton, 1984; Colvin, 1984, 1986; Bendel and Therres, 1993; Taylor, 1994). Furthermore, it has also been regarded as potential bio-control agents for rodent pests that harm agricultural crops and stored products in various countries (Kahila *et al*., 1994; Cayford and Percival, 1992; Kahila, 1993). Many success stories are known of their role in bio-control (Tomich, 1971; Lenton, 1978, 1983; Kahila, 1993; Kahila and Techernov, 1991; Wood, 1985).

It is found that Barn Owl consumed the lesser bandicoot rat *Bandicota bengalensis*, the soft-furred field rat *Millardia meltada*, the Indian field mouse *Mus booduga*, the Indian gerbil *Tatera indica*, the house rat *Rattus rattus*, and the field mouse *Mus booduga* from different districts of Tamil Nadu. Further, the grey musk shrew *Suncus murinus* was also found in the diet. The economic importance of Barn Owl as a potential rodent controlling agent has been increasingly recognized (Santhanakrishnan, 1987; Neelanarayanan *et al.,* 1994; Nagarajan, 1997; Nagarajan *et al*., 1999) and attempts have been made to improve the population of this bird in this area. Several reports on the foraging, nesting and breeding are available on Barn Owl (Santhanakrishnan, 1987; Nagarajan *et al*., 1993, 1999, 2002, Nagarajan, 1997, 1998; Neelenarayanan *et al*., 1999), but these studies are restricted to Nagapattinam district of Tamil Nadu. The rodent species found in the diet of Barn Owl include the lesser bandicoot rat *Bandicota bengalensis*, the soft-furred field rat *Millardia meltada*, the Indian field mouse *Mus booduga*, the Indian gerbil *Tatera indica*, the house rat *Rattus rattus*, the house mouse *Mus musculus*, and the grey musk shrew *Suncus murinus* (Nagarajan, 1997; Neelanarayanan, 1997; Nagarajan *et al*., 1999).

The Barn Owl diet had highest number of nine prey species in Thanjavur and Trichy districts. These two districts have various microhabitats viz., different types of water bodies, grooves, hillocks, human habitations (with urbanization), etc., The agricultural operations are also intensive with variety of crops both in sandy and clayey soils. Such habitat diversity would have increased the number of prey species available to the Barn Owl in these two districts. Hence, the presence of prey species such as small mammals, birds, amphibians and insects vary with reference to types and diversity of habitats. Teta *et al.* (2012) and Hindmarch and Elliott (2015) observed that the consumption of commensal rodents and smaller rats increased predominantly with increased urbanization within the hunting area of the Barn Owl. Earlier, it was well established in different parts of the world that Barn Owl's prey number was noticeably higher in the urban than in the agricultural landscapes (Marti, 2010; Teta *et al*., 2012; Veselovský *et al*., 2017; Horváth *et al*., 2018). Vilupuram district had lowest number of five prey species in the diet of the Barn Owl. The Barn Owl consumed considerably higher number of gerbil and rat pest species in this district. The presence of higher extent of sandy agricultural lands in this district would have influenced the consumption of gerbils. The percentage of unidentified prey was highest in this district which would have included some of the other unidentified prey species in this district. Further, the identification of such prey would increase the number of prey items in this district. The prey species diversity was highest in Nagapattinam district followed by Thiruvarur district. In these two districts, the Barn Owls predominantly fed on rodent pests which might be due to intensive agricultural operations. These two districts are in Cauvery deltaic region and agriculturists cultivate different types of crops throughout the year which would have provided opportunity for the Barn Owls to get agricultural rodent pests continuously for consumption. Further, as they get all the rodent pests throughout the year they consistently fed on them and hence the diversity of prey species would have been higher in these two districts. Szép *et al*. (2018) recorded that prey-composition of Barn Owls reflects the land use through the distribution and abundance of small mammal species. Therefore, the difference in the diet composition of the Barn Owl in different districts could be related to variations in habitat diversity, land use pattern and cropping patterns.

The diet selection of Barn Owls in different districts revealed that they forage on different rodent pests species as prey. Although, they prefer the rodent pests of different species, the preference for a specific prey species varied in relation to the dominant rodent pests of the area with specific cropping pattern. Furthermore, the result suggested that the percentage composition of different species of rodent pests and preference for a rodent pest changed among the districts. The availability of the rodent prey species varied in different districts which could be related to cropping pattern. Horváth *et al*. (2018) found that the diet composition of Barn Owls, mainly their food-niche pattern, reflected prey availability in the comparison of the landscapes viz., agricultural, mosaic, urban areas. Hence, it is inferred from the present results that different rodent pests can be controlled by Barn Owl in all districts. Still, many farmers do not know the role of Barn Owl in rodent pest control in the agricultural ecosystems as it is a nocturnal secretive species. The Barn Owl never hunts by sitting on the ground and also do not scavenge on dead preys. They do need a tall perch from where they hunt the rodent prey items. The agricultural fields without trees would not attract the Barn Owl for hunting. In such places, the farmers must provide "T" shaped perching poles for Barn Owls as perch for sitting and hunting the rodent prey (Kanakasabai *et al*., 1994). The perching poles should be between 9-12 feet tall, the height range, from where the Barn Owls hunt efficiently the rodent pests of the crop fields. Further, they do not construct nests like most other diurnal raptors instead, they use tree cavities, holes, and man-made structures, such as temple, church and mosque towers, unused buildings, dilapidated water tanks, etc. as nests (Nagarajan *et al*., 1994). The agricultural ecosystem without big and tall trees (which are having cavities and holes), or suitable mad-made structures would not support Barn Owls. But, the Barn Owl accepts the artificial nest boxes as nesting sites when the nest box is placed on trees, or in elevated positions (Nagarajan *et al*., 1999). It is well established that the Barn Owl uses the nest boxes with dimensions of length=36"; width=18" and height=21" (Neelanarayanan *et al*., 1995b; Nagarajan *et al*., 1999). Hence, the farmers of different districts are to be encouraged to place the nest boxes amidst their crop fields to attract the Barn Owl to nest in these areas. However, the agricultural areas without Barn Owl should be first installed with perching poles and as it attracts the Barn Owl then the provision of nest boxes should be done (Nagarajan *et al*., 2006). Many agriculturists in different districts are yet to know the ecosystem services provided by the Barn Owl in agricultural fields. Hence, the role played by Barn Owl in controlling rodent pest species and management strategies to use them to control rodent pests are to be popularised to them and to common public through different awareness programme.

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REFERENCES

Ali, S. and Ripley, S.D. 1967. *Hand book of Birds of India and Pakistan*. Oxford: Oxford University Press.

Aplin, K.P., Brown, P.R., Jacob, J., Krebs, C.J. and Singleton, G.R.. 2003. Field methods for rodent studies in Asia and the Indo-Pacific. ACIAR Monograph No. 100. 223p.

Bendel, P.R. and Therres, G.D. 1993. Differential mortality of Barn Owls during fledging from marsh and off-shore nest sites. *Journal of Field Ornithology* 64:326-330.

Cayford, J, and Percival, S. 1992. Born captive, dir free. *New Scientist* 8:29-33.

Colvin, B.A. 1984. Barn Owl foraging behaviour and secondary poisoning hazard from rodenticide use on farms. Ph.D. Thesis. Bowling Green State University, Bowling Green, Ohio.

Colvin, B.A. 1986. Barn Owls: Their secrets and habits. *Illinois Audubon* 216: 9-13.

Hartert, E. 1929. On various forms of the genus *Tyto*. *Novitates Ool. (Pring)* 35:93-104.

Hindmarch, S. and Elliott, J. E. 2015. A specialist in the city: the diet of Barn Owls along a rural to urban gradient. *Urban Ecosystems* 18:477–488.

Horváth, A., Morvai, A. and Horváth, G. F. 2018. Food-niche pattern of the Barn Owl (*Tyto alba*) in intensively cultivated agricultural landscape. *Ornis Hungarica* 26: 27–40.

Kahila, G. 1993. The Barn Owl (*Tyto alba*) as a biological controller of rodent populations in agricultural areas. M.Sc., Thesis, The Hebrew University of Jerusalam.

Kahila, G. and Tchernov, E. 1991. Barn Owl as biological pest controls. *Israel Land and Nature* 17:68-73.

Kahila, G., Viel, S.A. and Tchernov, E. 1994. Reproductive cycle of Barn Owl (*Tyto alba*) in nesting boxes. *Israel Journal of Zoology* 40:100.

Kanakasabai, R., Subiah, K. S., Neelanarayanan, P. and Nagarajan, R. 1994. Nest box and "T" shape perching pole for Common Barn Owl. *Newsletter for Birdwatchers* 34:88-89.

Lenton, G.M. 1978. Owls as rat controllers-preliminary report. *Planter, Kualalumpur* 54:72-83.

Lenton, G.M. 1983. Wise owls flourish among the oil palms. *New Scientist* 17: 436-437.

Lenton, G.M. 1984. The feeding and breeding ecology of Barn Owls *Tyto alba* in Peninsular Malaysia. *Ibis* 126: 551-575.

Marti, C. D. 2010. Dietary trends of Barn Owls in an agricultural ecosystem in Northern Utah. *Wilson Journal of Ornithology* 122: 60–67.

Nagarajan, R. 1997. The Indian Barn Owl in the Cauvery delta. *Barn Owl Trust Feedback* 17: 8-9.

Nagarajan, R. 1998. Nest characteristics, productivity and nestling growth pattern of the Barn Owl *Tyto alba stertens* Hartert 1929 in an agro-environment of Tamilnadu, Southern India. Ph.D. thesis, Bharathidasan University, Trichirappalli, India.

Nagarajan, R., Neelanarayanan, P. and Kanakasabai, R. 1994. Descriptions of Barn Owl nesting sites in Man-made structures. *Zoos' Print* X:15.

Nagarajan, R., Neelanarayanan, P. and Kanakasabai, R. 1999. Ecology and Conservation of Indian Barn Owl. In: Sharma B.D. (Ed.): *Indian Wildlife Resources Ecology and Development*: 111-133. Delhi.

Nagarajan, R., Thiyagesan, K., Natarajan, R. and Kanakasabai, R. 2002. Growth pattern of Indian Barn Owl (*Tyto alba stertens*). *Condor* 104:885-890.

Nagarajan, R., Thiyagesan, K. and Kanakasabai, R. 2006. Designing and placing a nest-box for Barn Owls (*Tyto alba stertens* Hartert (1929) on the basis of their natural nesting habit. Pages 217-221, In: *Proc. of Conference on findings of the young researchers on applied sciences 2006 (CAS 2006)*, Edited by Said C.M.S. and Ahmad, M.R. Vol 2: Chemistry & Environmental Technology and Biology and Agriculture, University Publication Centre, Universiti Teknologi MARA, Shah Alam, Malaysia.

Neelanarayanan, P. 1997. Predatory pressure of Barn Owl (*Tyto alba stertens* Hartert, 1929) on rodent pests-A field evaluation. Ph.D. thesis, Bharathidasan University, Trichirappalli, India.

Neelanarayanan, P., Nagarajan, R. and Kanakasabai, R. 1993. Tips for the identification of Common Barn Owl nests. *Newsletter for Birdwatchers* 33:93.

Neelanarayanan, P., Nagarajan, R. and Kanakasabai, R. 1994. Vertebrate pest as prey and their composition in the diet of Common Barn Owl *Tyto alba. Rodent Newsletter* 18:5-6.

Neelanarayanan, P., Nagarajan, R. and Kanakasabai, R. 1995a. Rats, mice and other vermin. *ILEIA Newsletter* 11:9.

Neelanarayanan, P., Nagarajan, R. and Kanakasabai, R. 1995b. Successful utilization of man-made nest boxes by Barn Owl, *Tyto alba*. *Zoos' Print* X:16-17.

Santhanakrishnan, R. 1987. Studies on population, food habits and nesting of Barn Owl, *Tyto alba* (Scopoli) in a portion of Cauvery basin. M.Phil., Dissertation, Bharathidasan University, Tiruchirappalli, South India.

Schueler, E.W. 1972. A new method for preparing owl pellets: boiling in NaOH. *Bird Banding* 43:141.

Sivaprakasam, C. 1988. Studies on the burrow ecology, population and food habits of field rodents in and around Mannampandal and Arupathy areas. M.Sc., thesis, Bharathidasan University, Tiruchirappalli, India.

Szép, D., Klein, Á. and Purger, J. J. 2018. The prey composition of the Barn Owl (*Tyto alba*) with respect to landscape structure of its hunting area (Zala County, Hungary). *Ornis Hungarica* 25:51–64.

Taylor, I.R. 1994. *Barn Owls: Predator-prey relationships and conservation*. Cambridge: Cambridge University Press.

Teta, P., Hercolini, C. and Cueto, G. 2012. Variation in the diet of Western Barn Owls (*Tyto alba*) along an urban-rural gradient. *Wilson Journal of Ornithology* 124: 589–596. DOI: 10.1676/11-173.1

Tomich, P.Q. 1971. Notes on food feeding behaviour of raptorial birds in Hawaii. *Elepaio* 31: 111-114.

Veselovský, T., Bacsa, K. and Tulis, F. 2017. Barn Owl (*Tyto alba*) diet composition on intensively used agricultural land in the Danube Lowland. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 65:225–233.

Wood, B.J. 1985. Population studies on the Malaysian woodrat (*Rattus tiomanicus*) in oil palms, demonstrating an effective nest control method and assessing some older ones. *Planter* 45: 510-526.

Wallace, G.J. 1948. The Barn Owl in Michigan. Michigan State College, Agricultural Experiment Station, Technical Bulletin No. 208.

EFFECT OF MANAGEMENT SYSTEM ON DISEASES PREVALENCE, HEALTH CONDITION AND VETERINARY CARE AMONG CAPTIVE ASIAN ELEPHANTS (*ELEPHAS MAXIMUS*) IN TAMIL NADU, INDIA

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ABSTRACT

While maintenance of animals in captivity is fraught with numerous challenges, including the control of disease, a systematic documentation on diseases, health condition and veterinary care are vital for the effective management of animals in captivity. Asian elephant, despite having a long history of captivity, is still suffering globally with wide range of welfare problems. This study evaluated the diseases prevalence, health condition and veterinary care among 144 Asian elephants managed under three captive systems—Hindu temple, private and forest department in Tamil Nadu, India between 2003 and 2010. Scrutinizing register of records and periodic monitoring, occurrence of diseases prevalence, health condition and veterinary care were obtained by direct observations on each elephant, going through register of records maintained at each facility and through inquiry with elephant keepers, and owners and veterinary experts concerned. Data on disease records showed that among the three systems, a higher occurrence of foot rot, stereotypies and arthritis was found among elephants managed in temple, followed by private system and least or absent in the forest department system. On the other hand, eye problems and parasitic prevalence were more among forest department elephants than those in temple and private systems. The growth curve obtained from the female elephant shoulder height records of various age class showed that the private elephants attained a lower asymptotic shoulder height (241 cm), compared to those in forest department (243 cm) and temple system (251 cm). Similarly, the growth curve obtained based on body weight records showed that asymptotic body weight was far higher among temple elephants (3890 kg) than those in private (3199 kg) and forest department elephants (3104 kg). The relatively higher height and weight recorded among temple elephants, as compared to those in the forest department and private systems attributed to a higher representation of elephants from north-eastern region and lack of physical exercise in temple system. Health condition assessed by numerical rating method based on visual observation on various body parts revealed that the proportion of elephants with poor health condition was highest in the private facility (24%) followed by temples (16%) and lowest in the forest department (6%). Data on veterinary care revealed that all elephants in the forest department system received regular veterinary care, while only 75% of elephants in temple and 25% of elephants in private systems had periodic medical checkup.

Keywords: Captive Asian Elephant, Diseases, Health Condition, Veterinary Care**.**

1. INTRODUCTION

The Asian elephant is considered an integral part of culture and mythology in India and elsewhere in Asia. The long association between captivity elephant and human dates back to the Indus Valley civilization 4000 years ago when Asian elephants were probably first captured (Carrington, 1959). Approximately 30,000 to 50,000 elephants captured throughout the Indian sub-continent during the last 100 years (Sukumar, 1989). Elephants in captivity have long been used for a variety of purposes, including warfare, timber operations, cultural and religious ceremonies, and for recreation in zoos and circuses. Given that, the global population of Asian elephants in captivity forms nearly one third of the total Asian elephant population, the study on captive elephants help in planning for their conservation (Santiapillai and Sukumar, 2006).

In India, captive elephants are distributed across almost all states (including numerous non-range states), as this animal is an integral part of the country's cultural and religious landscape. According to the Project Elephant Report (MoEF, 2004), about 3400–3600 captive elephants are distributed across 23 states and union territories including the Andaman and Nicobar Islands. A majority of these captive elephants are found in the northeastern (55%) and southern (25%) states. In Tamil Nadu, a southern state of India, elephants are managed in captivity by the state Forest Department, religious institutions such as Hindu temples, mutts, trusts, charities, mosques and individual owners, for various purposes. The Government of Tamil Nadu categorized these elephants into three captive systems: forest department captive elephants (managed at timber camps and zoo), temple elephants (managed at Hindu temples) and private elephants (managed by mutts, trusts, charities, mosques and individual owners) (Vanitha, 2007).

Many studies have been made in the past on the captive elephant management in Tamil Nadu, but these have been sporadic, isolated, short term in nature and/or have not been comprehensive (Sukumar *et al*., 1988, Gokula, 1993, Krishnamurthy, 1995; Krishnamurthy and Wemmer, 1995, Sukumar *et al*., 1997). Health and hygiene, diseases prevalence and veterinary care is an important aspect of managing elephants in captivity and a comparative analysis of different captive management systems and their influence on elephants natural behaviour has not been attempted. Further, most of the data available on captive elephants in India are pertaining to timber camp elephants managed by the state forest department and hardly any information exists on captive elephants managed by private owners and Hindu temples, which constitute over 50% of the captive population in southern India (Lair, 1997).

A working elephant may be exposed to many kinds of injuries and ailments. With the development of veterinary science, treatment of sick and injured elephants is not a problem. But in remote areas, experienced veterinary doctors and required medicines are not easily available and the *mahout* may be required to provide first aid or primary treatment before the services of a veterinarian. Herbal based medicines are practiced among captive elephants, which provide effective treatment against some common ailments of elephants. Veterinary care is important when Asian elephants managed in captivity, as they are prone to a number of diseases and ailments (Santiapillai and Jackson, 1990; Chandrasekaran *et al*., 1995) especially parasitic diseases (Dhungel *et al*., 1990). Although, the earlier reports state that captive elephants managed at the Hindu temple and private systems receive poor veterinary care (Krishnamurthy 1998; Bist et al., 2002), yet no detailed investigation attempted to fulfil the lacunae. This study assessed the effect of management system on the health and hygiene condition, diseases prevalence and veterinary care among captive Asian elephants managed in Hindu temples, private facilities and forest department in Tamil Nadu.

2. STUDY AREA:

The present study was carried out in Tamil Nadu, a southern in India (Fig. 1) between 2003 and 2010. Data pertaining to this study were collected from the captive elephants managed by (1) Tamil Nadu Forest Department in the timber camps at Mudumalai and Anaimalai Wildlife Sanctuaries (presently Tiger Reserves), and Aringar Anna Zoological Park (AAZP), Chennai, (2) Hindu temples and (3) privately owned ones.

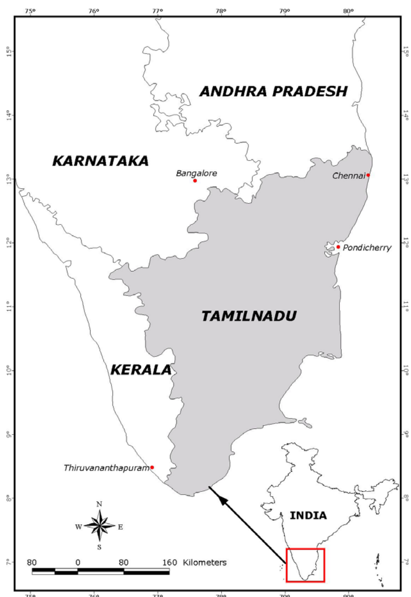


Fig. 1. Map showing the study area.

3. METHODS

3.1. Assessment of health condition

Health Assessment: Health condition was assessed employing visual-based non-invasive method that assigns numerical score to different regions of the body of captive elephants: (1) temporal depression, (2) bucal depression (3) prominence of back bone (spine), (4) prominence of ribs (5) prominence of pectoral and (6) prominence of pelvic bone, which are totaled to give a numerical index (Wemmer and Krishnamurthy, 1992). The depression or prominence levels of above regions vary according to health condition in elephants due to changes in the level of adipose fat deposition.

Shoulder height & body weight: Growth is one of the parameters to assess an elephant's health condition. Therefore, shoulder height and body weight of elephants managed by the three captive management facilities were collected from the register of records and by measurements during the present study. Adequate data on males was not available in the private and temple facilities due to limited number of males found in these two systems compared to the forest department (> 25 individuals) and thus the analysis was restricted to the females segments alone. Shoulder height and body weight data collected respectively by measuring each individual and from available register of records were fit with growth curve by using growth model exponential association formula $y = a\ (1-e^{-bx})$ for the shoulder height data and weight model formula y = a * (1-exp (-b*x))^3 for body weight data with the help of "Curve Expert", computer software (*Curve expert-1.36 Version*).

Hygiene evaluation: Keeping the elephant and its surroundings in a hygienic condition is important to manage the elephant free from diseases. The hygienic condition of a captive elephant was evaluated by examining the bathing frequency, types and frequency of use of sanitary items for the elephant (application of neem oil) and its house (disinfection practices using phenol, Dettol and bleaching powder), drainage conditions and waste disposal frequency and distance.

Disease prevalence appraisal: Prevalence of various diseases among the captive elephants in the past and at present was appraised by examining the register of records maintained in each facility and enquiring the concerned authorities. Additionally, intestinal parasitic load was assessed examining the dung sample following direct examination and floating methods (Watve, 1995; Vidya and Sukumar, 2002). Dung samples of captive elephants were collected within a few hours of defecation and stored in 10% formalin. Each sample was a mix of portions from the outer and inner part of the different boli of the dung pile. Parts of the boli in contact with the soil were avoided. (a) Direct examination method: A small quantity of feacal sample is placed on a glass slide with 3 to 4 drops of water. The feacal sample is thoroughly emulsified with a needle, evenly spread on the slide and examined under a microscope. This method is easy and useful, provided the infection is heavy. (b) Sedimentation Technique: Centrifugal sedimentation technique standardized by Monson - Bhar and Bell (1892) was followed. A small amount of feacal sample is emulsified with 10 ml of water in a centrifuge tube and was centrifuged for two minutes at 3000 rpm. The supernatant was poured off carefully. A drop of the sediment is placed on a slide and examined under the microscope. (c) Sedimentation floatation technique: The sedimentation floatation technique standardized by Watve (1992) was followed. Known weight of dung sample (in 10% formalin) was strained to remove the coarse debris and the filtrate was centrifuged. The dung that sedimented was dissolved in 10 ml of saturated zinc sulphate solution (specific gravity 1.8%) and centrifuged again. In the first centrifugation, nematode eggs sink with the feacal matter. But in the second, they float to the surface due to the high specific gravity of zinc sulphate. Six loopfuls of the solutions were removed from the surface using a wire-loop of 5 mm diameter and the eggs were counted. Parasite load was then expressed as the number of eggs per gram of dung. This is a minimum estimate as loss of eggs during the different stages of processing is inevitable. If no eggs were fond in a sample, 12 more loopfuls of the solution (six at a time) were scanned for eggs to confirm the absence of infection.

Veterinary care: Availability of professional veterinary care to each elephant was recorded inquiring the concerned authorities and also going through the registers of records available with each facility. Information such as periodic medical checkup by veterinarian and frequency of medical checkups per year were obtained.

4. OBSERVATIONS AND RESULTS

4.1 Health assessment

The health conditions assessed for the 128 elephants managed in the three captive facilities by the rating method revealed that the mean health rating was poorest (3.11) for the elephants managed by the private facility among the three captive systems (Fig. 2). Further, the proportion of elephants with health ratings more than 5 was also highest in the private facility (24%) followed by temples (16%) and lowest in the forest department (6%) (Table 1). In the forest department, among the three elephants that showed health ratings above 5, two were adult males of >50 years with health ratings of 6 & 7 and the third one, with health rating of 10 was the 37 years old adult female returned from a temple due to a dental problem (fourth molar has not fallen, although fifth one has erupted) and she was unable to feed fodder and was surviving only with supplementary diet. The week body condition in the case of two adult males in the forest department could also be due to *musth* (*i.e.*, they might have come out of *musth* just before the health assessment as bulls after musth have a poor body condition) or might also be due to old age. Excluding these few cases, most of the elephants in forest department facility were with health ratings <5, indicating a moderate health condition of almost all elephants in the forest department.

Figure 2. Mean health rating ($\bar{x} \pm$ SE) of elephants in the three management systems of Tamil Nadu (*n* = 128). Higher the health rating value poorer the health condition (Bars represent mean values and the vertical lines $\pm$ SE)

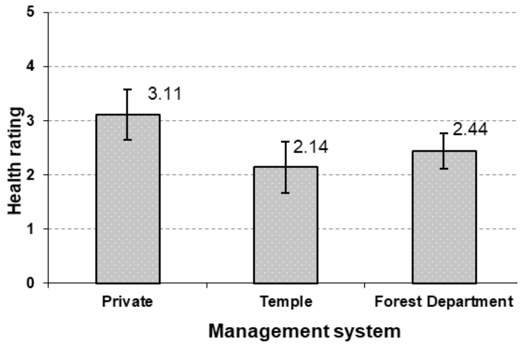


Table 1. Percentage of elephants with different health ratings recorded in the three captive management systems of Tamil Nadu

Health ratings	Percentage of elephants in different facilities		
	Private (*n* = 37)	Temple (*n* = 43)	Forest Department (*n* = 48)
0	27.0	39.5	25.0
1	5.4	20.9	14.6
2	21.6	14.0	20.8
3	5.4	0.0	10.4
4	8.1	7.0	6.3
5	8.1	2.3	16.7
6	8.1	11.6	2.1
7	8.1	0.0	2.1
8	5.4	2.3	0.0
9	2.7	0.0	0.0
10	0.0	0.0	2.1
16	0.0	2.3	0.0

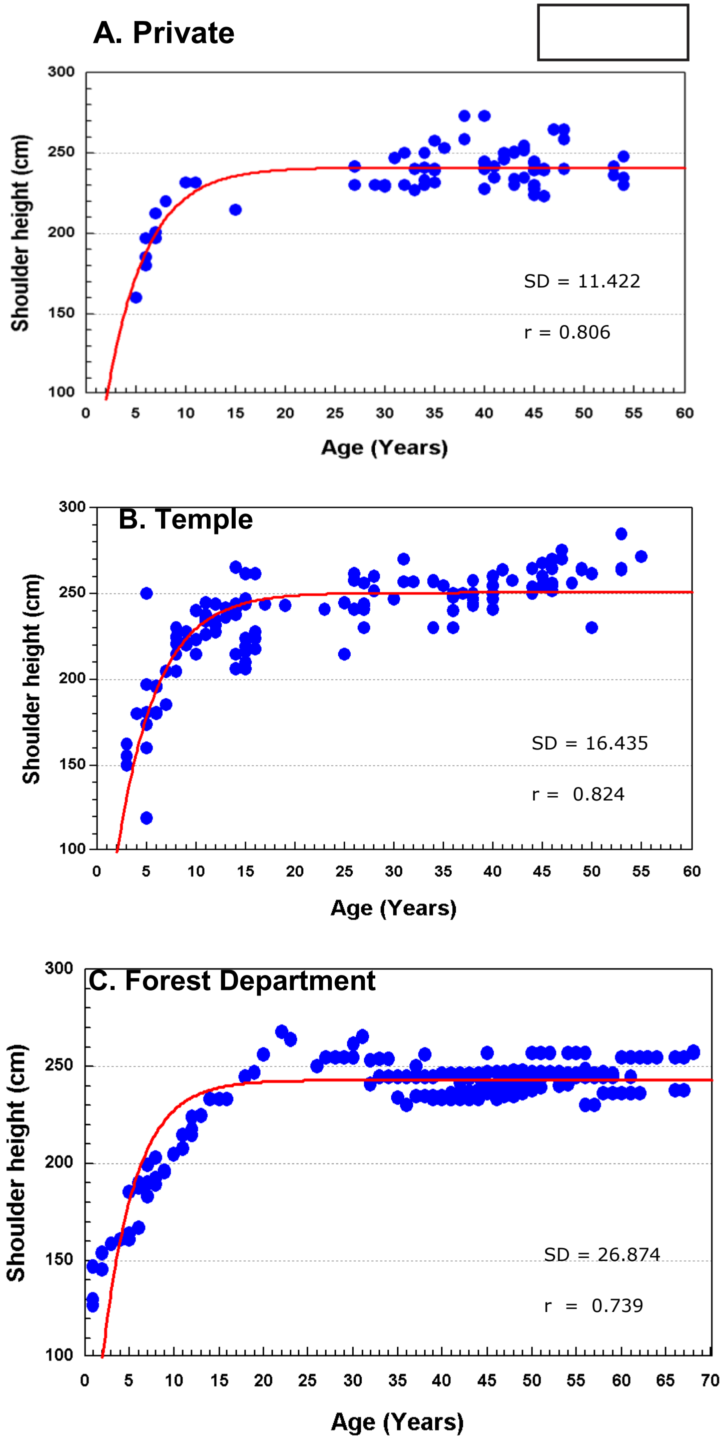
Health rating 0-2 = Good condition, Health rating 3-5 = Fair /Moderate conditions, 6-10 = Poor condition and >10 very poor condition.

Shoulder height: In total 378 shoulders height records were collected from female elephants of different ages (aged from <1-68 years old). Mean shoulder height was arrived for various age classes of elephants separately for the three management systems and are plotted in Table 2. From the figure it can be seen that elephants belonging to the private facility were relatively shorter compared to temple elephants almost in all age classes except in 35-40 years age class. A comparison of shoulder height of elephants belongs to temple and forest department revealed that while the temple elephants are taller than forest department elephants in many age classes and significantly more in the 40-45- and 50-55-years age classes, they are shorter than the forest department elephants in the10-15, 15-20- and 20-25-years age classes. Plots of shoulder heights against ages of elephants showed that the shoulder heights of private elephants reached asymptotic level relatively at a lower shoulder height (241 cm) compared to the females managed by the forest department (243 cm) and temples (251 cm) (Fig. 3).

Table 2. Comparison of shoulder heights of elephants of various age classes in the three captive management systems of Tamil Nadu. Values within parentheses are number of elephants ('F' represents one-way ANOVA and 'T' represents Two Independent sample T test).

Age class	**Shoulder Height (cm) - Mean ± SD (*n*)**			Statistical test	
(Years)	Private	Temple	Forest	F/ T	P
<1	-	-	97.4 ± 8.99 (9)	-	-
1-2	-	-	140.6 ± 11.59 (5)	-	-
2-5	160.0 (1)	172.8 ± 34.44 (10)	165.8 ± 10.94 (5)	F = 0.16	> 0.05
5-10	203.0 ± 17.48 (8)	210.6 ± 17.64 (18)	191.4 ± 10.0 (12)	F = 5.44	< 0.01
10-15	223.5 ± 12.02 (2)	233.8 ± 15.04 (27)	221.4 ± 8.96 (8)	F = 2.72	> 0.05
15-20	-	236.5 ± 16.24 (6)	242.8 ± 9.86 (5)	T = -0.79	> 0.05
20-25	-	233.7 ± 16.29 (3)	265.3 ± 2.31 (3)	T = -3.33	> 0.05
25-30	232.2 ± 5.50 (5)	248.5 ± 9.90 (11)	255.3 ± 3.83 (6)	F =12.42	< 0.05
30-35	239.38 ± 8.56 (16)	255.1 ± 11.18 (8)	248.6 ± 9.29 (9)	F = 8.02	< 0.05
35-40	250.56 ± 15.37 (9)	247.5 ± 7.24 (16)	240.2 ± 7.63 (15)	F = 3.79	< 0.05
40-45	239.68 ± 9.63 (22)	258.2 ± 5.56 (11)	239.4 ± 5.18 (21)	F =27.79	< 0.05
45-50	247.29 ± 15.97 (7)	259.4 ± 13.75 (15)	242.7 ± 5.25 (30)	F =13.78	< 0.05
50-55	238.20 ± 6.94 (5)	271.5 ± 9.68 (4)	247.3 ± 5.81 (18)	F =30.43	< 0.05
55-60	-	-	243.5 ± 7.60 (17)	-	-
60-65	-	-	248.1 ± 9.06 (7)	-	-
65-70	-	-	250.2 ± 9.50 (6)	-	-

Figure 3. Growth curves (Growth model-exponential) obtained from the shoulder height records of female elephants managed in the three captive management systems of Tamil Nadu.



Body weight

Body weight records of elephants were collected from 346 female elephants managed by the private (n = 12), temple (n = 174) and forest department (n = 160) managements and their mean weights in different age classes are compared in Table 3. Most of the body weight data of the private elephants especially in the sub-adult (5-10 and 10-15 years) and middle age adult (30-35 years) classes belonged to elephants managed by the non-individually owned and body weights representing the individually owned elephants (with majority of them are in poor health condition) are very less in the current data set due to absence of weight records. Mean body weights in relation to age classes showed that the temple elephants were heavier than the private elephants in all the age classes except the 10-15 years age class, in which elephants in the latter system were heavier than the former. However, the observed difference between the elephants in the private and temple management systems became very distinct at the 45-50 years age class. On the other hand, the private elephants were heavier than the forest department elephants in most of the age classes except older adult classes (>50 years) in which elephants in the latter system were heavier than earlier system that represented individually owned elephants (Table 3). A comparison of the body weight of the temple and forest department elephants showed that the temple elephants were heavier than the forest department elephants in 10-15 years age classes and also in all the age classes from 20-25 years onwards except 40-45 years age classes. Overall these results show that temple elephants are much heavier than the private and forest department elephants.

Table 3. Comparison of body weights of elephants of various age classes in the three captive management systems of Tamil Nadu. Values within parentheses are number of elephants (‘F’ represents one-way ANOVA and ‘T’ represents Two Independent sample T Test).

Age class (Years)	Body Weight (kg) - mean ± SD (n)			Statistical test	
	Private	Temple	Forest	F / T	P
<1	-	-	102.3 ± 13.8 (5)	-	-
1-2	-	-	567.5 ± 116.2 (4)	-	-
2-5	-	934.3 ± 318.0 (6)	918.8 ± 227.1 (5)	T = 0.09	> 0.05
5-10	1959.0 ± 630.2 (5)	2151.4 ± 660.8 (21)	1379.8 ± 217.3 (14)	F = 8.56	< 0.05
10-15	2905.0 (1)	2857.9 ± 665.5 (36)	2006.3 ± 218.0 (6)	F = 4.78	< 0.05
15-20	-	2708.6 ± 286.1 (20)	2533.3 ± 398.7 (3)	T = 0.95	> 0.05
20-25	-	3865.0 ± 968.7 (2)	2970.0 (1)	-	-
25-30	-	3434.2 ± 493.3 (9)	2562.5 ± 185.7 (6)	F = 16.78	< 0.05
30-35	3387.5 ± 901.6 (2)	3947.6 ± 978.1 (5)	2775.6 ± 434.5 (8)	F = 4.30	< 0.05
35-40	-	3873.3 ± 415.9 (38)	3043.2 ± 263.2 (14)	T = 6.95	< 0.05
40-45	3153.3 ± 128.6 (3)	4255.8 ± 983.8 (19)	3151.9 ± 227.8 (20)	F = 13.41	< 0.05
45-50	-	4331.1 ± 763.8 (15)	3112.3 ± 261.6 (27)	T = 7.59	< 0.05
50-55	2815.0 (1)	3797.3 ± 475.5 (3)	3209.9 ± 200.2 (19)	F = 9.46	< 0.05
55-60	-	-	3005.9 ± 344.2 (16)	-	-
60-65	-	-	3539.9 ± 497.4 (7)	-	-
65-70	-	-	3447.0 ± 621.1 (5)	-	-

Body weights of elephants plotted against their ages (Fig. 4) showed that for the forest department elephants the asymptotic body weight was reached at a lower weight (3104 kg) compared to the females managed by private elephants (3199 kg) and temples (3890 kg). However, the scattered distributions of body weights in the plots indicates wide variations in the body weights for a same age class with regard to temple and private elephants, while in the case of forest department elephants the distribution of almost all the body weight records (points) were closer to the curve indicating lesser variations in an age-class (Fig. 4) suggesting that the body conditions were almost uniform among all the individuals in a given age class, which was absent both in the private and temple elephants.

4.2 Hygiene condition of captive elephants and their shelter

Bathing: The captive elephants managed in the temple and private facilities were given bath less frequently as compared to the captive elephants managed by the forest department (Table 4). In the private facility only less than 50% of the elephants (46%) were given bath twice a day and the rest only once a day. In the case of temple facilities, <50% of elephants were given bath twice a day and the rest only once a day (47%) some elephants even in alternative days or once in a week (4.7%). In contrast, almost all the elephants in forest department bathed twice; once in the morning and another time in the evening hours, excepting for the newly captured elephants and orphan calves.

Neem oil and sanitary items use: After every bath neem oil is applied in between nail regions and around the tusk base of male elephants as a fly repellant for all the captive elephants managed by the forest department, while in the case of private elephants only about half (51%) and in temples only about three fourth (74%) get such treatment (Table 4). Use of disinfectants in the elephant houses was higher in the temples (37%) than those of the private elephants (9%), while in the forest department facility no such disinfectant use is followed.

Drainage conditions: Eighteen per cent of elephant houses in the temples and 6% of elephant houses in the private facilities had poor drainage provisions inside the elephant houses, while 39% of the elephant houses in the temples and 22% in the private facilities had poor drainage provisions outside elephant houses (Table 4). The drainage facility in the elephant houses at the AAZP of the forest department was good.

Waste disposal: Dung and residual feeds of captive elephants were dumped in areas nearer (<5 m distance) to their tethering sites in 28% of elephant houses managed by the temple system, while in the private facility, 21% of the houses disposed the wastes at <5m distance from the tethering sites (Table 4). These results indicate that temple elephants have been kept in relatively poor sanitary conditions compared to the private facility. The elephant dung and residual feed were dumped at a distance of <5 m in about one fourth of all the management systems.

Figure 4. Body Weight curves (exponential models to showed relationships between age and body weight) obtained from the body weight records of female elephants managed in the three captive management systems of Tamil Nadu.,

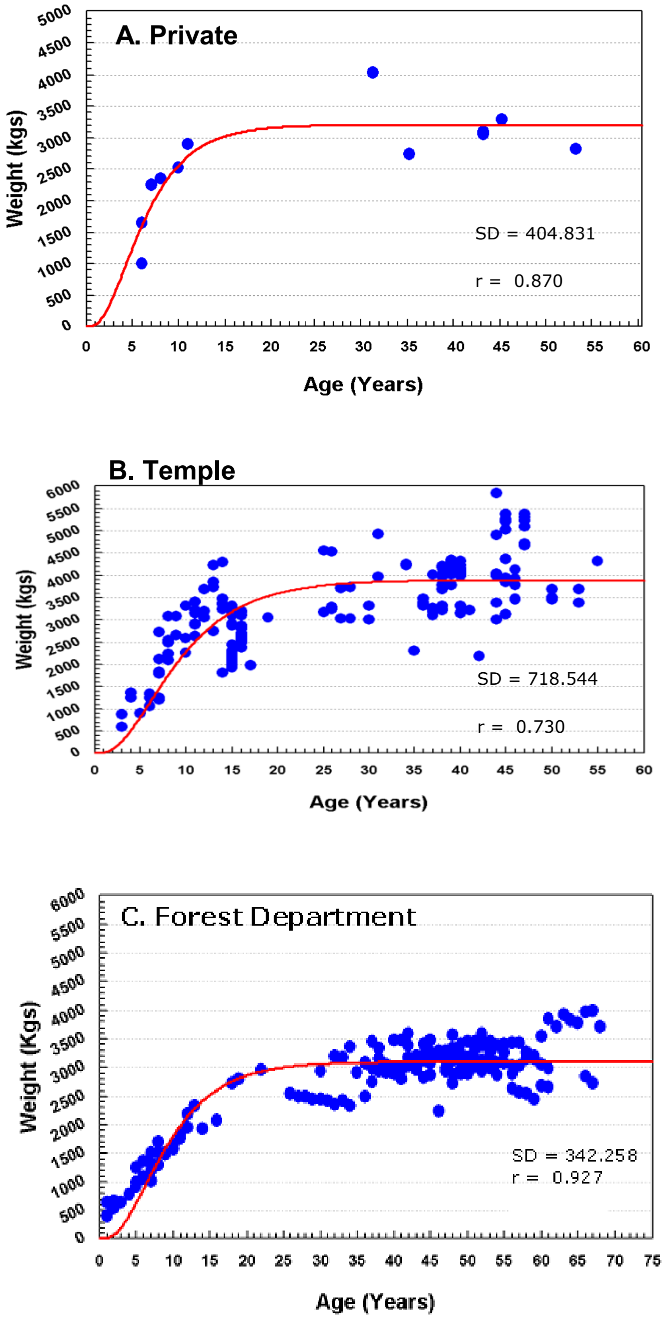


Table 4. Sanitary practices in vogue for the captive elephants in the three-management systems of Tamil Nadu

Sanitary Practices	Details	Percentage of elephants		
		Private	Temple	Forest Department
Bathing Frequency	One time/day	54	47	2
	Two times/day	46	49	98
	Alternative days or once in a week	0.0	4.0	0.0
Use of Neem oil elephant	Yes	51	74	100
	No	49	26	0.0
Use of Disinfectants (Dettol and Bleaching powder) the elephant houses	Yes	9.0	37	0.0
	No	91	63	100
Drainage fecilities inside the elephant House	Good	94	82	100
	Bad	6.0	18	-
Drainage fecilities out side the elephant house	Good	78	61	100
	Bad	22	39	-
Dung disposal distance	Nearby (<5m)	21	28	25
	Away (>5m)	79	72	74

4.3. Disease prevalence and veterinary care

Common diseases and physical impairments: Out of 135 elephants surveyed, 57.8% of the elephants had some or other health issues since their arrival to the present location (Table 5). Intestinal parasitic disease especially *Strongyloides* spp. occurred in 37.4% of the elephants examined. Diseases such as anemia (11.3%), indigestion (9.7%), foot rot (8.9%) and corneal opacity (8.1%) were the other common health problems appeared among the captive elephants (Table 5).

Table 5. Prevalence of major diseases and / or health impairments in the captive elephants in the three management systems of Tamil Nadu (values are percentages of elephants in that particular category affected with a particular disease/impairment at least once as per the records and enquiries).

Management Systems	Health problems / Impairments							
	Intestinal Parasites	Foot Rot	Corneal Opacity	Arthritis	Anemia	Indigestion	Others*	Overall
Private (*n* = 39)	32.4	14.3	5.7	2.9	5.7	5.7	2.9	46.2
Temple (*n* = 43)	30.8	15.0	7.5	5.0	10.0	17.5	17.5	65.1
Forest Dept. (*n* = 53)	47.6	0	10.2	0	16.3	6.1	10.2	61.5
Overall [n = 135]	37.4	8.9	8.1	2.4	11.3	9.7	10.5	57.8

*Others include diarrhoea, fever, skin peeling and ulcer

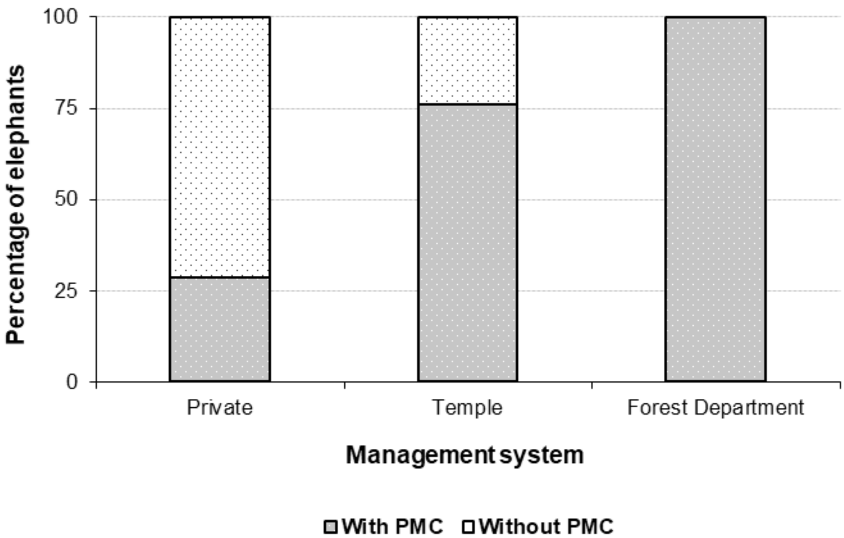
Across three systems, 2.4% of the elephants had arthritis, a physical impairment pertaining to knee joints. The occurrences of injuries/warts/scars were more in the private elephants (38.2%), the inflammation/warts in the forest department elephants (18.9%) and bedsores (32.6%) and sore patches (72%) in the temple elephants (Table 6). The bedsore was common among the elephants tethered in hard substrates such as the granite (35%), cements (33%) and least among elephants tethered in the earthen floors (7%). The small percentage of elephants with bedsore observed in the case of earthen floors could be due to their tethering in hard floors in the past before they brought to present systems.

Table 6. Details of other health problems observed among the captive elephants in the three management systems of Tamil Nadu.

Management Systems	Other health problems (%)			
	Injuries / Wounds / Scars	Inflammations / Warts	Bedsores	Sore patches
Private (34)	38.2	11.8	11.8	47.1
Temple (43)	11.6	16.3	32.6	72.1
Forest Department (53)	32.1	18.9	3.8	41.5

Periodic Medical Care: The data collected on the veterinary care in the three captive systems revealed that about one fourth of the elephants in the private and three fourth in the temple facilities had systematic periodic medical checkups and the rest of the elephants did not have periodical medical checkups, while in the forest department all the elephants had access to periodical medical Health Care check ups (Fig. 5). Tests of proportion also revealed that the elephants in the private facility had significantly lesser access to periodical medical check ups (Z = - 2.54; P < 0.011).

Figure 5. Percentage of elephants with or without Periodical Medical Checkup (PMC) in the three captive management systems of Tamil Nadu.



5. DISCUSSION

5.1 Health condition

Growth: The growth in terms of shoulder height and body weight in elephants could be useful to evaluate feeding, nutritional status and general health (Hile *et al*., 1997). The mean shoulder height of the elephants in different age classes showed that temple elephants were taller in almost all age classes than the other captive elephants belonging to the forest and private managements. While the shoulder heights of captive elephants belonging to forest department were taller than that of the private facilities for many adult classes, the sub-adult females in the latter facility were taller than the former facility. This could be due to the smaller sample size of shoulder height data for the sub-adult females in the private system unlike the forest department that had provided a large sample size for this age class. The growth curve obtained from the shoulder height records of various age classes showed that the private elephants attained a lower asymptotic shoulder height (241 cm) when compared to female captive elephants of the forest department (243 cm) and Temple facilities (251 cm). This higher asymptote observed in the Temple elephants when compared to the elephants of the forest department and private facility could be due to the absence of work that involves carrying weight such as joy ride and timber logging.

Similarly, the growth curve obtained based on body weights of various age classes showed that for the temple elephants' the asymptotic body weight (3890 kg) was far higher than the private (3199 kg) and the female elephants of the forest department (3104 kg). However, sample size obtained for the private facility was far smaller than the forest department system, and as such, the higher body weight observed in the case of private elephants might be due to smaller sample size. Further the scattered distribution of body weights from the fitted curves indicated a wide variation in the body weights within the same age class in the temple and private facilities. But in the forest department, the distribution of all the body weight records were closer to the curve indicating a high uniformity in the body weights of individuals of same age class, because of similar conditions of upkeep.

Largely the data on the shoulder height and body weight of captive elephants managed in the three captive systems showed that the captive elephants that belonged to the forest department had been maintained with a uniformly good health condition without much variation that resulted a moderate level of growth as inferred from their asymptotic shoulder height. On the contrary, the captive elephants of private facility although marginally were heavier than the captive elephants belonging to the forest department, their relatively smaller asymptotic shoulder height coupled with scattered distribution of body weights from the fitted curve indicated inconsistency in their overall health condition. The shoulder height and body weight of the temple elephants were far higher than the elephants managed in the other two systems. Nevertheless, the excessive body weight of temple elephants (shown by the asymptotic body weight–3890 kg, as compared to 3055 kg estimated for timber camp elephants (Sukumar *et al.,* 1988) is a matter of concern as far as welfare of temple elephants are concerned, as they are mostly kept chained in their indoor enclosures without much exercise.

5.2 Disease prevalence and veterinary care

Analysis of the data on the prevalence of different diseases and health impairments in the 135 captive elephants managed in the three systems showed that the intestinal parasitic (helminthic) disease was the most common disease affecting 37% of the captive elephants. The higher prevalence rate of intestinal helminthiasis observed in the captive elephants at Tamil Nadu is comparable to the prevalence rate (47%) recorded among the captive elephant populations in Kerala (Chandrasekharan et al., 1995). The regular vaccinations and de-worming provided during the special re-juvenation camps conducted for the temple and private elephants by the Tamil Nadu government during 2003 and 2005 might be the reason for lesser incidence of intestinal parasitic diseases among the captive elephants of Tamil Nadu during the present study period, which coincided with those Rejuvenation camps. Other diseases such as anemic conditions (11%), digestive problems (10%), foot rot (9%) and corneal opacity (8%), which were less prevalent had been reported to affect the captive elephants of Kerala also (Chandrasekharan *et al*., 1995). An exclusive study on the prevalence of eye problems in 140 domesticated elephants in Sri Lanka by Godagama *et al*. (1999) showed 27% of the elephants with eye defects.

Comparison of disease prevalence among the three management systems showed that the health problems were higher in the elephants of temple system followed by the forest department and least among the private elephants. These figures do not represent actual extent of health problems in each temple and private management because of following reasons. The disease details were collected for each elephant since their arrival at the present location from the register records and by enquiring the concerned *mahouts*. Firstly, the absence of register maintenance for most of the private facility (80%) followed by temple elephants (21%) may have resulted in under representation of the health problems in the private and temple systems compared to the forest department elephants, which had detailed register of records for each individual since their birth/capture. Secondly, information obtained through enquiry with the concerned *mahouts* in private elephants especially for the individual owned ones, were inadequate due to frequent changes of ownership and/or *mahouts*. Therefore, the poor record maintenance in the private, temple facilities, and frequent changes in the ownership and mahouts, the data obtained on the prevalence of disease in these two systems are clearly underestimations and as such cannot be compared with the forest department elephants. Although, the results of the present study do not reflect the actual extent of health problems of private and temple elephants, it still indicated a higher prevalence of diseases specific to the temple and private management systems. For example, diseases like foot rot and arthritis were found among the elephants in temple, and private systems but were absent in the forest department elephants indicating the high susceptibility of temple and private elephants to such diseases. The higher occurrences of foot rot among the temple and private institutional owned elephants could be attributed to chaining elephants in unhygienic damp conditions resulting from the build up of urine and faeces, which the elephants cannot escape, when they are chained in enclosures (Galloway, 1991; Chandrasekharan et al., 1995. Tripathy and Acarjyo, 1992; Roocroft and Ostuerhuis, 2001).

The poor sanitary conditions with relatively less frequency of bathing, poor drainage system and dung disposal at closer distance with relatively higher proportion of time elephants chained at the houses in temple and private managements could have affected the health condition of these elephants more than the captive elephants managed by the forest department that leaves most of their elephants into the natural habitat freely for grazing. Similarly, the higher occurrence of arthritis in the temple elephants followed by private elephants could also be due to the prolonged chaining and absence of sufficient exercise, as reported elsewhere for captive elephants in the western zoo (Galloway, 1991; Hittmair and Vielgrader, 2000; West, 2001). In support of this, the result of the present study, which estimated the chaining duration, to be highest for the elephants in temples (85% of time/day) followed by those in the private facility (72% of time/day). On the other hand, lowest chaining duration (27% of time/day) and higher time spent on foraging (55% of time of a day) in natural habitats seemed to have averted the appearance of foot rot and arthritis among the captive elephants managed by the forest department.

A higher proportion of captive elephants of the forest department experienced intestinal parasites, as compared to the private and temple elephants. The parasitic infections are easily contagious. If any one individual contacts dung pile with parasite belongs to wild elephants in the natural habitat, it gets spread to the other individuals more easily, especially when they are managed in social groups, as found in the forest department than among individuals managed in isolation, as in the case of private or temple systems. In support of this, it was found that 81% of the 16 forest department elephants from the timber camp from Anaimalai checked for intestinal parasite, showed a positive result. Therefore, elephants managed in social groups are highly susceptible to parasitic diseases and so for them more frequent diagnosis and treatments are essential. The appearance of corneal opacity among the elephants has been ascribed to deficiency of vitamin A and injury. The higher occurrence of corneal opacity in the forest department facility compared to private and temple facilities could be attributed to their nature of occupation (timber hauling) or forest dwelling habitat. The eyeball gets damaged by sticks or thorns from bushes or trees during foraging, timber logging and joy ride inside the forest areas and also from attacks by the wild elephants too, to which the temple and private elephants were never exposed. Tuberculosis has been emerged as one of the major diseases among captive Asian elephants in the western countries (Mikota *et al.,* 2000). Nevertheless, the present study has not recorded the disease, as its prevalence has not been diagnosed and documented in detail among the captive elephants in Tamil Nadu. It is likely be due to lack of resources and clinical facilities in India.

In general, wildlife medicine has received less interest in India compared to the western world. The situation is the same with regard to the captive elephant health care as well (Vanitha *et al.* 2011). Lack of appropriate equipments with clinical facility and lack of interest among the veterinarians in the past to serve in wildlife field under which the captive elephant management had been streamlined as a legal entity in India had been the major drawbacks. Among the three captive elephant facilities in Tamil Nadu, the forest department facility is known for scientific management since colonial period by veterinary experts called Forest Veterinary Officer (FVO). The FVO is the key person for the management of elephants in the timber camps where >95% of the elephants under the forest department are managed. He is based at a Central place between the two timber camps and visits both the camps on periodic intervals, while a Veterinary Assistant based in one of the timber camps (Mudumalai) that has a basic clinic facility takes care of elephants on day-to-day basis following prescriptions of FVO. The zoo (AAZP) also has a full-fledged veterinary unit, which takes care of the few elephants that have been managed in the zoo. Although, the FVO extending the service to the captive elephants managed by the temple and private facilities, his service is unavailable all the time to the private and temple facilities due to their wide distribution across the state. Thus, the temple and private facilities mostly take preventive measures by herbal medicine (called *Astasooranam*) at regular intervals for basic health problems like digestive and intestinal parasites etc, and take services of the local veterinarians from the live stock department on emergency. However, most of the local veterinarians do not have enough expertise in handling wild animals, especially elephants. Due to the financial constraints in some private facilities, especially in the case of individually owned elephants, proper veterinary care has not been provided. Therefore, there is a lack of proper veterinary care in the private and temple management systems through out India (Bist *et al.,* 2002), which needs immediate attention and remedial measures.

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REFERENCES

Bist, S.S., Cheeran, J.V., Choudhury, S., Barua, P. and Misra, M.K. 2002. The domesticated Asian elephants in India. *In*: *Giant in our hands*. *Proc. International workshop on the domesticated Asian elephants*. Bangkok, Thailand, February 2001. P. 129-148.

Carrington, R. 1959. Elephants: A short account of their natural history, evolution and influence on mankind. Basic books, Inc., New York.

Chandrasekharan, K., Radhakrishnan, K., Cheeran, J.V., Muraleedharan Nair, K.N. and Prabhakaran, T. 1995. Review of the incidence, ecology and control of common diseases of Asian elephants with special reference to Kerala. *In*: Daniel, J. C. and Datye, H. S. (*Eds*.), *A Week with Elephants*: *Proc. International seminar on the Conservation of Asian Elephant;* June 1993; Oxford Univ. Press, Oxford. P. 439-449.

Dhungel, S., Browner, C. and Yoder, S. 1990. Elephant training and management in Nepal. *Tigerpaper*. 17:1-6.

Galloway, M. 1991. Update on 1990 chaining survey. Proceedings of the 12th International Elephant Workshop, Syracase. New York.

Godagama, W.K., Wemmer, C. and Ratnasooriya, W.D. 1999. Prevalence of eye defects in domesticated Sri Lankan elephants (*Elephas maximus maximus*). *Ceylon Journal of Science, Biological Sciences* 27(1): 41-45.

Gokula, V. 1993. A comparative study on the status and management of Temple elephants with Forest camp and Zoo elephants. M. Phil., Thesis, A.V.C.College, Mayiladuthurai, India.

Hile, E., Hintz, H.F. and Erb, H.N. 1997. Predicting body weight from body measurements in Asian elephants (Elephas maximus) Journal of Zoo and Wildlife Medicine, Vol. 28. 424-427.

Hittmair, K.M. and Vielgrader, H.D. 2000. Radiographic diagnosis of lameness in African elephants (*Loxodonta africana*). *J. Vet. Radiol. and Ultrasound*. 41(6): 511-515.

Krishnamurthy, V. 1995. Reproductive pattern in captive elephants in the Tamil Nadu Forest Department: India. *In*: Daniel, J. C. and Datye, H. S. (*Eds*.), A *Week with Elephants*: *Proc. International Seminar on the Conservation of Asian Elephants;* June 1993; Oxford Univ. Press, Oxford: P. 450-455.

Krishnamurthy, V. 1998. Captive elephant management in India under different systems: Present trends. *Zoo's Print*. 13(3): 1-4.

Krishnamurthy, V. and Wemmer, C. 1995a. Timber elephant management in Madras Presidency of India (1844-1947). *In*: J. C. Daniel and H. Datye. (Eds.), *Week with elephants*. *Proc. International Seminar on the Conservation of Asian Elephants;* June 1993; Oxford Univ. Press. P. 456-472.

Lair, R.C. 1997. Gone Astray - The care and management of the Asian elephant in domesticity. Food and Agriculture Organization (FAO), Regional Office for Asia and the Pacific (RAP), RAP Publ. Thailand.

Mikota, S.K., Larsen, R.S. and Montali, R.J. 2000. Tuberculosis in elephants in North America. Zoo Biol. 19(5): 393-403.

MoEF. 2004. Project Elephant Report. Ministry of Environment and Forests, Government of India, New Delhi.

Monson – Bahr, P.E.C. and Bell, D.R. 1892. Manson's tropical diseases, English Language Book Society, Tindall.

Roocroft, A. and Oosterhuis, J. 2001. Foot care for captive elephants. *In*: Csuti, B., Sargent, E.L. and Bechert, U.S. (*Eds*.), The Elephant's foot. Lowa State Univ. Press, Ames. P. 21-52.

Santiapillai, C. and Jackson, P. 1990. *The Asian elephant*: An action plan for its Conservation. IUCN, Gland, Switzerland.

Santiapillai, C. and Sukumar, R. 2006. An overview of the status of the Asian elephant's. *Gajah.* 25: 3-8.

Sukumar, R. 1989. The Asian Elephant: Ecology and Management. Cambridge Univ. press, Great Briton.

Sukumar, R. Joshi, N.V. and Krishnamurthy, V. 1988. Growth in the Asian elephants. *In*: *Proc. Indian Academy of Sciences* (*Animal Sciences*). 97 (6): P. 561-571.

Sukumar, R., Krishnamurthy, V., Wemmer, C. and Rodden, M. 1997. Demography of Captive Asian Elephants (*Elephas maximus*) in Southern India. *J. Zoo Biol.* 16: 263-272.

Tripathy, S.B., Das, P.K. and Acarjyo, L.N. 1992. Treatment of stephanofilarial dermatitis in an Asian elephant. The Asian elephant - Ecology, Biology, Diseases, Conservation and Management. Kerala Agricultural Univ., Vellanikkara, Trichur, India. 162-163.

Vanitha, V. 2007. Studies on the status and management of captive Asian elephants (*Elephas maximus*) at Tamil Nadu in Southern India, Ph.D. thesis, Bharathidasan University, Tiruchirapalli, India.

Vanitha, V., Thiyagesan, K., Baskaran, N., 2011. Prevalence of intestinal parasites among captive Asian elephants Elephas maximus: effect of season, host demography, and management systems in Tamil Nadu, India. J. Threat. Taxa 3 (2), 1527–1534.

Vidya, T.N.C. and Sukumar. R. 2002. The effect of some ecological factors on the intestinal parasite lodes of the Asian elephant *(Elephas maximus*) in southern India. *J. Biosci.* 27: 521-528.

Watve, M.G. 1992. Ecology of host - parasite interactions in wild mammalian host community in Mudumalai, southern India. Ph. D., Thesis, Indian Institute of Science, Bangalore, India.

Watve, M.G. 1995. Helminthes parasites of elephant's ecological aspects. *In:* Daniel, J. C. & Daty, H. S. (*Eds.*), *A week with elephants*: *Proc. International seminar on the Conservation of Asian Elephants;* June 1993; Oxford Univ. Press. New Delhi. P. 289- 295.

Wemmer, C and Krishnamurthy, V. 1992. Methods of taking standard measurements in live domestic elephants. *In:* Silas, E. G., Nair, M. K. and Nirmalan, G. (Eds.), The Asian elephant: ecology, biology, diseases, conservation and management. Kerala Agricultural Univ. Trichur, India.

West, G. 2001. Occurrence and treatment of nail/foot abscesses, nail cracks, and sole abscesses in captive elephants. *In*: Csuti, B., Sargent, E. L. and Bechert, U. S. (Eds.), The Elephant's Foot. Iowa State Univ. Press, Ames. P. 93-97.

GEOMETRIC MORPHOMETRICS APPROACH: AN OVERVIEW

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1. INTRODUCTION

One needs advance computational tools, now a days, to solve complex problems in biology, and all such computations works with an appropriate mathematical framework; yet, most of them rooted precisely in matrix-algebra, multivariate statistics, non-Euclidean geometry, neural networks etc. Such mathematical treatments seldom come under comfort zone of biologist. However, many students (even faculties) apply them in their research simply by reading short manuals or using related software's, on trial and error basis, without understanding the rationale behind.

Although numerous studies use Geometric Morphometrics (hereafter GM) approaches, but they deal with application and interpretation of the GM results than explaining the basic theory. Indeed, in such cases explanations of GM theory are irrelevant to their objectives and hence it is justified for their limitations. Consequently, this review aims to explain the theoretical aspects of GM in simple terms, and a broad speculation on their application in the field of conservation biology. Therefore, here, we have not dealt with the procedure of GM analysis that the information would be normally available in help manuals along with different GM software packages.

It must be admitted that most the information discussed here is indeed derived from Zelditch *et al.* (2004), Rohlf (1998, 2000) and Bookstein (1991). Zelditch *et al.* (2004) is an excellent reference/ text book on GM. Therefore, readers who want to understand the advancement of GM may refer those references for further reading.

2. Shape Analysis

We covered broad aspects of GM in this review, namely measurement theory, concepts of shape, and kindle shape space. Shape analysis plays an important role, and explains morphological changes due to disease/injury, growth and development, and adaptation to local geographical conditions for long term evolutionary diversification. Thus, differences in morphology signal different functional roles either in response to the selective pressures or differences in selective pressures itself. Shape analysis is one approach to understand the diverse causes of morphological variation and corresponding shape transformations among individuals or in their parts.

Literature dealing with traditional morphometrics, shapes have been either mentioned or represented or compared with known observed shapes such as circles, ellipsoids, or letters of the alphabets or shape of well-known geographic features etc. Such comparisons assume meaningful in traditional morphometric studies as most of them were mainly qualitative in nature. However, GM is a quantitative way of addressing the shape comparisons among individuals or their parts, and the approach is, indeed, closer to statistics or algebra than mere description of biology or their morphology. GM allows one to visualize differences among complex shapes with nearly the same facility as one could visualize differences among circles and letter of alphabets.

2.1. Measurement Theory

Traditionally, length, depth and width measurements have been used for morphometric studies. Most of the information available in such datasets are highly ambiguous and contain less information than they appear to hold (Fig.1). One of the important measurement issues here is that several of the measurements radiate from a single point, so they are not independent and a small error in fact affects the entire structure of nearby measurements.

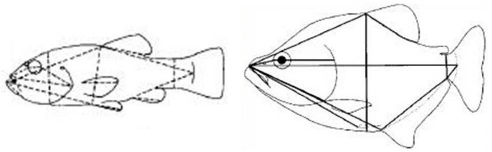


Figure 1. Conventional morphometric measurements of length, width, and depth on the specimens.

Box truss was a classical measurement scheme developed by Bookstein and colleagues (Strauss and Bookstein 1982; Bookstein *et al.,* 1985). Box truss is set of measurements may vary in length and more evenly spread with the size of the organism. All of them are more meaningful and their endpoints are biologically homologous anatomical loci – landmarks. Thus, box truss was a clear improvement over the classical, then existing, measurements schemes. However, the measurement schemes are neither fully free from redundancy nor measure of shape.

2.2. Landmarks

Landmarks are fixed, representing homologous points on the object/specimens of research interest. Oftentimes, researchers may also use semi landmarks which are points on a geometric feature of object/specimens (curve, edge, surface) defined mathematically in terms of its position on the feature (most commonly equally spaced). Semi landmarks provide information about curvature on the specimens, and should be used alongside fixed landmarks.

Ideally, landmarks are (1) homologous anatomical loci that (2) do not alter their topological positions relative to other landmarks, (3) provide adequate coverage of the morphology, (4) can be found repeatedly and reliably, and (5) lie within the same plane. Bookstein (1991) classified landmarks into three categories: Type 1, Type 2 and Type 3. This classification was based on the visibility of the homologous loci (landmarks) on the object/ specimens.

2.3. Kendall Shape

The idea of size and shape has been one of the most controversial subjects in traditional morphometrics. Kendall (1977) gave an interesting definition to the puzzling problems of size and shape. He defined shape as "*all the geometric information that remains when location, scale and rotation effects are filtered out from an object*".

Important implication of Kendall's definition is that curvature or shape is a feature of an object that remains after filtering out location, scale, and rotational effects, but it is not necessarily captured effectively by the coordinates of a set of landmarks. These operations and consequence are shown in the fig. 2. There are two configurations still differ in side by side and the change in location has no bearing on their shape difference, so both have been translated to same location (Fig. 2a). The two configurations still differ in scale, and again it has no bearing on shape so it is converted to the same scale (Fig. 2b). The two configurations still differ in orientation which has again no bearing on shape, so they are rotated to an alignment that leaves only shape difference. After removing all the differences that are not shape differences, and if this is done in a way that does not alter the shape, then one left with only shape differences. Here, one can use the coordinates of the final configuration of the object (Fig. 2c) to analyse shape differences. In the same way, two different shapes of triangles and corresponding coordinate configuration are shown in the figure 3a &b that would be used in the case study given below.

Kendall's definition of shape mentions that scale as one of the effects to be removed to extract differences in shape between two configurations. Here, centroid size is the one measure of size that is mathematically independent of shape, so centroid size may often be correlated with shape because larger organisms are differently shaped than smaller ones. Before computing geometric scale, one need to determine the location of the centre of the form (its 'centroid') which is calculated by the square of each of those distances, summing all the squared distances and then taking the square root of that sum. This quantity is called 'centroid size' which is mathematically and pictographically shown in figure 4 a & b.

Figure 2. Configuration objects showing changes with respect to location, scale, and rotational effects, (A) translate to a common location in the coordinate system (x, y) (B) Scale to unit size (C) Rotate to align corresponding landmarks (Images redrawn from Zelditch *et al.,* 2004).

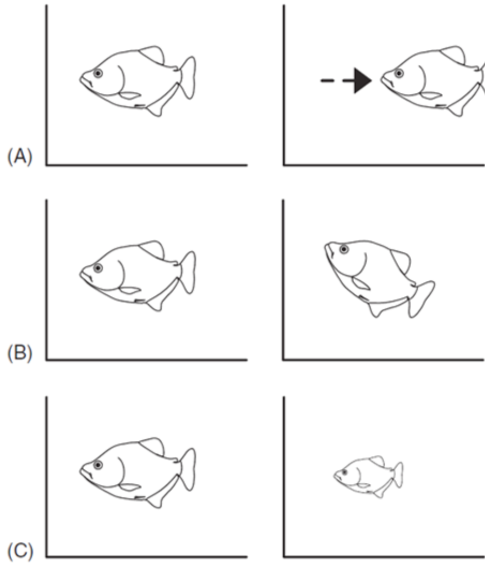
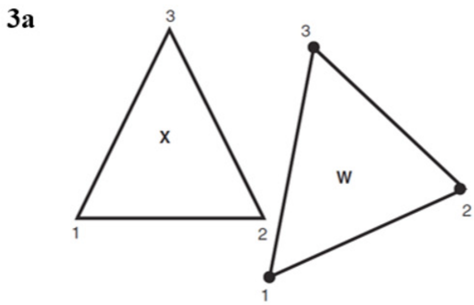


Figure 3. (a) Shows triangles of two different shapes represented as X and W. (b) Shows corresponding coordinates of the X and W respectively.



3b

$$X = \begin{bmatrix} -1 & -1 \\ 1 & -1 \\ 0 & 1 \end{bmatrix} \quad W = \begin{bmatrix} 1.07 & -1.64 \\ 3.10 & -0.72 \\ 1.55 & 0.82 \end{bmatrix}$$

3. Important conditions for GM analysis

Replacing the distances of traditional morphometrics with landmark coordinates does not forces us to sacrifice conventional statistical analyses of shape. The one important distinction between analyses of geometric shape data and those of conventional morphometric data is that all analyses of landmark configurations are necessarily multivariate.

It is defined as shape is a feature of the whole configuration of landmarks. Even the simplest shape, a triangle, cannot be analyzed univariately; more than one variable is needed to describe differences among triangles completely. Because the shape is defined in terms of the whole configuration of landmarks, so the analyses must be that of the whole. However, this does not prevent us from subdividing an organism to analyze relationships between parts. The tools of geometric shape analysis have a tremendous advantage when it comes to these purposes: not only does this method offer precise and accurate description, but also it serves equally important for purposes of visualization, interpretation, and communication of results. In emphasizing the biological component of morphometrics, we do not discount the significance of its mathematical component. Mathematics provides models that are used to analyze data, including the general linear models exploited in statistical analyses, and the models underlying exploratory methods (such as principal components analysis).

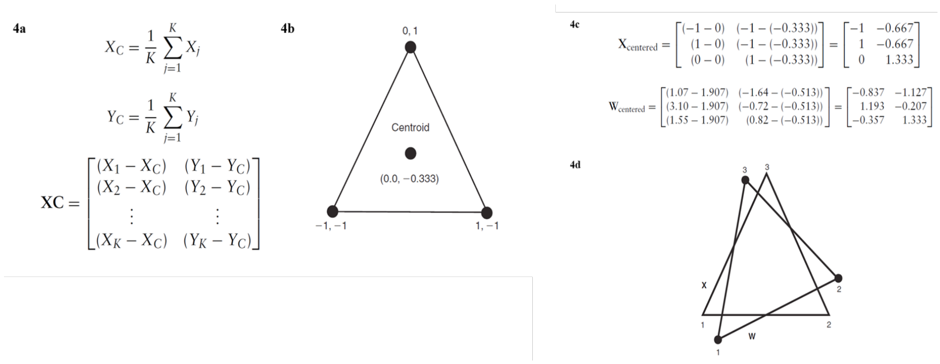
3.1. Case Study: Using Triangles as Objects / Specimens

Using various shapes of triangles, we have attempted to shown a more concrete and accessible parts/aspects of theory discussed above. The same example that has been used in the Zelditch *et al.* (2004) are reproduce here because any change in coordinates of triangle may often create either calculation error or misconception in the readers' mind, so the same triangle example mentioned in the book is followed here.

Will start with two triangles **X** and **W** drawn on a flat surface (Fig.3) with coordinates **X**= (-1, -1), (1, -1), and (0,1) and **W** = (1.07, -1.64), (3.10, -0.72), and (1.55, 0.82). Each triangle has K= 3 landmarks with M = 2 coordinates (x, y) or dimensions. Thus, the configuration matrix of each triangle has six entries in other words six pieces of information are needed to determine all the property of a given triangle namely, size, shape, location, and rotation. Because we need all six coordinates to determine the triangle, we can say there are six degrees of freedom. This is one of the simplest ways to understand the meaning of degrees of freedom.

For each triangle, the coordinates of respective centroid are calculated (Fig. 4a&b). By subtracting the centroid coordinate from the corresponding coordinate of each landmarks produced the centred configuration matrices (Fig. 4c&d).

Figure 4. a) Shows the calculation for measuring centroid size. b) Pictorial representation of the triangle with centroid size representing in the middle. c) The centred configuration of the matrices of X & W. d) Representation of centred X & W triangles



The centred triangles are rescaled to unit size 'one' or one centroid unit. This brings the triangles into pre-shape space. This is done using the calculation shown in the figure 5a. Now the triangles which are centred/translated and scaled are in pre-shape space which is a three-dimensional space with loss of three degrees of freedom due to changes in location and scaling (centroid size) (Fig 5b).

By rotating/orientating the triangle, choosing **X** as reference mean that **W** will be target, so the next step is to rotate **W**, in the plan of the page around its centroid through some angles( ). After rotation, the **X** and **Y** will be mapped on new coordinates as shown in the fig. (5a, b).

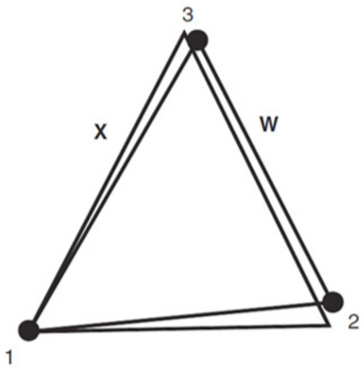
Now the $\mathbf{W}_{\text{pre-shape}}$ rotated is said to be in *partial Procrustes* superimposition on the reference form $\mathbf{X}_{\text{pre-shape}}$. Then, by slight changing the centroid size that would further reduce the distance between **X** and **W**. Now this triangle is in Kendall shape space with the reference of triangle $\mathbf{X}_{\text{pre-shape}}$ which is in *full Procrustes* superimposition.

Figure 5. a) Show the pre-shape rotated configuration matrices of W. b) Triangle of X & W after pre-shape rotation to minimize the Procrustes distance (p).

5a

$$\mathbf{W}_{\text{pre-shape, rotated}} = \begin{bmatrix} (-0.362\cos\theta) - (-0.488\sin\theta) & (-0.362\sin\theta) + (-0.488\cos\theta) \\ (0.516\cos\theta) - (-0.089\sin\theta) & (0.516\sin\theta) + (-0.089\cos\theta) \\ (-0.154\cos\theta) - (0.577\sin\theta) & (-0.154\sin\theta) + (0.577\cos\theta) \end{bmatrix}$$

5b



4. Tangent spaces

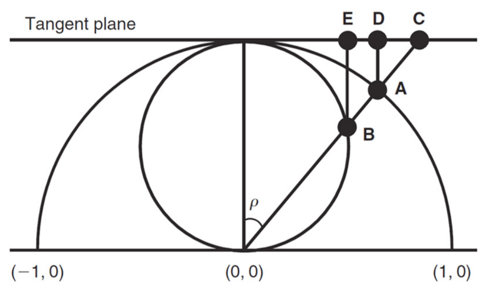
The important fact is that the curvature of shape space makes statistical inference more difficult in this space than it is in Euclidean spaces. Methods of multivariate statistical analysis assume a Euclidean space; therefore, replacement of Kendall's shape space to Euclidean approximation is important. The important technical terms related to various spaces are showed in the figure 6.

Outer hemisphere is the space constructed by aligning pre-shapes (with centroid size fixed at one) as shown in the figure 6. The inner sphere is Kendall's shape space, constructed by scaling the aligned target shapes to centroid size = cos (p). Tangent to both these spaces, at the reference shape, is a Euclidean plane.

It is important to note that the differences between the Procrustes, *partial Procrustes* and *full Procrustes* distance from the reference become negligible as (p) approaches to zero. Similarly, the differences among the stereographic and orthogonal projects also become negligible as (p) approaches zero.

Figure 6. Tangent space to shape spaces of triangles and projections onto the tangent space. Outer hemisphere is cantered and aligned shapes scaled to unit centroid size, and inner circle represents the Kendall's shape space of centred, aligned shapes scaled to cos(p). The plane is tangent to the sphere and the hemisphere at the point of the reference shape. The configuration at point B represents triangle in Kendall's shape space; A is the same shape scaled to unit centroid size; C is the stereographic projection of B onto the tangent plane. D is the orthogonal projection of A onto the tangent plane. E is the orthogonal projection of B onto the tangent plane (Images redrawn from Zelditch *et al.* 2004).

6



CONCLUSION

This main aim of this review is that the mathematical theory of shape is summarized in an easily readable and user-friendly manner that could benefit to anyone including a graduate student or any lay man. Here, we fully understand the negative consequences of the process of simplification of this complex subject and it was consciously done by keeping the essential elements intact. Otherwise, GM is a world of mathematics often impenetrable to any lay biologist. The other main caveat in this review is that we have not discussed the method of digitizing the specimens using landmark coordinates, the method of analysis and interpreting results. Instead, we focus on the way to understand the concept behind the theory of shape. If one understands the rationale and theory behind the computation work, it is expected that one would commit less mistakes. Such kind of simplification of term/procedures is very much need of the hour as more biologists venturing into GM without understanding the theory.

Using this advanced GM approaches, questions related to systematics including taxonomic, phylogenetic, and evolutionary history could be answered meaningfully (Rohlf 1998). Further, model species ranging from invertebrates to higher vertebrates has been covered under the preview of GM approaches in recent years (Adams and Rosenberg 1998, Rohlf 1998, Adams *et al.* 2004). Because the input data set for GM approach is a digital image, attempts have been made to estimate the animal morphometry in non-invasive ways (Mahendiran *et al.* 2017). Hope, this piece of little work would make meaningful way for understand the theory of shape as well as their applications, by any beginner, in this emerging field.

ACKNOWLEDGEMENTS

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REFERENCES

Adams, D.C. and Rosenberg, M.S .1998. Partial-warps, phylogeny and ontogeny: a comment on Fink and Zelditch (1995). *Systematic Biology.* 47: 167-172.

Adams, D.C., Rohlf, F.J. and Slice. D.E. 2004. Geometric morphometrics: Ten years of progress following the 'revolution.' *Italian Journal of Zoology* 71:5-16.

Bookstein, F.L. 1991. Morphometric tools for landmark data: Geometry and biology. Cambridge University Press, Cambridge.

Bookstein, F.L., Chernoff, B., Elder, R. *et al.* 1985. Morphometrics in Evolutionary Biology. The Academy of Natural Sciences of Philadelphia.

Kendall, D. 1977. The diffusion of shape. *Advances in Applied Probability* 9:428-430.

Mahendiran, M., Parthiban, M., Azeez. P.A., and Nagarajan, R. 2017. *Insitu* measurements of animal morphological features: A non-invasive method. *Methods in Ecology and Evolution.* 9: 613-623.

Rohlf, F.J. 1998. On applications of geometric morphometrics to studies of ontogeny and phylogeny. *Systematic Biology* 47: 147-158.

Rohlf, F.J. 2000. On the use of shape spaces to compare morphometric methods. *Hystrix.* 11: 8-24.

Strauss, R.E. and Bookstein, F.L. 1982. The truss-body form reconstructions in morphometrics. *Systematic Zoology* 31:113-135.

Zelditch, M. Swiderski, D. Sheets, H. and Fink, W. 2004. Geometric morphometrics for biologists: A primer. Elsevier Academic Press, London.

DIURNAL ACTIVITY PATTERN OF GOLDEN LANGUR IN DIFFERENT FRAGMENTED HABITATS OF WESTERN ASSAM, INDIA

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ABSTRACT

Activity patterns and time budgets are two important aspects of animal behavior that researchers use to investigate ecological influences on individual behavior. We collected data on activity patterns and time budgets in two groups of Golden Langurs (*Trachypithecus geei)* from May 2013 to April 2015 in different fragmented and isolated habitats of Western Assam, India via scan sampling method with 10-min intervals. The diurnal activity pattern of Golden Langurs showed morning and evening foraging peaks, with a midday resting peak. Time spent on foraging was highest during wet seasons for the habitats which did not vary significantly among seasons but varied across the day. Forging and resting were the most frequently observed behaviour of Golden Langur. Correlations between time budgets and activity with food availability clearly indicated that Golden Langurs might adopt to cope with the habitat when area and preferred foods were scarce in the prevailing habitat.

Keywords: Activity patterns. Golden Langur, habitat, time budgets

1. INTRODUCTION

Information on activity pattern of animals helps us to understand their foraging and survival strategies in their habitat (Ashokkumar, 2011). The way in which an animal allocate it's time to various activities provides a useful base to its overall ecological strategy and allocation of time and energy are important to the survival of all specie (Ghosh *et al.,* 2003). Optimal Foraging Theory predicts that animal should organize their feeding activities in such a way that they can balance with energy expenditure. It has been reported that folivorous with diets of unusually low nutritional quality should spend more time resting than those with higher quality diets, relating the feeding time with habitat condition (Solanki and Kumar, 2010). Nilgiri Langur shows this pattern of feeding on young leaves in Evergreen forest and mature leaves in Moist deciduous forest which could be low in nutritional value and also have digestion inhibitors. It would consequently spend more time in resting to allow digestion. The time spent on feeding is was more than 40% by Capped Langur in Tripura (Gupta and Kumar, 1994) and also in Arunachal Pradesh (Solanki and Kumar, 2010).

Activity Budget represents a quantitative description of an animal's response to a variety of factors influencing its survival and reproductive success (Defler, 1995).The amount of time an individual spends in an activity may be influenced by the characteristics of the individual, group, environment and other behaviours in the activity budget. On the other hand, environmental factors that may influence activity budget include the amount of daylight, risk of predation, and resource availability (Bunnell and Gilligham, 1985; Fleming, 1988; Alm *et al.,* 2002). As per Miller and Dietz (2006), resource availability may vary at different levels that includes space (e.g., habitat quality), time (e.g., seasonal), and nutrition (e.g., energetic content). Allocation of time to different activities and distribution of these activities throughout the day is also important to understand how animals adjust to various habitats to optimize resource use for survival and reproduction. From the ecological point of view activity budgeting is an important indicator of the health of the habitat, reflecting the status of the resources and it is a powerful method of interpretation of stress of the animal in the wild.

A thorough search in literature on the activity budget indicated that the Golden Langur distributes their time in performing various activities in fragmented habitats is sporadic. Moreover, there is absolute paucity of research on Golden Langur's activity profile that lives in different habitat conditions.

The flexibility of Langur's behavioural response to fluctuations in resource availability in fragmented habitats is an essential component of its adaptive strategy. The assessment of the time activity of the Golden Langur in fragmented habitats would provide information for making conservation and management plan for the species. Hence, it is aimed to assess the diurnal activity pattern of Golden Langur in different fragmented habitats of Western Assam, India.

2. STUDY AREA

Based on literature survey two fragmented sites were selected in Western Assam, Northeast India for the study.

2.1 Semi-evergreen Fragmented Forest

For this type of habitat, Kakoijana Reserve Forest (hereafter referred as "KRF") which is a semi evergreen forest (hereafter referred as "SEF"), an isolated habitat situated in Bongaigaon District of Southern Assam, (26° 24' N-latitude and 90° 36.5' E longitude) with a total area of 17.201 square km was selected to study the Golden Langur. The region has a tropical monsoon climate receiving an annual average rainfall of about 100cm with maximum and minimum temperature of 36°C and 10°C respectively. Altitudinal variation of KRF ranges between 35 meter and 60 meter above sea level. KRF is bounded on east by the river Aie and on west by river Kujia with its tributaries and the remaining sides of KRF possesses paddy fields. Vegetation type of KRF is semi evergreens to mix deciduous with a wide range of floral and faunal diversity, hence it was declared as reserve forest for biodiversity conservation (Fig. 1).

2.2 Mixed Deciduous Forest

Bamungaon Reserve Forest (hereafter referred as "BRF") which is a Mixed Deciduous Forest (hereafter referred as "MDF"), situated in Bongaigaon district of Southern Assam (26.362632° N and 90.678757° E), with a total area of 10.07square km was selected to study Golden Langur. This area has a tropical monsoon climate receiving an annual average rainfall of about 100 cm with maximum and minimum temperature of 36°C and 10°C respectively. Remaining sides of BRF possesses paddy fields. Vegetation type of Bamungaon Reserve Forest is semi evergreens to mix deciduous with a wide range of floral and faunal diversity.

Figure 2: Google map of Kakoijana Reserve forest situated in Bongaigaon District of Southern Assam, India

3. STUDY SPECIES

The genus *Trachypithecus* is the most diverse Langur taxon, having a broad distribution including India, Sri Lanka, Bangladesh, Southwestern China, and Southeast Asia (Groves, 2005; Wang *et al.,* 1999). It is phylogenetically embedded within the Family Cercopithecidae and closely related to Semnopithecus (Perelman *et al.,* 2011; Wang *et al.*, 2012). According to palaeontologists primates of the subfamily Colobinae might have first appeared in Africa near around 12 millions years age. As per the hypothesis put forth by Wangchuk, 2005, it was the Sankosh rivers and Pelela mountain systems that isolated a population of Capped Langurs during a warming period in central Bhutan and this population later speciated into the morphologically distinct Golden Langur.

The Golden Langur is a rare colobine monkey with a very restricted range being confined to Western Assam in India and Bhutan only. At the time of discovery in the early 1950s, it was believed that it is confined to the forests along Indio-Bhutan Border only but in fact it was found all over the Western Assam as is apparent from its present extent of occurrence. Golden Langur is commonly known as 'Sonali Bandar' ('Sonali'-Golden, 'Bandar'-Langur) in Assamese due to its golden coat color. For many local Hindu people, it is sacred, a living incarnation of the God hanuman, who played a key role in the triumph of good over evil (Roy and Nagarajan 2018).

Golden Langur is a beautiful and a charismatic species, characterized by its coat color. They are sexually dimorphic, and the genital organs are distinct. The coat of adult Golden Langur ranges from creamy white to golden color, gaining a more reddish tinge in winter season. On their flanks and chest, the hairs are darker and often rust colored with a black face. Neonates vary from creamy white to pale in color which gradually turns into golden color at the age of 09–15 months. Subadults can be distinguished from the adults by their relatively smaller body sizes and females lack visible teats. The overall shape of this primate species is slim, with long limbs and tail. The tail has a bobble on the end and is notably larger in males than in females. Adult males are slightly larger than adult females. Females are 490 mm and males are 640–720 mm in length. Tail length is 713 mm in females and 780–940 mm in males. The body weight also varies among the two sexes. Female weighs 9.5 kg against the 10.9 kg of male (Roy and Nagarajan, 2018).

4. MATERIALS AND METHODS

4.1. Observations

The individuals of different age-sex classes in all three habitats were observed by scan sampling (Altmann, 1974) in different time blocks across the day using binoculars. The time blocks 6-9, 9-12, 12-15 and 15-18 hours were referred as morning (6-9), noon (9-14), afternoon(12-15) and evening (15-18) hours for better understanding of the results. Observations were made on foot (ground) or from an elevated area depending on the topography during wet as well as dry season. The study was conducted covering all the four seasons of the year. As per Borthakur (1986), pre monsoon covers March to May, Monsoon covers June to September, retreating monsoon covers October and November and winter December to February. All the seasons were grouped into two seasons –Wet season (April to September) and Dry season (October to March) respectively. For comparative purposes daily data were grouped by seasons. This procedure enabled an estimate of activity/time budgets for various behaviours, which were calculated as a percentage over a set period of time.

Maximum care was taken to avoid disturbing the Langurs by keep adequate distance depending on visibility. Care was taken to ensure that the target animal or troop did not detect the observer's presence. If the study group was disturbed due to any reason, observation was stopped till the group settled down and performs normal activity (normally after 10-15 minutes). During the sampling, animals were systematically scanned from left to right of the observed group, thus the randomness was maintained on individuals or behaviours. The activities of Golden Langurs were categorized into ten major categories: foraging, resting, locomotion, vigilance, aggressive, comfort, playing, grooming, social behavior and parental care. Each group in all the three habitats was followed from dawn to dusk for six to ten consecutive days every month, although some days were not consecutive due to several environmental factors and on some days, activity had already begun by the time the researcher reached the group. Any opportunistic observations of rare but important events were collected along with scan sampling. Definitions which were adopted in the present study of the major behavioural activity are given below.

The activities were classified into following categories.

Foraging – An individual langur ingests food or is in the act of putting, manipulating, food items towards mouth, searching food materials. The food items are broadly categorized as leaves, fruits, flowers, bark, stem, bud, leaf petiole, and others.

Locomotion – An individual langur travel from one point to another, moving at least the length of its body size. This may include activities i.e. climbing, jumping, sliding, ascending, descending, running, walking, on the ground and carrying clinging immature.

Resting – An individual in stationary position, either remain awake or asleep but in a motionless state. Laying on abdomen with eyes open or closed (dozing) was also considered resting.

Grooming – One animal developing contact with other member or itself by picking up the fur may be mutually searching for ectoparasite or others. It may be allo-grooming or auto-grooming.

Monitoring / vigilance – An individual langur in sitting position, looking around and scanning the forest patch, which comes under visible range. Normally, this activity occurs in between other activities like, resting and locomotion or between locomotion and at the time of inter-troop interaction.

Playing – Any of a variety of self defending behaviours, usually seen among immature animals, which may be in the form of wrestling, chasing, jumping, running, slapping, etc.

Aggression – Any type of aggressive behavior in the form of facial display, vocal threat, bites, displacement and trans-aggression or inter troop aggression like run display, chase, kill or injure another animal.

Social behaviour – Any activity related to socialization within group like approach, depart, embrace, sit in contact, passive support, sexual activity like activity related to reproductive behaviour of an animal like mount, present or solicitation, penile erection, masturbation, inspect, harassment, etc.

Comfort- It includes defecation, urination, rubbing and relaxation.

4.2 STATISTICAL ANALYSIS

Descriptive statistics viz. mean and standard deviation were calculated for all the replicative variables and are given as $\overline{X}$±SD. Statistical analyses were performed by using Windows based statistical package *viz.* Microsoft Excel, MINITAB (Ryan *et al.,* 1992). Mainly parametric test *viz.* Analysis of Variance was used to test different hypothesis. For hypothesis testing $P < 0.05$ and $P < 0.01$ were considered and these level of significance were indicated at appropriate places.

5. RESULTS

5.1. Activity pattern in different habitats

The percent of time spent in different activities (irrespective of age-sex class) based on scan sampling in different seasons and habitats in the study area are given in the table-1 from a total of 9105 scans. Forging and resting were the most frequently observed behaviour of Golden Langur. The category social includes behaviours such as matting, pseudo matting, female-female mounting or female-male mounting and chasing during matting. Defecation and urination were grouped in a category- comfort and were observed throughout the day.

5.2. Time activity budget during different time blocks of a day

The percent time spent on different activities in different habitats across various seasons and time blocks are given in table-1. The time blocks 6-9, 9-12, 12-15 and 15-18 hours were referred as morning (6-9), noon (9-14), afternoon (12-15) and evening (15-18) hours for better understanding of the results.

5.3. Semi evergreen forest:

Among all the activities, Golden Langur spent the highest percentage of time in resting (43.8±26.3%) followed by foraging (29.6±26.8%), locomotion (8.66±9.44%), aggressive (0.37±1.22%) and vigilance (2.35±4.68%) (irrespective of time block).

5.3.1. Semi evergreen forest - Wet season

The overall percentage of resting during wet season was highest of 43.2±26.1% followed by foraging (30.3±26.7%), locomotion (8.60±9.45%), aggressive (0.35±1.18%) and vigilance (2.36±4.71%). Time spent on foraging was highest during morning hours in wet season (47.6±23.8%) followed by another foraging peak in the evening hours (43.5± 24.7%). Resting was dominant behaviour in the afternoon (68.6±18.3%). Locomotion was highest in the evening in wet season (10.7 ± 10.1%). Vigilance and playing behavior were highest in noon hours (2.97 ± 4.48% and 3.39± 6.06% respectively). Social and parental behaviors were more during the noon hours with 0.42 ± 1.43% and 7.59 ± 14.1% respectively. Grooming was found to be more in the afternoon hours (11. 27 ± 15.5%) (Table 1).

5.3.2. Semi evergreen forest - Dry season

The overall percentage of resting during dry season was highest of 44.3±26.9% followed by foraging (29.1±26.4%), locomotion (8.70±9.44%), aggressive (0.38±1.25%) and vigilance (2.35±4.67%). Time spent on foraging was highest during morning hours in dry season (47.2 ± 24.7%) followed by another foraging peak in the evening hours (40.7 ± 26.5%). Resting was dominant behaviour in the afternoon (69.6 ± 17.3%). Locomotion was highest in the evening in dry season (10.8 ± 9.96%). Vigilance was highest in noon hours (2.98 ± 4.19%). Comfort was highest in the morning hours (2.84 ± 10.35%). Playing and parental care were more in the noon hours with 3.28 ± 5.99% and 7.94 ±14.5% respectively. Grooming was found to be more in the afternoon hours (10.9 ± 14.9%) (Table 1).

5.4. Mixed deciduous forest:

Among all the activities, Golden Langur spent highest percentage of time in resting of 43.9±26.4% followed by foraging (29.7±26.7%), locomotion (8.54±9.40%), aggressive (0.37±1.21%) and vigilance (2.37±4.65%) (irrespective of time block).

5.4.1. Mixed deciduous forest - Wet season

The overall percentage of resting during wet season was highest of 43.5±26.1% followed by foraging (30.0±26.6%), locomotion (8.76±9.46%), aggressive (0.39±1.24%) and vigilance (2.36±4.69%). Time spent on foraging was highest during morning hours (40.4 ± 26.5%). Resting was dominant behaviour in afternoon hours (54.17 ± 25.6%). Locomotion and aggressive behaviours were highest in the morning in wet season (10.9 ± 9.59 %) and (0.53 ± 1.45%) respectively. Vigilance and Playing behaviour were highest in noon hours (2.86 ± 2.81% and 2.40 ± 5.32% respectively). Grooming was highest in the afternoon hours (7.85 ± 12.8%). Social and parental care is highest in the noon hours during wet season (0.29 ± 1.09%) and (6.41 ± 12.7%) (Table 1).

5.4.2. Mixed deciduous forest - Dry season

The overall percentage of resting during dry season is high 44.3±26.6% followed by foraging 29.4±26.7%, locomotion 8.31±9.33%, aggressive 0.35±1.18% and vigilance 2.38±4.61%. Time spent on foraging was highest during morning hours (34.4± 27.2%). Resting was dominant behaviour in afternoon hours (47.62± 26.7%). Locomotion and aggressive behaviour was highest in the morning in dry season (7.55± 9.07%) and (0.48 ±1.48%) respectively. Vigilance, comfort and playing behaviour was highest in noon hours (2.68 ± 5.30%, 2.87 ±8.71% and 1.83 ± 4.67% respectively). Grooming was highest in the evening hours (5.89 ± 8.85%). Social and parental care were highest in the noon hours during dry season (0.29 ± 1.28% and 6.25 ± 12.6% respectively) (Table 1).

6. DISCUSSION

The diurnal activity pattern of Golden Langur in fragmented habitats of Assam showed a resting peak in the midday with two foraging peaks in the morning and evening hours in different seasons and habitats which are in accordance with reports for some colobines. For example Capped Langurs (Solanki *et al.,* 2008) and Nilgiri Langurs (Sunderraj, 1984) have morning and evening foraging peaks with a long period of midday resting. The less feeding, more resting and two foraging peaks reflect the good habitat condition and food resource availability (Solanki and Kumar, 2010). These results are compatible with the findings of Roy and Nagarajan (2018), Zhou *et al.* (2007), who suggest that leaf-eating primates minimize energy expenditure in order to cope with the low protein content found in leaves. Resting time in the winter is shorter because they have 10 h on average to devote to feeding activities or moving between feeding sources. By contrast, resting time in summer may be longer owing to the increased ingestion of leaves in their diets. In primates that rely heavily on relatively low-quality (e.g., high-fiber) food, however, the capacity of the forestomach and the speed with which food residues are eliminated from it can influence the maximum amount of food that can be consumed (Roy and Nagarajan, 2018).

The percent time spent on all activities varied significantly across the day in all the habitats but did not varied across habitats and seasons. The activity pattern of morning and afternoon foraging peaks, with mid day resting peak may represent an adaptation to temperature variation (Clutton-Brock 1977; Hill 1999; Huang *et al.,* 2003). We have found that langurs often took shelters in the thick canopy or the shaded areas where it is cooler than outside, at noon summer days and had long resting periods of 3-4 hrs. Thus mid day resting peak in Golden Langur in its diurnal activity pattern may be an adaptation strategy to avoid the hot noon temperature and sunlight. In addition to an adaptation to temperature changes, the long midday resting of Golden Langur possibly aids fibrous food digestion after morning foraging peak. However, activity patterns may have been obscured by lumped data from different days because the diurnal activity patterns varied considerably between days (Clutton-Brock, 1974).

Percent of foraging is more in wet season of both habitats. This can be related to availability of quality food (McKey and Waterman, 1982). The percent time spent on resting was higher in dry season in both semi evergreen and Mixed Deciduous Forest. Enforced resting time requirements are in part set by the time needed for digestion (mainly imposed by the processes of leaf fermentation). Primates living in the regions with high levels of enforced resting time may be restricted in their behavioural responses to food constraints and disturbances. They will need to adopt energy-saving activity patterns such as minimizing travel (Dunbar, 1992b; Pollard and Blumstein, 2008). However, resting reflects not only time waiting to be allocated to something more useful, but also time needed for recuperation, predator avoidance, digestion, and thermoregulation (Korstjens *et al.*, 2010). In the case of Golden Langur, the large amount of time spent on resting could be mainly due to digestion and thermoregulation needs. The proximal section of the stomach in *Presbytis* has a high pH (5.0-7.0) and provides an environment capable of supporting a large and diversified micro bacterial flora (Roy *et al.,* 2012 Resting time is an important determinant of presence/absence, it is clearly not the only one. In fact, both foraging and moving time are positively affected by temperature or temperature variation in both frugivorous and folivorous primates (Dunbar, 1992a, b; Lehmann *et al.,* 2007, 2008; Dunbar *et al.,* 2009; Willems and Hill, 2009).

Biological, physical and climatic factors also influence the time budget pattern of Golden Langurs. The availability of quality dietary resources appears to influence the monkey's daily and seasonal activity budgets. Other than habitat condition, the animals' biological activities also affect the allotment of time. Time allotted for grooming was more in dry seasons. Primates grooming strategies can be related to control of parasite and hygiene. Silvia Rondón *et al.* (2017) reported higher parasite prevalence in the dry season from three primate species viz. *Alouatta seniculus, Ateles hybridus* and *Cebus versicolor*.

Monsoon season has been found to be the longest mating season in Golden Langur during the study period. During this period langurs undergo socialization or pairing, and mating activities due to which the energy demand also increases leading to more foraging during wet seasons. Hot mid days of summer, reduces the availability of time for travelling; animals confined themselves to rest. The available information on this aspect indicates that time budget activity is dependent on habitat condition, season and quality food availability. These findings are important piece of information on the behavioural patterns of this langur species and expand our information on its ecology. Such findings can aid in designing the management action plans for habitat and for better survival and conservation of the species.

REFERENCES

Altmann, J. 1974. Observational study of behavior: sampling methods. *Behavior* 49:227-267.

Alm, U., Birgersson, B. and Leimar, O. 2002. The effect of food quality and relative abundance on food choice in Fallow Deer. *Animal Behaviour* 64: 439–445.

Ashokkumar, M. 2011. Population, Foraging, and Activity Pattern of Gaur (*Bos gaurus* H. Smith, 1827) in Mudumalai Tiger Reserve, Southern India. Ph.D. Thesis, Bharathidasan University, Trichirappalli.

Borthakur, M. 1986. Weather and climate of Northeast India. *The Northeast Geographer* 18: 22 - 27.

Bunnell, F.L., and Gillingham, M.P. 1985. Foraging behavior: Dynamics of dining out. In Hudson, R. J., and White, R. G. (Eds.), *Bioenergetics of Wild Herbivores*, CRC Press, Boca Raton, FL, pp. 53–79.

Clutton-Brock, T. H. 1974. Activity patterns of Red Colobus (*Colobus badius tephrosceles*). *Folia Primatology* 21: 161–187.

Clutton-Brock, T. 1977. Some aspects of intraspecific variation in feeding and ranging behavior in primates. In: Clutton-Brock, T (Ed.) *Primate Ecology: studies of feeding and ranging behavior in Lemurs, Monkeys and Apes*. Academic Press, London, pp 539-556.

Dunbar, R.I.M. 1992a. Time: A hidden constraint on the behavioural ecology of baboons. *Behavioural Ecology and Sociobiology* 31:35–49

Dunbar, R.I.M. 1992 b. A model of the gelada socio-ecological system. *Primates* 33:69–83

Defler, T. R. 1995. The time budget of a group of wild Woolly Monkeys (*Lagothrix lagotricha*). *International Journal of Primatology* 16: 107–120

Fleming, T. H. 1988. *The Short-Tailed Fruit Bat: A Study in Plant-Animal Interactions.* University of Chicago Press, Chicago, p. 364.

Ghosh, N., Spering, M., Wilshaw, J. and Nagarajan, R. 2003. Diurnal activity budgets of breeding Eurasian Oystercatchers *Haematopus ostralegus* feeding on limpets on rocky shores. *Wader Study Group Bulletin* 101/102: 81-87.

Gupta, A. K., and Kumar, A. 1994. Feeding ecology and conservation of the Phayre's Leaf Monkey *Presbytis phayrei* in northeast India. *Primate Conservation* 69: 301–306.

Groves, C.P. 2005. Order primates. Wilson, D. E., Reeder, D. M. (Eds.) *Mammal Species of the World: A Taxonomic and Geographic Reference*. John Hopkins University Press, Baltimore. p.111-184.

Hill, R.A. 1999. Ecological and demographic determinants of time budgets in baboons: Implications for cross-populational models of baboon sociobiology. Ph.D. thesis, University of Liverpool, UK

Huang, C., Wei, F., Li, M., Li, Y. and Sun, R. 2003. Sleeping cave selection, activity pattern and time budget of White-headed Langurs. *International Journal of Primatology* 24: 813-824.

Korstjens, A.H., Lehmann, J. and Dunbar, R.I.M. 2010. Resting time as an ecological constraint on primate biogeography. *Animal Behaviour* 79:361-374.

Lehmann, J., Korstjens, A.H. and Dunbar, R.I.M. 2007. Fission–fusion social systems as a strategy for coping with ecological constraints: a primate case. *Evolutionary Ecology* 21: 613–634

Lehmann, J., Korstjens, A.H. and Dunbar, R.I.M. 2008. Time and distribution: a model of ape biogeography. Ethology Ecology and Evolution 20: 337–359.

McKey, D.B. and Waterman, P.G. 1982. Ranging behavior of a group of Black Colobus (*Colobus satanas*) in the Douala-Edea Reserve, Cameroon. *Folia Primatology* 39: 264– 304.

Miller, K.E. and Dietz, J.M. 2006. Effects of individual and group characteristics on feeding behaviors in wild *Leontopithecus rosalia*. *International Journal of Primatology* 26: 1291-1319.

Pollard, K.A. and Blumstein, D.T. 2008. Time allocation and the evolution of group size. *Animal Behaviour* 76: 1683–1699.

Roy, D., Ashokkumar, M. and Desai, A.A. 2012. Foraging ecology of Nilgiri Langur (*Trachypithecus Johnii*) in Parimbikulam Tiger Reserve, Kerala, India. *Asian Journal of Conservation Biology* 1: 92-102.

Roy, D. and Nagarajan, R. 2018. Biology, Ecology, and Conservation of Golden Langur, *Trachypithecus geei*. In: Pages 251-283. *Indian Hotspots- Vertebrate Faunal Diversity, Conservation and Management* Volume 1. (Eds. Sivaperuman C. and Venkataraman K.) Springer, Singapore. https://doi.org/10.1007/978-981-10-6605-4_13

Ryan, F.B., Joiner, B.L. and Ryan, A.T. 1992. MINITAB Handbook, PWS-KENT Publishing Company, Boston

Solanki, G.S., Kumar, A. and Sharma, B.K. 2008 . Feeding ecology of *Trachypithecus pileatus* in India. *International Journal of Primatology* 29:173-182.

Solanki, G.S. and Kumar, A. 2010. Time budget and activities pattern of Capped Langurs *Trachypithecus pileatus* in Pakke Wildlife Sanctuary, Arunachal Pradesh, India. *Journal of Bombay Natural History Society* 107: 86-90.

Sunderraj, S.F.W. 1984. Foraging ecology and ranging pattern of Nilgiri Langur, *Presbytis johnii*. M.Sc., thesis submitted to Bharathidasan University, Trichirappalli.

Wang, Y.X., Jiang, X.L. and Feng, Q. 1999. Taxonomy, status and conservation of leaf monkeys in China. *Zoological Research* 20: 206-315.

Wangchuk, T. 2005. The Evolution, Phylogeography, and Conservation of the Golden Langur (*Trachypithecus geei*) in Bhutan. Ph.D. thesis. Department of Biology, University of Maryland.

Willems, E.P. and Hill, R.A. 2009. A critical assessment of two species distribution models: a case study of the Vervet Monkey (*Cercopithecus aethiops*). *Journal of Biogeography* 36: 2300–2312.

Zhou, Q., Wei, F., Huang, C, Li, M., Ren, B. and Luo, B. 2007. Seasonal variation in the activity patterns and time budgets of *Trachypithecus francoisiin.* The Nonggang Nature Reserve, China. International Journal Primatology 28: 657-671

Table 1. Percent time spent in various activities by Golden Langur (*Trachypithecus geei*) in different time blocks of the day across the season in the fragmented habitats of Western Assam during the study period May 2013 to April 2015.

Habitat	Season	Time block	Behavioural Activity (% time spent)									
			Feeding	Resting	Locomotion	Aggressive	Vigilance	Comfort	Playing	Grooming	Social	Parental
Semi evergreen	Wet	Morning	**47.6± 23.9**	30.5 ± 19.5	10.1 ± 8.48	0.63 ± 1.61	1.57 ± 3.32	2.59 ± 9.72	1.16 ± 5.08	1.69 ± 4.42	0.19 ± 0.63	3.90 ± 9.60
		Noon	23.0± 21.9	43.2 ± 23.3	8.66 ± 11.2	0.19 ± 0.54	2.97 ± 4.48	2.56 ± 6.60	3.39± 6.06	8.07 ± 9.30	0.42 ± 1.43	7.59 ± 14.1
		Afternoon	7.05 ± 11.3	68.6 ± 18.3	4.92 ± 6.35	0.47 ± 1.56	2.2 ± 3.73	2.38 ± 5.87	0.61 ± 2.31	11. 27±15.5	0.27 ± 1.39	2.12 ± 6.82
		Evening	43.5 ± 24.7	30.8 ± 22.9	10.7 ± 10.1	0.12 ± 0.35	2.60 ± 6.55	0.38 ± 1.84	1.17 ± 3.82	3.03 ± 5.90	0.18 ± 0.62	7.53 ± 14.8
	Dry	Morning	47.2 ± 24.7	31.0 ± 20.1	10.0 ± 8.52	0.69 ± 1.70	1.33 ± 2.93	2.84 ± 10.35	1.13 ± 5.15	1.54 ± 4.33	0.19 ± 0.64	3.94 ± 9.46
		Noon	22.4 ± 21.7	43.3 ± 22.9	8.78 ± 11.1	0.21 ± 0.65	2.98 ± 4.19	2.31 ± 6.38	3.28 ± 5.99	8.21 ± 9.34	0.04 ± 1.55	7.94 ±14.5
		Afternoon	6.45 ± 9.88	69.6 ± 17.3	5.04 ± 6.45	0.47 ± 1.56	2.30 ± 3.68	2.27 ± 5.78	0.66 ± 2.47	10.9 ± 14.9	0.18 ± 0.90	2.12 ± 6.70
		Evening	40.7 ± 26.5	33.4 ± 25.1	10.8 ± 9.96	0.17 ± 0.60	2.78 ± 6.80	0.51 ± 2.43	1.09 ± 3.66	3.06 ± 6.09	0.15 ±0.57	7.35 ± 14.4
	Total		**47.3± 24.4**	30.8±19.8	10.1±8.50	0.67± 1.66	1.42 ±3.09	2.74 ±10.11	1.14±5.12	1.60±4.36	0.19±0.64	3.93±9.51
Mixed deciduous	Wet	Morning	**40.4 ± 26.5**	35.9 ± 24.4	10.9 ± 9.59	0.53 ± .45	1.40 ± 2.81	1.44 ± 6.79	1.11 ± .48	4.39 ± 0.42	0.21 ± 0.78	4.18 ± 11.1
		Noon	30.1 ± 26.6	40.6 ± 24.3	8.78 ± 9.59	0.28 ± 0.90	2.86 ± 2.81	2.59 ± 7.79	2.40 ± 5.32	5.58 ± 8.33	0.29 ± 1.09	6.41 ± 12.7
		Afternoon	20.6 ±22.8	54.17 ±25.6	7.55 ± 9.07	0.48 ± 1.48	2.50 ± 4.28	1.95 ± 5.83	1.19 ± 4.51	7.85 ± 12.8	0.26 ±12.8	3.37 ± 9.18
		Evening	28.9 ± 26.9	43.8 ± 26.7	8.27 ± 9.34	0.25 ± 1.00	2.70 ± 5.63	1.81 ± 6.24	1.64 ± 4.47	5.70 ± 8.32	0.19 ± 0.84	6.71 ± 13.9
	Dry	Morning	34.4 ± 27.2	40.7 ± 26.1	9.01 ± 9.34	0.45 ± 1.41	1.64 ± 3.04	1.85 ± 6.93	1.16 ± 4.29	5.90 ±10.8	0.24 ± 0.98	4.60 ± 11.3
		Noon	29.2 ± 27.4	42.43 ±26.5	8.48 ± 9.59	0.25 ± 0.82	2.68 ± 5.30	2.87 ± 8.71	1.83 ± 4.67	5.69 ± 8.98	0.29 ± 1.28	6.25 ± 12.6
		Afternoon	27.1 ± 25.5	47.62 ±26.7	7.96 ± 9.24	0.44 ± 1.35	2.65 ± 4.61	1.82 ± 6.55	1.40 ± 4.85	6.88 ± 11.5	0.26 ± 1.14	3.87 ± 9.69
		Evening	27.3 ± 26.5	46.47 ±26.9	7.81 ± 9.11	0.26 ± 1.00	2.56 ± 5.05	1.73 ± 5.14	1.57 ± 4.49	5.89 ± 8.85	0.28 ± 1.30	6.04 ± 12.6
	Total		29.7±26.7	43.9±26.4	8.54±9.40	0.37±1.21	2.37±4.65	2.01±6.84	1.54±4.66	5.98±10.1	0.25±1.07	5.18±11.8
ANOVA												
Habitat		F	0.03	0.05	0.53	0.07	0.05	0.05	0.09	0.02	0.15	0.24
		P	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
Season		F	1.39	1.95	2.08	0.6	0.01	0.4	0.47	0.31	0.34	0.02
		P	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
Time block		F	264.92	250.62	35.4	37.32	38.15	12.43	42.08	74.5	5.1	51.36
		P	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

CONSERVATION STATUS OF BIRDS IN EASTERN GHATS OF TAMIL NADU: SIGNIFICANCE OF KEY HABITATS

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ABSTRACT

A study to assess conservation status of birds in Eastern Ghats of Tamil Nadu was carried out in nine administrative districts of Tamil Nadu. Point Count method was used to analyse the diversity and distribution of birds. The result yielded 271 bird species from 181 transects, among which 16 were Rare Endemic and Threatened (RET). Geographical range constriction of the South Indian birds was defined as 'rarity' in this study. Malabar Parakeets, White-naped Tit and Nilgiri Flycatchers known to be Western Ghats RET endemics were recorded in this landscape, showing their range extension. 35 species of Raptors were recorded, including two Critically Endangered Vulture species and nine Owl species. Yellow-throated Bulbul was recorded from Scrub forests, whereas Nilgiri Wood Pigeon, Grey-fronted Green Pigeon, Grey-headed Bulbul, Great Hornbill, Crimson-backed Sunbird, Rufous Babbler, Oriental Dwarf Kingfisher, Grey-headed Fish eagle, Lesser Fish Eagle and Spot-billed Eagle Owl were recorded in denser forests like montane and riparian habitats. Given the species richness and boasting large number of RET species, the study evinced two conservation hotspots within the landscape, i.e. Erode and Kolli hills. Habitats that complemented dense forest were the associated open forest and riparian vegetation. Mosaic of habitats in the Eastern Ghats was found to be the major factor attributing to the species richness and density, thereby highlighting the conservation value of the landscape is highlighted. Locales above 1000 m elevation and forests thriving in proximity to Western Ghats have been accorded high conservation value within the Eastern Ghats complex.

Keywords: Eastern Ghats, Conservation status, Habitat, Point count, Rare Endemic and Threatened species.

1. INTRODUCTION

The ecological study of forest birds in India has made great strides in the past years and the results have had significant impacts on world-wide understanding of factors governing the distribution and diversity of tropical avifauna. The Eastern Ghats of Tamil Nadu have not received the same attention from ornithologists as have the hills in Andhra Pradesh or Orissa or Western Ghats and Himalayas, Here again, the focus was on the Eastern Ghats of Andhra Pradesh as Ali (1933-34), Whistler and Kinnear (1930-37) and Abdulali (1945 & 1953) would suggest. While there are reviews and checklists of birds published from time to time of selected landscapes in the Eastern Ghats of Tamil Nadu (Daniels, 1998; Daniels and Ravi Kumar, 1997) no comprehensive ecological study is available till date covering the entire segment.

Avifauna of the Eastern Ghats of Tamil Nadu is significant for many reasons. Many species of birds found here are considered to be 'climate relics' (Ali and Ripley, 1983; Daniels *et al*., 2005). Salim Ali has specifically drawn attention to certain species of localized birds such as the White-napped Tit (*Parus nuchalis*) in Satyamangalam. There are others like the Yellow-throated Bulbul (*Pycnonotus xantholaemus*) (Ali and Ripley, 1983) that patchily occur here and elsewhere in southern India, where it is endemic. Landscape-level surveys have revealed remarkable species richness of birds in the Eastern Ghats of Tamil Nadu. Available landscape-level checklists are incomplete considering the vastness of the region and the overall paucity of ecological studies in the Eastern Ghats of Tamil Nadu. Against this backdrop there is immense scope for a systematic study of the avifauna and outlining a conservation strategy for the region with birds as the 'flagship'.

There is a vast gap in knowledge of the ecology of forest bird communities of the Eastern Ghats. It is also noteworthy that the Eastern Ghats of Tamil Nadu harbour forests and bird communities that are contiguous with the Western Ghats that scientific knowledge of the factors that govern the distribution and diversity of species in the proposed study area will be of great value for conservation planning. Comprehensive data on habitat use and community structure of birds in the Eastern Ghats is lacking although information on the avifauna is available for certain areas in Krishnagiri district (Annon, 2010; George Tom and Praveen, 2014).

2. MATERIALS AND METHODS

The study was carried out in nine administrative districts (53,652 km^2). Most of the forests in this vast landscape are Reserve Forests, we chose the survey locations according to the Forest Circles. Transects were distributed according to the forest cover and habitat heterogeneity within the Forest Ranges and districts. The total number of transects thus worked is 181 (Each: 3.5-4km)

Each transects were surveyed with stop point of every 50m for conducting point counts (Daniels *et al*, 1992). Thus the time taken to cover one transect was around 6.00 hours starting at 6.00am and closing at around noon. In a survey of birds in the Melagiris (Krishnagiri district) in 2014 by KANS, Tamil Nadu Forest Department and India Bird Conservation Network the transect duration was 7.00-11.00 in the mornings (George Tom and Praveen, 2014). Birds observed were identified and recorded. In selected transects, observations were repeated after dark for crepuscular and nocturnal birds. Elusive birds were located using call-playback techniques. All seasons were included for the surveys although rainy days were avoided.

The total number of species observed in transects cumulated across each forest type and district has been taken as the 'Species Richness' for the geographical unit in focus. Abundance of individual species has not been estimated. Instead the frequency of sighting a species is taken as a measure of its abundance. Thus the number of times a species was encountered in transects has been taken as its frequency.

Six major terrestrial habitats were surveyed they are Dense forests, Open forests, Riparian habitat, Plantations, Cultivation and Rocky scrub. In addition, fragmented wetlands that were also included in the study. Open Forest type was encountered more in all the six forest circles (57 transects) followed by Dense Forest and Riparian forest (45 and 26 transects). Plantations and Wetland habitats are covered with 6 and 8 transects respectively. Rocky Scrub is encountered in only three districts (19 transects).

3. RESULTS

A total of 8455 observations of birds with 271species were made during the 3 years from the 181 transects. Of the 271 species, 40 species accounted for more than 62% of all observation. For practical purposes these may be considered as the most common species of birds in the study area.

The Red-vented Bulbul topped the list of common birds with 429 observations. Some of the other most frequently observed birds are Red-whiskered Bulbul, White-browed Bulbul, Common Iora, Purple-rumped Sunbird, Indian Robin, Spotted Dove, Common Tailorbird, Purple Sunbird, Rufous Treepie and Rose-ringed Parakeet. At the lower end 40 species including the Grey-headed Bulbul, Lesser Fish Eagle, White-naped Tit and Spangled Drongo were observed only once during the entire study. These are presumably the rarest birds in the study area.

Erode district had the highest number of bird species (206) followed by Salem (180), Krishnagiri (174), Dharmapuri (165), Tiruvannamalai (135), Namakkal (117), Viluppuram (83), Tiruchirapally (66) and Vellore (54). The Erode district in particular lies in the zone of transition between the Western Ghats and Eastern Ghats. Many species of forest birds that are found only in the Western Ghats within southern India have been observed in Erode district (Table. 1).

Of the major terrestrial habitats, the dense forests support the highest bird species richness of 152 followed by the open forests (141), riparian vegetation (141), cultivation (100), plantations (82) and rocky (54). That the dense forests support the highest species richness of birds is an interesting observation. The study area is much drier than the

Western Ghats with an average rainfall of around 1000mm. It is felt that the dense forests serve as habitat refuges for birds in drier habitats and this observation may have implications for the understanding of impacts of climate change on tropical birds.

4. DISCUSSION

Rare, endemic and threatened (RET) species attract greater attention in conservation planning. In the present study, rarity is defined by the geographical range of the species in southern India. Species with highly restricted ranges or those on the margins of their distribution are treated as rare. Threatened birds are those listed in one of the many categories provided by IUCN (2017) Red List Category Taking the above into consideration, 16 species have been identified as RET species.

The Erode district is one of the important Vulture conservation areas in the country. It has some of the last breeding sites of the critically endangered White-rumped Vulture. Erode is also outstanding in having the highest share of RET species. While this is attributed to the contiguity it shares with the Western Ghats, the fact that it is the only one of the 9 Eastern Ghats district that 29 has a Wildlife Sanctuary and Tiger Reserve within its geographical limits is to be noted.

Among 271 species 16 were Rare Endemic and Threatened (RET). Geographical range constriction of the South Indian birds was defined as ‘rarity’ in this study. Malabar parakeets, White-naped Tit and Nilgiri Flycatchers known to be Western Ghats RET endemics were recorded in this landscape, showing their range extension. 35 species of Raptors were recorded, including two Critically Endangered Vulture species and nine Owl species. Yellow-throated Bulbul was recorded from Scrub forests, whereas Nilgiri wood pigeon, Grey-fronted Green Pigeon, Grey-headed Bulbul, Great Hornbill, Crimson-backed Sunbird, Rufous Babbler, Oriental Dwarf Kingfisher, Grey-headed Fish Eagle, Lesser Fish Eagle and Spot-billed Eagle Owl were recorded in denser forests like montane and riparian habitats. Given the species richness and boasting large number of RET species, the study evinced two conservation hotspots within the landscape, i.e. Erode and Kolli hills. Habitats that complemented dense forest were the associated open forest and riparian vegetation. Mosaic of habitats in the Eastern Ghats was found to be the major factor attributing to the species richness and density, density, thereby highlighting the conservation value of the landscape is highlighted. Locales above 1000 m elevation and forests thriving in proximity to Western Ghats have been accorded high conservation value within the Eastern Ghats complex.

It is our sincere hope that the results of this study will shed light on the avifaunal significance of the Eastern Ghats of Tamil Nadu. And when the Tamil Nadu Government finally decides to manage the hills of Tamil Nadu as one bio-geographic unit of the State, ecosystem management using birds as the indicators will be the starting point. And finally, if there can be one phrase that sums up the diversity and conservation significance of the birds of the Eastern Ghats of Tamil Nadu it may be said “the Eastern Ghats landscape that is home to more than half its avifauna”.

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REFERENCES

Abdulali, H. 1945. Birds of the Vizagapatnam district. *JBNHS* 45: 333-347.

Abdulali, H. 1953. More about the Vizagapatnam birds. *JBNHS* 51: 746-747.

Ali, S. 1933-34. The Hyderabad State Ornithological Survey’ *JBNHS* Vol 36, 37: 5 parts.

Ali, S and Ripley, S D. 1983. Handbook of the Birds of India and Pakistan (compact edition). New Delhi, Oxford University Press.

Anon. 2010. Vertebrate faunal diversity in Hosur forest division and its contiguous habitats in Dharmapuri forest division of Tamil Nadu, India. A Draft Summary Report Submitted to the Tamil Nadu Forest Department.

Daniels, R.J.R *et.al.* 1992. On the relationship between bird species richness and woody plant species diversity in Uttara Kannada district of South India, Proceedings of the National Academy of Sciences (USA) 89:5311-5315.

Daniels, R.J.R. and Ravi kumar, M.V. 1997. Birds of Erimalai, *NLBW* Vol.37, No.5:80-82.

Daniels, R.J.R. 1998. South India: Bird Conundrum, Survey of the Environment 98:75-78.

Daniels, R.J.R. and Saravanan, S. 1998. Kolli Hills: A Little Known Endemic Bird Area in Southern India, *NLBW* Vol. 38:No.3, 49-51.

Daniels, R J R, Vencatesan, J. and Ramachandran, V S 2005 Fragile Ecosystems and the Eastern Ghats. *EPTRI-ENVIS Newsletter* 11(2): 5-8.

George Tom and Praveen, J. 2014. Bird diversity of Melagiris. Kenneth Anderson Nature Society.

IUCN. 2017. The IUCN Red List of Threatened Species. Version 2017-3. <http://www. iucnredlist.org>. Downloaded on 05 December 2017.

Whistler, H and Kinnear, N B. 1930-37. The Vernay Scientific survey of the Eastern Ghats, Ornithological Section. *JBNHS* Vols 34-39: 16 parts.

Table 1. RET bird species and their occurrence in various districts

Species	Ve	Tiv	Tri	Dh	Kr	Er	Sa	Na	Vi
White-naped Tit					+				
White-rumped Vulture						+			
Nilgiri Wood Pigeon					+	+			
Grey-fronted Green Pigeon						+			
Yellow-throated Bulbul						+	+		+
Grey-headed Bulbul						+			
Great Hornbill						+			
Blue-winged Parakeet					+	+	+	+	
Crimson-backed Sunbird						+			
Rufous Babbler								+	
Oriental Dwarf Kingfisher						+			
Grey-headed Fish Eagle				+		+			
Lesser Fish Eagle				+					
Spot-bellied Eagle-Owl				+		+			
Egyptian Vulture								+	
Nilgiri Flycatcher							+		

Ve - Vellore; **Tiv** - Tiruvannamalai; **Tri** - Tirichirapalli; **Dh** - Dharmapuri; **Kr** - Krishnagiri; **Er** - Erode; **Sa** - Salem; **Na** - Namakkal; **Vi** – Viluppuram

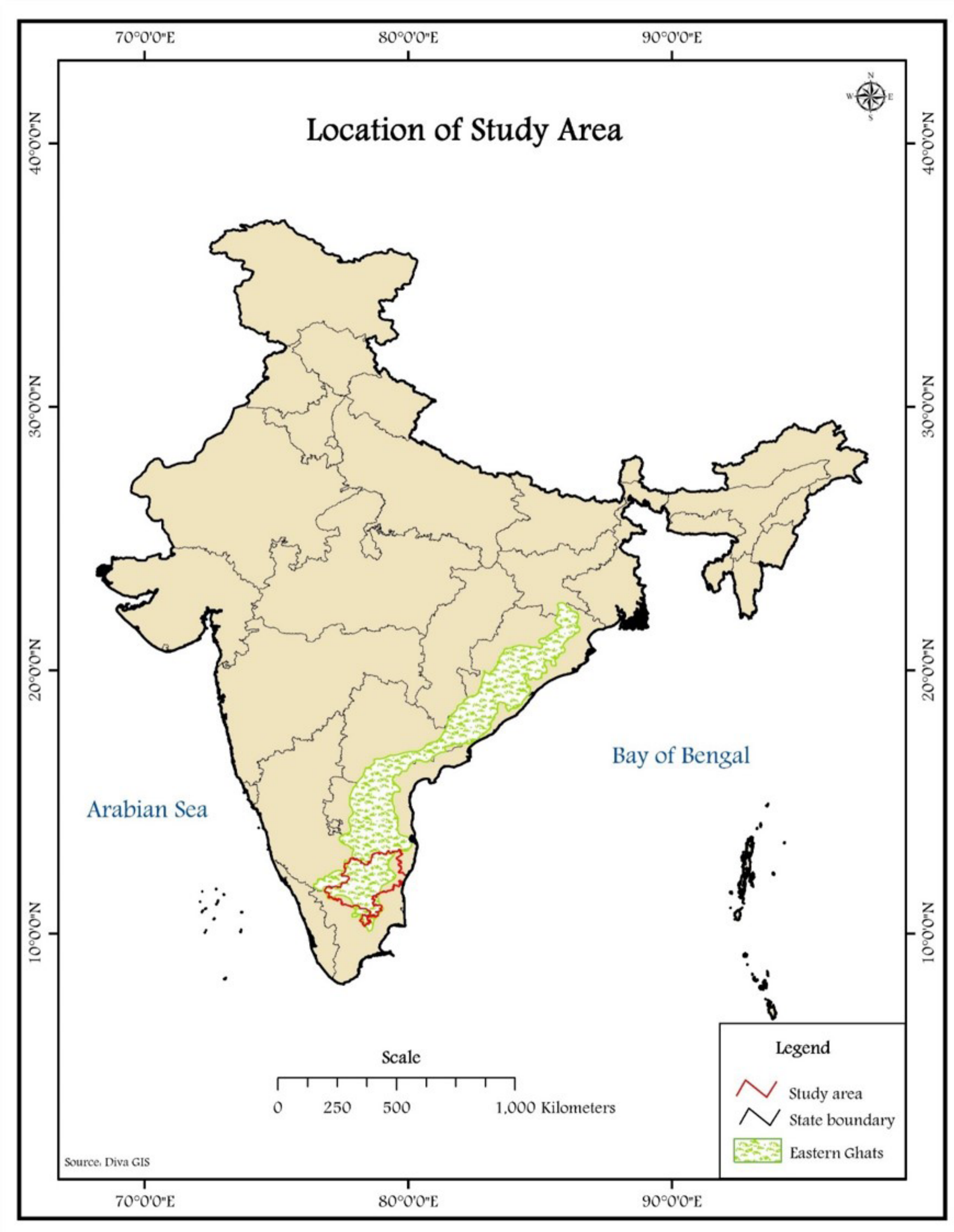

Figure 1. Location of the study area

ECOLOGICAL STATUS OF INDIAN BRIDAL SNAKE *DRYOCALAMUS NYMPHA* (DAUDIN, 1803) IN TAMIL NADU AND PUDUCHERRY

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ABSTRACT

We update the present status and distribution of Indian bridal snake (*Dryocalamus nympha*) in Tamil Nadu and Union Territory of Puducherry based on a literature review and a personal observation (2012-2016) in an agricultural landscape where cropping is the dominant farming practice, which provided further details into its natural history. Colouration of breeding pair and distribution record is differing from existing descriptions in literature. Erroneous identification and publication of this species are provided here. Pioneer descriptions of its breeding biology indicate that a better sampling of this species would give more detail on its natural history.

Keywords: *D. nympha*, distribution, breeding, misidentification

1. INTRODUCTION

Bridal snake *Dryocalamus nympha* (Daudin 1803) is small, nocturnal, semi- arboreal, egg-laying, colubrid found in India (Kerala in the West to Orissa in the East) and Sri Lanka, it appear like wolf and common krait to a remarkable degree (Fig. 1) (Whitaker and Captain, 2008; Smith, 1943). It feeds on geckos (Whitaker and Captain, 2008). Dr. Henderson found a *Eutrophis carinata* in its gut (Wall, 1921). Once we have sighted a live individual at 22:00 h in our base camp, possibly looking out for geckos; such foraging behaviors have been previously reported by Daudin (1803) and Wall (1909). *D. nympha* (derived from Latin *nympha* = the yellow mark on the back of the head suggests a “bridal veil”) was originally described by Francois Marie Daudin in 1803 based upon collection obtained by Patrick Russell (1796). Within the genus of *Dryocalamus,* three species have been listed (Smith, 1943). Though common in Tropical Dry ever green forest, which lies parallel to Coromandel Coast, It is wary in nature and difficult to site in the wild make it sparse about it’s natural history in the wild. It has been catogrized as Least Concern in IUCN and Indian Wildlife (Protection) Act, 1972 listed on schedule IV.

2. Distribution in Tamil Nadu and Puducherry

Live and precise records of bridal snake occurrences in various regions of Tamil Nadu, *viz.,* Vellore (Russell, 1796), Tirchirappalli (Wall, 1909); Kalpakkam (Ramesh *et al*., 2013), Chengalpattu

Fig. 1 A view of Indian Bridal Snake

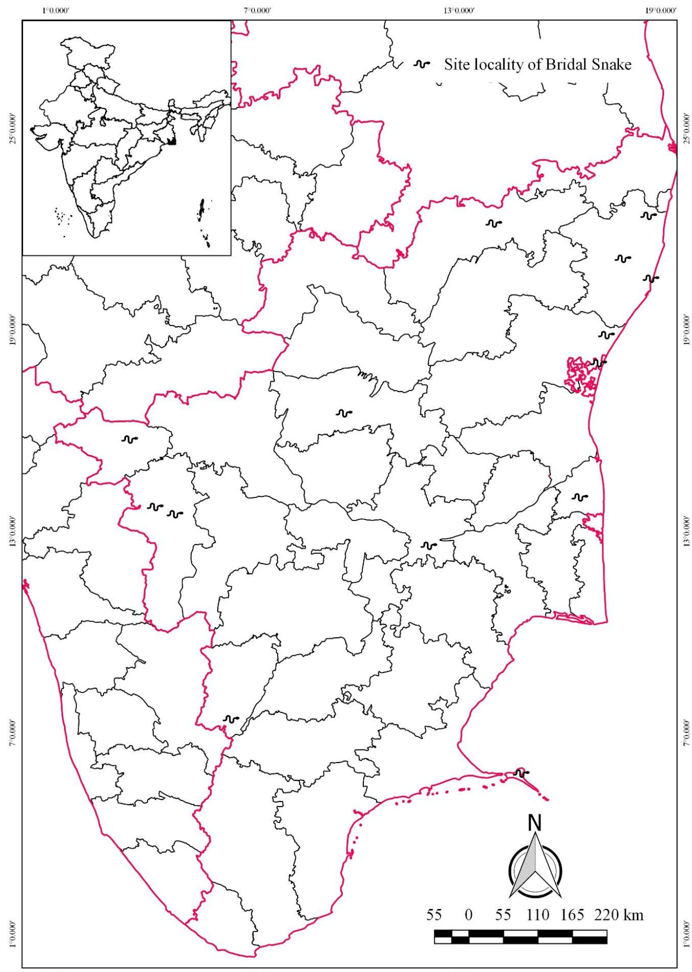
(Whitakar and Captain, 2008), Rameshwaram (Ravichandran and Siliwal, 2010), Megamalai

Bhupathy and Sathiskumar, 2013), The Nilgiri Hills, The Cardamom Hills (Hutton, 1949; and Villupuram (Krishnakumar, 2014), together with specimens from Madras in Madras museum, that were collected in Pallavaraum, Tambaram and Madras respectively (Ganesh and Asokan, 2010) and Beddome has collected three (two male and one female) specimens from South Yercot and Salem. Recently two individuals were rescued from Somarpalayam and Singanallur of the Coimbatore district (Reported in The Hindu, 7th May 2012 and 13th February 2014). In addition to this we have sighted (unpublished) both live and slough of bridal snake from Pitchandikulam forest, Auroville, in the Villupuram district, Tamil Nadu (Figure 2). The most recent field observation on this species was in 2016 (Krishnakumar and Selvan, 2016). In Union Territory of Puducherry (Previously known as Pondicherry) *D. nympha* has been erroneously identified as *Lycodon aulicus* and that positively recorded that Bridal snake occur in Union Territory of Puducherry.

3. PRESENT POPULATION STATUS

Until now nothing was known about the current numbers of *D. nympha* in this province; it is likely that populations have declined, simply because of habitat modification by human's activity.

Figure 2. Site locality of *Dryocalamus nympha* in Tamil Nadu and Puducherry.



3.1. Breeding habits

It breeds in the month of August or predominantly in south east monsoon (Krishnakumar, 2014). An adult female found with three eggs under bricks at Auroville (Fig. 3), Tamil Nadu on August (Krishnakumar and Selvan, 2016). Morphometric details of eggs are summarized in Table 1. Details of incubation period and hatchlings are unknown in wild.

Table 1. Morphometric details of eggs. (Length and width are in millimeters).

Egg Number	Length	Width	Annotations
1	21	8	Wrinkled and decayed
2	27	9	Partially wrinkled and compressed well
3	28	7	Smooth but compressed

Figure 3. Egg of *D. nympha* found under the bricks at Auroville, Tamil Nadu

3.2. Conservation Issues

Erroneous records

As *D. nympha* appears to be *Lycodon aulicus*, *L. striatus*, and *Bungarus caeruleus* it is often misidentified even by researcher. Muthukumaran *et al.*, (2014) misidentified *L. striatus* as *D. nympha* in some cases *D. nympha* as *L.aulicus* (Alexander and Jayakumar, 2014) even though the morphology and scalation varied between these species. Such erroneous identification occurs due to confirmation based on morphology instead of scalation or variation of shields. Species misidentifications are very important as it confuses the known area of occurrence of both species, as well as having implication for compiling biodiversity species lists. Such erroneous identifications lead to further compounding of unsuspected error.

4. CONCLUSION

Bridal snakes meet unfortunate ends at the hands of humans due to misidentification as it closely resembles Common Krait (*Bungarus caeruelus*). In addition, habitat destruction, fragmentation and road kills are major threat to snakes. As snake play major role in the ecosystem they inhabit both as predator and prey. It keep the pest population under the control in Agriculture ecosystem, in addition snake being prey to various predator. Distribution in eastern regions of Tamil Nadu, and clutch size, incubation period, maturation of young are remain unknown about rare bridal snake. Research on these will be of great value.

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REFERENCE

Aengals, R., Sathis Kumar, V.M. and Palor, M.J. 2011. Updated Checklist of Indian Reptiles. Zoological Survey of India. zsi.gov.in/checklist/Reptiles.

Alexander, R., and Jayakumar, J. 2014. Reptile of Ousteri riparian area, Puducherry, India. *Reptile Rap.*, 16: 6-14.

Bhupathy, S. and Sathishkumar, N. 2013. Status of reptiles in Meghamalai and its environs, Western Ghats, Tamil Nadu, India. *J. Threat. Taxa.,* 5 (15): 4953-4961.

Boulenger, G.A. 1890. The Fauna of British India, Including Ceylon and Burma. Reptilia and Batrachia. Taylor & Francis, London, xviii, pp 298.

Daudin, F.M. 1803. Histoire Naturelle Generale et Particuliere des Reptiles. F. Dufart, Paris, Vol.6pp – 244.

Ganesh, S.R. and Asokan, J.R. 2010: Catalogue of Indian herpetological specimens in the collection of the Government museum, Chennai, India. *Hamadryad*., 35(1): 46-63.

Hutton, A.F. 1949. Notes on the snakes and mammals of the High Wavy Mountains, Madura district, South India. Part I – Snakes. *J. Bombay Nat. His. Soc.*, 48 (3): 454-460.

Krishnakumar, B.M. 2014. First observation on breeding habits of Indian Bridal snake *Dryocalamus nympha* (Daudin, 1803). *Herpetol. Notes.,* (7): 337 -338. London: Taylor & Francis Ltd. 583 pp.

Ramesh, T., Jahir H., K.., Satpathy, K.K. and Selvanayagam, M. 2013. Community composition and distribution of herpetofauna at Kalapakkam Nuclear campus, Southern India. *Herpetol. Notes*., (6): 343-351.

Ravichandran, B. and Siliwal, M. 2010. Snakes of Rameshwaram. *Reptile. Rap*., (9): 2-4.

Russell, P. 1796. An account of Indian Serpents collected on the coast of Corommandal; containing description and drawings of each species, together with experiments and remarks on their several poisons. London. 90

Smith, M.A. 1943. *Fauna of British India, including Ceylon and Burma. Vol- III Serpentes,*

Vijyaraghavan, B and Ganesh, S.R. 2011. *The illustrated book of South Indian snakes*. A publication of the Chennai Snake Park Trust.

Wall, F. 1909. A popular Treatise on the Common Indian Snake, . *J. Bombay Nat. His. Soc.*, 19 (2): 287-290.

Wall, F. 1921. *Ophidia taprobanica* or Snakes of the Ceylon. H.R.Cottle government museum, Ceylon. 166-168.

Whitaker, R and Captain, K. 2008. Snakes of India: The Field Guide. Draco Books., Chennai.

ABUNDANCE AND NESTING STATUS OF AVIFAUNA IN THIRUPPUDAIMARUTHUR CONSERVATION RESERVE, TIRUNELVELI DISTRICT, TAMIL NADU

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ABSTRACT

Thiruppudaimaruthur Biosphere Reserve is first and only Conservation Reserve in Tamil Nadu. Abundance of birds, and nesting status of select bird species were studied between May 2008 and August 2008 following standard ecological methods. Study revealed occurrence of 69 species of birds comprising 40 families. Among families Ardeidae had the highest number of species (7) followed by Rallidae (4). Among the species, Cattle Egret had the highest abundance followed by Little Egret and Painted Stork. Totally 578 nests comprising five species of birds, namely Little Cormorant, Cattle Egret, Little Egret, Intermediate Egret and Painted were observed. Among species, Cattle Egret had the highest nest numbers followed by Painted Stork and Intermediate Egret. Nesting trees used by the breeding birds revealed variation. Most of the bird species selected any one of five tree species, namely *Azadirachta indica*, *Prosopis juliflora, Tamarindus indica*, and *Thespesia populnea* and *Polyalthia longifolia* for their nesting. The major factors for selecting these trees were tree height and canopy volume, which ultimately provided protection from predation. Villagers of Thiruppudaimaruthur are tolerant of nesting birds, and consider their arrival in large number as 'Angels of God' and harbinger of good harvest. Similarly, a prolonged stay of birds in the village is considered as an indication of probable double crop. However, in addition to soliciting local people's whole-hearted support, conservation measures including regular monitoring of birds along with their threat factors are very essential to protect the birds and bats of this reserve.

Keywords: Avifauna, Breeding ecology, Conservation reserve, Thiruppudaimaruthur Nest-site selection.

1. INTRODUCTION

Indian subcontinent has diverse species of avifauna with 1300 species (Grimmett *et al.,* 1999) and there are studies on birds in India in a wider level (Ali and Ripley, 1987). Most of these studies are confined to forest ranges (Mahabal, 2000), collective studies on bird species have also brought out from Wetlands (Vijayan, 1989), hills (Babu and Bhupathy, 2013), mangroves (Sandilyan *et al.,* 2010), river ecosystems (Bashir *et al.,* 2012), agro-ecosystems (Jayakumar *et al.,* 2013), university campuses (Devi *et al.,* 2012) and heronries (Jayakumar, 2013). Nevertheless, no such attempt has been made in Thiruppudaimaruthur Conservation Reserve (TCR). Therefore, the survey around Conservation Reserve was undertaken to assess the list of birds, abundance and nesting status of selected avifauna.

2. STUDY AREA & METHODS

Thiruppudaimaruthur is a first Conservation Reserve (08° 43' N & 77° 29'E) in Tamil Nadu located in Ambai Taluk of Tirunelveli District in Tamil Nadu. It is situated 23 km away from Tirunelveli town and has an elevation of 78 MSL. The south-west and north-east monsoons determine the rainfall of this area, with some occasional showers during winter and summer (Subramanya, 2005). Prime water bodies and the agricultural fields serve as the chief foraging grounds for birds in this area. Thamirabarani River flowing through this area is extensively being used to irrigate agricultural lands making it an ideal foraging site for birds. The dominant crops raised in the area includes rice and plantain. Moreover, this area also contains 10 ha of social forest which offers wonderful roosting opportunities to birds.

Abundance of birds was estimated by direct total count method which has been employed by several workers for aquatic and other birds (Weller, 1975; Sivasubramanian, 1992). Furthermore, chance encounters of birds were also recorded in major vegetation types while walking around the village. All observations were made between May and August 2008 and the birds were mostly observed during the most active period of the day, i.e., from 0600 to 1000 hr. and 1600 to 1800 hr. The bird species were identified using standard field guides (Grimmet *et al.,* 1999). A pair of binoculars (Nikon 8' x 42") was used for observation and care was taken to avoid double count by watching the birds' direction of flight and landing in case they are disturbed by predators. Focal nests were numbered and monitored throughout the season to measure the breeding success. Nesting trees were identified up to species and were measured for their structural features like tree height, pole height, girth at breast height and canopy. Besides, nest distance from ground and human settlements were also gathered. The selected nests were checked every week from the suitable vantage points since the beginning of egg lying.

3. RESULTS AND DISCUSSION

The present study revealed the occurrences of 69 species of birds comprising 40 families. Among the 40 families, Ardeidae had the highest number of species (7 species) followed by Rallidae (4 species). Families, such as Accipitridae, Alcedinidae, Charadriidae, Corvidae and Threskiornithidae had three species each, while the remaining families were represented by one or two species. Out of 69 species, 46 species were resident birds and the remaining were local migrants. Birds of diverse food habits were observed, viz., insectivores (26 species), piscivores (11 species), omnivores (8 species), carnivores (4 species), frugivores (4 species), granivores (4 species) and nectarivores (2 species).

A greater diversity of avian species was recorded at the Tamirabaraniriver banks because of the greater availability of vegetations and food. Occurrence of many wooded tree species, scrub and bushy type vegetations provided nesting, roosting and perching opportunities for many species of birds along both sides of the river banks. According to Jayakumar *et al.* (2013), insectivore birds such as Cattle Egrets, Black Drongo, Indian Roller, Small Bee-eater, Blue tailed Bee-eater, Black-winged Stilt, Common Myna, etc., are very common birds in the agricultural lands and feed mostly on insects. Such birds play major role in the control of harmful insects in various crops (Asokan, 1998; Jayakumar *et al.,* 2013). The number of species recorded in the present study was compared with earlier studies in Tamil Nadu (Subramanya, 2005, Reginald *et al.,* 2007; Jaya kumar, 2013).

3.1. Population and breeding status of colonial nesting birds

To know the abundance of colonial nesting birds, a total of 10 species of birds comprising of five families were recorded. Among the four species recorded in the family Ardeidae, Cattle Egret showed the highest population followed by Little Egret. Out of two species recorded in the family Threskiornithidae, Black-headed Ibis sowed the maximum numbers (Table 1). Number of birds and species recorded in the present study were compared with in earlier studies in Tamil Nadu (Beulah, 2002; Venkatraman 2007, Jayakumar, 2013). Availability of paddy fields, irrigation tanks and tree covers might have extended comfortable shelter and suitable foraging grounds for these birds.

Table 1. Abundance of colonial nesting birds in Thiruppudaimaruthur Conservation Reserve.

Family	Species	Month			
		May 2008	June 2008	July 2008	August 2008
Pelecanidae	Spot-billed Pelican	10	30	32	46
Phalacrocoracidae	Little Cormorant	56	100	142	178
Ardeidae	Indian Pond Heron	76	126	130	166
	Cattle Egret	1005	2582	3000	2988
	Intermediate Egret	45	212	220	229
	Little Egret	72	220	231	212
Ciconiidae	Painted Stork	84	205	210	197
Threskiornithidae	Black-headed Ibis	113	103	102	95
	Black Ibis	43	47	40	41
	Glossy Ibis	32	50	54	51
Total		**1536**	**3675**	**4161**	**4203**

Out of 65 species, five species, *viz.,* Cattle Egret, Intermediate Egret, Little Egret, Little Cormorant and Painted Stork were found to have nesting sites in the study area. Among the various species, Cattle Egret was found to be breeding in more numbers followed by Painted Stork and Intermediate Egret. Little Cormorant and Little Egret were observed only in few numbers (Table 2). In an earlier study, TCR was found to provide an ideal habitat for the colonial nesting birds. Of the species considered, Little Cormorant, Night Heron, Indian Pond Heron, Indian Cormorant, Cattle Egret, Little Egret and Painted Stork are the common nesting species (Subramanya, 1996; 2005). The number of birds nesting in the Conservation Reserve varied greatly according to availability of food and nesting trees. Clutch size of birds vary greatly among species, sometimes even within the same genus. It also differed within the same species due to factors such as, health, nutrition, predation pressures and time of year (Urfi and Kalam, 2006). In the present study, the clutch size did not vary among species. Among the species, Painted Stork, Cattle Egret, Little Egret and Little Cormorant laid the maximum number of eggs in their clutch.

Information on breeding success of selected species of colonial nesting birds were gathered. Totally 75 nests belonging to five species of birds comprising three families, viz., Phalacrocoracidae, Ardeidae and Ciconiidae were selected as focal nests. Among the birds, Little Egret showed the highest breeding success followed by Intermediate Egret and Painted Stork, while the cattle egret showedthe lowest success (Table 2). In Tamil Nadu, comprehensive studies pertaining to breeding success of heronry birds are limited except a few. Breeding success of the Little Egret, Cattle Egret, Painted Stork and Little Cormorant in the present study was similar to the earlier studies done in India (Hilaluddin *et al.,* 2003; Gopi and Pandav, 2007; Jha, 2012)

Table 2. Breeding status of colonial nesting birds in Thiruppudaimaruthur Conservation Reserve

Bird family	Bird species	No. of active nests recorded	No. offocal nests	Clutch size	Breeding Success (%)
Phalacrocoracidae	Little Cormorant	20	5	3-4	83.3
Ardeidae	Cattle Egret	395	30	3-4	79.2
	Intermediate Egret	53	10	2-3	88.3
	Little Egret	44	10	3-4	92.5
Ciconiidae	Painted Stork	66	20	3-4	88.2
	Total	**578**	**75**		

3.2. Nest and nest site selection used by colonial nesting birds

Totally 578 nests belonging to five species of birds were observed and most of them were located either at Thepakkulam street or Sannathi street of Thirupudaimaruthur village. The observation on nesting preference of different species of birds showed that the Cattle Egret prefered four species of trees, namely *Azadirachta indica*, with an average height of 7.6 m, *Prosopis juliflora,* with an average height of 6 m, *Tamarindus indica*, with an average height of 10 m, and *Thespesia populnea*, with an average height of 6 m. Intermediate Egret, Little Egrets and Little Cormorant P*. juliflora* and *T. indicus*. Painted Storks nests were primarily found on *Palyaithia longifolia*, with an average height of 19 m, *Madhuca longifolia* with an average height of 18 m, *Terminalia arjuna* with an average height of 17 m. Few nests were also observed on *P. juliflora.* Smaller birds, such as Cattle Egret, Intermediate Egret and Little Cormorant were found to be nesting typically on the middle canopy layer of the nesting trees, whereas Painted Stork used the top canopy. Similarly, Painted Stork used taller trees (63.7 ± 3.6 m), while Intermediate Egret preferred shorter trees (19.0 ± 1.6 m). Nests of Painted Stork (51.6 ± 12. 0 m) was found on the trees with taller poles while the nests of Little Egret (6.8 ± 0.3 m) was on tree with shorter poles. Among the different species of birds, Painted Stork preferred matured trees with highest mean dbh of 248.1 ± 3.6 cm., while Cattle Egret mostly selected younger trees with the lowest mean dph of 66.3 ± 3.2 cm. In general, nests of Little Cormorant, Little Egret and Intermediate Egret were found near to human settlements.

In colonial birds, nest site selection provide protection for developing young from predators and adverse climatic conditions during the breeding season, the most vulnerable period in the birds life cycle. However, very few studies on nest site selection of birds especially relating to heronries are available in India (Ishtiaq *et al.,* 2004; Venkatraman, 2007). According to Venkatraman, (2007) habitat selection appears to be a hierarchical procedure with landscape features playing a crucial role at a regional scale and vegetation quality at the sites. Similarly in the present study, structural characteristic of nest-tree were found to be the crucial factor in the nest site selection of birds in TCR. In particular, matured trees with thick canopy and with the maximum diameter breast height had more nests. The matured trees were found to be suitable for nest placement as their size and geometry of branching provided the preferred vertical range of bird species to place their nests. Furthermore, matured trees provided greater space and nest site availability for the birds that are colonial by nature. Apart from colonial nesting, nests on trees that contain many potential nests may also have been a strategy to reduce their predation as suggested by Martin (1993).

4. CONCLUSION

Thiruppudaimaruthur Conservation Reserve is one of the less know bird breeding sites in Tamil Nadu. Study revealed occurrence of 69 species of birds comprising 40 families. Among the several species, highest numbers of nests were observed for Cattle Egret followed by that of Painted Stork and Intermediate Egret. Nesting trees used by the breeding birds revealed variation suggesting the major factors for selecting these trees as tree height and canopy level, which ultimately provided protection to these birds from predation. Villagers of Thiruppudaimaruthur were found to be tolerant of nesting birds, and considered their arrival in large number as 'Angels of God' and harbinger of good harvest. Similarly, a prolonged stay of birds in the village is also considered as an indication of probable double crop. However, in addition to soliciting local people's whole-hearted support, conservation measures including regular monitoring of birds along with their threat factors are very essential to protect the birds of this area.

REFERENCES

Ali, S. and Ripley, S.D. 1987. *Compact handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka.* Oxford University Press, Delhi.

Asokan, S. 1998. Food and feeding habits of the small Green Bee-eater *Merops orientalis* in Mayiladuthurai. *Journal of Ecobiology* 10(3): 199–204.

Babu, S. and Bhupathy, S. 2013. Birds of Meghamalai Landscape southern Western Ghats, India. *Journal Threatened Taxa*. 5(15): 4962-4972.

Bashir, T., Behera, S.K. Khan, A. and Gautam, P. 2012. An inventory of mammals, birds and reptiles along a section of the river and banks of upper Ganges, India. *Journal of Threatened Taxa* 4(9): 2900–2910.

Beulah, S. 2002. The study on the conservation of Biodiversity of Koonthankulam Birds Sanctuary in Thirunelveli District in Tamil Nadu. *PhD thesis* submitted to Manonmaniam Sudaranar University, Thirunelveli. 277 pp.

Devi, O.S., Islam, M., Das, J. and Saikia, P.K. 2012. Avian fauna of Gauhati University Campus, Jalukbari, Assam. *The Ecoscan* 6 (3&4): 165-170.

Gopi, G.V. and Pandav, B. 2007. Observation on breeding biology of three stork species in Bhitarkanika mangroves, India. *Indian Birds* 3(2):45-50.

Grimmett, R., Inskipp, C. and Inskipp, T. 1999. *Pocket guide to the birds of the Indian subcontinent*. Oxford University Press, Delhi.

Hilaluddin K.R., Junid, N.S. and Tahir, A.S. 2003. Nest site selection and Breeding success by Cattle Egret and Little Egret in Amroha, Uttar Pradesh, India. *Colonial Waterbirds* 26: 444-448.

Ishtiaq, F., Rahmani, A.R., Javed, S and Coulter, M.C. (2004). Nest-site characteristics of Black-necked Stork and White-necked Stork in Keoladeo National Park, Rajasthan, India. *Journal of Bombay Natural History Society*.101: 90-95 pp.

Jayakumar, S., Asokan, S. and Vasudevan, V. 2013. Abundance, Diversity and Richness of Birds in Different Days after Transplantation of Paddy Cultivated in Cauvery Deltaic Region in Tamil Nadu. *Mayur*. Vol. 9. 67-71.

Jayakumar, S. 2013. Organochlorine pesticides, population and reproductive success of fish-eating birds in select heronries in Tamil Nadu. PhD Thesis, Bharathiar University, Coimbatore (Unpublished).

Jha, K.K. 2012. Some breeding and ecological aspects of heronry birds at Soor Sarovar Bird Sanctuary Agra, Northern India. *Asian Journal of Conservation Biology* 1(1): 35–41.

Mahabal, A. 2000. Birds of Talra Wildlife Sanctuary in lower Western Himalaya. H.P notes on their status and altitudinal movement. *Zoos' Print Journal.* 15 (10): 334-338 pp.

Martin, T.E. 1993. Nest predation and nest sites: new perspectives on old patterns. *BioScience* 43: 523-532

Reginald, L.J., Mahendran, C., Kumar, S.S. and Pramod, P. 2007. Birds of Singanallur Lake, Coimbatore, Tamil Nadu. *Zoos' Print Journal* 22(12): 2944–2948.

Sandilyan, S., Thiyagesan, K., Nagarajan, R. 2010. Major decline in species-richness of waterbirds in the pichavaram mangrove wetlands, southern India. Wader Study *Group Bull* 117(2):91–98.

Sivasubramanian, C. 1992. Ecological Investigation on the Piscivorous birds in Keoladeo National Park, Bharatpur. *Ph.D thesis* submitted to Saurashtra University, Rajkot, India.

Subramanya, S. 1996. Distribution, Status and conservation of Indian Heronries. *Journal Bombay Natural History Society*. 93: 459-486 pp.

Subramanya, S. 2005. Heronries of Tamil Nadu. *Indian Birds* . 1 (6): 126-140 pp.

Urfi, A.J., Kalam, A. 2006. Sexual size dimorphism and mating pattern in the Painted Stork (*Mycteria leucocephala*) *Waterbirds* 29:489–496. doi: 10.1675/1524.

Venkatraman, C. 2007. Nest site selection by colonial waterbirds at Vedanthangal Waterbird Sanctuary, Tamil Nadu, India. *Journal of Scientific Transactions in Environment and Technovation.*1 (2): 77-83 pp.

Vijayan, V.S. 1989. Keoladeo National Park Ecology Project. *Annual Report* 1988. Bombay Natural History Society, Bombay.

Weller, M.W. 1975. Habitat selection by waterfowl of Argentina Isla Grandi *Wilson Bulletin.* 87(1):83-90 pp.

PELLET ANALYSIS OF SELECTED INSECTIVOROUS BIRDS LIKE BLACK DRONGO (*DICRURUS MACROCERCUS*) AND INDIAN ROLLER (*CORACIAS BENGHALENSIS*)

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ABSTRACT

The food habits of Black Drongo and Indian Roller were determined through the analysis of their regurgitated pellets. The pellets were collected on their nesting and roosting sites from three different habits viz., a cultural lands, river banks and social forests. The morphometry of pellets of Black Drongo had a mean length of 1.84 cm width of 0.76 cm and weight of 0.24 gm. The overall mean prey number in the pellet was 15.91± 6.17. Of them coeleopteran beetles (22.94%) were predominant prey remains followed by other insect order. The morphometry of pellets of Indian Roller pellets showed 2.63 cm in length, 1.18cm in width and o.36 gm in weight. The coleopterans were the most abundant insects which constituted 23.6% the mean number of prey pellet was 18.63±7.31. The beneficial role of these birds as biological control agents against pests of agro-ecosystem as such, the beneficial effects of the thriving position of these birds in the vicinity of agro-ecosystems convey to a fine focus and should be encouraged as an ideal measure of pest control.

Keywords: Black Drongo , Indian Roller, Morphometry, Pellet, Coeleoptera.

1. INTRODUCTION

A large number of birds directly or indirectly depend upon the crop fields and hence they are integral part of the agro-ecosystem. Birds constitute an important component of agro-ecosystems which serve as food sources in the form of grains, seeds, fruits, barks, twigs of plants grasses, insects other rodents etc., (Connor and Shrubb, 1986). The present study area Nagapattinam District, Tamil Nadu is also the “Granary of south India” due to its vast agricultural areas, where integrated pest management methods have led to adoption of various strategies to control the pests crop plants. The insectivorous birds in crop lands south India (Mathew *et al.,* 1978; Daniesls, 1991). Insectivorous and predatory birds play a very useful role in controlling insects and rodent pests of crops.

2. MATERIALS AND METHODS

In the present investigation the pellets of two common insectivorous birds viz., Black Drongo (*Dicrurus macrocercus*), Indian Roller (*Coracias benghalensis*) in three different habitats were collected from their perching, roosting and nesting/ breeding sites. The collected pellets were packed and labelled in the field itself for later analysis in the laboratory. The pellets collected were dried in hot air oven at 60°C for 24 hours to kill the associated invertebrates. The length and width of the pellets were measured by using a verniercaliper (nearest mm) and weight with the help of a spring balance to the accuracy of 1 mg.

The methods described by Herrera and Ramirez (1974) was followed for the analysis of pellet contents the pellets were placed in 5% NaOH to isolate the hard prey remains. To dissolve the pellets a known quantity of solvent was used depending on the pellet size. The insect prey items were identified by comparing with museum specimens collected from the study areas. The insects order was identified by looking at the sum of most important features. For example, the elytra of beetles, H shaped tergal plates of hemipterans, raptorial legs of orthopterans, the intact head capsules of hymenopterans, unique wings of odonates and lepidopterans etc.,

3. RESULTS AND DISCUSSION

Pellet was collected in six month for 148 in Black Drongo and 92 in Indian Roller. The insects prey identified were of orders orthoptera (Grass hopper and Crickets) Hemiptera (bugs) Coleoptera (Beetles) lepidoptera (months and butterflies) hymenopter (bees) diptera (flies) and odonata (dragon flies) while few remains could not be identified.

3.1 Black Drongo

The morphometry of pellets means length 1.84±0.8 cm width 0.76±0.66 cm weight 0.24 ± 0.58 gm. The mean number of pray per pellet was 15.91 ± 6.17 (range 7 to 29) (Table 1).The mean present occurrence of different insect orders as prey remains in the pellets. Coleopteran insects were the most frequent prey items (22.94 ± 11.89%) in the diet of the black drongofollowed by Hemiptera (19.78 ± 8.03%) Hymenoptera (15.58 ± 7.24%) Orthoptera (10.29 ± 6.64%) Diptera(8.78 ±4.81 %) Odonata (8.48 ± 4.12%) Lepidoptera (6.90± 3.89%) and unidentified insects7.25±3.66% (Table 2) in that order.

3.2 Indian Roller

The morphometric of pellets means length 2.63 ± 1.14 cm width was1.18 ± 0.94 cm weight was0.36 ± 0.83 gm. The mean number of pray per pellet was 18.63 ± 7.31and it ranged 9 to 26 (Table 3). The Coleopteran beetles were the predominant prey items as the constituted 23.6 ± 11.08% followed by hemiptera 16.67 ± 8.94% Hymenoptera (16.19 ± 7.44%) Orthoptera (9.59 ± 4.54%) Diptera(9.22 ±4.13%) Odonata (6.96 ± 3.4%) Lepidoptera (4.56 ± 1.58%) the unidentified prey remains was 13.08% in their diet (Table 4).

Pellet analysis inferred that coleopterans were the principal food of Indian roller. Further insects body parts constituted almost 100% of the prey remains in the pellets of Indian roller an indication that it could be a very potential insect pest controlling agent Parasharya *et al.* (1994) are also recorded the Indian roller to be an important bio control agent against the white group (Holotrichasp, Scarabidae) which is an important subterranean pest damaging root system of several crops.

Black Drongo has also consumed large number of coleopteran beetles when compared to other Parasharya *et al.* (1994). Black Drongo is another avian predator against agricultural crop pests. Mathew *et al.* (1978) stated that 63% of the 28 families of insect food in the black drongo stomachs were injurious to agriculture.

However, Herrera and Ramirez (1974) cautioned that results obtained from pellet analysis of insectivorous birds can be mistaken to some extent, because Swift (1959) state that remains of week bodied prey, such as butterfly (lepidoptera) dragon flies (odonata), and some flies (dipera), often might not be detected, small insects being digested or caddies flies (trichoptera) and may flies (ephemeroptera) were detected in several analysis of stomach contents of insectivorous birds (Valverde, 1967), but not in the pellets analyzed by Herrera and Ramirez (1974) and also in the present investigation. It is possible that they were taken by insectivorous birds but fully digested. Numbers of week bodied prey remains of many therefore have been under estimated. On the other hand remains of many very small hard bodies insects such as beetles (coleoptera) and bugs (hemiptera) were readily found in the pellets and their numbers could be correctly ascertained. These sources of bias are inherent to pellet analysis and such future studies encompassing stomach content analysis would be able to provide a totally correct picture on prey selection by insectivorous birds.

Various factors accounting for seasonal variation in prey to surface activity of prey (Fitch, 1974; Heth, 1991) relative abundance of prey (Ticehurst, 1935; Wallace, 1948) climate and weather (Errington, 1931; Stewart 1952) vegetative changes (Marti, 1974) agricultural practices such as irrigation and land clearing (Laub *et al.,* 1979; Colvin 1985).

Table 1. Morphometric of pellets collected from Black Drongo in three different habitats (N=148)

Variable	Range	Mean ± SD
Length (cm)	2.10-2.50	2.35 ± 0.96
Width (cm)	1.0-1.30	1.10 ± 0.74
Weight (gm)	0.31-0.53	0.44 ± 0.72
No.of prey/ pellet	9.00-33.0	15.45 ± 8.41

Table 2. Prey composition of (%) Black Drongo pellets collected in the three different habitats.

Insect order	% Composition
	Mean ± SD
Orthoptera	10.29 ± 6.64
Hemiptera	19.78 ± 8.03
Coleoptera	22.94 ± 11.89
Lepidoptera	6.90 ± 3.89
Hymenoptera	15.58 ± 7.24
Odonata	8.48 ± 4.17
Diptera	8.78 ± 4.81
Unidentified	7.25 ± 3.66

Table 3. Morphometric of pellets collected from Indian Roller in the three different habitats (N=94)

Variable	Range	Mean ± SD
Length (cm)	2.10-3.10	2.63 ± 1.14
Width (cm)	0.82-1.35	1.18 ± 0.94
Weight (gm)	0.26-0.41	0.36 ± 0.83
No. Of prey/ pellet	9.00-26.00	18.63 ± 7.31

Table 4: Prey composition of (%) Indian roller pellets collected in the three different habitats

Insect order	Percent composition
	Mean ± SD
Orthoptera	9.59 ± 4.54
Hemiptera	16.67 ± 8.95
Coleoptera	23.6 ± 11.08
Lepidoptera	4.58 ± 1.58
Hymenoptera	16.19 ± 7.44
Odonata	6.96 ± 3.41
Diptera	9.22 ± 4.13
Unidentified	13.08 ± 6.44

REFERENCES

Colvin, B.A. 1985. Common Barn owl population decline in Ohio and the relationship to agricultural trends. *J.Field ornithol*., 56(3): 224- 235.

Connor, R.J. and Shrubb, M. 1986. Farming and birds. *Condor* 76: 45-61.

Daniesls, R.J.R. 1991. Island biogeography and the birds of the Lakshadweep Archipelago Indian Ocean. *J.Bombay. Nat.Hist.Soc.* 88(3):320-328.

Errington, P.L. 1931. Winter killing of barn owl in Wisconsin. *Wilson Bull*.43:60

Fitch, H.S. 1974. Predation by owls in the sierra foothills of California. *Condor* 49(4): 137-151.

Heth, G. 1991. Evidence of above ground predation and eye determination of the preyed, in subterranean mole rats (*Spala xehrenbergi*) in Israel. *Ecology* 54: 427-432.

Herrera, C. and Mand Ramirez. 1974. Food of bee-eaters in Southern Spain. *Brit. Birds* 67:159-164

Laub, K., Frost, S.L. and Melvin, R.W. 1979. Changing land use. In M.B.Lafferty (ed.), Ohis

Mathew, D.N., Narendren, T.C. and Zacharias, V.J. 1978. A comparative study of the feeding habits of certain species of Indian birds affecting agriculture. *J.BombayNat. Hist.Soc.* 75(3): 1178-1197.

Marti ,C.D. 1974. Feeding ecology of four sympatric owls. *Condor* 76: 45-61.

Parasharya, B.M., Dodia, J.F. Mathew, K.L. and Patel. R.C. 1994. Natural regulation of white grup (*Holotrichia sp. scrabidae*) by birds in agro-ecosystem. *Journal of Biosciences.* 19(4):381-390.

Stewart, P.A. 1952. Disperal, breeding, behaviour and longevity of Banded Barn owls in North America. AUK 69(3): 227-245.

Ticehurst, C.B. 1935. Les pelotesdequeiques Rapaces. *Nosoiseaux.* 26: 124-131.

Valverde, J.A. 1967. Estructura deunacomunidad mediterranea de vertebrados terrestres.*Cons. Sup.Inv.Cient.,Madrid*.

Wallace, G.J. 1948. The Barn owl in Michigan, its distribution, natural history and food Habits. *Mich. State coll. Agr.Exp.Sta.Teh.* 208.61p.

INFLUENCE OF TANNERY INDUSTRIAL EFFLUENTS INDUCED HISTOPATHOLOGICAL ALTERATIONS IN GILL AND LIVER OF FRESHWATER FISH *CATLA CATLA* (HAMILTON, 1822)

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ABSTRACT

Water pollution has now become an international issue. As water is carce and its demand is likely to intensify, it mandates more attention. The tannery industries are one of the water based industries as they use large quantity of water and chemicals in processing the leather. Of all the industrial wastes, the tannery effluent is found as most dangerous pollutant. In the present investigation focused on influence of tannery industrial effluents induced histopathological alterations in gill and liver of freshwater fish *Catla catla*. The fish, *Catla catla* when exposed to sub lethal concentration of tannery effluents for 21 days showed marked histopathological changes in their gill. Excessive secretion of mucous in the intercellular spaces, fusion of secondary gill lamellae, reduction in length, swelling of epithelial cells of secondary lamellae and cytoplasmic vacuolization were some of the observable changes. Likewise liver shows, rupture of hepatocytes and their nuclei, necrosis and vacuolization of the tissue and extension and displacement of nuclei were some of the observable changes.

1. INTRODUCTION

Water pollution has now become an international issue. As water is scarce and its demand is likely to intensify, it mandates more attention. Pollution of water ismainly due to contamination with hazardous chemicals from agricultural runoff andwastewater fromhouse hold and industries. The tannery industries are one of the water based industries as they use large quantity of water and chemicals in processing the leather. Of all the industrial wastes, the tannery effluent is found as most dangerous pollutant.

2. MATERIALS AND METHODS

The effluent was collected from Vaigai Leather Industry at Dindigul, TamilNadu. The effluent was collected in 25 liter plastic containers and was tightly packed. The samples were stored at uniform temperature. As the Tannery effluents contained organic matter the samples were refrigerated (without freezing) at temperatures between 0°C to 4°C. Duration of storage prior to testing was kept to a minimum.

2.1 Collection of fish and maintenance

Catla catla were collected from local ponds. The collected fish were brought to the laboratory in an aerated plastic bag. These fish were kept in a large rectangular tank. The dissolved oxygen was maintained by aerating the water with compressed air. The fish were regularly fed with rice brawn and oil cake during acclimatization period. The feeding was stopped at 48 hrs before the commencement of the experiment in order to avoid fecal contamination to the environment. The sizes of the fish ranging from 14 to 16cm with weight 18 to 20 gm were taken for experiments.

2.2 Exposure to Tannery effluent

The experimental fishes were exposed to LC_{50} concentration of Tannery effluent for 21 days. The control and experimental fishes were dissected out and the samples were collected at the end of 21 days. The tissues like liver and gills were collected for histological studies.

2.3 Histopathological studies

To examine the extent of cellular damage caused by the tannery effluent, the liver and gill of *Catla catla* treated with sub-lethal concentration and maintained as controls were fixed in Bouin's fluid for 24 hours. Following a rinse with water, the tissues were dehydrated in graded alcoholic series, cleaned in xylol and embedded in paraffin wax (58-60°C). Using a rotary microtome 6 to 8m thick sections were cut. The sections were deparaffinized in xylene and were hydrated in graded series of alcohol from 100%, 90%, 70%, 50%, 30% and then with distilled water. Then the sections were stained with Heidenhain's haematoxylin and counterstained with aqueous eosin for microscopic observations (Gurr, 1959). The stained sections were mounted in DPX.

3. RESULTS

3.1. Histology of Gill

The normal gills of *Catla catla* comprised of laterally compressed leaf like gill filaments (primary gill lamellae) arranged alternately on either side of the interbranchial septum. Each primary filament bore a row of secondary gill lamellae on both sides perpendicular to its long axis. Primary gill lamellae comprised of a central core of cartilaginous rod, lining epithelial cells and blood vessels whereas secondary lamellae consisted of a layer of flattened epithelial cells attached to the basement membrane, contractile pillar cell system and blood spaces.

3.2. Histopathology of Gill

The fish, *Catla catla* when exposed to sublethal concentration of tannery effluents for 21 days showed marked histopathological changes in their gill. Excessive secretion of mucous in the intercellular spaces, fusion of secondary gill lamellae, reduction in length, swelling of epithelial cells of secondary lamellae and cytoplasmic vacuolization were some of the observable changes. The necrotic changes in the tip regions of the secondary gill lamellae were noticed on 21st day.

3.3. Histology of Liver

The liver of control *Catla catla* comprised of a continuous mass of hepatocytes arranged in irregular cords. The hepatic cells were large, polygonal in shape with the nucleus almost centrally placed. Blood sinusoids were also seen among the hepatocytes.

3.4. Histopathology of Liver

The structural organization of the liver appeared disturbed when fish were exposed to 21 days sublethal concentration of tannery effluents. Rupture of hepatocytes and their nuclei, necrosis and vacuolization of the tissue and extension and displacement of nuclei were some of the observable changes. Additionally, disintegration of blood sinusoids and central vein were also observed in the liver tissue.

4. DISCUSSION

In fish the gill is the most important organ for respiration and osmoregulation and it is the first organ to which, pollutant comes into contact. Hence, it is more vulnerable to damage than any other tissue (Vijayalakshmi and Tilak, 1996). Gill covers more than sixty percent surface of the fish and its external location renders the most vulnerable target organ for the pollutants (Roberts, 1989). The rupturing of secondary gill lamellae, excessive secretion of mucous, fusion of secondary gill lamellae, reduction in length and vacuolization are some of the important histopathological abnormalities observed in the gill of *Catla catla* exposed to sublethal concentration of tannery effluents. Similar histopathological changes have been observed in the gill of zebra fish exposed to mixture of heavy metals (nickel chloride, cadmium chloride and lead nitrate) and mixture of pesticide (aldrin, dieldrin, hepatachlor and mirex) (Bhuvaneshwari *et al.,* 2015) The fish, *Danio rerio* exposed to leather industry effluents showed degeneration, fusion and clubbing of secondary gill lamellae were observed in the gill (Sivakumar *et al.,* 2015).

Liver is the most important centre for metabolising and also for detoxification. Rupture of hepatocytes and their nuclei, necrosis and vacuolization of the tissue, extrusion and displacement of nuclei and disorganization of sinusoids and central vein are the important histopathological abnormalities observed in the liver of *Catla catla* exposed to tannery effluent. Similar changes in the liver of fishes have been reported in different species treated with various toxicants. Rajiv *et al*. (1995) have reported that the breaking of the intercellular junction and necrosis were observed in the liver of *Heteropneustes fossilis* when exposed to hair dye. In *Liza parsia* exposed to mercuric chloride and DDT caused severe liver damage due to hepatic lesions, destruction of cytoplasmic materials, vacuolization of the hepatocytes and blood sinusoids exhibited complete disorganization (Pandey *et al*., 1996). The fish, *Danio rerio* exposed to leather industry effluents showed rupture of hepatocytes, hepatocyte lost polyhedral shape, degeneration, aggregation of hepatocytes and vacuolization were observed in the liver (Sivakumar *et al.,* 2015).

5. CONCLUSION

In the present investigation the histopathological changes in gill and liver were evident in the sublethal concentration of tannery effluent exposed *Catla catla*. Severe gill lesions at longer period exposure such as lifting and general necrosis of gill epithelium were very much evident in this test levels. Degenerative changes in the liver of *Catla catla* demonstrated the liver to be the organ affected most severely in response to tannery effluent intoxification. These responses can impair the gill functions and could eventually lead to the death of the fish. The tannery effluent consists of variety of toxic components such as heavy metals, soda, lignin, chlorine, resin acid, dioxin, and furan. These toxicants deliberately affect the aquatic organisms including fish and through food chain that toxicant affects human beings.

REFERENCES

Bhuvaneshwari, R., Padmanaban, K. and BabuRajendran, R. 2015. Histopathological alterations in muscle, liver and gill tissues of Zebra fish *Danio rerio* due to environmentally relevant concentrations of organochlorine pesticides (OCPs) and Heavy metals. *Int. J. Environ. Res.,* 9(4):1365-1372.

Gurr, E. 1959. Methods for analytical histology and histochemistry, Leonard Hill (Books) Ltd., London.

Pandey, A.K., George, K.C. and Peer Mohamed, M. 1996. Histopathological alterations induced in the liver of an estuarine mullet, *Liza parsia* by mercuric chloride and DDT. *Indian. J. Fish.,* 43: 277-284.

Rajiv, R., Upadhyay, Usha and Lokesh Upadhyay, 1995. Carcinogenic effect of hair dye in the liver of *Heteropneustes fossilis*. *J. Ecotoxicol. Environ. Monit.,* 5: 151-153.

Roberts, R.J., 1989. Fish Pathology. 2nd Edn. Bailliere Tindall, London.

Sivakumar, P., Kanagappan, M. and Sam Manohar Das, S. 2015. Chronic histopathological changes in selected tissues of *Danio rerio* exposed to effluents from leather tanning industry, *World Journal of Pharmaceutical Research*, 4(4): 1001-1009.

Vijayalakshmi, S. and Tilak, K.S. 1996. Effect of pesticides on the gill morphology of *Labeo rohita*. *J. Ecotoxicol. Environ. Monit,* 6: 59-64.

A STUDY ON THE TAXONOMIC CLASSIFICATION OF AVIFAUNAL DENSITY IN THE GREAT VEDARANYAM SWAMP, POINT CALIMERE WILDLIFE SANCTUARY, SOUTHERN INDIA

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ABSTRACT

We investigated the Taxonomic Classification of Avifaunal Density in the Great Vedaranyam Swamp, Point Calimere Wildlife Sanctuary, Southern India between 2004 and 2006. Classification was used to group the birds by using different orders and families. These aspects would revealed by successive levels such as species, genus, family, order, class indicating the degree of relationship among species and higher level taxonomy. Water bird communities experience seasonal and annual fluctuations in abundance and species composition, on a local as well as on a regional scale. Hence, we assess the population density of waterbird monthly and seasonal variation. The water birds included in different orders were Ciconiiformes, Anseriformes, Pelecaniformes and Charadriiformes and in various families viz., Phoenicopteridae, Threskiornithidae, Ardeidae, Ciconiidae, Anatidae, Pelecanidae and Charadriidae. The taxonomic orders showed significant difference among the years of study and the monthly variations was also significant. The seasonal variations in the population of different orders showed significant difference among the years of study.

Keywords: Taxonomic Classification, Ciconiiformes, Anseriformes, Phoenicopteridae, Threskiornithidae.

1. INTRODUCTION

Knowledge of the species composition and diversity of migrant shorebirds is essential in the development of management and conservation strategies (Davis and Smith, 1998). Taxonomical Classification of birds is important, because the recognition of the birds and basic unit of biological diversity, two or more species are quite similar in their morphology, physiology, behaviour and ecology, they can be classified in the same genus. These aspects would revealed by successive levels such as species, genus, family, order, class indicating the degree of relationship among species and higher – level taxonomy. Water bird communities experience seasonal and annual fluctuations in abundance and species composition, on a local (DuBowy, 1988; Bethke, 1991; Lopez de Casenave and Filipello, 1995), as well as on a regional scale (Bethke and Nudds, 1995).

2. STUDY AREA

Point Calimere Wildlife & Bird Sanctuary is located along the Palk Strait in three districts of Tamil Nadu: Nagapattinam, Tiruvarur and Thanjavur. It lies in between 79.399 E & 79.884 E longitudes and 10.276 N & 10.826 N latitudes, covering an area of 38,500 hectares from Point Calimere in the east to Adirampattinam in the west. The entire swamp belt is about 30km long and 9km wide. In total, it has an area of about 349 km^2. The Point Calimere Wildlife Sanctuary which was declared as a Ramsar Site on 19th August 2002. Bio-geographically this Ramsar Site is a mix of salt swamps, mangroves, backwaters, mudflats, grasslands and tropical dry evergreen forest. It was first identified as an area of high significance in the conservation of birds by the renowned ornithologist late Dr. Salim Ali in 1962 (Ali 1963). A total of 257 species of birds have been recorded from the sanctuary of which 119 were water birds and 138 landbirds (Ramsar Site Report, 2002).

3. MATERIALS AND METHODS

3.1. Study Period and Seasons

Data were collected from January 2004 to December 2006. Four seasons namely Post-monsoon (January-March), Summer (April-July), Pre-monsoon (August and September) and Monsoon (October-December) of three successive years were classified to analyze the data.

3.2. Waterbird Population Counts

The populations of different species of water birds were estimated by direct counts (Nagarajan and Thiyagesan, 1996). The birds were observed through 7'x50'' field binocular and 3x60 telescope. The birds were identified with the help of their special features using field guides (Grimmet *et al*., 1999). The population was estimated once in a week across the study period. Counts were not made on days with rain, strong wind and extreme temperature to minimize the bias caused by the effect of weather. From the data obtained, densities of birds were calculated and expressed as number per hectare.

3.3. Calculations Population Characteristics

3.3.1 Water bird density

The individual and total water bird densities of different taxonomical and ecological groups of the swamp were calculated as numbers per hectare (Nagarajan and Thiyagesan, 1996).

3.3.2 Taxonomic Classification of Birds

The taxonomic classification was used to group the birds by using different orders and families. The water birds included in different orders were Ciconiiformes, Anseriformes, Pelecaniformes and Charadriiformes and in various families viz., Phoenicopteridae, Threskiornithidae, Ardeidae, Ciconiidae, Anatidae, Pelecanidae and Charadriidae

4. RESULTS

4.1 Density of Water Birds

4.1.1 Order - Monthly Variations

The density of water birds of different orders across the month is given in table 1

4.1.2 Ciconiiformes

In all the three years of study, population of order Ciconiiformes was lowest in April 2004 with a mean value of 18.9 ± 1.28/ha and highest in December 2005 with a mean value of.728.0 ± 160.22/ha. In 2004, Ciconiiformes population ranged between 18.9 ± 1.28/ha in May and 167.5 ± 38.83/ha in December. During 2005, Ciconiiformes density varied from 38.1 ± 1.92/ha in September to 728.0 ± 160.2/ha in December. During 2006, Ciconiiformes population was minimum in December with a mean value of 35.45 ± 2.12/ha and maximum in January with a mean value of 254.5 ± 101.01/ha. The variation in the density of Ciconiiformes showed significant difference among years (F= 5.23; P<0.05) and among the months (F= 7.22; P<0.001) (Table.1)

4.1.3 Charadriiformes

Charadriiformes population varied from 11.5 ± 12.56/ha in November 2006 to 791.8 ± 72.76/ha in January 2004 during the study period. During 2004, Charadriiformes population was minimum in April with a mean value of 24.8 ± 1.45/ha and maximum in January with a mean value of 791.8 ± 72.76/ha. During 2005, Charadriiformes density ranged between 64.6 ± 4.68/ha in September and 497.7 ± 197.36/ha in December. Charadriiformes population was lowest in November with a mean value of 11.5 ± 12.56/ha and highest in January with a mean value of 143.9 ± 30.74/ha in 2006. The variation in the density of Charadriiformes across different years was significant (F= 17.76; P<0.001) and the monthly variation was also significant (F= 9.59; P<0.001) (Table.1)

4.1.4 Anseriformes

Anseriformes population was lowest in February 2006 with a mean value of 0.39 ± 0.39/ha and highest in December with a mean value of 591.1 ± 129.84/ha during the study period. During 2004, Anseriformes density ranged between 8.8 ± 0.58/ha in March and 538.9 ± 16.82/ha in January. Anseriformes population was minimum in March with a mean value of 13.8 ± 2.94/ha and maximum in December with a mean value of 591.1 ± 29.84/ha in 2005. During 2006, Anseriformes population varied from 0.39 ± 0.39/ha in February to 60.8 ± 24.36/ha in November. The variation in the density of Anseriformes across different years was significant (F= 27.78; P<0.001) and as well as the monthly variation was also significant (F= 25.54; P<0.001). (Table.1)

4.1.5 Pelecaniformes

In all the three years of study, Pelecaniformes population ranged between 0.2 ± 0.17/ha and 0.2 ± 0.23/ha in both July 2004 and April 2006 respectively and 29.1 ± 10.34/ha in October 2004. During 2004, Pelecaniformes density was lowest in July with a mean value of 0.2 ± 0.23/ha and highest in

October with a mean value of 29.1 ± 10.34/ha. In 2005, Pelecaniformes population varied from 1.2 ± 0.46/ha in March to 15.8 ± 3.62/ha in November. Pelecaniformes population was minimum in April with a mean value of 0.2 ± 0.17/ha and maximum in January with a mean value of 9.1 ± 2.51/ha in 2006. The variation in the density of Pelecaniformes showed significant difference among years (F= 12.38; P<0.001) as well as among the months (F= 6.19; P<0.001) (Table.1)

4.2. Order – Seasonal Variations

The density of waterbirds in different orders across the month is given in table 2.

4.2.1. Ciconiiformes

Among the three years of study, population of order Ciconiiformes varied from 41.9 ± 5.14/ha in summer of 2004 to 302.9 ± 69.39/ha in monsoon of 2005. The variation in the density of Ciconiiformes across different years was significant (F= 4.71; P<0.001) as well as the seasonal variation was also significant (F= 7.39; P<0.001) (Table.2)

4.2.2 Charadriiformes

In all the three years of study, Charadriiformes population ranged between 28.1 ±1.28/ha in summer during 2004 and 388.3 ± 54.38/ha in post-monsoon during 2004. The variation in the density of Charadriiformes showed significant difference among years (F= 16.70; P<0.001) and the seasonal variation was also highly significant (F= 16.90; P<0.001) (Table.2)

4.2.3. Anseriformes

Anseriformes density was lowest in monsoon during 2006 with a mean value of 7.2 ± 2.37/ha and highest in monsoon in 2005 with a mean value of 273.7 ± 55.73/ha during the study period. The variation in the density of Anseriformes across different years was significant (F= 19.96; P<0.001) and as well as the seasonal variation was also significant (F= 18.19; P<0.001) (Table.2)

4.2.4. Pelecaniformes

In all the three years of study, Pelecaniformes population was minimum in summer during 2006 with a mean value of 0.2 ± 0.18/ha and maximum in monsoon during 2004 with a mean value of 20.9 ± 4.57/ha. The variation in the density of Pelecaniformes showed significant difference among years (F= 11.72; P<0.001) and the seasonal variation was also highly significant (F= 15.29; P<0.001) (Table.2)

5. CONCLUSION

In conclusion the taxonomic orders showed significant difference among the years of study and the monthly variations was also significant. The seasonal variations in the population of different orders showed significant difference among the years of study.

REFERENCES

Ali, S. 1963. Point Calimere as a refuge for Wintering Shorebirds. J. Bombay Natural History Society, 60:458-460.

Bethke, R.W. 1991. Seasonality and interspecific competition in waterfowl guilds: a comment. *Ecology*: 72-1115- 1158.

Bethke, R.W., and Nudds, T.D. 1995. Effects of climate change and land use on duck abundance in Canadian prairie-parklands. Ecol. Appl 5: 588–600.

Davis, C.A. and Smith, L.M. 1998. Ecology and management of migrant shorebirds in the Playa Lakes region of Texas. *Wildlife Monograph* 140: 1–45.

DuBowy, P.J. 1988. Water fowl communities and seasonal environments: temporal variability in interspecific competition. *Ecology*. 69: 1439-1453.

Grimmett, R., Inskipp, C. and Inskipp, T. 1999. Birds of Indian Subcontinent Oxford University Press, Delhi.

Lopez de Casenvae. J. and Filipello, A.M. 1995. Las Aves acuaticas de la Reserva Costanera Sur: cambios estacionales en la composicion especifica y en la abundancia de poblaciones y gremios. *Hornero* 14: 9-14.

Nagarajan, R. and Thiyagesan, K.1996. Waterbirds population and substrate quality of Pichavaram Wetlands, Southern India. *Ibis* 138:710-721.

Ramsar Site Report. 2002. Information sheet on Ramsar wetlands (RIS). Categories approved by recommendations 4.7 of the Conference of the Contracting Parties. Extracted from http://www.wetlands.org/reports/ris/2IN015en.pdf.

Table 1: Monthly[a] variations in the density of birds of different orders (no./ha) during the study period (2004-2006) at the swamp of Point Calimere Wildlife Sanctuary, Tamilnadu, Southern India. Values are Mean ± SE.

Taxonomic Order	Year	Jan	Feb	Mar	Apr	May	July	Aug	Sep	Oct	Nov	Dec	ANOVA Month F	ANOVA Month P	ANOVA Year F	ANOVA Year P
Ciconiiformes	2004	133.6± 6.56	72.4± 7.36	34.3± 2.14	18.9± 1.28	29.8± 6.41	83.2± 6.50	58.3± 20.84	0	118.1± 25.39	58.3± 9.37	167.5± 38.83	7.22	0.001**	5.23	0.006*
	2005	56.1± 7.55	88.8± 11.11	93.6± 14.61	0	0	0	075.5± 12.21	38.1± 1.92	58.2± 0.97	118.9± 25.95	728.0± 160.22				
	2006	254.5± 101.01	59.8± 11.02	115.6± 23.45	109.8± 16.38	0	0	0	0	65.4± 4.37	221.4± 68.01	35.45± 2.12				
Charadriiformes	2004	791.8± 72.76	216.1± 36.95	55.9± 4.34	24.8± 1.45	30.2± 2.76	30.6± 2.44	41.6± 3.92	0	215.6± 43.77	311.6± 50.60	433.4± 62.00	9.59	0.001**	17.76	0.001**
	2005	319.5± 84.66	255.4± 35.62	445.8± 109.38	0	0	0	99.6± 10.85	64.6± 4.28	128.1± 8.46	231.2± 24.55	497.7± 197.36				
	2006	143.9± 30.74	101.5± 35.74	26.8± 2.65	29.4± 2.22	0	0	0	0	110.3± 4.93	11.5± 12.56	69.44± 8.57				
Anseriformes	2004	538.9± 16.82	86.5± 24.22	8.8± 0.58	0	0	0	0	0	69.1± 9.44	104.1± 31.76	471.2± 72.96	25.54	0.001**	27.78	0.001**
	2005	114.2± 29.76	39.3± 9.01	13.8± 2.94	0	0	0	0	0	32.3± 4.86	215.8± 28.53	591.1± 129.84				
	2006	19.9± 5.45	0.39± 0.39	0	0	0	0	0	0	0	60.82± 24.36	3.14± 2.55				
Pelecaniformes	2004	15.9± 1.72	9.3± 1.51	4.8± 0.35	0.3± 0.18	0.6± 0.26	0.2± 0.23	0.6± 0.63	0	29.1± 10.34	23.4± 5.79	8.1± 2.21	6.19	0.001**	12.38	0.001**
	2005	5.3± 1.77	3.3± 0.77	1.2± 0.46	0	0	0	1.4± 0.44	1.1± 0.46	5.1± 0.84	15.8± 3.62	12.3± 4.38				
	2006	9.1± 2.51	1.9± 0.64	1.1± 0.36	0.2± 0.17	0	0	0	0	6.9± 1.75	5.52± 1.26	3.1± 1.08				

[a]During June no data collected was done because the swamp was dry in all the years of the study period.

*P < 0.05; ** P<0.01

Table 2: Seasonal[a] variations in the density of birds of different orders (no./ha) during the study period (2004-2006) at the swamp of Point Calimere Wildlife Sanctuary, Tamilnadu, Southern India. Values are Mean ± 1 SE

Taxonomic Order	2004				2005				2006				ANOVA			
	Mon	Post-mon	Sum	Pre-mon	Mon	Post-mon	Sum	Pre-mon	Mon	Post-mon	Sum	Pre-mon	Season		Year	
													F	P	F	P
Ciconiiformes	116.7± 16.77	84.2± 6.76	41.9± 5.14	58.3± 20.84	302.9± 69.39	79.0± 6.89	0	57.3± 7.03	114.4± 27.63	147.6± 38.22	109.8± 16.38	0	7.39	0.001**	4.71	0.010*
Charadriiformes	312.2± 31.68	388.3± 54.38	28.1± 1.28	41.6± 3.92	282.6± 70.00	344.3± 49.74	0	82.6± 6.59	101.3± 6.59	91.7± 16.94	29.4± 2.22	0	16.90	0.001**	16.70	0.001**
Anseriformes	217.0± 33.30	236.6± 35.10	0	0	273.7± 55.73	56.5± 12.14	0	23.1± 9.85	7.2± 2.37	0	0	0	18.19	0.001**	19.96	0.001**
Pelecaniformes	20.9± 4.57	10.5± 1.03	0.4± 0.12	0.6± 0.63	10.5± 1.90	3.2± 0.70	0	1.3± 0.31	5.4± 0.85	4.2± 1.06	0.2± 0.18	0	15.29	0.001**	11.72	0.001**

[a]**Mon** = Monsoon ; **Post-mon** = Post-monsoon; **Sum** = Summer; **Pre-mon** = Pre-monsoon

*P < 0.05; ** P<0.01

DIVERSITY OF AMPHIBIAN POPULATION WITH REFERENCE TO DEGREES OF INFESTATION OF *EICHHORNIA CRASSIPES* IN SELECTED PONDS OF CAUVERY DELTAIC REGIONS IN TAMIL NADU, INDIA

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ABSTRACT

Amphibians are considered as “Environmental sponges” because of their semi-permeable skin allows environmental toxins. In India, 342 species of amphibians are classified, in which 161 are still under the data deficient category which indicates the need of elaborative, systematic and coordinated efforts for estimating the population and delimiting the distribution of species. The faunal diversity of amphibian in Tamil Nadu includes 76 species in which 23 species of amphibians include Schedule IV reported by Tamil Nadu Forest Department. In the present study was carried out in the Cauverydeltaic regions of selected village ponds of Nagapattinam, Thiruvarur and Thanjavur Districts of Tamil Nadu to identify the diversity of amphibian population. A total of 12 amphibian species were recorded from 31 village ponds during the study period. About 6 species of *Euphlyctis cyanophlyctis, Euphlyctis hexadactylus*, *Hoplobatrachus tigerinus*, *Hoplobatrachus crassus, Fejervarya limnocharis and Sphaerotheca breviceps* were belonging to the family Dicroglosidae whereas only three species of *Microhyla. ornata, M. rubra* and *Ramanella varigata* were belonging to the family Microhylidae and toads of terrestrial species *Duttaphrynus melanostictus* and *D. scaber* were observed from the family Bufonidae. The only one arboreal species *Polypedatus maculates* also encountered which belonging to the family Rhacophoridae. Regarding amphibian diversity, about 12 species were reported from Nagapattinam, 11 species from Thiruvarur and only 10 species from Thanjavur Districts.

Keywords: Amphibia, Diversity, *Eichhornia crassipes*, Nagapattinam, Thiruvarur and Thanjavur District

1. INTRODUCTION

Amphibians are excellent “Bio indicator species” because they can provide information on the health of two habitats. Due to their biphasic lifestyle and permeable skins, amphibians are commonly used as “Bio indicators”, which in turn makes it very common for amphibian populations to be severely affected when there are serious disturbances to their natural habitats (Blaustein and Belden, 2003; Carey and Alexander, 2003; Collins and Storfer, 2003,). Throughout the history of civilization, human activities have been detrimental to the natural biota, which is particularly evident in the clearing of the forest that houses the greatest diversity of anurans (Duellman and Treub, 1986). For nine out of every 10 amphibian species that are classified as threatened, habitat loss is a key threat (Baillie *et al.,* 2004). There are several possible causes for the decline of amphibians, such as agriculture, habitat destruction, exotic species, pollution, toxic substances, acidification and excess nutrients.

Disease, pollution, invasive species, over collecting, global changes and other causes have been documented or proposed to be responsible for particular or widespread amphibian declines (Collins and Storfer, 2003; Weldon *et al.,* 2004; Thenmozhi *et al.,* 2015). Scientists estimate that about 43% of amphibians or about 1,856 species are threatened and are declining at a rapid rate worldwide (Stuart *et al.,* 2004). Globally 7,044 amphibians have been reported (Frost, 2013) and 342 species are known from India (Dinesh *et al*., 2012).The faunal diversity of amphibian in Tamil Nadu includes 76 species. Besides habitat loss, over exploitation or introduced species, amphibians are affected due to the pollution of surface waters with fertilizers and pesticides (Richard, 2010). However, amphibian populations naturally fluctuate (Skelly *et al.,* 1999). Habitat alteration has been found to be one of the major causes of the current global amphibian decline.

2. MATERIALS AND METHODS

2.1. Amphibian counting

A field survey wa s conducted in selected ponds of Cauvery delta area during June 2012 to June 2015 in order to document the diversity and conservation issues of the amphibians in the area. The selected village ponds were monitored monthly once to find out the diversity and density of amphibian population. Visual Encounter Survey Method (VES) was carried out to estimate the amphibian population (Heyer *et al.,* 1994) in various ponds and the diversity of frog species was recorded in the morning or evening time. Amphibians were thoroughly searched in the water bodies, edge of the water, grasses, bushes, holes, crevices and over the surface of the water.

2.2 Statistical analysis

Species richness was calculated based on the number of amphibians recorded in the pond (Heyer *et al.*, 1994) and the species diversity was calculated by using the Shannon –Wiener Index (Shannon and Wiener, 1949). Individual amphibian density was calculated as number per hectare of the pond in each season. Statistical analyses were performed by using Windows based Statistical package viz., Microsoft Excel, SPSS.

3. RESULTS

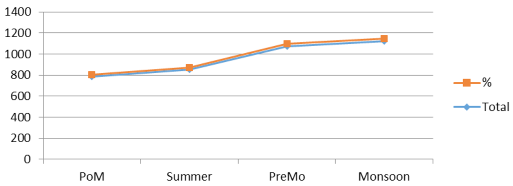
A total of 12 amphibian species were recorded from 31 village ponds during the study period. About 6 species of *Euphlyctis cyanophlyctis, Euphlyctis hexadactylus* , *Hoplobatrachus tigerinus*, *Hoplobatrachus crassus, Fejervarya limnocharis and Sphaerotheca breviceps,* were belonging to the family Dicroglosidae, whereas only three species of *Microhyla ornate, Microhyla rubra* and *Ramanella varigata* were belonging to the family Microylidae and toads and terrestrial species of *Duttaphrynus melanostictus* and *Duttaphrynus scaber* were observed from the family Bufonidae. The only one arboreal species *Polypedatus maculates* also encountered which belonging to the family Rhacophoridae. Regarding amphibian diversity; about 12 species were reported from Nagapattinam, 11 species from Thiruvarur and only 10 species from Thanjavure districts (Table1).

Table 1. List of amphibian species encountered in the study area during the study period 2013-2015.

Sl. No	Family	Species Name	Common Name	NGT	TVR	TAN
1	**Bufonidae**	*Duttaphrynus melanostictus*	Indian Toad	√	√	√
2		*Duttaphrynus scaber*	Dwarf Toad	√	√	x
3	**Dicroglossidae**	*Euphlyctis cyanophlyctis*	Indian Skipper Frog	√	√	√
4		*Euphlyctis hexadactylus*	Indian Pond Frog	√	√	√
5		*Hoplobatrachus tigerinus*	Indian Bullfrog	√	√	√
6		*Hoplobatrachus crassus*	Jordon`s Bull Frog	√	√	x
7		*Fejervarya limnocharis*	Paddy Field Frog	√	√	√
8		*Sphaerotheca breviceps*	Indian Burrowing Frog	√	√	√
9	**Microhylidae**	*Microhyla ornate*	Ornate Narrow-Mouthed Frog	√	√	√
10		*Microhyla rubra*	Marbled Narrow –Mouthed Frog	√	√	√
11		*Ramanella varigata*	Termite Nest Frog	√	x	√
12	**Rhacophoridae**	*Polypedates maculatus*	Tree Frog	√	√	√

NGT- Nagapattinam; TVR- Thiruvarur; TAN- Thanjavore; √- Present; x- Absent

Fig. 1 Season wise amphibian population in the study area during the study period



The season wise amphibian density was higher in the monsoon season whereas less in post monsoon season. (Fig.1). The *Euphlyctis cyanophlyctis* was the highest amphibian species in all the seasons, whereas the species *Ramanella varigata* was less in all seasons. (Fig. 2).

Fig. 2 Season and species wise amphibian population in the study area during the study period

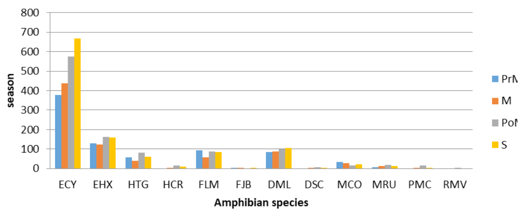


Table 2. Density, Diversity and Richness of amphibian species on *Eichhornia* infested village ponds of the study area during the study period (n=31)

Category	Amphibian	Density/ acre	Diversity	Richness
Dense	1047	0.273797	0.15403	12
Medium	889	0.232479	0.1473	11
Less	1888	0.493724	0.15133	11

Amphibians were higher in the less *Eichhornia* infested ponds than densely infested ponds (Table 2). The results of Shannon Weiner clearly showed that the variation is significant in different village ponds i.e., (H = 0.151 (less), 1.54 (Dense) and 0.14 (less) in various water hyacinth infested ponds. The diversity indices showed that the amphibian population was higher in less water hyacinth ponds and lower in dense water hyacinth ponds which were influenced by *E. crassipes* infestations (Table 2). The density of amphibians were also estimated with various degrees of *E. crassipes* infested ponds, in which low density of amphibians (0.23/ acre) were in medium and (0.27/acre) in dense water hyacinth ponds when we compared with less infestation ponds (0.49/acre). The only one species RMV was couldn't observe in low and medium of infestation of *Eichhornia* ponds (Fig. 2).

4. DISCUSSION

Thenmozhi *et al.* (2015) reported that the amphibian species were severely disturbed with exotic species. All of these species are breed in ponds. Most parts of the Cauvery delta areas have been transformed into aquaculture farms and plot areas. As a result, various Microhabitats such as leaf litter, rotten logs, tree holes, shrubs and bushes have been destroyed. Breeding sites such as swamps, freshwater marshes, small creeks and ditches become dry due to increase light intensity. This phenomenon will affect the population of frog species and some species that cannot survive in a new environment will die. Infestations of invasive species like Water hyacinth, *Eichhornia crasipes* role is one of major role in decline of amphibian population (Thenmozhi and Thenmozhi *et al*., 2015).

In the present study, the anuran population got suddenly decreased during post monsoon and summer. This might have happened due to aestivation of anurans because of the unfavorable conditions. Certain external factors like weather fluctuations, biomass of aquatic plants, predator's population and variations in water levels, harvesting of crops etc. also directly influenced the collection of data. In some months, ponds were full of water with ideally warm and moist, and some were too cold, thus on nights leading up to rain events anuran calling was more prevalent. Originally, each site of four habitats was supposed to have been visited daily twice.

Similar observation made by several researchers in various regions of Tamil Nadu and India. Seshadri *et al.* (2012) reported 14 species of amphibians from the wetlands of Puducherry, India. Grazy Kutty (2007) recorded 12 species of amphibians from agricultural areas of Periyakulam Taluk. Jayasekar (2013) has reported 10 species of amphibians from agricultural areas of Kanyakumary District. Tews *et al*. (2004) emphasized the Community ecology theory which predicts that heterogeneous habitats will have higher species richness than homogenous habitats at local and regional scales. Parris (2002) suggested that the baseline information on species distribution, abundance, and habitat requirements are needed, especially in the case of poorly known and/or threatened species to clarify the extent and pattern of population declines. Analysis of habitat variables can help to elucidate the distribution, habitat requirements and preferences of a particular amphibian species. Thenmozhi and Thangapandian, (2013) observed more number of *Duttaphrynus melanostictus* was encountered in the non-cultivable habitat, *Euphlyctis cyanophlyctis* was more in the field of cultivable and pond Habitats. But in the present study *Euphlyctis hexadactylus* was encountered more in number in ponds. These results emphasize the importance of the variation in various natural habitats and their role in supporting biodiversity.

5. MANAGEMENT RECOMMENDATIONS

Anurans are habitat specific and highly sensitive animals. If the habitat is degraded, anurans population and density might have been decreased. Hence the anurans need urgent and immediate conservation to protect the environment and the balanced ecosystem.

5.1 Recommendations

- ➢ Water hyacinth (*Eichhornia crassipes*) is one of the world's most prevalent invasive aquatic plants and is known to cause significant ecological and socio-economic change.
- ➢ Water hyacinth can change water quality by altering water clarity
- ➢ An Intensive survey and regular monitoring of amphibians in Cauvery delta regions
- ➢ Minimize the degradation or alteration of lands into plots.
- ➢ Details of the impacts and causes of water quality on amphibian needs to be studied for preventing severity of declining amphibian population
- ➢ Conservation of species from unprotected ponds should also be strengthening particularly urban areas.
- ➢ Community and School based awareness programs should be conducted

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REFERENCES

Baillie, E.M., Craig Hilton-Taylor and Simon Stuart, N. 2004. A Global species assessment.IUCN, Gland,Switzerland and Cambridge,UK.

Blaustein, A.R. and Belden, L.K. 2003. Amphibian defenses against ultraviolet-B radiation. *Evolution & Development* 5:89–97.

Carey, C. and Alexander, M.A. 2003. Climate change and amphibian declines: Is there a link? *Divers. Distribut.*, *9*, 111-121.

Collins, J.P. and Storfer, A. 2003. Global amphibian declines: sorting the hypotheses. *Divers. Distrib.*9.Pp.89-98.

Dinesh. K.P., Radhakrishnan. C., Gururaja. K.V,, Deuti. K. and Bhatta, G. 2012. A Checklist of Amphibia of India with IUCN Red list Status. *Zoological Survey of India*.

Duellman, W.E. and Trueb, L. 1986. *Biology of Amphibians*. McGraw-Hill, New York.

Frost, D.R. 2013. Amphibian Species of the World: an Online Reference. Version 5.6 Electronic Database accessible at American Museum of Natural History, New York, USA.

Grazy Kutti, T.I. 2007. Studies on anuran resources of Periyakulam Taluk, Theni District, India. P.hD., Thesis submitted to Madurai Kamaraj University, Madurai.

Heyer, W.R., Donnelly, M.A., Mcdiarmid, R.W., Hayek, L.C. and Foster. M.S. 1994. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press. Washington, 364.

Jeyasekhar, M.P. 2013. Anurans from agro-ecosystems of Kanyakumari District, Tamil Nadu. *Int. J. Cur. Tr. Res (2013) 2 (1): 69-73*

Parris, K.M. 2002. The distribution and habitat requirements of the great barred frog (*Mixophyes fasciolatus). Wildlife Res.* 29: 469-474.

Richard I. 2010. Pesticides reduce biodiversity. *Pesticides News*, 88, 4-7

Seshadri, K.S.A., Chandran, V. and Gururaja, K.V. 2012. Anurans from Wetlands of Puducherry, along the East Coast of India. *Checklist.* 8 (1) 203 - 026.

Shannon, C.E. and Weaver, W. 1949. The mathematical theory of communication, University of Il linois press, Urbana.

Skelly, D. K., Werner, E. E. and Cortwright, S. A. 1999. Long-term distributional dynamics of a Michigan amphibian assemblage. *Ecology* 80:2326–2337.

Stuart, S.N., Chanson, J.S., Cox, N.A., Young, B.E., Rodrigues, A.S.L., Fischmann, D.L. and Waller, R.W. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* 306, 1783-1786.

Tews. J., Brose, U., Grimm. V., Tielborger, K., Wichmann, M.C., Schwager, M. and Jeltsch, F. 2004. Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structure. *Journal of Biogeography* 31:79-92.

Thenmozhi, K. and Karthik, T. 2014. Effect of water hyacinth (*Eichhornia crassipes*) on amphibian diversity and population in Water village ponds of Nagapattinam, Thiruvarur and Thanjavur Districts of Tamil Nadu. National Conference on Research Challenges in Modern biological Science.

Thenmozhi, K., Karthik, T. and Karunakaran, K. 2015. Assessment of Anuran diversity and microhabitats in various wetland ecosystem of Nagapattinam district, Tamilnadu. Held at St. John's College, Palyankottai, Tirunelveli.

Thenmozhi. K. and Thangapandian, S. 2013. Amphibian community and microhabitat Association in Agarakeeragudi Agro ecosystem. Mayiladuthurai, Tamilnadu. *Cobra* 7:2.

Weldon, C., Du Preez, L.H., Hyatt, A.D., Muller, R. and Speare, R. 2004. Origin of the amphibian Chytrid Fungus. *Emerging Infectious Diseases* 10:2100-2105.

COMPARISON OF TRACE METALS ACCUMULATION ON THE MUSSEL *PERNA VIRIDIS* IN THE COASTAL WATERS OF NAGAPATTINAM, TAMIL NADU, INDIA.

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ABSTRACT

The concentration of Fe, Mn, Zn and Cu in the whole soft tissue of male and female *Perna viridis* and coastal water from three sampling sites (Tranquebar-1, Thirukkadaiyur-2 and Thirumullaivasal-3) along the Nagapattinam coastal waters revealed that higher concentration of Fe, Mn and Zn in station -1 followed by Cu in station -3. In all the sampling sites female showed higher trace metals accumulation, except in station -1 water showed high accumulation of Fe content. Among the different trace metal accumulated by *P.viridis*, their level was within the maximum permissible limit. So the mussels are suitable for human consumption. The trace metal content may be due to a variety of natural and anthropogenic activities.

Keywords: Iron, Manganese, Zinc, Copper, Accumulation, *Perna viridis*

1. INTRODUCTION

The marine bivalves form an important component of fisheries in various parts of the world in terms of commercial value. Among bivalves green mussel *P.viridis* constitutes about 14% of total bivalve landing in India. Green mussel is a good source of protein, glycogen, fat and minerals on par with other animals food conventionally eaten by human. Nowadays Pollution continues to emerge as one of the world leading environmental threats. In the present environment, marine organisms are simultaneously exposed to a mixture of metals, so it is very likely that exposure to one metal may influence the bioaccumulation of other metals (Amiard *et al.*, 1986). Trace metals in coastal water are derived from a variety of natural and anthropogenic sources. Urban and industrial developments along the coastal area, river and estuaries contribute to a major part of the anthropogenic metal load of the sea (Phillips, 1980).

Marine Bivalve mollusks are the most widely used bioindicators (Krishnakumar *et al.*, 2006 and Verlecar *et al.*, 1998). In this respect, *P.viridis* has been used as a biological monitoring of metal pollution in tropical and subtropical coastal waters (Chong and Wang, 2001). It reprepresents one the most effective and informative method to detect and to identify marine contaminations and characterize the possible effects of contaminations on biological resources and the quality of their marine habitats. However, information on levels of trace metals in natural populations of green mussel *P.viridis* from south east coast (Tranquebar, Thirukkadiyur and Thirumullaivasal) of Nagapattimam district is lacking. Hence the present study was planned to assess the levels of selected trace metals like Fe, Mn, Zn and Cu in water and whole animal tissues of male and female *P.viridis* during summer season (2010) from various habitats.

2. STUDY AREA

A total of three sampling stations were selected in Nagapattinam district in coastal area based on variation in soil characteristics and pollution load and distance.

Station 1 (Tranquebar - Long 79^{0} 8' E, Lat. 11^{0} O'N)

It is an intertidal rocky shore area. Situated about 300 km south of Chennai. This area is nearer to Uppanar estuary and it is an important tourist place.

Station 2 (Thirukkadaiyur - Long 79° 51' E, Lat 11° 4'N)

A thermal power plant located area. It is 5 km away from station 1; it contains a Number of concrete pillars towards the seaside for intake of water and also releases effluents into the sea. The study area bottom is consisting of sandy soil. The pillar of study area also provides shelter for lot of gastropods and bivalves. *P.viridis* attach to the surface of pillars by byssus threads colonizing submerged during high tide and exposed at the time of low tide. The depth of the study area is 1 to 2 m from the sea surface.

Station 3 (Thirummulaivasal - Long. 79°50' E, Lat 11° 14'N)

It is located 24 km away from station 1; Fishing is the main activity here. It also receives urban and agricultural runoff from nearly area.

3. Materials and methods

In the present study accumulation of heavy metals such as Fe, Mn, Zn and Cu, was estimated from three different sampling stations. The water samples were collected and preserved following the APDC-MIBK extraction procedure (Brooks *et al.,* 1967). The resulting solution was aspirated to the Flame Atomic Absorption Spectrometer for metal determination.

For mussel sampling more than 30 mussels of the similar size were collected from each sampling station and brought to the laboratory and kept for 24 hours in sea water–glass troughs for emptying and cleaning the gut content. The whole body tissue were removed, washed with deionized water then dried at 60° for 24 hours in a hot air oven and then powdered using pestle and mortar. The powder was sieved through a 0.2 mm mesh size plastic sieve and stored in desiccators for further analysis. Approximately 1 gram of dried powder was used to analyze metals by using Atomic Absorption Spectrophotometer following the method described by Topping (1973).

4. RESULT AND DISCUSSION

The variation in the bioaccumulation of trace metals in water, male and female mussel recorded from each sampling area are shown in table. The maximum allowable concentration of trace metals in various water bodies and mussel sample are given in table 2. So, the order of metal accumulation from the present study is,

Station I -- Fe- water >Male> female

Mn-Male>Female>Water

Zn-Male>Female>Water

Cu-Female>Male>Water

Station II & III -- Fe-Male>Female>Water

Mn-Male>Female>Water

Zn-Male>Female>Water

Cu-Male>Female>Water

Table 1. Comparison of trace metal accumulation (ppm) in whole animal of female, male and costal water in study area (Mean ± SD, n=3)

	Samples	Fe	Mn	Zn	Cu
Station 1	**Water**	29.95±1	0.29±0.01	0.34±0.01	0.09±0.01
	Female	18.98±0.12	0.72±0.02	0.93±0.01	0.22±0.01
	Male	25.01±0.01	0.74±0.01	0.98±0.03	0.19±0.02
Station 2	**Water**	15.27±0.02	0.21±0.01	0.48±0.01	0.12±0.01
	Female	16.23±0.02	0.67±0.01	0.82±0.01	0.34±0.01
	Male	17.2±0.02	0.69±0.02	0.92±0.02	0.41±0.01
Station 3	**Water**	5.53±0.03	0.17±0.01	0.28±0.02	0.14±0.01
	Female	15.92±0.01	0.65±0.01	0.08±0.01	0.32±0.01
	Male	16.96±0.01	0.67±0.01	0.82±0.01	0.46±0.01

Table 2. Permissible limits of metals recommended by various organization

Organizations	Metals			
	Fe	Mn	Zn	Cu
WHO (1971) drinking water µg/l	100	50	50	50
National Environmental Board Report (1994) (Coastal waters mg/l)	0.1	0.1	0.02	0.1
Maximum permissible levels (Sea food) (WHO, 1982) (µg g^{-1} dry wt.)	_	_	100	10
Maximum permissible levels (Sea food) (FDA, 2001) (µg g^{-1} dry wt.)	_	_	150	100
Maximum permissible levels (mussel) (MFR, 1985) (µg g^{-1} dry wt.)	_	_	100	30

-data not available.

5. DISCUSSION

Heavy metals usually present in trace amounts in natural waters, but many of them are toxic even at very low concentrations. The present investigation shows that the contamination level of heavy metals in different habitat of coastal waters and whole mussel tissues are mainly related to local and regional sources. Trace metals are more concentrated in tissue of marine animals than in sea water (Gold berg, 1983) due to biomagnifications. The same trend has been observed in the present study also.

Iron: Among the metals analyzed, Fe level is higher in all the stations and iron accumulation is highest among the metals studied. According to Phillips (1980) the total iron in oceans is estimated to be 4110×10— metric tons, contributed by geological processes and man induced activities. The present study indicates that station 1, has high level of iron content than stations 2 and 3. It was also inferred that Fe concentration in coastal waters is a function of fresh water input and is greatly influenced by riverine waters (Rivonker and Parulekar, 1998), and this might be mainly due to marine vessel and fishing activity, domestic sewage and agricultural run-off in the Uppanar estuary, and also due to various anthropogenic sources. Further, the mussel samples have higher level of Fe content than water samples in all the stations which clearly indicate the tendency of organism in accumulating higher concentration of Fe in soft tissue and it might be due to the major role played by this essential metal in catalyzing various enzymatic activities (Kamaruzzaman *et al*., 2011). This could be due to its being a major and essential element required for the normal metabolic mechanisms and for byssal formation and attachment (Yap and Tan, 2007).

Manganese: Manganese is an essential element for the formation of bone and connective tissues and for metabolism of carbohydrate and lipids in animals as well as in human. The main sources of manganese are production of steel, nonferrous alloys, dry cell batteries, chemical industry and fungicides. The present result showed that maximum Mn level is present in station 1 and minimum in station 3 in water samples, but the level exceeds the international standard unit (0.1mg/l). In all the stations the tissue level does not exceed the permissible limit. The higher level of Mn was also reported in intertidal mussel in Karnataka coast by Sasikumar *et al*. (2006), and he also noted that Mn concentration differs from site to site.

Zinc: In the present investigation Zn shows second highest concentration among the metals. Station 1 shows higher level of Zn than stations 2 and 3 in mussel samples. Zinc is a rare metal in nature but it is commercially one of the most important metals in the world (Hietanen *et al.,* 1988). It is also an important trace element for the organism as a cofactor for approximately 300 enzymes involved in nearly all aspects of metabolism (Vallee and Auld, 1990). According to Berrow and Webber (1972) the sewage and city waste were the major source of Zn in the aquatic environments. The high level of Zn recorded in station 1 followed by station 2 in coastal waters could be attributed to its proximity to sewage, agricultural runoff, zinc coated pipes, effluent from Thermal power plant and small fishing activities in the sea near the study area. When compared to water samples the mussels showed high level of accumulation. Concentrations of Zn in the present study are clearly below the limit set by WHO (1982), FDA (2001) and MFR (1985) for sea food.

Copper: The higher level Copper in the soft tissues of the bivalve might be due to the various mechanisms which included homeostatic processes in the body in response to varying metabolic demands and entrapment of Cu under certain conditions by additional mucilage production/extrusion by the animal (Pyatt *et al.,* 2003). In the present study Cu level in whole animal tissue does not exceed the maximum permissible level (WHO, 1982). But, in water samples it exceeds the National Environmental Board Report (1994). According to Chang and Wong (2001) the Cu resembles or even overlaps with the role of iron in the metabolism of molecular oxygen in containing Cuproprotein hemocyanin. He also reported that the higher level of Cu is used for the formation of shell greening in *P.viridis*. Probably the induction of metalothionein in the tissue distribution of metals of *P.viridis* could explain the present results. Viarengo *et al.* (1985) also confirmed that metallothioneins played a fundamental role in the accumulation of Cu in *Mytilus galloprovincialis*.

In conclusion trace metals accumulation indicated variations in mussel and water samples in the study area. In all the stations mussel samples had trace metals within the maximum permissible limit of WHO, FDA, and MFR standards for sea food. However, water samples of a few elements like Cu and Zn exceeded the permissible limit. The mussels are free from trace metal contaminations in the study area and are suitable for human consumption. Care should be taken to minimize the contamination of the sea by the anthropogenic activities.

REFERENCES

Amiard, J.C., Amiard-Triquet, C., Birthet, B. and Metayer. C. 1986. Contribution to ecotoxicological study of Cadmium, lead, copper and zinc in the mussel *Mytilus edulis*: Field study. *Mar. Biol*., 90, pp. 425-431.

Berrow, M.L. and Webber.J. 1972. Trace elements in sewage sludge. *J. Sci. food Agri*., 23, pp. 93-100.

Brooks, R.R., Presley, B.J.and Kalplan. I.R. 1967. ABDC- MIBK extraction system for the determination of trace metals in saline water by atomic absorption spectroscopy Talanta, 14, pp. 809- 816.

Chong, K. and Wang. W.X. 2001. Comparative studies on the biokinetics of Cd, Cr and Zn in green mussel *Perna viridis* and the Manila clam *Ruditapes philippinarum*. *Env. Pollut.,* 1, pp. 107–121.

Eustace, 1974. Zn, Cd, Cu and Mn in species of finfish and shellfish caught in the Derwent Estuary, Tasmania. *Aust. J. Mar. Fresh water. Res*., 25, pp. 209-220.

FDA, 2001. Fish and Fisheries Products Hazards and Controls Guidance. 3rd Edn., Department of Human Services, USA.

Goldberg, E.D., Koide, M. Hodge, V., Flegal, A.R. and Martin. J. 1983. US Mussel Watch: 1977–1978 results on trace metals and radionuclides. *Estuar. Coast. Shelf. Sci*., 16, pp. 69–93.

Hietanen, B., Sunalia, I.and Kristoffersson. R. 1988. Toxic effects of zinc on the common mussel *Mytilus edulis* L. (Bivalvia) in brakish water. II Accumulation studies.*Ann. Zool. Fennici*., 25, pp. 349-352.

Kamaruzzaman, B.Y. Mohd Zahir, M.S. Akbar John, B..Jalal, K.C.A Shahhbudin, S. Barwani S.M. and Goddard. J.S. 2011. Bioaccumulation of Some Metals by Green Mussel *Perna viridis* (Linnaeus 1758) from Pekan, Pahang, Malaysia. *Int. J. Biol. Chem*., 5(1) , pp. 54-60.

Krishnakumar, P.K., Bhat, G.S. Vaidya, N.G. and Pillai. V.K. 1998. Heavy metal distribution in the coastal waters of Karnataka, west coast of India. *Ind. J. Mar. Sci*., 27, pp. 201–205.

MFR, 1985. Malasiyan Law on food and Drugs. Malaysia Law Publisher, Kaula Lumpur.

Phillips, D.J.H. 1980. Quantitative aquatic biological indicators: Their use to monitor trace metal and organochlorine pollution. *Applied science Publishers, London*, Pp.488.

Pyatt, F.B., Metcalfe, M.R.and Payatt. A.J. 2003. Copper bioaccumulation by the fresh water snail *Lymnaea peregra:* A toxicological marker of environmental and human health. *Environ. Toxicol. Chem*., 22, pp. 561-564.

Rivonker, C.U. and Perulekar. A.H. 1998. Seasonal variation of major elements (Carbohydrate, Mg) and trace metals (Fe, Cu, Zn, Mn) in cultured mussel *Perna viridis*(L.) and sea water in the Dona Paula Bay. Goa. Indian. *J. Mar. Sci*., 27, pp. 411-415.

Sasikumar, G., Krishnakumar, P.K. and Bhat. G.S. 2006. Monitoring Trace Meta Contaminants in Green Mussel, *Perna viridis* from the Coastal Waters of Karnataka, Southwest Coast of India Arch. *Environ. Contam. Toxicol*., 51, pp. 206–214.

Topping, G. 1973. Heavy metals in fish from Scottish waters. *Aquaculture,* 1, pp. 373-377.

Vallee, B.L. and Auld. D.S. 1990. Zinc coordination, function and structure of zinc enzymes and other proteins. *Biochemistry*, 29, pp. 5647-5659.

Verlecar, X.N., Jena, K.B. and Chainy. G.B.N. 2008. Seasonal variation of oxidative stress biomarkers in gills and digestive gland of green lipped-mussel *Perna viridis* from Arabian Sea. *Estuarine Coastal Shelf Science,* 76, pp. 745–752.

Viarengo, A., Palmero, S., Zanicchi, G., Capelli, R., Vaissiere, R. and Orunesu. M. 1985. Role of metallothioneins in Cu and Cd accumulation and elimination in the gill and digestive gland cells of *Mytilus galloprovincialis* (Lam*.). Mar. Environ. Res*. 16, pp. 23–36.

WHO (World Health Organization), 1982. Toxicological Evolution of Certain Food Additatives. *World Health Organization,* Geneva, ISBN: 978-92-4-120940-3, pp. 106.

Yap, C.K. and Tan. S.G. 2007. Iron (Fe) concentrations in the byssus and soft tissues Green- lipped mussel *Perna viridis* (L.): Byssus as an excretion route of Fe and Fe bioavailability in the coastal waters. *Indian Journal of Marine Sciences*. Vol., 36(3, pp. 227-234.

DETERMINATION OF CHEMICAL PROPERTIES IN MICROBIAL (*PSEUDOMONAS SP.*) DEGRADED COIR PITH IN RELATION TO PARTICLE SIZE

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ABSTRACT

The elastic cellular cork like pithy material forming the non-fibrous tissue of the husk is generally referred to as the coir pith, which accounts for 50-60% of the total weight of the husk. The extraction of one kilogram of coir fiber generates two kilograms of coir pith. In the present investigation was carried out the chemical properties of microbial degraded coir pith. The standard methods were employed to analyze the chemical properties of microbial degraded coir pith in relation to particle size. The chemical parameters such as pH, Electrical conductivity, Total organic carbon, Lignin, Cellulose, Chloride, Nitrate, Nitrite, Sodium, Sulphate, Calcium and Magnesium. From the results, the medium size degraded particles i.e 500 to 850 µm showed good chemical properties which will be suitable for potting medium. The results clearly showed that, the medium size particles have been agreed for suitable potting medium even though it will be used for soilless medium. Hence the present study prove a substantial solution to fill the gap in the constructive utilization or recycling of coir pith as a potential soilless medium for any kind of culture operations in indoor culture, green house farming, terrace gardening or field culture and wild plant cultivation in their native location.

Keywords: Particle size, coir pith, chemical properties, wild plant cultivation, degradation

1. INTRODUCTION

Coir pith or coir dust is a major waste product of coir fiber extracting industries Pazhanivel *et al.,* 2011). The estimated annual production of coir pith in coir industries of India is about 7.5 million tons (Viswanathan, 1998). The extraction of one kilogram of coir fiber generates two kilograms of coir pith (Paramanandham *et al.,* 2012).

Moroever, it contains higher proportions of cellulose besides potash and lignin and it has excellent moisture retaining capacity but is slow in decomposition (Jothimani, 1994). It decomposes very slowly in the soil as its pentosan-lignin ratio is below 0.5 (Ghosh *et al.,* 2007) and because of the chemical and structural complexity of its lignin-cellulose complex (Ramalingam *et al.,* 2004). In such a situation, it is felt that employing microbes during the composting process will be helpful in the activation of decomposition. Biodegradation is an oxidative process that demands excessive quantities of oxygen. The microorganisms in the process consume the substrates and liberate large quantities of carbon dioxide as end products. The degradation process is exothermic and usually conducted in heaps. As a result of the heap structure, access of oxygen and release of carbon dioxide into the bulk of the heap are slow. These conditions result in the lowering of the rates of degradation (Ghosh *et al.,* 2007).

The composting process, mediated by microbial activity, is affected by physical and chemical environment inside the compost heap which include temperature, aeration, moisture content, C/N ratio and pH (Boulter *et al.,* 2000). However, inoculation with more efficient microorganisms may prove beneficial and make the process of biodegradation quick and economically viable. In the present investigation aimed to be analyze the chemical properties of microbial degraded coir pith in relation to particle size.

2. MATERIALS AND METHODS

2.1 Collection and grading of coirpith

The coir pith required for the present investigation was collected from the coir industries of Cuddalore district, located 1km away from Cuddalore Town and 50kms away from the Annamalai University, Chidambaram, Tamil Nadu. While collecting coir pith from the mounds, the surface layer of the mound to a depth of 15cms was scrapped and discarded and the inner fresh layer was collected. The collected coir pith was stored in gunny bags and transported to the laboratory immediately for further studies.

As soon as the coir pith samples were brought to the laboratory, a portion of coir pith was sun dried for 3 to 4 days so as to remove moisture for chemical analysis and the remaining was kept afresh to facilitate the determination of physical characteristics. Extraneous materials if any like stones, pebbles, dusts, fibres, etc., were removed from the coir pith manually. After that, dried coir pith was well-mixed and passed through 250 micron sieve. The coir pith mass, retained below the sieve, was separated, packed and labeled as 0 to 250 micron particles. The left over coir pith mass was then passed through 500 micron sieve. The retained mass below the sieve was separated and labeled as 251 to 500 micron particles. The left over coir pith was again passed through 850 micron sieve. The retained mass below the sieve was labeled as 501 to 850 microns and the mass retained above the sieve was labeled as >850 micron particles. The main purpose of studying the particle size distribution by sieve fractionation (Agnew and Leonard, 2003) was to know the particle-wise physical and chemical characteristics which would have a direct bearing on the functioning of growing medium (Richard, 2006).

2.2. Determination of chemical parameters

After coirpith sieved, the different sized coirpith was subjected chemical analyses. An aqueous extract was prepared from the coir pith as described by Ross (2002). Coir pith extract was prepared for all the graded particles that were sequentially washed as per the method followed by Ross (2002). The pH and Electrical conductivity were recorded by the digital pH meter (HANNA) and conductivity meter respectively. TOC was estimated using the method described by Walkley and Black (1934) and the lignin content was estimated by the method adopted by Bhat and Narayan (2003). The cellulose content was estimated by the method described by Updegroff (1969) and the chloride content was carried out by APHA, (1992). Nitrite and nitrate were analyzed colorimetically as described by Greenberg *et al.* (1992) and sulphate was determined by turbidimetric method using barium chloride and colorimetric method (APHA, 1992). Sodium content was determined in a digital flame photometer (Model Systronics 130) and the calcium and magnesium contents were estimated by EDTA titration method described in APHA (1992).

2.3 Microbial degradation

One particular beneficial species (*Pseudomonas sp.)* was repeatedly isolated from the slant culture with the help of Kings' B medium (King *et al.,* 1954). Further, it was allowed for mass cultivation with the help of the mineral salt medium (Sexena and Thakur, 2005) which acted as broth. The broth medium was inoculated in the sequentially washed coir pith (500ml/litre of coir pith) aseptically. The degradation process was maintained at a temperature of 26 to 28ºC, with the moisture at 50 to 60 percent.

Microbial degradation in coir pith was carried out in plastic tubs during which the moisture content was maintained at 50-60 % and kept for 60 days in shade place (Kuo *et al.,* 2004). To accelerate the decomposition process turning was manually done every week during composting. During inoculation, each tub contained 1 litre of coir pith followed by *Pseudomonas sp.* containing broth media (500 ml). The microbial degraded coir pith was analyzed for its chemical characteristics by using above described methods.

3. RESULTS

The microbial degraded coir pith samples were collected from the test troughs during the 15th, 30th, 45th and 60th days. All these samples were shade dried and packed in polythene bags. The chemical parameters in coir pith after the microbial degradation were studied. The initial pH level was in increasing order from smaller to larger particles of coir pith but the final pH at 60 days of degradation remained almost at constant level in all the grades. In the sequentially washed coir pith grades, the smaller particles exhibited a lower pH and the larger particles had a substantially higher pH (Table 1). The EC decreased dramatically when the size of the coir pith particles advanced. It was decreasing in microbial degraded coir pith and in successive washings. The results when compared with the washings recorded a sudden decrease. Among the grades of coir pith the large particles exhibited comparatively lower EC (Table 2).

The total organic carbon in 250 micron particles decreased from 0.120% to 0.072% when treated with microbes. The percentage of decrease was higher in smaller particles and lesser in bigger particles. The organic carbon gradually and steadily decreased in all the coir pith grades (Table 3).

Table 1: pH of the microbial degraded coir pith (Mean ± SD) grades

Groups	0-250µm	250-500µm	500-850µm	>850µm
I Wash	5.97 ± 0.18*	5.98 ± 0.51*	6.74 ± 0.01*	6.52 ± 0.04*
VII Wash	8.02 ± 0.02*	8.05 ± 0.03*	8.24 ± 0.04	8.38 ± 0.06*
15 days	8.03 ± 0.02*	8.04 ± 2.65	8.16 ± 0.07*	8.25 ± 0.07
30 days	8.02 ± 0.02	8.02 ± 0.03*	8.12 ± 0.15	8.16 ± 0.04*
45 days	8.01 ± 0.03	8.02 ± 0.14	8.05 ± 0.07	8.05 ± 0.04
60 days	8.00 ± 0.04*	7.95 ± 0.04*	8.00 ± 0.08	8.00 ± 0.04

* The mean difference is significant at the 0.05 level

Table 2: Electrical conductivity of the microbial degraded coir pith grades (mS/cm) (Mean ± SD) (Six replicates)

Groups	0-250µm	250-500µm	500-850µm	>850µm
I Wash	5.2 ± 0.141*	4.5 ± 0.200*	3.9 ± 0.312*	3.4 ± 0.200*
VII Wash	0.21 ± 0.008*	0.16 ± 0.046*	0.14 ± 0.006*	0.10 ± 0.045*
15 days	0.20 ± 0.026*	0.14 ± 0.014*	0.13 ± 0.141	0.10 ± 0.063*
30 days	0.19 ± 0.023*	0.13 ± 0.031*	0.12 ± 0.089	0.09 ± 0.500*
45 days	0.17 ± 0.028*	0.12 ± 0.014	0.11 ± 0.085	0.09 ± 0.028*
60 days	0.12 ± 0.014*	0.10 ± 0.022	0.10 ± 0.028	0.09 ± 0.014*

* The mean difference is significant at the 0.05 level

Table 3: TOC level in microbial degraded coir pith grades (%) (Mean ± SD) (Six replicates)

Groups	0-250µm	250-500µm	500-850µm	>850µm
I Wash	0.120 ± 0.01*	0.126 ± 0.01*	0.136 ± 0.01	0.141 ± 0.02*
VII Wash	0.105 ± 0.02	0.106 ± 0.01	0.106 ± 0.01*	0.105 ± 0.01*
15 days	0.091 ± 0.02*	0.092 ± 0.03	0.093 ± 0.01	0.097 ± 0.01*
30 days	0.085 ± 0.01*	0.091 ± 0.03*	0.089 ± 0.01	0.089 ± 0.01
45 days	0.074 ± 0.04*	0.086 ± 0.01*	0.085 ± 0.01	0.084 ± 0.01
60 days	0.072 ± 0.01*	0.081 ± 0.02	0.082 ± 0.01*	0.082 ± 0.01

* The mean difference is significant at the 0.05 level

Lignin and cellulose levels rapidly decreased in all the grades of microbial degraded coir pith. Lignin shows that, the pronounced, 31.6 to 14.3 percent decrease in 250 micron size; 30.7 to 14.1 percent decrease in 500 micron size; 30.3 to 13.8 percent decrease in 850 micron size and 30.2 to 12.8 percent decrease in >850 micron sized particles respectively. Likewise, cellulose shows a decrease in 250 micron sized particles from 35.6 ± 0.3 to 22.3 ± 0.7, in 500 micron sized particles from 35.6 ± 0.4 to 21.5 ± 0.2 %, in 850 micron sized particles from 35.3 ± 1.1 to 21.8 ± 1.2 and in above 850 micron sized particles from 35.2 ± 0.8 to 22.8 ± 1.2% (Fig 1 & Table 4).

Fig 1. Lignin content in microbial degraded coir pith grades (%) (Mean ± SD) (Six replicates)

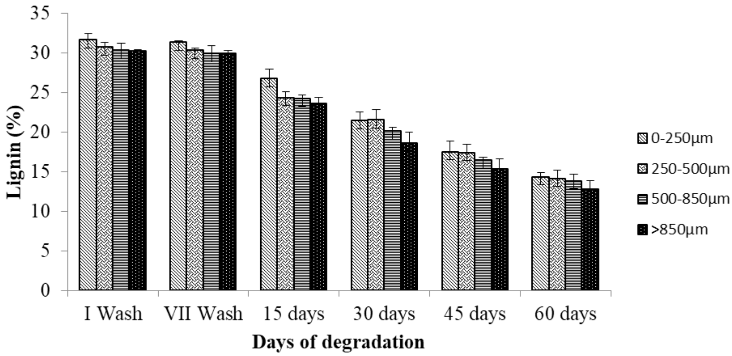

Table 4. Cellulose content in microbial degraded coir pith grades (%) (Mean±SD) (Six replicates)

Groups	0-250µm	250-500µm	500-850µm	>850µm
I Wash	35.6±0.3*	35.6±0.4	35.3±1.1	35.2±0.8*
VII Wash	35.3±1.2	34.3±1.3*	34.8±1.0*	34.8±1.4
15 days	32.4±0.8	31.5±1.1*	32.1±0.8*	31.2±0.6
30 days	29.4±1.2*	28.9±1.4*	28.3±0.3*	28.0±0.7
45 days	25.3±0.4	25.8±1.1*	25.9±0.4*	25.7±1.3
60 days	22.3±0.7	21.5±0.2*	21.8±1.2*	22.8±1.2

* The mean difference is significant at the 0.05 level

The level of chloride showed a direct relationship with the number of days of degradation. Among the grades of coir pith the larger sized particles retained lesser level of chloride than the other grades (Table 5). A gradual increase in the level of nitrite was observed when coir pith grades were subjected to microbial degradation. The highest nitrite content was observed in smaller (250 micron) particles (0.78 ± 0.01 mg/l) followed by the bigger particles. Among the period, 60 days of degradation yielded maximum amount of nitrite. The level of nitrate in the microbial degraded coir pith grades also exhibited the same trend as that of the nitrite. The nitrate level of increased nearly threefold after 60 days of degradation (Table 6). The sodium level in the microbial degraded coir pith increased with the advancing days. Substantial amount of sodium was present in 500 micron (34.8 mg/l) particles and comparatively lesser amount of sodium was present in >850 micron sized (31.6mg/l) particles in degraded coir pith (Table 29) after 60 days of degradation (Table 7).

Table 5. Chloride level in microbial degraded coir pith grades (mg/l) (Mean±SD) (Six replicates)

Groups	0-250µm	250-500µm	500-850µm	>850µm
I Wash	44.6 ± 0.4*	43.3 ± 0.7*	42.8 ± 0.5	41.7 ± 2.0
VII Wash	14.5 ± 0.4*	13.4 ± 0.2	12.6 ± 0.7*	12.4 ± 1.2
15 days	15.9 ± 0.5*	14.6 ± 0.8*	13.8 ± 0.5	13.6 ± 1.4
30 days	17.8 ± 0.4*	16.8 ± 1.1	16.3 ± 0.5	14.9 ± 0.7*
45 days	19.1 ± 1.2*	17.6 ± 0.5*	17.1 ± 0.6	16.3 ± 0.0*
60 days	21.7 ± 1.1*	18.3 ± 0.5*	18.2 ± 0.5	17.2 ± 0.5*

* The mean difference is significant at the 0.05 level

Table 6. Nitrite and Nitrate level in microbial degraded coir pith grades (mg/l) (Mean ± SD) (Six replicates)

Groups	Parameters	0-250µm	250-500µm	500-850µm	>850µm
I Wash	Nitrite	0.78 ± 0.01*	0.75 ± 0.02*	0.71 ± 0.01*	0.64 ± 0.02*
	Nitrate	0.14 ± 0.01*	0.13 ± 0.01*	0.09 ± 0.01	0.09 ± 0.02*
VII Wash	Nitrite	0.73 ± 0.02*	0.52 ± 0.02*	0.35 ± 0.01	0.33 ± 0.01*
	Nitrate	0.09 ± 0.02*	0.07 ± 0.01	0.06 ± 0.01	0.05 ± 0.01*
15 days	Nitrite	0.74 ± 0.31*	0.54 ± 0.11*	0.41 ± 0.14*	0.38 ± 0.13*
	Nitrate	0.12 ± 0.13*	0.10 ± 0.01	0.08 ± 0.23	0.08 ± 0.14
30 days	Nitrite	0.75 ± 0.06*	0.55 ± 0.05*	0.43 ± 0.21	0.40 ± 0.11*
	Nitrate	0.15 ± 0.11*	0.11 ± 0.14	0.10 ± 0.05	0.10 ± 0.12
45 days	Nitrite	0.75 ± 0.05*	0.55 ± 0.08*	0.42 ± 0.11*	0.38 ± 0.21*
	Nitrate	0.19 ± 0.22*	0.13 ± 0.07	0.13 ± 0.14	0.12 ± 0.13*
60 days	Nitrite	0.75 ± 0.11*	0.55 ± 0.12*	0.39 ± 0.31	0.38 ± 0.43
	Nitrate	0.23 ± 0.21*	0.17 ± 0.05	0.15 ± 0.14*	0.13 ± 0.21*

* The mean difference is significant at the 0.05 level

Table 7. Sodium level in microbial degraded coir pith grades (mg/l) (Mean ± SD) (Six replicates)

Groups	0-250µm	250-500µm	500-850µm	>850µm
I Wash	32.6 ± 0.6*	31.8 ± 0.8	28.5 ± 2.1*	27.2 ± 0.2*
VII Wash	12.2 ± 0.4	11.5 ± 0.8*	10.5 ± 0.9*	10.2 ± 0.7*
15 days	22.6 ± 0.8	23.3 ± 1.6*	22.1 ± 1.3*	22.3 ± 0.2*
30 days	28.8 ± 0.6	28.3 ± 0.6*	26.0 ± 0.5*	25.1 ± 2.1*
45 days	30.1 ± 0.4	30.4 ± 3.1*	29.8 ± 0.1*	28.9 ± 1.1*
60 days	34.2 ± 0.5*	34.8 ± 2.4*	32.5 ± 2.2*	31.6 ± 1.1*

* The mean difference is significant at the 0.05 level

Sulphate, an increasing trend was observed in the degraded coir pith and decreasing trend was observed in all the successive washings. There was a marked decrease in the level of sulphate in the smaller to bigger particles after 60 days of microbial degradation (Table 8). The calcium level increased in a steady state during the various stages of microbial degradation after sequential washing. The results showed an increase from 4.12 to 4.88 mg/l; 3.52 to 4.82 mg/l; 2.40 to 4.69 mg/l and 2.37 to 4.39 mg/l respectively in 250, 500, 850 and >850 particle sizes. It showed a gradual increase with the increase in the particle size. The magnesium level also increased in a slow and steady pattern during microbial degradation. The results showed an increase from 9.50 to18.94 mg/l; 8.50 to 18.56; 8.20 to 16.08 and 7.80 to 15.87 mg/l respectively in 250, 500, 850 and >850 particle sizes. It showed a gradual increase with the increase in particle size (Table 9).

Table 8. Sulphate level in microbial degraded coir pith grades (mg/l) (Mean ± SD) (Six replicates)

Groups	0-250µm	250-500µm	500-850µm	>850µm
I Wash	87.0 ± 0.08*	70.0 ± 0.89*	35.5 ± 0.13*	19.0 ± 0.11*
VII Wash	9.0 ± 0.13*	8.1 ± 0.06*	7.9 ± 0.08	7.4 ± 0.07
15 days	14.0 ± 0.32*	11.5 ± 0.51*	10.7 ± 0.61	7.5 ± 0.25*
30 days	18.3 ± 0.21*	15.7 ± 0.52	16.8 ± 0.91*	10.2 ± 0.61*
45 days	28.7 ± 0.85*	21.6 ± 0.61*	20.6 ± 0.34*	15.3 ± 0.81*
60 days	37.2 ± 0.91*	24.5 ± 0.48*	21.5 ± 0.28*	18.6 ± 0.57

* The mean difference is significant at the 0.05 level

Table 9. Calcium and magnesium levels in microbial degraded coir pith (mg/l) (Mean ± SD) (Six replicates)

Groups	Parameters	0-250µm	250-500µm	500-850µm	>850µm
I Wash	Calcium	4.75 ± 0.08*	4.20 ± 0.04*	4.00 ± 0.06*	3.60 ± 0.05*
	Magnesium	18.25 ± 1.40*	18.20 ± 0.66	18.01 ± 0.62	18.00 ± 1.41*
VII Wash	Calcium	4.12 ± 0.01*	3.52 ± 0.02	2.40 ± 0.02*	2.37 ± 0.04*
	Magnesium	9.50 ± 0.37*	8.50 ± 0.37*	8.20 ± 0.64	7.80 ± 0.61*
15 days	Calcium	4.18 ± 2.11*	4.01 ± 0.51*	3.47 ± 2.27*	3.02 ± 0.06*
	Magnesium	16.41 ± 1.52*	16.08 ± 1.21*	13.48 ± 0.98*	12.54 ± 1.78*
30 days	Calcium	4.45 ± 1.03*	4.41 ± 3.08	4.16 ± 1.06	3.78 ± 0.07*
	Magnesium	17.48 ± 1.32*	17.12 ± 0.56	14.65 ± 0.13*	13.54 ± 1.9
45 days	Calcium	4.65 ± 0.56*	4.59 ± 2.04	4.51 ± 1.04	3.92 ± 0.11*
	Magnesium	18.56 ± 2.10*	18.21 ± 1.41	15.09 ± 0.14*	14.56 ± 1.61*
60 days	Calcium	4.88 ± 0.03*	4.82 ± 2.01	4.69 ± 0.71	4.39 ± 0.04*
	Magnesium	18.94 ± 0.18*	18.56 ± 0.13*	16.08 ± 1.54*	15.87 ± 1.51*

* The mean difference is significant at the 0.05 level

4. DISCUSSION

Microbial degradation of any solid waste is generally considered as safe, effective and environmentally friendly process, and certain mushrooms and bacteria have showed good potential for degrading coir pith, eg. *Pleurotus sajor caju* and *Pleurotus spp*. *Cellulomonas fumii* was found effective in lignin and cellulose degradation. Many microbes could metabolise lignins (Kirk, 1971; Crawford and Crawford, 1976; Crawford and Sutherland, 1980; Ulmer *et al.,* 1983). Basidiomycetes fungi are well known for lignin degradation and most of the studies on the biochemistry of lignin degradation were focused on *Phanerochaete chrysoporium* (Janshekar and Fiechter, 1983).

Bacteria are also capable of solubilizing, transforming and mineralising a variety of lignin preparations and lignin-like polymers and monomers (Zimmermann, 1990). Actinomycetes such as *Streptomyces sp*. also had the capacity to attack and degrade lignins (Crawford, 1978; Phelan *et al.,* 1979). Laccase, manganese peroxidase and lignin peroxidase were the main enzymes involved in lignin degradation during secondary (Idiophasic) metabolism, whose onset was triggered by depletion of nitrogen, carbon or sulphur (Gold and Alic, 1993). Lignin degradation also depends on the presence of a readily metabolisable co-substrate such as glucose. In addition, increasing the oxygen levels in culture has strong activating effect on the rate of lignin degradation (Gold and Alic, 1993). Degradation of coir pith resulted in increased content of N, P, K and micronutrients and reduction in lignin and C:N ratio (Nagarajan *et al.,* 1985).

In the present study, *Pseudomonas sp.* was admitted to degradation process for a span of 60 days. *Pseudomonas* species are normally associated with soil and fecal matter and therefore are found on the hide of beef and pork (Sutton, 2004). The genus *Pseudomonas* is one of the most diverse Gram-negative bacterial genera, isolated from sources ranging from plants to soils and water to clinical samples. Members of this genus are straight or slightly curved rods, motile by means of polar flagella (Tian, 2004).

The pH in degraded coir pith was an excellent marker of the final successful completion of degradation process. Very similar result was obtained by Naik (2007) where the pH level stood between 6 and 8 during composting and between 4 and 7 for end products. Suresh Kumar and Ganesh (2012) stated that the pH increased gradually and reached neutral level in coir pith. In this context, the present study achieved a decreased pH because the sequential washing already turned up the pH to almost alkaline level. Ndegwa *et al.* (2000) quoted that, the shifting of pH to lower level could be attributed to mineralization of nitrogen and orthophosphates and bioconversion of organic materials into intermediate species of organic acids.

Ross (2002) stated that the pH of the potting medium was significantly altered by the addition of coir pith and the electrical conductivity of the medium increased due to the high salt content of raw coir pith. Also Chin (2001) recommended the EC in coir pith to be 0.2 mS/cm for effectively utilizing as plant growth medium. Similar observation was made by Suresh Kumar and Ganesh (2012) in coir pith during different bio-composting techniques. Murali *et al.* (2011) and Sumathi and Kalaiarasi (2013) reported similar EC level in coir pith when vermicomposting process was undertaken. Lignin is a biopolymer with complex phenylpropanoid structure and contributes to environmental pollution. Degraded coir pith showed a decline in its accumulated lignin content. It indicates that, the lignolytic process could convert lignin to ligninase enzyme production. Lignin degradation could be enhanced at high oxygen supply rates (Kirk *et al.,* 1978) and the development of simple techniques for enhancing aeration in compost pile could be helpful in getting better quality compost. Nagarajan *et al.* (1985) also found that the inoculation of coir pith with *Pleurotus* spp had resulted in drastic reduction in lignin and cellulose contents indicating the degradation of lignocelluloses by *Pleurotus sp,* and hence a similar microbe was included in the present study for the biodegradation of coir pith. The microbial degraded coir pith showed a steady decline in cellulose during the degradation process. It indicates that the cellulolysis process was initiated in degradation. It might produce glucose and glucose feed for the harboring microorganisms. Similar result was obtained by several researchers in line during microbial degradation (Vinodhini *et al.,* 2006) and vermicomposting process (Abbiramy, 2012; Murali *et al.,* 2011; Sumathi and Kalaiarasi, 2013).

The chloride level marginally increased when subjected to microbial degradation. Similar trend was observed by Shyamala and Belagali, (2012) in different maturity stages of municipal solid waste composting. The concentrations of chloride for the samples are attributed to the dissolution of chlorinated soluble salts present in the solid wastes. The same trend was observed by Bastos *et al.* (2002) in the enrichment of microbial culture. Among the nutrients, the chloride level was high but lower than the sulphate level. Similar observation was made by Kasthuri *et al.* (2011) in coir pith effluent. In microbial degraded coir pith, nitrite and nitrate contents increased with the increase in the duration of degradation. It may be due to the conversion of ammonia into nitrates. A similar observation was made in microbial degraded coir pith by Illmer *et al.* (1995). Anandhraj *et al.* (2012) documented that the nitrate was higher when treated with the cyanobacterium *O. annae* during coir pith degradation. Christopher *et al.* (2007) revealed that, even plant nitrate level increased when treated with cyanobacterial basal and foliar biofertilizer on coir pith medium.

Calcium content increased in microbial degraded coir pith and showed a steady increase during degradation. Calcium is a micronutrient and it is important for plant growth. Shyamala and Belagali (2012) stated that calcium increased in different maturity stages of municipal solid waste in composting process. Magnesium increased steadily during the degradation of coir pith. Similar result was made Edwards and Loffy (1980) and Uma Maheswari (2005) when composting with earthworms. Shyamala and Belagali (2012) stated that magnesium increased in matured municipal solid waste in composting process. The principal sources of magnesium in the solid wastes include domestic, food and vegetable wastes, fine earth, small scale industrial wastes etc. (Shivakumar *et al.,* 2004).

5. CONCLUSION

The results of the present investigation showed that coir pith particle size has significant role to play in the recycling ability of coir pith. Furthermore, if coir pith is being washed, treated and degraded properly, it could be well substituted as a soilless medium in terrace gardening and green house farming operations with ornamental plants or vegetable crops effectively. The medium size particles have been agreed for suitable potting medium even though it will be used for soilless medium. Hence the present study prove a substantial solution to fill the gap in the constructive utilization or recycling of coir pith as a potential soilless medium for any kind of culture operations above said in their native location.

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REFERENCES

Abbiramy, K.S. and Ross, P.R., 2012. Efficacy of vermicomposted coir pith on the growth physiology of *Abelmoschus esculentus. International J. Environl. Biol.* 2(3): 153- 155.

Anandhraj, B., Krishna Moorthy, S. and Malliga, P., 2012. Studies on the degradation of coir pith using fresh water cyanobacterium *Oscillatoria annae* BDU 6 and its lignolytic enzyme activity in response to coir pith degradation. *Int. J Curr. Sci.* 2012, 78-86.

APHA, 1992. Standard Methods for the examination of water and waste water, 18th Edn., American Public Health Association, Washington D.C.

Bastos, F., Bessa, J., Pacheco, C.C., Paolo De Marco, D.P., Paula, M.L., Castro Manuel Silva, C.M. and Jorge, R.F., 2002. Enrichment of microbial cultures able to degrade 1,3-dichloro-2-propanol: A comparison between batch and continuous methods, *Escola Superior de Biotecnologia, R. Dr. Ant´onio Bernardino de Almeida, 4200-072 Porto, Portugal.*

Bhat, A.D. and Narayan, P. 2003. Chromatographic Analysis of phenolics and study of Klason lignin biodegraded coir pith using "*Pleurotus sajorcaju*" (dissertation), University of Kerala, Alappuzha.

Chin, A. 2001. Cocopeat media for agricultural application experiences in Israel and India. *In*: *Proc. of India internal. Coir Fair,* 12th Oct., 2001, Coir Board, Cochin, India.

Christopher, P.A., Viswajith, V., Prabha, S., Sundhar, K. and Malliga, P., 2007. Effect of coir pith based cyanobacterial basal and foliar biofertilizer on *Basella rubra* L., *Acta agriculturae Slovenica*. 89: 59-63.

Crawford, L.D. and Crawford. R.L., 1976. Microbial degradation of lignocelluloses: the lignin component. *Appl. Environ. Microbiol.* 31:714-717.

Crawford, D.L. and Sutherland, J.B., 1980. Isolation and characterization of lignocellulose-decomposing actinomycetes. In Kirk T.K., Higuchi T., Chang H.-m. (eds.) Lignin Biodegradation: Microbiology, Chemistry and Applications, Vol. II. CRC Press, USA, pp: 95-101.

Crawford, D.L. 1978. Lignocellulose decomposition by selected Streptomyces strains. *Appl. Environ. Microbiol.* 35: 1041-1045.

Edwards, C.A. and Lofty J.R., 1980. The effects of earthworms inoculation upon the root growth of direct drilled cereals. *J. Applieed Ecology*. 17: 553-543.

Ghosh, P.K., Sarma, U.S., Ravindranath, A.D., Radhakrishnan, S. and Ghosh, P. 2007. A novel method for accelerating composting of coir pith. *Energy Fuels.* 21: 822-827.

Gold, M. H. and Alic, M., 1993. Molecular biology of the lignin degrading basidiomycete *PhanerocFwele chrysosporiwn. Microbial. Rev. 51* : 605-622.

Greenberg, A.E., Clesceri, L.S. and Eator, A.D., 1992. Standard methods for the examination of water and wastewater. 18th (Ed.) Pub: American Public Health Association (APHA).

Illmer, P. and F. Schinner, 1995. Solubilization of inorganic calcium phosphate solubilization mechanisms. *Soil Biol. Biochem.* 27: 257–63.

Janshekar, H. and Fiechter, A. 1983. Lignin :biosynthesis, application and biodegradation. *Adv. Biochem. Engg./Bioreclmol.* 27 :120-178.

Jothimani, S. 1994. Organic farming in coconut. *Ind. Coco. J.* 48-49.

Kasthuri, J., Cholarajan, A., Vijayaumar, R. and Muthuumaran. P., 2011. Physico-chemical and Microbial analysis of coir industry effluent. *Asian J. Res. Pharm. Sci.* 1(2): 44-46.

King, E.O., Ward, M. K. and Raney, D.E., 1954. Two simple media for the demonstration of pyocenin and fluorescin. *J. Lab. Clin. Med*. 44: 301-307.

Kirk, T.K., Schultz, E., Connors, W. J., Lorenz, L.F. and Zeikus, J.G., 1978. Influence of culture parameters on lignin metabolism by *Phanerochaete chrysosporium*. *Archives of Microbiol.* 117: 277-285.

Kirk, R. K. 1971. Effects of micro-organisms ori lignin. *Arm. Rev. Phytopathol.* 9: 185-210.

Kuo, S., Ortiz-Escobar, M. E., Hue, N. V. and Hummel, R. L., 2004.For the review book of Recent Developments in Environmental Biology, Running Title: Composting and Compost Utilization, Department of Crop and Soil Sciences, Washington State University Research and Extension Center, Puyallup, WA. pp: 1-60.

Murali, M., Bharathiraja, A. and Neelanarayanan, P., 2011. Conversion of coir waster (*Cocos nucifera*) into vermicompost by utilizing *Eudrilus eugeniea* and its nutritive values. *Indian J. Fund. and Appl. Life Sci.* 1 (3): 80-83.

Nagarajan, R., Manickam, T.S., Kothandaraman, G.V., Ramasamy, K. and Palanisamy, G.V., 1985. Manurial value of coir pith. *Madras Agric. J.,* 72: 533-535.

Naik, S.P., 2007. Studies on microbial consortia for production and Enrichment of bio-compost from grapevine residues. M.Sc., Thesis. Dharwad University Of Agricultural Sciences, Dharwad – 580 005.

Ndegwa, P.M. and Thompson, S.A. 2000. Effects of C to N ratio on Vermicomposting of biosolids. *Biores. Tech., 75*:7-12.

Paramanandham, J., Ronald Ross, P. 2012. The Quantification Beyed questionnaire survey on coir industries in Cuddalore District, TamilNadu. In. J.Enviran Biol. 2(3): 113-114.

Comparative investigation on the nutrient status on two vermicomposted organic wastes by *Esenia fetida*. Citation: Ronald Ross, P., Muthulingam, M., Vivekananthan, T and Elangovan, A. *Proc of the International Confer on "Science and Technology for Clean and Green Environment"* (STCGE- 2012), at Zoology Wing, Annamalai University on 27th of July. pp:396-397.

Pazhanivel, G., Chandrasekaran, P., Prabha, D.S., Bhuvaneswari, B., Malliga, P. and Chellapandi, P. 2011. Effect of coir pith based cyanobacterail biofertilier for improving fatty acid contents in *Arachis hypogaea.* L (Groundnut) oil seeds. *J. Advan. In. Develop. Resea.* 2(1): 38-41.

Phelan, M.B., Crawford, D. and Land Pometto, A. L., 1979. Isolation of lignoocellulose decomposing actinomye¢t,es and degradation of specifically 1'C·labelled lignocelluloses by six selected *Streptomyces* strains. *Canadian J. Microbiol. 25:* 1270-1276.

Ramalingam, A., Gangatharan, M. and KasturiBai, R., 2004. 'Solid state bio-treatment of coirpith and paddy straw'. *Asia. J. of. Microbiol. Biotech and Environ.Sci.* 6:141-142.

Ross, P.R. 2002. Studies on coir pith as an artificial soil medium. Ph.D., Thesis, Madurai Kamraj University, Madurai, India.

Saxena, P. and Thakur, S., 2005. Purification and characterization of catechol 1,2-dioxygenase of *Pseudomonas fluorescens* for degradation of chlorobenzoic acid. *Indian J. Biotechnol.* 4:134–138.

Shivakumar, B.S., Thandaveswara. and Chandarasekaran, K.D., 2004. Solid waste leachate quality & its effects on soil properties, *Pollution Research.* 23(1), 179-182.

Shyamala D.C. and Belagali S.L., 2012. Studies on Variations in Physico-Chemical and Biological Characteristics at Different Maturity Stages of Municipal Solid Waste Compost. *Int. J Environ. Sci.* 2 (4): 1984-1997.

Sumathi.P and Kalaiarasi. G., 2012. Evaluation Of Cocoon Production And Vermicompost Produced By *Eudrilus Eugeniae* And *Eisenia Fetida* In Coirpith Waste, Garden Soil Mixed With Cowdung. *Int J of Interdisci Res and Revs.*1(2):43.

Suresh Kumar, R and Ganesh, P., 2012. Effect of different bio-composting techniques on physico - chemical and Biological changes in coir pith. *Int. J Recent Scientific Research. 3(11):914 - 918.*

Sutton, G.H.C. 2004. Enumeration of total airborne bacteria, yeast and mold contaminants and identification of *Escherichia coli* O157:H7, *Listeria* Spp., *Salmonella* Spp., and *Staphylococcus* Spp. in a beef and pork slaughter facility. Ph.D., Thesis. University of Florida.

Ulmer, D., Leisola, M., Puhakka, J. and Fiechter. A., 1983. *Phanerochaete chrysosporium*: growth pattern and lignin degradation. *Eur. J. Appl. Microbiol. Biotechnol.* 18:153–157.

Umamaheswari, S. 2005. Vermicomposting of Mango litter using earthworm *Perionyx excavates. J. Ecotoxicicol. Environ. Monit*. 15(1) : 69-72.

Updegraff, D.M. 1969. Semi micro determination of cellulose biological materials, *Anal. Biochem.* 32: 420-424.

Vinodhini, S., Gnanambal, V.S., Sasikumar, J.M. and Padmadevi, S.N. 2005. 'Growth of two medicinal plants using biodegraded coirpith'. *Plant Archives*. 5:277-279.

Viswanathan, R. 1998. A process for the production of particle board from coconut pith. *Indian Cocon. J.* 29(7): 5-7.

Walkley, A. and Black, C.A. 1984. 'An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method', *Soil Science.* 37:29-38.

Zimmermann, W. 1990. Degradation of lignin by bacteria. *J. Biotechnol.* 13: 119–130.

DIVERSITY OF COMMERCIAL CLAMS IN UTTARA KANNADA ESTUARIES, KARNATAKA, INDIA

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ABSTRACT

Estuaries are ranked among the most productive ecosystems of the earth due to a variety of factors, the most prominent being mixing up of freshwater from the rivers with the marine tides creating varying degrees of salinity in different parts of the estuary. When these natural tidal rhythms are affected due to natural causes or anthropogenic activities, estuarine organisms, especially sedentary ones, get affected. The sedentary organisms such as bivalves make ideal cases for assessment of especially anthropogenic environmental impacts on estuaries. The rivers of Uttara Kannada district, Karnataka particularly Sharavathi and Kali have been dammed for power production, which collapsed the clam fishery. Hence, a survey was conducted in dammed river estuaries Sharavathi and Kali to know the impact of hydroelectric dams on the clams and compared with the studies from undammed river estuaries Aghanashini and Gangavali. The study reveals that the execution of hydroelectric projects in the Sharavathi and Kali rivers of Uttara Kannada district in Karnataka is seen as the major causes for the elimination of most clam bivalves from the Sharavathi estuary and habitat shifts and shrinkage for the bivalves in the Kali estuary, due to decreased salinity on account of continuous discharge of freshwater after power generation, a situation not favouring the bivalves. River valley projects are drastic interventions by humans with far reaching implications affecting even the estuarine regions, primarily due to fall in salinity creating adverse conditions. The bivalve situation in two more estuaries, of the rivers Aghanashini and Gangavali in Uttara Kannada, undammed and more natural, is compared with that of the dam affected ones to understand the situation better.

Keywords: Bivalve, dam, hydroelectric project, Kali, Sharavathi, salinity.

1. INTRODUCTION

The Molluscs are soft bodied invertebrates which inhabit marine, estuarine, freshwater, and terrestrial areas. Estuaries are among the unique and fragile ecosystems of the earth, the organisms here living in an ever changing environment, especially in relation to salinity factor. Salinity here keeps fluctuating constantly depending on the input of freshwater from upstream rivers and from rising and receding oceanic tides. The ocean salinity, in general, shows greater stability as compared to freshwater inputs into the estuary from land sources. Mainly due to their widely acknowledged high rates of productivity estuarine areas are often densely populated. Shallower parts of estuaries, in recent centuries, have been undergoing tremendous transformations due to their reclamations for human habitations, agriculture, and fish and shrimp farming. Seldom was ever the impact of such transformations studied, especially on the molluscs which are known to be some of the very sensitive organisms. The impact of salinity increase in estuaries, as a consequence of upstream dam constructions to meet freshwater demands, has been indeed a subject that has captured some attention (Seddon, 2000; Chen, 2005; Dandekar, 2012).

As far as Uttara Kannada district of the Indian west coast is concerned, there was hardly ever any concerted efforts at documentation of estuarine molluscs, especially the ones used traditionally as food resources by scores of coastal people, and in the collection and trade of which thousands, more so women, have been engaged. Details of the molluscan species from Karnataka estuaries, particularly bivalves, exploited for food and lime shells are found in some of the earlier studies (Rao *et al*., 1989). Boominathan *et al*. (2008), dealt in detail about the dynamics of bivalve production and trade and village-wise and gender-wise employment generated in the

Aghanashini estuary of Uttara Kannada. The annual production of edible bivalves from Aghanashini, based on at least eight species, *Paphia malabarica*, *Meretrix meretrix* and *Meretrix casta* leading among them, accounted for a phenomenal annual production of about 22,006 tonnes, generating 357,995 man-days of employment for altogether for about 2,347 bivalve collectors. However, Rao *et al*. (1989) alluded to a serious decline of clam resources of Sharavathi estuary, and raised apprehensions about a fall in such resources from Kali, incidentally both these estuaries have hydroelectric projects executed in the upstream areas of the respective rivers. As especially many of the west flowing rivers from the Western Ghats are subjected to dam constructions, to meet the rising needs for freshwater and for hydroelectricity, hardly any study is found on the impact of such drastic developmental interventions on estuarine ecology, especially on clam bivalves. Hence, in this paper, I have dealt with the commercial clams of four major estuaries of Uttara Kannada district, namely Kali, Sharavathi, Gangavali, and Aghanashini, the first two of them, as earlier stated, having hydroelectric projects. The current work, while briefly reviewing the studies hitherto carried out on commercial clams of Uttara Kannada estuaries, is an attempt to understand the status of clam diversity and distribution in the district.

2. MATERIALS AND METHODS

The study was carried out during 2011-12 in the estuaries Kali, Sharavathi, Gangavali and Aghanashini of Uttara Kannada district, Karnataka State of India (Fig. 1 and Table 1 for locations and details). Sharavathi River has two major hydel projects (Sharavathi and Gerusoppa) with total installed capacity of 1469.20 MW. Kali river has four hydel projects (Supa, Nagjhari, Kodashalli, and Kadra) with total installed capacity of 1255 MW. Kali, Sharavathi, and Aghanashini estuaries were larger in size in the range of 2813, 2842, and 1336 ha area respectively, whereas Gangavali was smaller estuary with 558 ha (Ramachandra *et al*., 2013).

Fig. 1. Sampling stations in the Uttara Kannada estuaries.

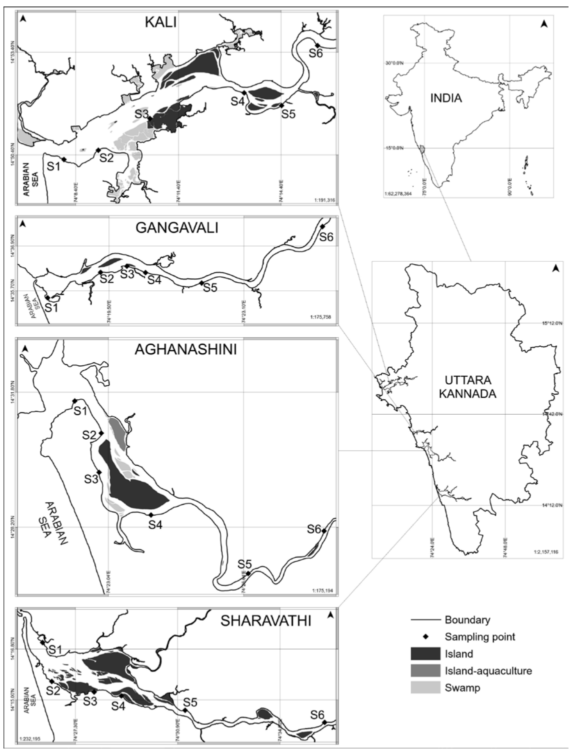

Table 1: Sampling station name with approximate distance (km) from river mouth in parentheses.

Station	Aghanashini	Gangavali	Kali	Sharavathi
S1	Aghanashini (1.5)	Gangavali (1)	Kodibag (1)	Honavar (2.5)
S2	Gudkagal (4)	Agragone (3)	Sunkeri (3)	Kasarkod (4.5)
S3	Hini (6)	Joog (4.5)	Ambejug (6)	Hosapatna (6)
S4	Masur (9)	Sagadgeri (6)	Kinnar (12)	Kelagin-Idgunji (8)
S5	Divgi (16)	Ulware (8)	Wailwada (13)	Jalawalli (12)
S6	Hondad Hakkal (21)	Mangankan (15)	Kerwadi (18)	Upponi (23)

The study area map was created in QGIS version 2.2.0 (Quantum GIS Development Team, 2014). Surface water salinity levels of these four estuaries were measured using EXTECH EC400 meter during high tide, during December-February, the winter period that marks the onset of full-fledged collection season for bivalves in the region, following the complete cessation of monsoon rains by mid-November. Clam bivalves were collected at different distances from the river mouth towards their upstream limits of distribution in the respective estuaries. A questionnaire based survey was also conducted among traditional bivalve harvesters to know the bivalve diversity and distribution range of individual species within respective estuaries currently as well as in the past. The clam bivalves were identified using available keys (Morton, 1984; Rao, 1989; Rao *et al*., 1989; Apte, 1998; Dey, 2006). Line graph for salinity was prepared in PAST version 3.01 (Hammer *et al*., 2001) and Kruskal-Wallis test was performed in R version 3.1.1 (R Core Team, 2014) and Rlplot version 1.5 to see the difference between estuaries using salinity values.

3. RESULTS AND DISCUSSION

3.1 Salinity trend: dammed Vs undammed

Both the estuaries of undammed rivers, namely Aghanashini and Gangavali had higher salinity values towards the river mouth (28.55 and 28.85 ppt) than the river mouth of Kali and Sharavathi (11.75 and 13.80 ppt). The mid estuarine stations of undammed rivers had fairly high salinity (26.35 and 25.00 ppt) whereas the dammed ones had it as low as 1.71 and 0.67 ppt in Kali and Sharavathi respectively. Whereas the upstream salinity of dammed river estuaries were at 0.05 ppt in Kali and 0.01 ppt in Sharavathi, in the undammed river estuaries it was higher at 4.61 ppt in Aghanashini and 1.48 ppt in Gangavali (Fig. 2).

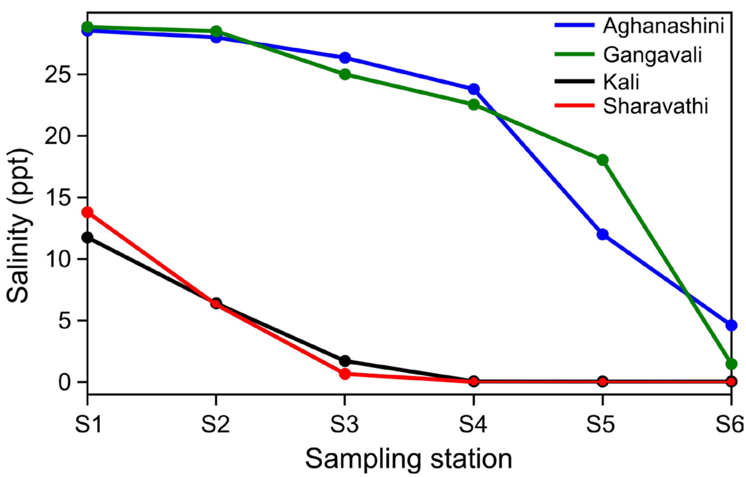

Fig. 2: Salinity trends of Uttara Kannada estuaries. Gangavali and Sharavathi (December 2011); Aghanashini and Kali (February 2012). Source: Boominathan *et al*. (2014a, 2014b).

3.2 Clam diversity

The four estuaries of Uttara Kannada district studied had six notable commercial clam bivalves, viz. *Meretrix casta, Meretrix meretrix, Paphia malabarica, Polymesoda erosa, Tegillarca granosa*, and *Villorita cyprinoides*. All six species occurred in Aghanashini, Gangavali and Kali whereas, Sharavathi was impoverished of even clams like *M. casta* and *M. meretrix* which were recorded in abundance in earlier studies (Alagarswami and Narasimham, 1973; Rao and Rao, 1985). *Polymesoda erosa* was the only clam present during our survey.

3.3 Clam distribution

The station-wise distribution of the clams are given in the Table 3. In undammed river estuary Aghanashini all six commercial were distributed as they were during earlier studies (Rao *et al*., 1989). Likewise, in Gangavali, the species mentioned by Alagarswami and Narasimham (1973) were present. Although in Kali all the clams continued to be present, the dam effect notwithstanding, there has been notable shifts more towards the river mouths in their distribution ranges as well as certain shrinkage in their occupation zones as compared to the pre dam distribution details from earlier studies. Whereas before dam construction during 1978, *Meretrix meretrix* occurred from 2 to 12 km range from river mouth (Nair *et al*., 1984) the post dam distribution range was from 1-4 km in a 1984 study (Rao *et al*., 1989), Our study in 2012 showed the species confined to still narrower range of 1-3 km. *M. casta* range also got substantially diminished from 7-11 km in 1984 (Rao *et al*., 1989), to 1-3 km in 2012. *V. cyprinoides* shifted from 11 to 26 km distribution range in 1978 (Nair *et al*., 1984) to 7-24 km in 1984 (Rao *et al*., 1989) and in 2012, and a much greater range compression to 6-12 km from the river-mouth in the current study.

Table 2: Station-wise clam distribution in four Uttara Kannada estuaries.

Station	Tg	Pm	Pe	Mm	Mc	Vc
S1	A, G, K	A, G, K	A, G, K, S	A, G, K	A, G, K	
S2		G	A, G, K, S	G, K	A, G, K	
S3			A, K		A, G	K
S4			A		A, G	A, G, K
S5						A, G
S6						A, G

A – Aghanashini, G – Gangavali, K – Kali, S – Sharavathi, Tg – *Tegillarca granosa* (Linnaeus), Pm – *Paphia malabarica* (Chemnitz), Pe - *Polymesoda erosa* (Solander), Mm – *Meretrix meretrix* (Linnaeus), Mc – *Meretrix casta* (Chemnitz), Vc – *Villorita cyprinoides* (Gray). Source: Boominathan *et al*. (2014a, 2014b).

The result of Kruskal–Wallis test also was significant (H=12.98, d.f.=3, P=0.0047) and the rank sum was different among estuaries (Table 3). Undammed river estuaries were strikingly similar at the rank sum of 106 whereas the rank sum was considerably smaller for Kali at 49 and Sharavathi at 39. It clearly shows that the continuous releases of freshwater from the upstream hydel projects had serious impact on estuarine salinity. The river mouths were relatively better while the fall in salinity was more serious in the bulk of the estuaries of both the dammed rivers- in the mid and upstream parts as well, in comparison to the undammed rivers.

Table 3: Summary of Kruskal-Wallis test.

Groups	N	Median	25% - 75%	Range	Rank Sums
Aghanashini	6	25.08	14.95 – 27.59	4.61 – 28.55	106
Gangavali	6	23.78	19.18 – 27.63	1.48 – 28.85	106
Kali	6	0.89	0.05 – 5.23	0.05 – 11.75	49
Sharavathi	6	0.35	0.02 – 4.89	0.01 – 13.8	39

The major changes that have been taking in the upstream areas of Sharavathi were the addition of more hydroelectric power generators (from original installed capacity of 120 MW in 1948 to 1469.20 MW at present including power generation for Gerusoppa dam commissioned in the downstream of the river in 1999). The combined releases of freshwater from several generators, obviously, had taken a heavy toll on the clam resources of the Sharavathi estuary, through mainly a drastic reduction in salinity. This observation can be supported by the fact Chandran *et al*. (2012) noticed the precarious state or near absence of high salinity tolerant mangroves like *Rhizophora* spp., *Sonneratia alba*, and *Avicennia marina* from this estuary which are otherwise more well represented in other estuaries of the district and elsewhere along the Indian west coast. The rich presence throughout in the estuary of the very low salinity tolerant *Sonneratia caseolaris* is a clear indication of the human altered ecological conditions, especially of salinity decline.

Despite lower salinity recorded from Kali during February 2012, the onset of the clam collection season, comparable in salinity with that of Sharavathi, the former had all the six commercial clam bivalves unlike a single surviving species in the latter. While admitting the need for year-round monitoring of salinity in the case study estuaries it may be pointed out that the rivers dammed for electricity generation might experience rise and fall of salinity in pulses, on day-to-day and hour to hour basis, as more generators keep working during demand-related power production peaks. Ramachandra *et al*. (2013) monthly observations revealed that the Sharavathi estuary as having less than 0.5 ppt salinity throughout 2011-12. The same study placed Kali in a far better position with pre-monsoon salinity towards river mouth stations touching about 35 ppt, mid estuary around 15 ppt and upstream stations showing 8-10 ppt. Aghanashini and Gangavali, normal estuaries without any dams, showed highest pre-monsoon salinities closer to that of sea water towards river mouths, mid estuary in the range of 25-28 ppt and upstream stations in both showing 10 to a little above 20 ppt. Hence, the clam diversity in the Sharavathi estuary, most impacted by upstream hydel projects, is bound to be affected to the maximum extent among all the four case study areas.

4. CONCLUSION

Clam bivalves apparently did not merit as much importance as finfish and shrimp fishery along Karnataka coast, despite clam collection through ages, employing thousands of people and the plentiful output from coastal estuaries providing protein rich food and relatively lower costs. This scenario has been changing over the last few decades due to ecological degradation on account of pollution, unregulated mining of sand and shell beds, mangrove degradation and divers other causes. Seldom was any thought ever given that execution of hydroelectric projects in the upper reaches of rivers, as in the Western Ghats, could destabilise estuarine ecology, primarily through lowered salinity conditions caused by incessant discharge of freshwater after power generation, such unprecedented phenomena not favouring rise of natural salinity even during the dry months of summer. The decline of clam diversity and clam fishery seems to have started with beginning of electricity generation from the Linganmakki dam in the 1960s and the increases in installed capacity for power generation due to additional power houses and commencement of one more dam at Gersoppa, could be considered the major reasons for near total collapse of clam diversity and clam fishery altogether. Kali estuary being a bigger one and with relatively wider river mouth did not witness the elimination of clam bivalves despite a series of hydroelectric projects upstream. Nevertheless, almost bivalves showed shifts from their original occupation zones in the estuary towards the river mouth obviously seeking optimum salinity conditions. The Kali bivalves also were confined to narrower zones in the estuary than their earlier occupation zones. This study underscores the need for consideration of environmental impacts on a wider scale, incorporating even impacts on coastal and marine domains, from major river valley projects in the Western Ghats, and have a second look at the fresh proposals cropping up for diversions of west flowing rivers towards meeting the water needs of the drier Deccan region.

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REFERENCES

Alagarswami, K. and Narasimham, K. A. 1973. Clam, cockle and oyster resources of the Indian coasts. In: *Proceedings of the symposium on living resources of the seas around India, 1968*. *Special Publication*. Central Marine Fisheries Research Institute, Cochin, India, p. 648–658. Available at: http://eprints.cmfri.org.in/2760/ [Accessed February 28, 2012].

Apte, D. 1998. *The book of Indian shells*. Bombay Natural History Society and Oxford University Press, Mumbai, India, 115 pp.

Boominathan, M., Chandran, M. D. S. and Ramachandra, T.V. 2008. Economic valuation of bivalves in the Aghanashini estuary, west coast, Karnataka. *ENVIS Technical Report* (30). *Sahyadri Conservation series–9*. Centre for Ecological Sciences, Indian Institute of Science, Bangalore, India, p. 33.

Boominathan, M., Ravikumar, G., Chandran, M. D. S. and Ramachandra, T. V. 2014a. Impact of hydroelectric projects on bivalve clams in the Sharavathi estuary of Indian west coast. Submitted to *The Open Ecology Journal*.

Boominathan, M., Ravikumar, G., Chandran, M. D. S. and Ramachandra, T. V. 2014b. Impact of hydroelectric projects on commercial bivalves in a south Indian west coast estuary. Submitted to *Journal of Biodiversity*.

Chandran, M. D. S., Ramachandra, T. V., Joshi, N. V., Mesta, P. N., Settur, B. and Mukri, V. D. 2012. Conservation and Management of Mangroves in Uttara Kannada, Central Western Ghats. *ENVIS Technical Report* (50). *Sahyadri Conservation series–20*. Centre for Ecological Sciences, Indian Institute of Science, Bangalore, India, p. 160.

Chen, J. 2005. Dams effect on coasts. In: Schwartz, M. (Ed.), *Encyclopedia of Coastal Science*, p. 357–359.

Dandekar, P. 2012. *Damaged rivers, collapsing fisheries: Impacts of dams on riverine fisheries in India*. Available at: http://www.indiaenvironmentportal.org.in/reports-documents/damaged-rivers-collapsing-fisheries-impacts-dams-riverine-fisheries-india [Accessed July 30, 2013].

Dey, A. 2006. Handbook on mangrove associate molluscs of Sundarbans. *Zoological Survey of India*, Kolkata, India, 96 pp.

Estevez, E. D. 2002. Review and assessment of biotic variables and analytical methods used in estuarine inflow studies. *Estuaries*, 25 (6) : 1291–1303.

Hammer, O., Harper, D. A. T. and Ryan, P. D. 2001. PAST: Paleontological Statistical software package for education and data analysis. *Palaeontologia Electronica*, 4 (1) : 9.

Morton, B., 1984. A review of *Polymesoda* (*Geloina*) Gray 1842 (Bivalvia: Corbiculacea) from Indo-Pacific mangroves. *Asian Mar. Biol.*, 1 : 77–86.

Nair, K. N., Ramadoss, K., Rajan, C. T. and Sundaram, N. 1984. Molluscan resources of Kali River estuarine system in Karnataka. *Technical and Extension Series* (58). Marine Fisheries Information Service. Central Marine Fisheries Research Institute, Cochin, India, p. 1-8.

Parada, J. M., Molares, J. and Otero, X. 2012. Multispecies mortality patterns of commercial bivalves in relation to estuarine salinity fluctuation. *Estuaries and Coasts*, 35 (1) : 132–142.

Quantum GIS Development Team, 2014. *Quantum GIS Geographic Information System*. Open Source Geospatial Foundation Project. Available at: http://qgis.osgeo.org/.

R Core Team. 2014. *R:* A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: http://www.R-project.org/.

Ramachandra, T. V., Chandran, M. D. S., Joshi, N. V., Bhat, M., Mesta, P. N. and Naik, S. G. 2013. Estuarine fish diversity and livelihood in Uttara Kannada district, Karnataka state. *ENVIS Technical Report* (64). *Sahyadri Conservation series–34*. Centre for Ecological Sciences, Indian Institute of Science, Bangalore, India, p. 99.

Rao, G. S. and Rao, K. S. 1985. Survey of clam and oyster resources of some Karnataka estuaries. *Indian J. Fish.*, 32 (1) : 74–89.

Rao, G. S., Kuriakose, P. S., Ramachandran, N., Meiyappan, M. M., Achari, G. P. K., Nagaraja, D. and Shivanna. H. S. 1989. Atlas of clam resources of Karnataka. *Special Publication 46*. Central Marine Fisheries Research Institute, Cochin, India, p. 56.

Rao, N. V. S. 1989. Handbook, freshwater molluscs of India. *Zoological Survey of India*, Calcutta, India, 289 pp.

Rodriguez, C. A., Flessa, K. W. and Dettman, D. L. 2001. Effects of upstream diversion of Colorado River water on the estuarine bivalve mollusc *Mulinia coloradoensis*. *Conservation Biology*, 15 (1) : 249–258.

Seddon, M. B. 2000. Molluscan biodiversity and the impact of large dams. Prepared for Thematic Review II.1. *Dams, Ecosystem Functions, and Environmental Restoration*. World Commission on Dams, Cape Town, South Africa.

DIVERSITY OF BUTTERFLIES IN DHARMAPURI DISTRICT, TAMIL NADU, INDIA

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ABSTRACT

Butterflies are known for their colour, beauty, wondrous shape and variability. Among invertebrates, butterflies are suitable for ecological studies, as taxonomy, geographic distribution and status of many species are relatively well known. In the present study, was carried out in Melagiri hills of Eastern Ghats, Hosur forest Division. This tract of forest is a block of 950 km^2 and lies between 12^o 7' and 12^o 7' and 12^o 44' N latitudes and 77^o 30' and 78^o 27' E longitudes, Melagiri hills are a part of the Hosur plateau which run irregularly as a chain from north-east to south-west. The results showed that, 56 species of butterflies belongs to eight families, were collected during the study period i.e. December 2014 to March 2015. The families Pieridae, Nymphalidae were represented by the highest number of species. The most abundant species with reference in the mixed deciduous forest were *Leptosia nina*, *Ceprora nerissa* and *Neptis hylas*. *Leptosia nina*, *Ixas marianne*, *Neptis hylas* and *Danias chrysippus* were the most abundant species in the riverine forests. In the scrub jungle *Leptosia nina*, *Neptis hylas* and *Erogolis ariadne*, *Terias hecabe*, *Neptis hylas* and *Erogolis ariadne* were the most dominant species. *Precis iphita. Danais Melissa Danais chrysippus*, *Danais plexippus* and *Euploea core* were the most abundant species in the shola forests. In conclusion the present study brought out the richness and diversity of butterfly fauna at the study area.

Keywords: Butterflies, density, diversity, Dharmapuri, Tamil Nadu.

1. INTRODUCTION

Butterflies are ecologically very important. Their role in the ecosystem is worth mentioning than their size would make it seems. Along with bees they are top pollinators of flowers and their various forms constitute food for a lot of birds. Further, their larvae which feed on foliage are the primary herbivores in the ecosystem and are important in transfer of radiant energy fixed by plants and making it available to the other organisms in the ecosystem. Butterflies are good indicators for the general ecological conditions. They are capable of supplying information on changes in the ambient features of any ecosystem (Gunathilagaraj *et al*., 1997). Butterflies are well adapted to special ecological conditions of its corresponding vegetation type. Even closely related types of vegetation which belong to the same plant sociological association can be differentiated by their lepidopteron fauna (Thomas, 1984). Once a habitat is no longer found suitable, they will emigrate and disappear very rapidly.

At present butterflies including extinct forms account for about 20,000 species (Smart, 1977). There are about 1,400 species have been found in india (Wynter-Blyth, 1957). According to Chaturvedi *et al.* (1980) the Indian subcontinent alone has over 1,443 species of butterflies. Bailey (1951) reported more than 200 species of butterflies from Nepal. Two hundred and twenty four species of butterflies were recorded Palani hills by Ugarte and Rodricks (1960). Larsen (1987) carried out an intensive study of butterflies fauna of Nilgiris and reported 300 species which are virtually known to occur in South India. Thirty eight species of butterflies, have been reported from Mudumalai Wildlife Sanctuary by Asaithambi (1989).

A total of 56 species of butterflies there belonging to eight families were collected from Srivilliputhur Grizzled Giant Squirreled Sanctuary during December 1992 to March 1993 by Kumar (1993). Agoram *et al*. (1992) reported 27 species of butterflies from Pichavaram mangroves. About 100 species of butterflies belonging to 9 families were collected from Silent Valley National Park by Mathew and Rahamathulla (1993). An intensive survey of the city and its environs by Gunathilagaraj *et al*. (1997) revealed 104 species of butterflies.

From the foregoing review of literature it is evident that study of butterflies in an area could give important clues about forest wealth conditions. Further there has been no comprehensive report on the butterfly fauna of the forest of Dharmapuri District. The present study was made to explore the butterfly fauna of this region.

2. STUDY AREA

The present study was carried out in Melagiri hills of Eastern Ghats, Hosur forest Division. This tract of forest is a block of 950 km^2 and lies between 12^o 7’ and 12^o 44’ N latitudes and 77^o 30’ and 78^o 27’ E longitudes, Melagiri hills are a part of the Hosur plateau which run irregularly as a chain from north-east to south-west. On the South-Eastern end Melagiri culminates in the impressive peak of Guttirayan Durg with an elevation of 1395.1 m MSL. This is the highest point for considerable distances around. The geographical situation of the Melagiri hills favours the Northern and Western aspects by blocking the clouds of south-west and north-east monsoon and makes these slopes to experience the maximum rainfall 950-1000 mm and enriched the area with bamboo dominated mixed deciduous forest interspersed with dry evergreen forest patches. Hence it forms a rain shadow area on the other side of the slopes which lies in Dharmapuri forest.

3. MATERIALS AND METHODS

This study was conducted in Hosur forest division, Dharmapuri district, Tamil Nadu from December 2014 to March 2015. Butterflies were collected using the following standard equipments *viz.* Net, Killing jar, Relaxing jar, Spreading, Pinning and Labeling. In order to ensure the scientific value of the collected specimen a small label bearing information concerning their systematic position, was attached to the pin of the each specimen. The butterflies collected and seen in the field were indentified by Evans (1932). Butterfly species and family diversity were calculated Shannon-Weiner diversity index (H’). The relationships between the butterfly population parameter and the habitat variables were evaluated by correlation analysis (Sokal and Rholf, 1981).

4. RESULTS AND DISCUSSION

A total of 56 species of butterflies were collected from the study area during the study period. These belong to eight families (Table 1).

Table 1 List of butterflies collected from Hosur forest

Sl. No.	Common name	Scientific name
	Family: Papilionidae	
1.	Southern Birdwing	*Triodes minos* Cramer
2.	Common Blue Bottle	*Graphium sarpedon* Felder and Felder
3.	The common jay	*Graphium dosaoneleius* Scopoli
4.	Common Banded Peacock	*Papilio crino* Fabricus
5.	Common Rose	*Pachliopta aristolochiae* (Fabricus)
6.	Crimson Rose	*Pachliopta hector* (Linnaeus)
7.	Lime Butterfly	*Papilio demoleus* Linnaeus
8.	Blue Mormon	*Papilio polymenstor* (Cramer)
9.	Common Mormon	*Papilio polytes* Linnaeus
	Family: Danidae	
10.	Dark Blue Tiger	*Tirumala septentrionis* Fruhstorfer
11.	Striped Tiger	*Danaus genutia* (Cramer)
12.	Plain Tiger	*Danas chrysippus* (Linnaeus)

13.	Common Crow	*Euploea core* (Cramer)
	Family: Libytheidae	
14.	Club beak	*Libythea myrrha* Linnaeus
	Family: Lycaenidae	
15.	Gram blue	*Euchrysops cnejus* Linnaeus
16.	Red Pierrot	*Talicada nyseus* (Guerin-Meneville)
17.	The plain cupid	*Euchrysops parrhasius Evans*
18.	The powdered oakblue	*Narathura bazaloides* (Hewitson)
	Family: Satyridae	
19.	Common Four Ring	*Ypthima huebneri* (Kirby)
20.	Common Evening Brown	*Melanitis leda* (Drury)
21.	The dark evening brown	*Melanitis phedima* (Stoll)
22.	The commonfourning	*Ypthima ceylonica* Kirby
23.	The tamil tree brown	*Lethedrypetis todara* (Moore)
	Family: Nymphalidae	
24.	Common Nawab	*Polyura athamas* Drury
25.	Indian Red Admiral	*Vanessa indica* Fruhstorfer
26.	Common Sailor	*Neptis hylas* (Moore)
27.	The common lascar	*Pantoporia hordonia* (Stoll)
28.	Danaid Eggfly	*Hypolimnas misipus* (Linnaeus)
29.	Great Eggfly	*Hypolimnas bolina* (Drury)

30.	Yellow Pansy	*Precis hierta* (Fabricius)
31.	Blue Pansy	*Precis orithya* (Linnaeus)
32.	Lemon Pansy	*Precis lemonias* (Linneus)
33.	Peacock Pansy	*Precis almanac* (Linneus)
34.	Chocolate Pansy	*Precis iphita* (Cramer)
35.	Common Leopard	*Phalanta phalanta* (Drury)
36.	The angled castor	*Ergolis ariadne* (Linnaeus)
37.	Common Castor	*Ariadne merionne* Cramer
38.	Baronet	*Symphaeda nais* Forester
	Family: Acraeidae	
39.	Tawny Coster	*Acrea violae* (Fabricius)
	Family: Pieridae	
40.	Common Jazebel	*Delias eucharis* (Drury)
41.	Great Orange Tip	*Hebomoia glaucippe* Butler
42.	The small salmon arob	*Colotis amata* (Fabricus)
43.	Pioneer	*Anaphaeis aurota* (Fabricus)
44.	Mottled Emigrant	*Catopsilia pyranthe* (Linneus)
45.	African Emigrant	*Catopsilia florella* (Fabricus)
46.	Common Grass Yellow	*Eurema hecabe* Moore
47.	Yellow Orange Tip	*Ixias pyrene* Fabricius
48.	White Orange Tip	*Ixias marianne* (Cramer)

49.	Common Gull	*Cepora nerissa* (Fabricus)
50.	Psyche	*Leptosia nina* (Fabricus)
51.	Common Wanderer	*Parenonia valeria* (Fabricus)
52.	Lemon Emigrant	*Catopsilia pomona* (Fabricus)
53.	The striped albatross	*Appias libythea* (Geyer)
54.	Three Spot Grass Yellow	*Eurema blanda* Wallace
55.	Crimson Tip	*Colotis dane* (Fabricus)
56.	The common albatross	*Appias albina* C. Felder & R. Felder)

4.1 Butterfly density

Absolute and relative densities of different species of butterflies in the four forest types are given (Table 2). The most abundant species with reference to the mixed decidous forest were *Leptosia nina* (43.3/m^2), *Ceprora nerissa* (38.33km^2) and *Neptis hylas* (48.33/km^2). *Leptosia nina* (61.7/km^2), *Ixas marianne* (50.0/km^2), *Neptis hylas* (31.7/km^2) and *Danias chrysippus* (48.3/km^2) were the most abundant species in the riverine forests. In the scrub jungle *Leptosia nina* (38.37/km^2), *Neptis hylas* (28.33/km^2) and *Erogolis ariadne* (25.0/km^2), *Terias hecabe* (30.0/km^2), *Neptis hylas* (28.33/km^2) and *Erogolis ariadne* (25.0/km^2) were the most dominant species. *Precis iphita* (26.7/km^2) *Danais Melissa* (20.0/km^2) *Danais chrysippus*, *Danais plexippus* (50.0/km^2) and *Euploea core* (43.3/km^2) were the most abundant species in the shola forests. Highest densities of Papilionidae occurred in the riverine forest (73.36/km^2) and the least in the scrub jungle (32.7/km^2) with the mixed deciduous and the shola forests had the highest densities of Papilionidae (Table 2). Riverine forests had the highest densities of Pieridae as well when compared to the other forest types. Families Lycaenidae, Libytheidae, Libytheidae and Acraeidae were found in higher densities in the mixed deciduous forests while they were totally unrepresented in the scrub jungle and shola forests. Families Nymphalidae and Satyridae as found in the greatest densities in the mixed deciduous forests when compared to the other forest types. Danaids were found in highest densities in the shola forests. Family Pieridae dominated the mixed deciduous forest, riverine forest and scrub jungle and family Danaidae the shola forests.

Table 2. Absolute (No.km^2) relative (%) densities of different species of butterflies in different forest types

Sl. No.	Species name	Forest types							
		Moist deciduous		Riverine		Scrub jungle		Shola	
		AD	RD	AD	RD	AD	RD	AD	RD
	Family: Papiliondae								
1.	*Triodes minos*	3.3	66.0	1.7	34.0	0	0	0	0
2.	*Polidours hector*	15.0	22.5	26.7	40.0	10.0	15.0	15.0	22.5
3.	*Papilio aristolochiae*	10.0	20.0	13.3	26.6	6.7	13.4	20.0	40.0
4.	*Papilio demoleus*	8.3	53.2	3.3	21.2	1.7	10.9	1.7	10.9
5.	*Papilio polytes*	10.0	31.5	11.7	36.9	1.7	5.4	8.33	26.2
6.	*Papilio polymnestor*	5.0	29.9	5.0	29.9	0	0	6.7	40.1
7.	*Graphium sarpedon*	3.33	33.3	3.33	33.3	0	0	3.33	33.3
8.	*Graphium doson*	3.33	39.6	3.33	39.6	0	0	3.7	20.2
9.	*Papilio crino*	8.33	41.5	5.0	24.5	0	0	6.7	33.4
	Total	66.59	29.7	73.36	32.7	20.10	9.0	65.46	29.2
	Family: Pieridae								
10.	*Delias eucharis*	11.7	36.8	6.7	21	6.7	21	6.7	21
11.	*Leptosia nina*	43.3	28.6	61.7	40.7	38.33	25.3	8.33	5.5
12	*Appais libythea*	0	0	3.3	100	0	0	0	0
13.	*Appais albina*	15	39	13.33	34	1.7	4.4	8.33	21.7
14.	*Colotis amata*	6.7	60.4	1.7	16.8	1.7	16.8	0	0
15.	*Colotis dane*	1.7	100	0	0	0	0	0	0
16.	*Cepora nerissa*	38.33	50	11.7	15.2	13.33	17.4	13.33	17.4
17.	*Ixias Marianne*	16.7	16.4	50	49.1	25	24.6	10	9.8
18.	*Ixias pyrene*	11.7	20	23.33	40	11.7	20	11.7	20
19.	*Hebomia giaucippe*	5	60	3.3	40	0	0	0	0
20.	*Parenonia avator*	5	27.3	10	54.6	3.33	18.2	0	0
21.	*Catopsilia Pomona*	3.3	28.4	3.3	28.4	5	43	0	0
22.	*Catopsilia pyranthe*	3.3	33	6.7	67	0	0	0	0
23.	*Terias laeta*	5	42.7	6.7	57.3	0	0	0	0
24.	*Terias becabe*	25	29.4	18.3	21.5	30	35.3	11.7	13.8
25.	*Catopsilia florella*	15	52.8	1.7	6	11.7	41.2	0	0
26.	*Colotis eucharis*	0	0	5	100	0	0	0	0
	Total	206.73	31.7	226.76	34.8	148.49	22.8	0.09	10.7

	Family: Lycaenidae								
27.	*Talicada nyseus*	6.7	67	3.3	33	0	0	0	0
28.	*Euchrysops cnejus*	0	0	3.3	100	0	0	0	0
29.	*Euchrysops pandave*	6.7	44.7	8.3	55.3	0	0	0	0
30.	*Amblypodia bazaloides*	3.3	100	0	0	0	0	0	0
	Total	16.7	52.8	14.9	47.2	0	0	0	0
	Family: Libytheidae								
31	*Libythea myrrha*	5	60.2	3.3	39.8	0	0	0	0
	Total	5	60.2	3.3	39.8	0	0	0	0
	Family: Acraeidae								
32.	*Telchinia violae*	8.3	55.3	6.7	44.7	0	0	0	0
	Total	8.3	55.3	6.7	44.7	0	0	0	0
	Family: Nymphalidae								
33.	*Eriboea athamas*	3.3	66	1.7	34	0	0	0	0
34.	*Vanessa indica*	0	0	3.3	100	0	0	0	0
35.	*Neptis hylas*	48.33	40.8	31.7	26.8	28.33	23.9	10	8.4
36.	*Neptis hordonia*	8.33	45.8	5	27.1	1.7	9.2	3.33	18.1
37.	*Hypolimnas missipus*	3.33	12.1	8.33	45.3	0	0	6.7	36
38.	*Hypolimnas bolina*	3.3	50	3.3	50	0	0	0	0
39.	*Precis hierta*	15	37.5	10	25	13.3	33.25	1.7	4.25
40.	*Precis orithya*	15	75	1.7	8.5	3.3	16.5	0	0
41.	*Precis lemonias*	15	42.1	2.33	6.5	15	42.1	3.33	9.3
42.	*Precis almana*	6.7	57.3	5	42.7	0	0	0	0
43.	*Precis iphita*	15	22.5	10	15	15	22.5	26.7	40
44.	*Altella phalanta*	3.3	25	0	0	10	75	0	0
45.	*Ergolis ariadne*	6.7	16.8	8.3	20.8	25	62.5	0	0
46.	*Ergolis merionne*	6.7	100	0	0	0	0	0	0
47.	*Euthalia nais*	1.7	66	3.3	44	0	0	0	0
	Total	151.69	37.1	93.96	23.0	111.63	27.3	51.760	12.7
	Family: Satyridae								
48.	*Melanitis leda*	6.7	17.5	3.3	8.6	0	0	22.3	73.9
49.	*Melanitis phedima*	5	60.2	3.3	39.8	0	0	0	0
50.	*Lethe drypetis*	5	60.2	3.3	39.8	0	0	0	0
51.	*Ypthima baldus*	8.3	3	3.3	12.4	5	18.7	10	34.4
52.	*Ypthima hubneri*	8.3	41.5	11.7	58.5	0	0	0	0
	Total	33.3	35.1	24.9	26.0	5	5.2	32.3	33.7

	Family: Danaidae								
53.	*Danais mlissa*	10	26.1	8.3	21.7	0	0	20	52.2
54.	*Danais chrysippus*	13.3	13.5	48.3	49.2	18.3	18.6	18.3	18.6
55.	*Danais plexippus*	8.3	10.2	13.3	16.2	10	12.3	50	61.3
56.	*Euploea core*	16.7	17.0	25	25.5	13.3	13.57	43.3	44.2
	Total	48.3	15.3	94.9	30.0	41.6	13.1	131.6	41.6

(AD = Absolute density; RD = Relative density)

4.2 Butterfly diversity Index (H')

A summary of butterfly species-wise and family-wise diversity Index(H') values were given in Table 3. Butterfly species diversity Index was highest in the mixed deciduous forest (H'= 3.64) and least in the shola forest (H' = 2.98). Butterfly family diversity was highest in the mixed deciduous forests (H' = 1.59) and least in the shola forest (H' = 1.34).

Table 3. Density and diversity (H') of butterflies for the different forest types

Sl. No.	Parameter	Mixed deciduous	Riverine	Scrub jungle	Shola
1.	Species-wise				
	a. Butterfly absolute density (no./km^2)	536.61	523.78	222.63	**351.8**
	b. Butterfly relative density (no./km^2)	43.15	36.26	6.81	**13.12**
	c. Butterfly species richness (no of species)	52	52	27	**27**
	d. Butterfly species diversity	3.64	3.45	2.98	**2.98**
2.	Family wise				
	a. Butterfly family (all richness	8	8	6	**6**
	b. Butterfly family diversity	1.59	1.57	1.55	1,34

The result of the present study showed that the great variety of butterflies exist in the study area, as 56 species could be collected within a short period of 4 months covering a single season of an year. The butterflies recorded from Hosur forest division, Dharmapuri district, Tamil Nadu represent all the major families with Nymnphalidae, Pieridae and Papilionidae dominating followed by Danidiae, Lycaenidae and Satyridae. Libytheidae and Acraeidae are represented to only one species each. With regard to the distribution of species in Moist deciduous and Riverine foreasts was found to be the most species richness (8 families each). This was followed Scrub jungle and Shola (6 species each).

The species richness was higher in the study area compare to 38 species represented by Asaithambi (1989) from Mudumalai Wildlife Sanctuary. This study also revealed that the occurrence of the South Indian endemic forms such as *Appias albina* and *Aparia hica*, *Appias litrythera* protected under Schedule IV of the Wildlife (Protection) Act. Even though this study showed that the areas has a very rich and characteristic butterfly fauna, a long term study covering all the three seasons of an year should be undertaken to have a complete list of butterfly fauna of this area as Smart (1977) had suggested that the habitat may be temporary for the species because, either the weather is only suitable at certain this of the year or the found plants in available only in certain season.

Highest butterfly species richness was recorded in the mixed deciduous and riverine forest with the mixed deciduous forests showing higher diversity value than the riverine forests. Larsen (1987) also stated that one of the richest habitat in terms of species is the mixed deciduous forest which agreed with the present study. Asaithambi (1989) and Kumar (1993) reported that riverine vegetation had highest butterfly diversity in Mudumalai Wildlife Sanctuary and Grizzled Giant Squirrel Wildlife sanctuary which is comparable with our present study.

However, the abundance and richness could also be due to features other than vegetation such as climate, topography, availability of larval host plants and flowers etc. (Evans, 1932; Gilbert and Singer, 1975; Devries, 1989; Asaithambi, 1989). In conclusion the present study brought out the richness and diversity of butterfly fauna at the study area. However a further understanding requires a long term study, which addresses the above discussed biological and environmental factors as well.

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REFERENCES

Agoram, M., N. Anandan, J. Balu, R. Elangovan and Elangovan, V. 1992. Studies on the Ecology of Butterflies of Pichavaram, Tamil Nadu, South India. *B.Sc., Dissertation*, A.V.C. College, Mannampandal.

Asaithambi, P. 1989. A study of the butterfly species distribution and abundance over the major vegetation types of the Mudumalai Wildlife Sanctuary, Tamil Nadu. *M.Sc., Dissertation*, A.V.C. College (Autonomous), Mayiladuthurai, South India.

Bailey, F.M. 1951. Notes on butterflies from Nepal. *J. Bombay Nat. Hist. Soc*. 50(1): 64.

Chaturvedi, Naresh and Satheesan, S.M. 1980. Butterflies of Mombay, *Hornbill* Vol. 1.

Devries, P.J. 1989. The butterflies of Costa Rica and their natural History, Princeton University Press, Princeton.

Evans, W.H. 1932. The identification of Indian butterflies, *Bombay Natural History Society Publication*, Bombay.

Gilbert, L.E. and Singer, R. 1975. Butterfly ecology. *Annual review of ecology and systematics*. 6: 365-397.

Gunathilagaraj, M., Ganeshkumar and Ramesh, P.T. 1997. Butterlifes of Coimbatore. *Zoo's Print* 97(1): 26-27.

Larsen, B. 1987. The butterflies of the Nilgiri Mountain of Southern India. *J. Bombay Nat. Hist. Soc.* 84(2): 291-316.

Mathew, G. and Rahamathulla, U.K. 1993. Studies on Butterflies of Silent Valley National Park. *Entomon* 18(3): 185-192.

Kumar, S.P. 1993. The butterflies of Srivilliputhur Grizzled Giant Squirrel Sanctuary, Tamil Nadu, South India. *M.Sc. Dissertation*, A.V.C. College, Mannampandal.

Smart, P. 1977. The illustrated Encyclopedia of the butterfly world in colour. Salamandar books limited, London.

Sokal, R.R. and Rohlf, F.J. 1981. Biometry. W.H. Freeman and Company, New York.

Thomas, J.A. 1984. The conservation of butterflies in temperature countries: Past efforts and lessons for the future. In: The Biology of butterflies (vane-wright, R.I. and Ackery, P.R. eds) Royal Entomological Society, London 333-353 pp.

Ugarte, E. and Rodricks, L. 1960. Butterflies of the Palani hills. A complementary list. *J. Bombay Nat. Hist. Soc.* 57(2): 270.

Wynter-Blyth, M.A. 1957. Butterflies of the Indian Region, *Bombay Natural History Society Publication*, Bombay.

GARDEN: AS REFUGE FOR BIODIVERSITY CONSERVATION OF SPIDERS

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ABSTRACT

Spiders are polyphagous predators of insect pests belonging to order Araneae. They are cosmopolitan in distribution. Despite their wide distribution, detailed data are not available on their distribution in different habitats. The garden is considered to be a place of aesthetic value. We studied the diversity and density of various spider species found in a garden habitat (spread over 0.3 acre) at A.V.C. College, Mayiladuthurai, Tamil Nadu during 2007–2010. Density and diversity were assessed in four seasons *viz.,* post-monsoon, summer, pre-monsoon, monsoon in a year selecting five major plants species found in the garden viz. *Hibiscus rosa-sinensis, Ixora* sp., *Tabernaemontana coronaria, Cycas* sp. and *Codiaeum* sp. In addition, a quadrat of 1m^2 laid at ground level was also surveyed to record the spider species. The populations were estimated by direct count method. The density of spiders was calculated as number/plant and number/m^2. The diversity of spiders across different seasons was analyzed by widely used indices. Bray-Curtis similarity measures (1-B) were calculated to assess similarities in spider species assemblages between climatic seasons. We identified twenty four species of spiders belonging to nine families with Aranedae being the most dominant one. The spider species densities and diversity varied among plant species studied. All the spider species except *L. decorata* were recorded in all the seasons of all the three years of the study in the garden. Multiple comparisons (Tukey's test) recorded that the post-monsoon season had significantly higher densities ($p<0.05$) for the species *O. javanus, O. shweta, L. decorata* and *T. pugilis,* while *T. dimidiata* was significantly higher during the monsoon season of the present study period. The monsoon season of 2008-2009 had a highest Shannon-Wiener Diversity index (H'=2.6406), while the summer of 2007-2008 had the highest Margalef Richness index (R= 3.6775). A highest Bray–Curtis Similarity co-efficient of spider species composition in between the monsoon and post-monsoon seasons (0.9005), while the lowest similarity was between the pre-monsoon and post-monsoon seasons (0.8404). The assemblages of diversified species of spiders in different climatic seasons of the garden field indicated that the garden act as an important refuge for spider biodiversity conservation.

Keywords: Climatic season, Density, Diversity, Garden, Spiders.

1. INTRODUCTION

Spiders are polyphagous predators of insect pests belonging to order Araneae. They are cosmopolitan in distribution. Despite their wide distribution, detailed data are not available on their distribution in different habitats. The garden is considered to be a place of aesthetic value. Even in the garden several insects destroy the flowers and degrade the beauty of it. In order to avoid this precarious condition the spiders play a major role in controlling them as their natural enemies. Spiders have been reported to be abundant in habitats such as rose fields (Ghavami and Nematollahi, 2006), a variety of inflorescences (Souza and Modena, 2004), flowering plants in the Eastern Himalayas Satpathi (1995) as well. Further, the population density of spiders can be influenced by climatic seasons, temperature, humidity, rain fall, weather, crop seasons, prey availability and plant architecture, (Marc and Canard, 1997). Keeping in mind the various aspects of the forgoing account on spiders, an attempt has been made in the present study to document the influence of seasonal fluctuation on the spider species density and diversity in the garden.

2. METHODS

This study was carried out in a garden habitat (spread over 0.3 acre) located at A.V.C. College, Mayiladuthurai, Tamil Nadu during 2007–2010. Density and diversity were assessed in four seasons *viz.,* post-monsoon, summer, pre-monsoon, monsoon in a year selecting five major plants species found in the garden viz. *Hibiscus rosa-sinensis, Ixora* sp., *Tabernaemontana coronaria, Cycas* sp. and *Codiaeum* sp. In addition, a quadrat of 1m^2 laid at ground level was also surveyed to record the spider species. The populations were estimated by direct count method. The density of spiders was calculated as number/plant and number/m^2. The diversity of spiders across different seasons was analyzed by widely used indices. Bray-Curtis similarity measures (1-B) were calculated to assess similarities in spider species assemblages between climatic seasons.

3. RESULT AND DISCUSSION

3.1. Occurrence of Spiders

Twenty four species of spiders belonging to nine families were recorded in the garden of the present study (Table 1). This finding is similar to Satpathi (1995) who recorded twenty one species of spiders belonging to eight families on different flowering plants at 1000 to 1500m above mean see level in the Eastern Himalayas. lycosid and linyphiid spider were higher in organic fertilizer with flowering plants

3.2. Variations in the densities of spiders

Only eight of the most predominant spider species of the garden of the present study area were taken for further analysis. The spider species densities were varied among four seasons studied. All the spider species except *L. decorata* were recorded in all the seasons of all the three years of the study in the garden. Taxonomically diverse plant habitats often provide microclimates, greater availability of food sources, alternative hosts that encourage the natural enemies (Moretti *et al.,* 2002; Munyuli *et al.,* 2008). Multiple comparisons (Tukey's test) recorded that the post-monsoon season had significantly higher densities ($p<0.05$) for the species *O. javanus, O. shweta, L. decorata* and *T. pugilis,* while *T. dimidiata* was significantly higher during the monsoon season of the present study period (Table 2). This result was in accordance with Faragalla and AL-Ghamdi (2001). They reported that the Lycosidae population was higher in the monsoon and post-monsoon seasons (November to March) in the crop Ecosystem and the natural habitat in Western Saudi Arabia. Mineo *et. al*. (2010) pointed out the abundance of individuals and species richness was higher during the monsoon season.

Studies on the biology of spiders indicated that the Thomisidae prefer warm habitats (Nyffeler and Sunderland, 2003), with more inflorescence (Rocha-Filho and Rinaldi, 2011). Among the major characteristic to be taken into account by spiders in a given environment are the habitat structure, microclimatic conditions (Canard, 1990) and availability of prey (Turnbull, 1964). Moreover, El-Nabawy *et. al.* (2016) reported that lycosid and linyphiid spider were higher in organic fertilizer with flowering plants. The post-monsoon season provide suitable microclimatic condition for spiders by way of good structural complexity with more inflorescence plants in the study area and this might be the reason for the higher density of spiders observed during the study period.

3.3. Variations in the diversity of spiders

Spider species diversity measures in the garden were also varied. The monsoon season of 2008-2009 had a highest Shannon-Wiener Diversity index (2.6406) and Shannon-Wiener Evenness index (0.8603), while the pre-monsoon of 2008-2009 had the highest Simpson index (l) value (0.1735). The Margalef Richness index (R) was 3.6775 in summer of 2007-2008 and Evenness index (E) value (0.9667) was the highest in the post-monsoon of 2009-2010. Variation in the diversity of spider families during different climatic seasons of the present study period indicated that there were differences in the diversity, richness and evenness among the seasons. It also indicated that all the climatic seasons of the present study period showed different spider family compositions. Kato *et al.* (1995) also opined that it might be expected that climatic changes would influence the abundance of spiders. This might be due to the differences in the insect prey availability during different seasons of the study period as reported by (Peter, 1988) the crops having more insects and insect visitors always had more spiders.

3.4 Variations in the spider species similarity co-efficient values (Bray-Curtis similarity co-efficient)

Similarities in the spider species composition in the garden among different climatic seasons showed a highest Bray–Curtis Similarity co-efficient of spider species composition in between the monsoon and post-monsoon seasons (0.9005), while the lowest similarity was between the pre-monsoon and post-monsoon seasons (0.8404). This result also suggested that seasonal segregation of spiders might promote species co-existence (Buddle and Draney, 2004). Nyffeler and Sunderland (2003) reported that spider communities may respond to climate directly, and also indirectly via food availability and antagonists. In addition, differences in habitat diversification and cultural practices could influence spider density and community organisation.

Spider populations showed certain association not only between their structure and heterogeneity but also to structural complexity of the plant community, Riechert and Reeder, (1970) and environmental characters, Uetz (1991). Obviously, as the spiders directly depend on plants for their web construction, prey availability, shelter, etc. and the plant growth is indirectly influenced by the climatic seasons, it might be concluded that difference in climatic season and microclimate exert the major influence in shaping the different community structure of spiders in the garden of the present study. Permanent grassy and weedy borders at field's margins provide shelters and alternate food source for spiders in frequently disturbed habitats such as conventional agricultural fields (Nentwing, 1987; Oberg *et. al.,* 2008). The present study area is surrounded by the conventional agricultural fields and during the farm operations the spiders might have used the garden as alternate habitat for their survival. In general, in the garden selected for the present study, the management practices were few and limited. The grassing and pruning were done at the maximum thrice a year. Plants were irrigated periodically by a small canal and no chemicals were used either as fertilizers or pesticides. Thus the diversified occurrence of spider species in the garden field suggests that the garden act as an important refuge for spider biodiversity conservation.

Table 1. List of spider species recorded in garden of the study area during the study period.

S. No.	Common Name	Species	Family
1	Giant Cross Spider	*Argiope anasuja*	
2	Jungle Tent-Web Spider	*Cyrtophora citricola*	
3	Garden Spiny Spider	*Gasteracantha geminata*	
4	Two-Tailed Spider	*Hersilia savignyi*	Hersiliidae
5	Common Funnel-Web Spider	*Hippasa agelenoides*	Lycosidae
6	Grass Funnel-Web Spider	*Hippasa greenalliae*	
7	Pond Wolf Spider	*Pardosa pseudoannulata*	
8	Common Grass Spider	*Pardosa sumatrana*	
9	Striped Lynx Spider	*Oxyopes javanus*	Oxyopidae
10	Lined Lynx Spider	*Oxyopes lineatipes*	
11	White Lynx Spider	*Oxyopes shweta*	
12	Orange Lynx Spider	*Oxyopes sunandae*	
13	Green Lynx Spider	*Peucetia viridana*	
14	Heavy-Bodied Jumper	*Hyllus semicupreus*	Salticidae
15	Brown Ant Mimic Spider	*Myrmarachne orientales*	
16	Yellow-Haired Beetle Jumper	*Rhena danieli*	
17		Rhena sp	
18	Two-Striped Jumper	*Telamonia dimidiate*	
19	Green Crab Spider	*Olios millet*	
20	Three Humped Leucauge Spider	*Leucauge decorate*	Tetragnathidae
21	Green Tetragnathid Spider	*Tetragnatha viridorufa*	
22		*Achaearanea* sp.	Theridiidae
23	Common Rose Spider	*Thomisus pugilis*	Thomisidae
24		*Thomisus* sp	

Table 2. Multiple comparisons of year - wise and climatic season - wise variations in the mean densities of predominant species of spiders in the garden. (Tukey's test; similar means are indicated by continuous underlines).

Species of spiders	Years			Climatic Seasons				ANOVA	
								Sources of variations	F
Cyrtophora citricola	08-09	09-10	07-08	Sum	Mon	Pr.Mon	Po.Mon	**Year**	**1.38**^{ns}
	1.4	1.8	2.1	1.4	1.7	2.0	2.3	**C.Season**	**1.61**^{ns}
Pardosa sumatrana	09-10	08-09	07-08	Pr.Mon	Po.Mon	Sum	Mon	Year	1.70^{ns}
	0.2	0.3	0.3	0.2	0.3	0.3	0.3	C.Season	0.31^{ns}
Hippasa agelenoides	07-08	09-10	08-09	Pr.Mon	Sum	Po.Mon	Mon	**Year**	**1.01**^{ns}
	0.4	0.5	0.6	0.5	0.5	0.6	0.6	**C.Season**	**0.55**^{ns}
Oxyopes javanus	07-08	09-10	08-09	Pr.Mon	Sum	Mon	Po.Mon	Year	16.37***
	0.5	0.8	1.0	0.5	0.6	0.9	1.2	C.Season	19.95***
Oxyopes shweta	07-08	09-10	08-09	Sum	Pr.Mon	Mon	Po.Mon	**Year**	**1.02**^{ns}
	0.5	0.5	0.6	0.4	0.4	0.6	0.7	**C.Season**	**6.26*****
Telamonia dimidiata	07-08	08-09	09-10	Sum	Pr.Mon	Po.Mon	Mon	Year	0.46^{ns}
	0.5	0.5	0.6	0.3	0.4	0.7	0.7	C.Season	7.28***
Leucauge decorata	09-10	08-09	07-08	Pr.Mon	Sum	Mon	Po.Mon	**Year**	**0.51**^{ns}
	0.3	0.3	0.3	0.1	0.1	0.4	0.5	**C.Season**	**16.46*****
Thomisus pugilis	08-09	09-10	07-08	Sum	Pr.Mon	Mon	Po.Mon	Year	1.43^{ns}
	0.3	0.3	0.4	0.2	0.3	0.4	0.4	C.Season	3.07*

REFERENCE

Buddle, C.M. and Draney, M.L. 2004. Phenology of Linyphids in an old-growth Deciduous forest in central Alberta, Canada. *J. Arachnol*., 32: 221-230.

Canard, A. 1990. Heathland spider communities : a functional group study. *In:* Proc. 11th Int. congr. of Arachnology, Turku, Finland, *Acta Zool. Fenn.* 190 : 45-50.

Faragalla, A. and AL-Ghamdi, K.M. 2001. Comparison of the seasonal occurrence of the major true spiders (Araneidae) in some crop systems and a natural habitat in Western Saudi Arabia. *Arch. Phytopath. Pflanz.,* 34 : 361-377.

Ghavami, S. and Nematollahi, M. 2006. Investigation spider fauna of rose orchards in Kashan. *Proc. of 17th Iranian Congress on Plant Prot. Sci.,* 9: 1839-1851.

Kato, M., Inoue, T., Hamid, A.A., Nagamitsu, T., Merdek, M.B., Nona, A.R., Hino, T., Yamane, S. and Yumoto, T. 1995. Seasonality and vertical structure of light attracted insect communities in a dipterocarp forest in Sarawak. *Res. Popul. Ecol*., 37 : 59-79.

Marc, P. and Canard, A. 1997. Maintaining spider biodiversity in agroecosystems as a tool in pest control. *Agric. Ecosyst. Environ*., 62: 229-235.

Mineo, M.F., Claro1, K.D. and Brescovit, A.D. 2010. Seasonal variation of ground spiders in a Brazilian Savanna. *Zoologia* 27 (3): 353–362.

Moretti, M., Conedera, M., Duelli, P. and Edwards, P.J. 2002. The effects of wildlife on ground-active spiders in deciduous forests on the Swiss Southern slope of the Alps. *J. Appl. Ecol.,* 39: 321-336.

Munyuli, T.M.B., Kyamanywa, S. and Luther, G.C. 2008. Effects of groundnut genotypes, cropping systems and insecticides on the abundance of native arthropod predators from Uganda and Democratic Republic of Congo. *Bull. Insect*., 61 (1): 11-19.

El-Nabawy, E. M., Tsuda, K., Sakamaki,Y., Oda, A and Ushijima, Y. 2016. The Effect of Organic Fertilizers and Flowering Plants on Sheet-Web and Wolf Spider Populations (Araneae: Lycosidae and Linyphiidae) and Its Importance for Pest Control. *J. Ins. Sci.*, 16(1): 18; 1–8

Nentwig, W. 1987. The prey of spiders. *In*: Nentwig, W.(Ed.). *Ecophysiology of Spiders*. Springer, Berlin, p. 249-263.

Nyffeler, M. and Sunderland, K.D. 2003. Composition, abundance and pest control potential of spider communities in agroecosystems: a comparison of European and US studies. *Agric. Ecosyst. Environ*., 95: 579-612.

Oberg, S., Mayr, S. and Dauber, J. 2008. Landscape effects on recolonisation patterns of spiders in arable fields. *Agric. Ecosyst.Environ.,*123: 211–218

Peter, C. 1988. New records of natural enemies associated with BPH, *N. lugens. Curr. Sci.,* 57 (19) : 1087-1088.

Riechert, S.E. and Reeder, W.G. 1970. *Effects of fire on spider distribution on southwestern Wisconsinprairies*, *In* : Zimmerman, J.H. (Ed.) Proc. 2nd Midwest Prairie Conference. p.73-90.

Rocha-Filho, L.C. and Rinaldi, I.M.P. 2011. Crab spiders (Araneae: Thomisidae) in flowering plants in a Brazilian "Cerrado" ecosystem. Braz. J. Biol., 71(2): 359-364.

Satpathi, C.R. 1995. Spiders controlling different insect pests of flowering plants in Kalimpong, West Bengl, India. *Ann. Entomol*., 13 (2): 97-98.

Souza, A.L.T.de and Modena, E.de.S 2004. Distribution of spiders on different types of inflorescences in the Brazilian Pantanal. *J. Arachnol*., 32: 345-348.

Turnbull, A.L. 1964. The search for prey by a web-building spider *Achaearanea tepidariorum* (Koch) (Araneae : Theridiidae). *Can. Entomol.,* 96 : 568-579.

Uetz, G.W. 1991. Habital structure and spider foraging. *In* : Bell, S.S. Me Coy, E.D. and Mushinsky, H.R. (Eds), *Habitat structure. The physical Arrangement of objects in space*. Chapman and Hall, London, p. 325-348.

NUTRITION AND YIELD EVALUATION OF OYSTER MUSHROOM (*PLEUROTOUS OSTREATUS*) IN DIFFERENT SUBSTRATES

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ABSTRACT

Edible mushroom *Pleurotous ostreatus* was cultivated on different natural wastes viz. Bamboo leaves (substrate -I), coconut husk (substrate-II), and mixture of Bamboo leaves + coconut husk (substrate-III) to determine the suitability of these waste on yield and nutritional content. Coconut husk showed significantly highest yield (No/kg) among the substrate up to third harvest. The difference in the biochemical content it has been reported that not only the content of fruit body but also the nature of content depends on used substrate. When compare to second harvest and maximum protein, carbohydrate and lipid were observed in the first harvest. Among the three substrate coconut husk are very much suitable for mushroom cultivation (*Pleurotous ostreatus*) and also showed high nutrients then other substrate during the study period. Bamboo leaves had long incubation time and differ significantly than the other substrate composition it was not suitable for mushroom cultivation. Mushroom can be considered as an alternative source of protein and this can solve problems of people all over the world who often suffer from protein deficiency and also gives self *employment for women's.*

Keywords: *Pleurotous* ostreatus, yield, Nutritional analysis, coconut husk, bamboo leaves.

1. INTRODUCTION

Cultivation of oyster mushroom *(Pleurotus ostreatus)* has increased tremendously throughout the world because of their abilities to grow at a wide range of temperature and utilizing various agro-based residues. Mushroom with their flavor, texture, nutritional value and high productivity per unit area have been identified as an excellent food source to alleviate malnutrition in developing countries (Eswaran and Ramabadran, 2000). Growing oyster mushroom convert a high percentage of the lignocelluloses substrate to fruiting bodies increasing profitability. Especially, *Pleurotus ostreatus* demands few environmental controls and their fruiting bodies are not often attacked by diseases and pest, and they can be cultivated in a simple and economic way (Kues and Liu, 2000), it requires a short growth time in comparison to other edible mushroom. *Pleurotous species* are efficient lignin degraders which can grow on wide variety of agricultural wastes (Jandaik and Goyal, 1995), it require less nitrogen and more carbon, thus most organic matters containing cellulose, hemi cellulose and lignin can be used as mushroom substrate since mushroom can be grow on nearly any type of agricultural and forest residues, they are an ideal crop for rural areas with large amounts of cultivated residues from field crops. Mushroom production gives additional/alternative income to farmers and employment opportunities in the rural area and providing income opportunities for disadvantageous group, small family farms. Gruen and wong (1982) indicated that edible mushrooms were highly nutritional and compared favorably with meat, egg and milk food sources. In the present study the efficiency of different natural substrate production of the edible mushroom *Pleurotous ostreatus* have been evaluated. The nutritional value of the resulted mushroom will be determined.

2. MATERIALS AND METHODS

Oyster mushroom *P.ostreatues* was selected for the study of nutritional composition and Yield study because they are easy to grow and are readily available. The spawns of *P.ostreatues* were collected from Tamilnadu Agriculture Research institute (TNARI) Aduthurai. The cultivation of mushroom was determined using different type of substrate such as, Bamboo leaves (substrate-I), Coconut husk (substrate-II) and mixture of Bamboo leaves+ Coconut husk (substrate-III), they were selected because they are readily available as wastes and cause environmental problem by their burning in the fields.

The substrate was dried in shadow then they were chopped separately into 2-4 cm long soaked into the water overnight, excess of water dried off, and the moisture content in the substrate approximately 80%. Then they were separated and packed in polythene bags were dipped separately sterilized into the hot water bath at 80^0c for 1 hour, in an autoclave. The polythene bags of the size 35x 45cm were filled with sterilized substrate and spawning. Each bag was filled with 1 kg dry substrate and the spawn was added at the rate of 2% of wet weight basis of substrate. Then 10-12 holes were made in the polythene bags manually for gases elimination than transferred to the incubation room for spawn run. The humidity of bags was (70- 80%) accomplished by spraying of water on them twice a day.

After incubation of 22 days, bags were transported to the fruiting site; colonization of mycelia was seen clearly by naked eyes in these bags, all bags remained at the fruiting site for 3-5 weeks under dark condition at temperature of 25^0c.The first harvest was done at 22 days followed by 2nd and 3^{rd} harvesting was done at the time of each harvesting the fully grow mushrooms were removed from the substrate and the number were counted and recorded after that they were dried used for analysis of the nutritional values. The protein was estimated by Lowry's *et al*., (1951) carbohydrate by Anthrone method (Corral *et al.,* 1956) and lipid by Vanillian method (Barnes and Stack, 1973).

2.1 Statistical methods

The statistical program for scientific studies package (SPSS, 120 for window, SPSS inc.) was used to perform statistical analyses. Data are presented as mean with standard deviations (mean ± SD). A statistical significance difference was determined by One – way variance analysis (ANOVA). However, the P value of less than 0.05 was seemed to be statistically significant.

3. RESULTS AND DISCUSSION

The fastest mycelia extension was observed in coconut husk (substrate-II) followed by mixture of bamboo leaves + coconut husk (substrate- III), but only a few mycelia observed in bamboo leaves (substrate –I). Colonization of the substrate was completed in between 22-35 days of incubation. The total day for the first harvest of mushroom took between 20-22 days depending on substrate used. The Second harvest 23-27 days and third harvest 28-35 days. The poor natural substrates for the mycelia growth yield and nutritional value in oyster mushroom was substrate I (bamboo leaves) which may be due to different degradation by *P.ostreatus*. Mycelia growth is preliminary step that suitable internal conditions for fruiting. Thus standing growth of mycelia is a vital factor in mushroom cultivation (Pokhrel *et al*. 2009). Similar result was reported by Sharmila *et al*. (2015) in bamboo shoot.

Among the three substrate used for cultivation up to third harvesting (Fig-3) the higher percentage of fruiting bodies were found in case of coconut husk (substrate-II) 50 % and followed by combined substrate of bamboo leaves + coconut husk (substrate-III) 39 %,whereas the least number of fruit bodies obtained an bamboo leaves of substrate-I was 11% .

Nutrient content showed variation among the substrate is given in tables 1&2 During first harvest among three substrate coconut husk showed maximum protein (44.4g) and minimum protein was observed in substrate I (39.13g). The maximum carbohydrate content was observed in coconut husk of substrate II (33.1g) and minimum in substrate I (21.69g). The maximum lipid was observed in coconut husk (3.26g). And minimum was recorded in substrate I (1.68g).

During second harvesting minimum amount (30.1g) of protein was observed in substrate I and maximum was recorded in substrate II (40.87g). Carbohydrate showed maximum level in substrate II (25.53g) and minimum level in substrate I (20.28g). Lipid was observed in maximum level in substrate II (3.1) and minimum in substrate I (1.31 g).

In the present study the higher protein content (44.4g) was obtained from substrate II while the lowest (30.1g) from substrate I. protein contents of mushroom were reported to vary according to genetic structure of species, and physical and chemical differences in growing medium (Sanme *et al*; 2003; Biasaria *et al*.,1987; Agrahar- murugkur and Subbulakshmi, 2005). According to other worker (Breene, 1990; Co-Kuner and Ozdemir, 2000) protein contents of mushroom range from 19 to 39 g in 100g dried matter. Alam *et al.* (2008) found that the protein values (g/100g dried matter) as 23.91g in *P.ostreatus*, 24.63g in *P.sajar-caju*, 20.56g in *P.florida* and 21.4 g in *C.indica*. Edible mushrooms are highly valued as a good source of protein and their protein contents usually range from 28.93% to 39.1% of dry weight (Ragunathan and Swaminathan, 2003; Sanme *et al.*, 2003). It seems that the present study showed protein content was higher than that of reported early and also highly nutritious and good for human consumption. Both harvesting the study showed carbohydrate content range from 20.28 to 33.1 g/100 g was relatively high carbohydrate content. The study made by Wantanable *et.al,* (1994) found that the carbohydrate value as 47.9g in 100 g dry matter it was higher than our study. Edible mushrooms are highly valued as a good of carbohydrates and their contents usually range from 40.6% to 53.3% of dry weight (Khanna *et al.*,1992: Ragunathan *et al.*, 1996).

When compared with protein the carbohydrate and lipid content during both harvesting were less. These results suggest that mushroom is very good protein source for mankind who looks for new and alternative nutrition source all the time. Ramy and Yehia (2012) reported that mushroom can be considered as an alternative source of protein as it contain large quantities of essential amino acids and this can solve problems of vegetarian people all over the world who often suffer from protein deficiency. Mushrooms are very poor in lipid and very rich in protein characteristics of the edible wild mushrooms have been previously reported by Diez (2001), Sanme *et al.* (2003) Agrahan- Murugkar and Subbulakshmi (2005) and Mehmet Akyuz and Sevda Kubag (2010). Sharmila *et al.* (2015) suggested that mushroom are high in protein which is vital in maintenance of body tissue, including development and repair, they are not attacked by diseases and pest, so they can be grown in rural areas. In this experiment, different substrate has different nutrient composition of *P.ostreatus.* This result may be probably due to biological, chemical differences and the C/N ratio of the substrates which is also indicated by several authors (Sangwan and Saini, 1995).

One way ANOVA revealed significant variation on protein, carbohydrate and lipid in all the substrate (table 1&2) of both harvest during the study period. In conclusion the substrate coconut husk showed higher number of yield up to third harvest and nutritional value in both harvest. Hence coconut husk (substrate II) is very suited for mushroom cultivation in rural areas. The poor natural substrates for the nutritional value in oyster mushroom were substrate I (Bamboo leaves) which may be due to different degradation by *P.ostreatus*. Mushroom cultivation gives self employment for small farmers and especially for women's.

Table: 1 Nutritional composition of *Pleurotous ostreat*us during first harvest on various substrates (g/100g).

Nutrients	Substrates		
	Bamboo leaves	Coconut husk	Bamboo leaves+ Coconut husk
Protein	39.13±1.02*	44.4±0.30*	40.33±0.10*
Carbohydrate	21.69±0.16*	33.1±1.90*	25.73±0.03*
Lipid	1.68±0.40*	3.26±0.12*	1.83±0.29*

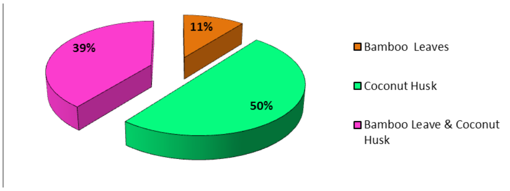
(Mean ± SD, n=3) *Significant at 0.05 level

Table: 2 Nutritional composition of *Pleurotous ostreatus* during second harvest on various substrates (g/100g).

Nutrients	Substrates		
	Bamboo leaves	Coconut husk	Bamboo leaves+ Coconut husk
Protein	30.1±0.00*	40.87±0.21*	40.07±0.07*
Carbo hydrate	20.28±0.05*	25.53±1.96*	21.43±0.87*
Lipid	1.31±0.04*	3.1±0.20*	1.4±0.38*

(Mean ± SD, n=3) *Significant at 0.05 level

Fig 3.



REFERENCES

Alam Nuhu, Ruhul Amin, R., Asaduzzaman Khan, Ismot Ara, Mi Ja Shim, Min Woong Lee and Tae SooLee, 2008. Nutritional Analysis of Cultivated Mushrooms in Bangladesh- *Pleurotus ostreatus,V Pleurotus sajor-caju Pleurotus florida* and *calocybe indica. Mycology,* 36(4), PP.228-232.

Agrahar-Murugkar, D. and Subbulakshmi. G. 2005. Nutritional value of edible wild mushrooms: collected from the Khasi hills of Meghalaya. *Food Chemistry*, 89, PP.599-603.

Breene, W.M. 1990. Nutritional and medicinal value of specialty mushrooms. *J. Food Protect,* 53(10), PP. 883-894.

Bernas and Stack, 1973. Edible mushroom as a source of valuable nutritive constituents. *Acts sci. pol. Technol Aliment* 5(1), PP.5-2.

Bisaria, R., Madan, N., Biseria,V.S. and Mukhopadhyay, 1987. Amino acid composition of mushroom *pleurotus sajor- caju* cultivated on different agro residues. *Biological wastes,* 20, PP.257-259.

Carrol, W.V., Longley, R.V. and Roe. J.H., 1956. The determination of glycogen in the liver and muscle with use of anthrone reagent. *J.Biol. chem*. 220, PP.583-593.

Ço-_kuner, Y. and Özdemir. Y. 2000. Acid and EDTA blanching effects on the essential element content of mushrooms (*Agaricus bisporus*). *J. Sci. Food Agric*, 80(14),PP. 2074-2076.

Diez, V.A. and Alvarez. A. 2001. Compositional and nutritional studies on two wild edible mushrooms from northwest Spain. *Food Chemistry*, 75, PP.417-422.

Eswaran, A. and Ramabadran. R. 2000. Studies on some physiological cultural and post harvest aspects of Oyster mushroom, *Pleurotus ostreatus*. *Tropi Agric Res,* 12, PP.360-374.

Gruen, V.E.C. and Wong. H.X. 1982. Immunomodulatory and Antitumor activities of a polysaccharide-peptide complex from a mycelia culture of *Trichoderma sp*.Sciences. 57, PP.269-261.

Jandaik, C. L. and Goyal. S.P. 1995. Farm and farming of oyster mushroom (*Pleurotus spp*). In; Singh and Chaube (eds) Mushroom Production Technology. G. B. Pant Univ. *Agri. and Tech*., Pantnagar, India. pp 72-78.

Kues, U. and Liu. Y. 2000. Fruiting body production in basidiomycetes. *Appl Microbiol Biotec* 54,PP. 141-152.

Khanna, P.K.R. Bhandari, G.L. and Soin, 1992. Evaluation of *Pleurotus spp*. For growth nutritive value and antifungal activity. *Indian J .Microbiol*., 32,PP.197-200.

Lowry, O.H., Roserbroug, N.J., Farr, A.L. and Randall. R.J. 1951. Protein measurement with the folin phenol reagent .*J Bio. Chem*.193, PP. 265-275.

Mehmet Akyuz. and Sevda Kubag, 2010. Nutritive value of wide edible and mushrooms. *Turkish. Biol*., 34, PP.97-102.

Pokhrel, C.P. Yadav, R.K.P. and Ohga. S. 2009. Effects of physical factors and synthetic media on mycelial growth of *Lyophyllum decastes*. *J. Ecobiotech* 1, PP. 46-50.

Ragunathan, R. Gurusamy, R. and Palaniswamy. M. 1996. Cultivation of *Pleurotus spp*. On various agro-residues. *Food Chemistry*, 55, PP.139-144.

Ragunathan, R. and Swaminathan. K. 2003. Nutritional status of *Pleurotus spp*. grown on various agro-wastes. *Food Chemistry*, 80,PP., 371-375.

Ramy, S. and Yehia, 2012. Nutritional value and biomass yield of the edible mushroom *Pleurotus ostreatus* cultivated on different wastes in Egypt. *Innovative Romanian Food Biotechnology*.11, PP. 9-14.

Sangwan, M.S. and Saini. L.C. 1995. Cultivation of *Pleurotus Sajor caju* (Fr.) Singer on agroindustrial wastes. *Mush Res* 4, PP. 33-34.

Sanme, R.B., Dell Lumyoung, P., Izumori, K. and Lumyoung. S. 2003. Nutritive value of popular wide edible mushrooms from Northern Thailand. *Food Chem*.82, PP.527-532.

Sharmila, S., Jeyanthi Rebecca, Trisha Tissopi. and Kowsalya. E. 2015. Effect of substrates on the cultivation of *Pleurotus ostreatus* and its nutritional analysis. Scholar Research Library,*Der Pharmacia Lettre*.7(8),PP.193-196.

Watanabe,T., Tsuehihasi, N., Takai, Y., Tanaka, K. and Suziki. A. 1994. Effect of ozone exposure during cultivation of oyster mushroom (*Pleuratus ostratus*) on chemical components of the fruit bodies. *J jpn Soc. Food Sci.* Technol.41,PP.705-708.

DIVERSITY, DISTRIBUTION AND CONSERVATION STATUS OF HERPETOFAUNA OF THE SHERPALLI- A PROPOSED SITE FOR URANIUM MINING PROJECT AT NALGONDA DISTRICT, TELANGANA, SOUTHERN INDIA

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ABSTRACT

In many ecosystems of India the amphibians and reptiles exist with great diversity of habitats and microhabitats such as deserts, grasslands, forests, oceans, hills, agro-ecosystems and even at Human Settlements Amphibians are widely considered to be useful as indicator species In India. During the present investigation, a total of 58 species, 46 genera and 18 families of herpetofauna were recorded, of which, 45 species were of reptiles, belonging to 33 genera and 14 families. Amphibians observed included 13 species belonging to 12 genera and 5 families. As per the Wildlife Protection Act, 1972, out of 13 species of amphibians 10 species are listed under the least concerned category and remaining species Guntur's toad (*Duttaphrynus hololis*) is listed under Rare category and Skittering frog (*Euphlyctis cyanophlyctis*) in Schedule IV category. Among reptiles, 26 species (58%) were common, 13 species (29%) were uncommon and 6 species (13%) were rare in occurrence in the study area. The status of reptiles under IWPA showed that 2 Species, Indian Rock Python (*Python molurus*) and Red sand boa (*Eryx johnii*) were listed under endangered category. Indian Black turtle (*Melanochelys trijuga*) was listed under Near Threatened category. Six species were under rare in nature and all other species were least concerned. This report indicated that the area is rich and must contain many more species of amphibians and reptiles that would fill gaps in understanding these species diversity and distribution patterns. Awareness programmes are needed in order to make people aware with herpetofaunal communities and their essential role for a balanced ecosystem.

Keywords: *Duttaphrynus hololis, Euphlyctis cyanophlyctis, Python molurus,* Diversity, Distribution

1. INTRODUCTION

In many ecosystems of India the amphibians and reptiles exist with great diversity of habitats and microhabitats such as deserts, grasslands, forests, oceans, hills, agro-ecosystems and even in our houses. More than 518 species of reptiles (Aengals *et al*., 2011) and 314 species of amphibians are found in India (Dinesh *et al*., 2011). According to IUCN criteria 57 percent of the amphibians in India are 'threatened' (Vasudevan *et al*., 2001). The prevailing climate, availability of food, moisture, microhabitat and human interference influence the herpetofaunal community in a particular area (Daniels, 1992). Habitat destruction and the resulting fragmentation of population are the most important factors affecting amphibian populations (Adams, 1999). Amphibians are widely considered to be useful as indicator species (Welsh and Ollivier 1998, Sheridan and Olson 2003). In India, besides the forest floor and stream communities of amphibians, there are few widely spread species in human modified and agro ecosystems (Daniels, 2005). The human modified ecosystems of the plains as that in rural, cultivated and semi urbanized areas attract number of species of frogs and toads. Studies on Herpetofauna in India include those of Dar *et a*l. (2008), Sarkar *et al*. (1993), Srinivasulu *et al*. (2006). Work on the herpetofauna in an area adjacent to a uranium mine is necessary, in order to demonstrate the effect of mining and further survey the herpetofauna of Peddagattu and Sherpalli area, Nalgonda district, Telangana state in India's Eastern Ghats. The study was carried out with an aim to generate the current status of herpetofauna in the area and to sensitize the conservation efforts.

2. METHODOLOGY

2.1 Study area

The present study was undertaken on the herpetofauna of proposed Uranium site at Sherpalli in Nalgonda district. The study was carried out over three years and estimated the annual herpetofaunal populations in all the three zones, habitats and seasons. Sherpally is located in Devarakonda mandal, Nalgonda district, Telangana state. The area was bounded on the north, east and west by Nalgonda District and in South by parts of Mahaboobnagar District. The study area forms a fragmented stretch between Nagarjuna Sagar Tiger Reserve (NSTR) and Krishna river associated forests. The area covered with varied types of habitats *viz*, scrub jungle, rocky hills, agriculture fields and wetlands (mainly back waters of Nagarjunasagar reservoir).

2.2 Methods

The study was carried out for three years between August, 2011 to March, 2014. The study area was divided into 3 zones *viz.,* 0 -5 Km (Core zone), 5-15 km (Buffer zone-I) and 15 –30 km (Buffer zone-II) as per BRNS guidelines. As per the topographical conditions the study area was further divided into several comportments or sectors. For the present investigation at Core zone was selected for 100% survey to record the biodiversity while at Buffer zone I and Buffer zone II the area coverage was10 % and 5% respectively. Sampling of amphibians were done both in aquatic and terrestrial systems. Sampling was done through day and night searching in all three seasons at all specified habitats (under the logs and stones, digging through litter and soil, searching short bushes and tree hollows and under fallen barks and water- catching and identifying the amphibians residing within). Samplings of amphibians were also done by quadrate method (10 x 10m) in well-defined plots by laying temporary or permanently in a variety of habitats. Care was also taken to place quadrats closer to water bodies as amphibians and some reptiles' show clustered distributional pattern (Daniels, 2005). Reptiles include Snakes, lizards, monitor lizards, chameleons, tortoise and turtles, Garden lizards were the common reptiles which were generally identified by direct or indirect evidences.In most of the cases a good photograph was taken for the identification. The road kills or dead were collected for preparing specimens and were preserved directly in 90% alcohol or 4-5% formalin. Identification was done mostly by using keys include Fauna of British India.

3. RESULTS

During the present investigation, a total of 58 species, 46 genera and 18 families of herpetofauna were recorded, of which, 45 species were of reptiles, belonging to 33 genera and 14 families. Amphibians observed included 13 species belonging to 12 genera and 5 families (Table 1). As per the Wildlife Protection Act, 1972, out of 13 species of amphibians 10 species are listed under the least concerned category and remaining species Guntur's toad (*Duttaphrynus hololis*) is listed under Rare category and Skittering frog (*Euphlyctis cyanophlyctis*) in Schedule IV category. Among reptiles, 26 species (58%) were common, 13 species (29%) were uncommon and 6 species (13%) were rare in occurrence in the study area. The status of reptiles under IWPA showed that 2 Species, Indian Rock Python (*Python molurus*) and Red sand boa (*Eryx johnii*) were listed under endangered category. Indian Black turtle (*Melanochelys trijuga*) was listed under Near Threatened category. Six species were under rare in nature and all other species were least concerned (Table 1&2).

The mean population of herpetofauna in different zones showed significant variations (Table 3). The mean population was high at buffer zone-I (6.6 ± 1.89) followed by buffer zone-II (5.6 ± 1.86) and Core zone (39 ± 1.27), while the species composition was high at buffer zone-I (35 species) followed by core zone

(25 species). The species diversity and Simpson's diversity values in all the 3 zones of study did not show any variations and indicate the homogeneity moderate distribution pattern of herpetofauna in the region. In agricultural areas, the mean population of herpetofauna was high (11.6 ± 3.9), having 1.4 diversity and 0.7 evenness values, followed by open habitat 3.4 ± 1.2 with 1.2 diversity and 0.8 evenness. The other habitats were showed more or less uniform density and diversity values (Table 3).

4. DISCUSSION

The herpetofauna of the Nallamala hills consist of 20 species of amphibians belonging to 12 genera in four families and 64 species of reptiles belonging to 42 genera in 15 families (Srinivasulu and Das, 2008). Prior to the studies, Tulsi Rao *et al.,* 2005, published an account of herpetofauna of the Nallamala hills putting on record about 66 species of herpetofauna including 18 species of amphibians in 11 genera in 34 genera in 12 families and in Seshachalam biosphere reserve reported 8 species of amphibians and 34 species reptiles (Guptha *et al*., 2012). Similarly, Reddy *et al.,* 2013, conducted studies at Thummalapalle Uranium mining area and reported 52 species belonging to 17 families. In the present study, outside the NSTR, reveals a total of 58 species 46 genera and 20 families very close to the collections made by earlier authors. It clearly indicates that in the present study, the available habitat features supporting reasonably good diversity of herpetofauna as evidenced by the reports of Srinvasulu and Das, (2008), Tulsi Rao *et al.,* (2012), Gupta *et al.,and* the data also clearly indicate that the mean population of herpetofauna and occurrence of species in different zones, habitats and seasons depends on the availability rocky hills, forest cover, wetlands and other critical habitats (Ryan *et al*., 2002). During the present study, *Rana hexadactyla* had the ability to adapt to all climate conditions, high reproductive capacity and utilization of variety resources. Another interesting observation made in the present investigation is reporting of range extinction of *Hemiductylus treutleri* (Laxmi Narayana *et al*., 2014), similarly occurrence of Gunther's toad (*Duttaphrynus hololius*) from Nagarjunasagar reservoir (buffer zone-II) (Adimallaiah *et al*., 2013). This report indicated that the area is rich and must contain many more species of amphibians and reptiles that would fill gaps in understanding these species diversity and distribution patterns. Awareness programmes are needed in order to make people aware with herpetofaunal communities and their essential role for a balanced ecosystem.

5. CONCLUSION

Major threats for herpetofauna of the Sherpally and surrounding environs were forest destruction, habitat fragmentation, habitat erosion and poaching activities. Present study has established the presence of a rich herpetofaunal diversity in the study area including 2 species Gunthur's toad and Skittering frog (*Euphylyctis cyanophlyctis*) and are listed under rare category. Among reptiles 6 species were rare occurrence and 2 species listed under endangered and two species listed under Near threatened category. This area needs urgent attention to preserve and conserve the remaining vegetation composition to protect the Herpetofauna diversity for long term sustainability.

Table 1. Statistics of reptiles with respect to family, genus, species and number.

Family	Genera	Percentage	Species	Percentage	Individual	Percentage
Agamidae	3	6.52	4	7.14	811	52.77
Boidae	2	4.35	2	3.57	7	0.46
Chamaeleonidae	1	2.17	1	1.79	9	0.59
Colubridae	13	28.26	14	25.00	110	7.16
Elapidae	2	4.35	2	3.57	15	0.98
Gekkonidae	1	2.17	7	12.50	52	3.38
Geoemydidae	2	4.35	2	3.57	16	1.04
Lacertidae	1	2.17	3	5.36	77	5.01
Scincidae	5	10.87	4	7.14	223	14.51
Typhlopidae	1	2.17	1	1.79	1	0.07
Viperidae	2	4.35	2	3.57	12	0.78
Pythonidae	1	2.17	1	1.79	1	0.07
Bufonidae	2	4.35	3	5.36	51	3.32
Dicroglossidae	1	2.17	1	1.79	18	1.17
Mycrohylidae	2	4.35	2	3.57	21	1.37
Ranidae	5	10.87	5	8.93	87	5.66
Rhacophoridae	1	2.17	1	1.79	19	1.24
Mycrohylidae	1	2.17	1	1.79	7	0.46
Total	46	100	56	100	1537	100

Table 2. Statistics of amphibians with respect to family, genus, species and number.

Family	Genera	Percentage	Species	Percentage	Individual
Bufonidae	2	16.7	3	23.08	51
Dicroglossidae	1	8.3	1	7.69	18
Mycrohylidae	3	25.0	3	23.08	21
Ranidae	5	41.7	5	38.46	87
Rhacophoridae	1	8.3	1	7.69	26

Table 3. Mean number and diversity indices of herpetofauna observed in relation to zones habitats and seasons

Zones							
Zones	**Mean**	**S.E**	**Richness**	**Range**	**Shannon**	**Simpson**	**Evenness**
Core	3.9	1.27	25	1-11	1.27	0.13	0.8
BZ-I	6.6	1.89	35	1-5	1.4	0.11	0.78
BZ-II	5.6	1.86	23	1-6	1.27	0.13	0.79
Habitats							
Habitat	**Mean**	**S.E**	**Richness**	Range	**Shannon**	**Simpson**	**Evenness**
Agri	11.6	3.9	27	1-10	1.4	0.1	0.7
Open	3.4	1.2	20	1-6	1.2	0.2	0.8
Wetland	2.1	0.8	14	1-2	1.1	0.1	0.9
Scrub	2.6	1	14	1-15	1.1	0.2	0.8
Rocky Hill	2.5	0.8	20	1-8	1.2	0.1	0.8
Season							
Season	**Mean**	**S.E**	**Richness**	Range	**Shannon**	**Simpson**	**Evenness**
Monsoon	8.5	1.2	24	1-18	1.9	0.03	0.9
Winter	5.6	0.8	43	1-12	1.8	0.03	0.6
Summer	5.6	0.9	26	1-7	1.7	0.04	0.5

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REFERENCES

Adams M. 1999. Correlated factors in amphibian decline: Exotic species and habitat change in western Washington. *J Wildlife Manage*, 63: pp. 1162- 1171.

Adimallaiah, D. Rao, V. V. and Surender, G. 2013. A Report on Gunther's Toad *Duttaphrynus hololius* (Gunther 1876) from Nalgonda District, Andhra Pradesh. *Cobra*,Vol, 6 (2), pp. 8-11.

Aengals, R.V., Satish, M. and Palot, M.J. 2011. Updated checklist of Indian reptiles. Zoological Survey of India. http://zsi.gov.in/checklist/Reptiles

Amarnath Reddy, Y., Sadasivaiah, B., Indira, P. and Pullaiah, T. 2013. Herpetofauna of Thummalapalle uranium mining area, Andhra Pradesh, India. *Int. J. Biodivers. Conserv,* Vol. 5(8), pp. 515-522.

Daniels, R.J.R. 1992. Geographical distribution patterns of amphibians in the Western Ghats, India. *J Biogeography*, 19: pp. 521-529.

Daniels, R. J. R., 2005. Amphibians of Peninsular India. Universities Press, Hyderabad, India, pp. 286.

Dar, T.A., Khan, J.A., Habib, B., Kushwaha, S.P. and Mendiratta, N. 2008. Assessment of Herpetofaunal Assemblage in Phakot and Pathri Rao Watershed Areas, Uttarakhand, India. *Int. J. Ecol Environ. Sci.* 34 2, pp 207-213

Dinesh, K.P., Radhakrishnan, C., Gururaja, K.V., Deuti, K. and Bhatta, G. 2011. A checklist of amphibia of India. Zoological Survey of India. http://zsi.gov.in/checklist/ Amphibia.

Guptha, M.B., Chalapathi Rao, P.V., Sivaram Prasad, N.V. and Sekhar Maddala, S.R.S.C., Madhu Babu, P. and Srinivas Reddy, D. 2012. Status of herpetofauna in Seshachalam Bioshere Reserve, Eastern Ghats, Andhra Pradesh, India. *World J. Zool,* 7(2), pp.131-134.

Laxmi Narayana, B., Naresh, B., Surender, G., Swamy, K. and Vasudeva Rao, V. 2014. Amphibian diversity (Order: Anura) at northern and central parts of Telangana, India. *Journal of Entomology and Zoology Studies* 2 (6), pp. 153-157.

Ryan, T.J., Philippi, T. , Leiden, Y.A., Dorcas, M.E., Wigley, T.B. and Gibbons, J.W. 2002. Monitoring herpetofauna in a managed forest landscape Effects of habitat types and census techniques, *Forest Ecology and Management*, 16, pp. 83–90.

Sarkar, A.K., Chandra, P.K. and Ray, S. 1993. Reptelia In, the Director, Zoological Survey of India (Eds) - Fauna of Andhra Pradesh, Part - I (Amphibia, Reptelia, Fishes). Zoological Survey of India, Kolkata, pp. 1-64.

Sheridan, C.D. and Olson, D. H. 2003. Amphibian assemblages in zero-order basins in the Oregon Coast Range. *Canadian Journal of Forest Research* 33, pp. 1452-1477.

Smith, P.W. 1961. The amphibians and reptiles of Illinois. Illinois Nature. Hist. Surv. Bull. 28(1): 1-298.

Srinivasulu, C. Srinivasulu B. and Nageswara Rao, C.A. 2006. Amphibian Fauna of Nagarjunasagar Srisailam Tiger Reserve, Andhra Pradesh. Records of Zoological Survey of India, Occasional Paper No. 245, pp. 1 - 57.

Srinivasulu, C. and Das, I. 2008. The Herpetofauna of Nallamala Hills, Eastern Ghats, India: An Annotated Checklist, With Remarks on Nomenclature, Taxonomy, Habitat Use, Adaptive Types and Biogeography. *Asiatic Herpetological Research* 2, pp. 110-113.

Tulasi Rao, K., Ghate, H.V., Sudhakar, M., Maqsood Javed, S.M. and Sivarama Krishna, I. 2005. Herpetofauna of Nallamalai hills with eleven new records from the Region including ten new records from Andhra Pradesh. *Zoos' Print journal*. 20 (1), pp. 1737-1740.

Vasudevan, K., Kumar A. and Chellam, R. 2001. Structure and composition of rainforest floor amphibian communities in Kalakad - Mundanthurai Tiger Reserve. *Curr Sci.* 80(3): pp. 406-412.

Welsh, H.H.J. and Ollivier, L.M. 1998. Stream amphibians as indicators of ecosystem stress: A case study from California's redwoods. *Ecological Applications.* 8, pp. 1118-1132

Whitaker, R. and Captain, A. 2004. Snakes of India– The Field Guide. Draco Books, Chengalpet, South India, pp. 481 pp.

STATUS, DISTRIBUTION AND DIVERSITY OF BIRDS IN AGRICULTURAL LANDSCAPES OF PEDDAGATTU AND SHERPALLY AREA: A PROPOSED URANIUM MINING SITES IN NALGONDA DISTRICT OF TELANGANA, INDIA

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1. INTRODUCTION

Birds constitute an important component in the agro-ecosystems, and gaining more and more attention (Ali, 1949 & 1971). The role of birds in agriculture is well known as agricultural landscapes provide a concentrated and highly predictable source of food to many birds (Ali, 1949). This food includes grains, seeds, fruits, green vegetation of the crop plants and grasses, insects, other arthropods, rodents etc. (O'Connor and Shrubb 1986; Asokan *et al.,* 2009). Birds that feed on harmful insects and other pests from the agro-ecosystem are beneficial to agriculturists (Asokan *et al.,* 2010; Narayana *et al.,* 2011 and 2014). In such situations, birds are considered as important bio-control agents, suppressing the insect pests. Therefore important predators like insectivorous birds need to be encouraged in the agro-ecosystem by use of appropriate management practices (Narayana *et al.,* 2016). Since these birds have attracted for many reasons, studies in agricultural ornithology in India have been given low priority and most of the attention is given to threatened species (Mukherjee *et al.,* 2002). No substantial data is exists on the Agri-biodiversity of Eastern Ghats hill ranges of Telangana region. Uranium Corporation of India Limited (UCIL) is undertaking mining and processing of Uranium ore on large scale and it is expanding its operation in Nalgonda district of Telangana state, which is endowed with huge uranium deposits. Uranium deposit has been established in Lambapur and Peddagattu in Nalgonda district of Telangana. In this context, the present study made an attempt to record avifaunal diversity in agricultural landscapes of the proposed uranium mining sites of Nalgonda. The generated data will help in preparation of environmental impact assessment studies and conservation of avian species for future endeavourers.

2. METHODOLOGY

2.1. Study area

Eddagattu is a proposed site for uranium mining is located close to Nagarjuna sagar reservoir at an elevation of around 719 fts from sea level and Sherpally located in Devarakonda mandal of Nalgonda district, Telangana state. It is about 100 km away from Hyderabad and the region has a general elevation of around 520 fts from sea level.

2.2. Methods

A field survey was conducted during the period December 2010 to March 2014 to obtain the checklist, diversity and richness of birds in five different agricultural habitats *viz*., Paddy, Cotton, Castor, Red gram and Fruit garden. One kilometer transect was laid and at every 200 m distance one point was taken and the bird species were recorded in the 20 m radius in a duration of 20 minutes (Hostetler and Main, 2001); bird species, number of individuals, starting and ending time, weather condition, - crop type, phenology of the crop, *etc*. were also recorded. Bird species were identified using binoculars (7×50) and standard field guides (Ali, 2002; Grimmett *et al.,* 2011). The bird surveys were carried after two hours of sunrise and before two hours of sunset.

2.3 Data analysis

The BIODIVERSITY-PRO version 2.0 software was used for the statistical analysis. Species diversity was calculated using Shannon-Weiner (1949) index: $H' = -\Sigma Pi(\ln Pi)$ where H'= Shannon-Weiner Index Pi = the proportion of the each species in the sample, The Evenness calculated by using following formula $J' = H'-1/S$ H=Species diversity index; S=Number of species and Species richness was calculated using the number of species recorded in various habitat types. We have also applied Bray-Curtis Cluster Analysis (Single Link) test to understand the similarity or impact of bird diversity and richness with reference to the different crop types.

3. RESULTS

A total of 128 species of birds belonging to 59 families and 19 orders were recorded in the study area. Of which six bird species were listed as Near Threatened (Black headed Ibis *Threskiornis melanocephalus,* Painted Stork *Mycteria leucocephala*, Oriental Darter *Anhinga melanogaster*, Pallid Harrier *Circus macrourus*, River Tern *Sterna aurantia* and Alexandrine Parakeet *Psittacula eupatria*) and one species as Vulnerable (Woolly-necked Stork *Ciconia episcopus*) in (IUCN, 2016) category. The species diversity and species richness were showed high in Paddy (n=111) 2.07 *H'* (199 species, 33.80 ± 4.97) followed by Cotton (n=69) 1.86 *H'* (73 species, 18.64 ± 3.34), Castor (n=57) 1.83 *H'* (11.39 ± 1.92), Fruit garden (n=31) 1.80 *H'* (67 species, 7.72 ± 1.64) and Red gram (n=36) 1.79 *H'* (6.18 ± 1.09). Out of total 128 birds, 32 species found to be common, 27 are abundant, 32 are occasionally seen and 9 are rare in occurrence. Whereas, 64 species are resident, 53 species are breeding, 9 species are local migrant and 27 species are winter migrants to the study area (Table 1 and 2). Bray-Curtis Cluster Analysis (Single Link) was performed to show the bird species association in relation to different crops. The percent similarity matrix values were showed high relation in Castor/Fruit garden (71.46%) followed by Castor/Cotton (70.11%), Castor/Red gram (67.60%) and Paddy/Castor (63.72%) (Fig.1-3). Among the six foraging guilds Insectivorous birds were highly represented with 35% (45 species), followed by Omnivorous 31% (39 species), Granivorous 17% (17 species), Frugivorous 13% (10%), Carnivorous 7% (9 species) and Nectarivorous 4% (5 species).

4. DISCUSSION

Results of the present study indicate that the study area is an ideal habitat for terrestrial bird composition. Red-vented Bulbul, Common Babbler, Common Myna, Black Drongo, Small Green Bee-eater were widespread and common occurring abundantly in all habitats. Black Drongo was observed as the most dominant bird during the study period. These generalist birds are capable of thriving in a variety of habitats. Generalist is any phenotype whose fitness in one patch preciously equals its fitness in the other (Rosenzweig, 1981). Though Common Crow was common species but was not recorded in all the habitats during the study period. The trends indicate that agricultural fields surrounded by shrubs are attracts in more number of insectivorous birds by providing the required food resources. Besides the food supply, the shrubs also serve as ideal perching sites for the insectivore birds.

Foraging categories of birds revealed that insectivorous were recorded in high percentage in all habitats. However, a few graminivorous and nectarivorous bird species were recorded during the study period, in association of flowering and fruiting crops (Red gram, Fruit garden). Bird species richness and community structure differ from region to region (Richards, 1996; Pearson, 1975). Within a single community, the structure may vary. There were noticeable variations among species richness and diversity in the present study. Species diversity was observed to be the highest in Paddy due to presence of more number of sources such as food, feeding sites, roosting, nesting sites, *etc*. The avian diversity of an area indicates the health of that ecosystem. They are highly mobile vertebrates and easily observed indicators of change. In recent year's loss of primary forest has been intensified more rapidly due to various reasons (Raman and Sukumar, 2002). Bird community studies have been frequently used for conservation assessment and monitoring (Daniels, 1989). Research at community level of birds in the Indian subcontinent is essential as large-scale changes have been taking place in natural habitat of birds (Khan *et al,*. 1993). A thorough understanding of the effect of habitat on birds may also help in predicting the effects of management on bird population (Javed and Kaul, 2002). Density and diversity are very useful attributes and are valuable indicators of habitat quality and have great significance from the management perspective (Javed, 1996).

5. CONCLUSION

The present study indicates that the agricultural landscapes were attracting more number of bird diversity due availability variety of sources such as food, feeding sites, roosting, nesting sites and are important for the occurrence and abundance of Insectivorous birds. Insectivorous birds need to be encouraged in the agro-ecosystem by use of appropriate management practices. Eco-friendly management methods are essential for conservation of avian species in agricultural ecosystem. Further studies are needed for a longer period to determine the species specific relations to develop conservation measures for agricultural birds.

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REFERENCES

Ali, S. 1949. Bird friends and foes of the cultivator, *Indian Farming*, vol. 10, pp. 385-387.

Ali, S. 1971. Sunder Lal Hora memorial lecture. Ornithology in India: its past, present and future; Proc. *Indian Natl. Sci. Acad*, vol. B37, pp. 99-113

Ali, S. 2002. *The book of Indian birds (13th Edition)*, Mumbai: Bombay Natural History Society, Oxford University Press, pp. 326.

Asokan, S., Ali, A.M.S. and Manikannan, R. 2009. Diet of three insectivorous birds in Nagapattinam District, Tamil Nadu, India-a preliminary study, *Journal of Threatened Taxa* vol. 1(6), pp. 327-330.

Asokan, S., Ali, A.M.S. and Manikannan, R. 2010. Foraging behavior of selected birds in Cauvery Delta region of Nagapattinam District, Tamil Nadu, India - a preliminary study. *Journal of Threatened Taxa*, vol. 2(2), pp. 690-694.

Daniels, R.J.R. 1989. A conservation strategy for the birds of the Uttar Kannada District, *Ph.D. Dessertation*, Indian Institute of Science, Bangalore.

Grimmett, R, Inskipp C. and Inskipp T. 2011. *Birds of the India, Pakistan, Nepal, Bangladesh, Bhutan, Sri Lanka and the Maldives*, New Jersey: Princeton University Press, pp. 528.

Hostetler, M. E. and Main, B. M. 2001. *Florida Monitoring Program: Point Count Method to Survey Birds*, University of Florida IFAS Extension.

Javed, S. 1996. Study on Bird Community Structures of Terai Forest in Dudwa National Park, *Ph.D. Dissertation*, Aligarh, India: Aligarh Muslim University.

Javed, S. and Kaul, R. 2002. *Field Methods for Bird Surveys*, Mumbai: Bombay Natural History Society.

Khan, J, Khan, N.D. and Ahmed, A. 1993. Preliminary investigation of bird community structure at Aligarh, India, *Tropical Ecology*, vol. 34(2), pp. 217-225.

Mukherjee A K, Board, C. K. and Parasharya, B.M. 2002. Breeding Performance of the Indian Sarus Crane in the Agricultural Landscape of Western India, Biological Conservation, vol. 105, pp. 263-269.

Narayana, B.L, Pandiyan, J. and Rao V.V. 2011. Studies on avian diversity in selected croplands of Nalgonda District, Andhra Pradesh, Southern India. In: Bhupathy S, Prusty BAK, Kumara HN, Jayaraj RSC, Quadros G, Pramod P, editors, Status of Indian Birds and Their Conservation, *Proceedings of "First International Conference on Indian Ornithology*", Coimbatore: Salim Ali Centre for Ornithology and Natural History (SACON), pp. 47-49.

Narayana, B.L, Rao, V.V. and Pandiyan, J. 2016. Four insectivorous birds in search of foraging niche in and around an agricultural ecosystem of Nalgonda district of Telangana, India, *Ambient Science*, vol. 3(1), pp. 1-9. DOI: 10.21276/ambi.2016.03.1.ra01.

Narayana, B.L, Rao, V.V. and Venkateswara Reddy, V. 2014. Foraging behavior of Black drongo (*Dicrurus macrocercus*) in Nalgonda district of Andhra Pradesh, India, *The Bioscan,* vol. 9(2), pp. 467-471.

O'Connor, R. and Shrubb, M. 1986. Farming and birds (Cambridge: Cambridge University Press) Parasharya, B.M, Dodia, J.F, Yadav, D.N & Patel, R.C. (1986) Sarus crane damage to paddy crop, *Pavo*, vol. 24, pp. 87-90

Pearson, D.L. 1975. Range extensions and new records for bird species in Ecuador, Peru, and Bolivia. Condor 77: 96-99.

Shannon, C.E. and Weiner, W. 1949. The Mathematical theory of Communication. University of Illinois Press, Urbana.

Raman, T.R.S. and Sukumar, R. 2002. Responses of tropical rain forest birds to abandoned plantations edges and logged forest in the Western Ghats, India, *Animal Conservation*, vol. I5, pp. 201-216.

Richards, P.W. 1996. The tropical rain forest an ecological study, Second edition. Cambridge: Cambridge University Press.

Rosenzweig, M.L. 1981. A theory of habitat selection, *Ecology*, vol. 62(2), pp. 327-335.

Table 1. Status of birds recorded with respective to different orders during the study period.

Sl. No	Order	Family	Species	Genus	Occurrence				Status			
					Common	Abundant	Rare	Occasional	Resident	Breeding	Local Migrant	Winter Migrant
1	Podicipediformes	1	1	1	1	0	0	0	1	1	0	0
2	Pelecaniformes	2	10	8	7	1	1	2	8	5	1	1
3	Suliformes	2	2	2	0	1	1	0	2	1	0	0
4	Ciconiformes	1	4	3	0	1	2	0	1	0	1	2
5	Anseriformes	1	1	1	0	0	0	1	0	0	1	0
6	Accipitriformes	1	6	6	3	1	1	2	6	3	0	1
7	Galliformes	1	3	3	1	2	0	0	3	3	0	0
8	Gruiformes	1	4	4	1	2	0	1	4	3	0	1
9	Charadriformes	5	8	7	1	1	0	5	2	2	2	4
10	Columbiformes	1	6	2	3	1	0	2	4	3	0	3
11	Pterocliformes	1	1	1	0	0	0	1	0	0	0	1
12	Psittaciformes	1	2	2	1	0	1	0	2	1	0	0
13	Cuculiformes	1	7	6	1	2	2	2	3	3	1	3
14	Strigiformes	2	3	3	0	1	1	1	2	2	0	1
15	Caprimulgiformes	1	1	1	0	0	0	1	0	0	1	0
16	Apodiformes	1	1	1	1	0	0	0	1	1	0	0
17	Coraciformes	2	3	2	3	1	0	0	2	2	0	2
18	Piciformes	1	1	1	0	0	0	1	1	1	0	0
19	Passeriformes	24	63	38	1	13	0	13	22	22	2	8
	Total	**59**	**128**	**92**	**32**	**27**	**9**	**32**	**64**	**53**	**9**	**27**

Table 2. Bird species diversity, evenness and richness recorded in the different crops.

Crop type /Habitat (N=304)	Shannon index (H')	Shannon evenness (J')	Simpsons Diversity (D)	Species richness	Mean ± S.E	No. of Individuals	Range
Paddy (N=111)	2.07	0.83	0.03	119	33.80 ± 4.97	4211	1-325
Castor (N=57)	1.83	0.86	0.04	68	11.39 ± 1.92	1401	1-109
Cotton (N=69)	1.86	0.84	0.04	73	18.64 ± 3.34	2293	1-224
Red gram (N=36)	1.79	0.87	0.04	61	6.18 ± 1.09	760	1-75
Fruit garden (N=31)	1.80	0.82	0.05	67	7.72 ± 1.64	964	1-136

Fig.1. Percent similarity matrix of birds in relation to different crops.

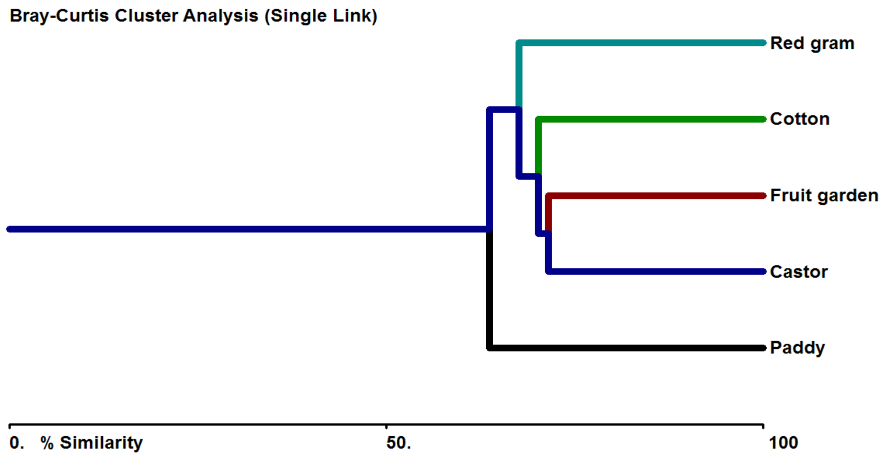


Fig.2. Grouping of birds in relations to different orders recorded during the study period.

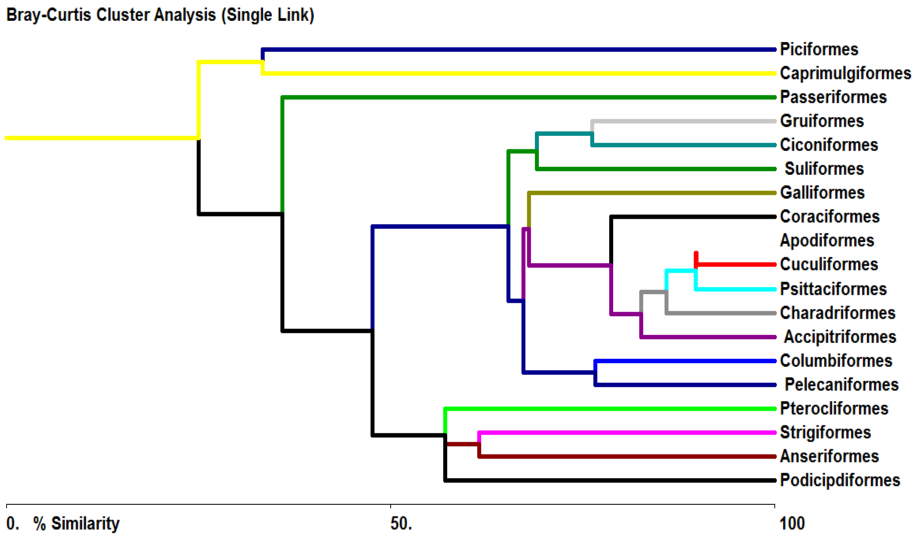
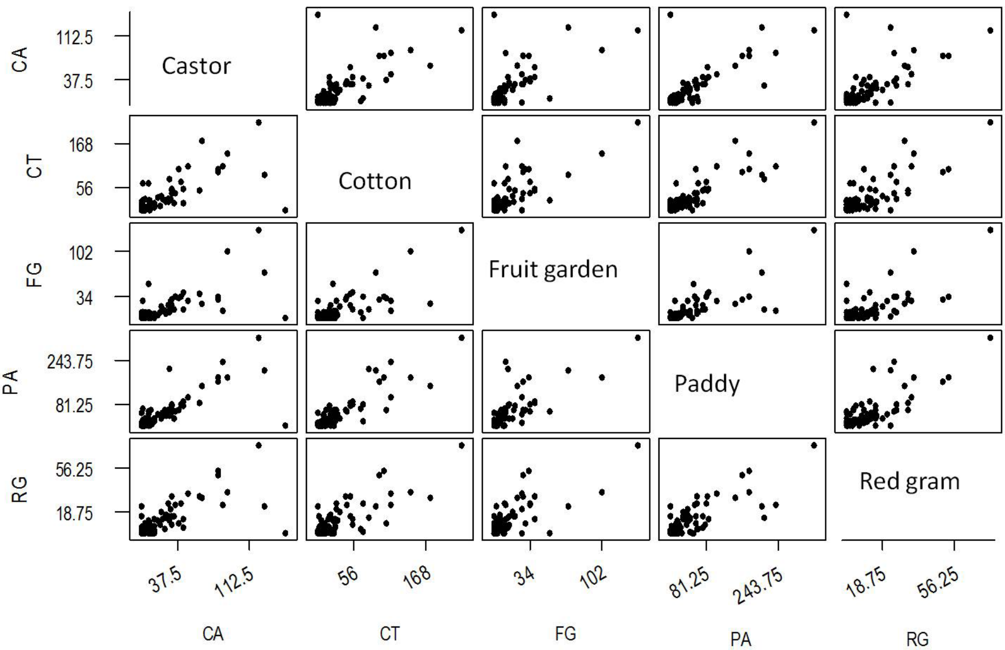


Fig.3. Multidimensional species abundance plots of the Bray–Curtis similarity among all crops plotted during sampling period. Each individual species is represented by one point, and closer points indicate greater dietary similarity



EFFECT OF INSECTICIDE AND FUMIGATION ON SPIDERS: THE BIO-CONTROL AGENT IN GODOWN

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ABSTRACT

Food grains form an important part of the Indian diet. Storage of grain plays a vital role in preventing their loss caused by insects, rodents and micro-organisms. A large number of insect pests are well known to affect the stored grains. Although, many physical and chemical measures are developed to prevent the infestation of stored products, integrated pest management, biological methods is more essential for safety of consumers and the environment as a whole. Spiders play a major role in controlling insect pest especially in agriculture crops and stored grains, with their diverse range of foraging behavior. To understand the spider community of storage godown and assess the effect of insecticide and fumigation used in godown on the spiders of storage places, we surveyed the spiders community in different godowns and compared their density before and after the application of insecticide and fumigation in the godown in Nagapattinum District, Tamil Nadu between December 2011 and March 2012. The survey was carried out in two different godowns (one with paddy and another with grocery items) employing six random plots ($1m^2$) on weekly interval. Overall, nine species of spiders—*Crossopriza lyoni, Pholcus phalongioides, Plexippus paykuli, Plexippus petersi, Lycosa tista, Cyrtophora cicatrosa, Achearanea mundula, Priitha* sp. and *Heteropoda venatoria*—belonging to seven families were recorded with varied densities in the two godowns. In paddy godown, Shannon-Wiener diversity (1.3856) and Evenness index (0.63062) were higher compared to grocery godown, while Species Richness (1.1484) and Dominance Index (0.4149) were higher in the grocery godown. Comparison of density estimated, based on selected spiders, for both before and after the applications of insecticide and fumigation revealed that the density decreased significantly after the applications ('t' test; $p<0.05$), indicating the detrimental effect these chemicals on spiders, which act as potential predators of insect pest in the godowns. Therefore, measures to be taken to minimize the usage of such chemicals and conserve the spiders in the godown so as to maintain hygienic food and environment.

Keywords: Density, Diversity, Fumigation, Godown, Insecticide, Spider.

1. INTRODUCTION

Food grains form an important part of the Indian diet. Grain storage plays an important role in preventing quantitative as well as qualitative losses caused mainly by the insects, rodents, and micro-organisms. A large number of insect pests have been reported to be associated with stored grains. The prophylactic measures to prevent the infestation of stored products have been developed. Even though, the integrated pest management would be necessary for maintaining the quality of food grains with biological methods that are safe for the grains, the farmers, the consumers and the environment as a whole. In this context the spiders are considered to be one of the best friends of farmers as bio-control agents, because they feed on insects pests with diverse range of foraging behaviour.

Spiders (Araneae) are a ubiquitous predator within the class Arachnida. Spiders can limit insect densities as well as stabilize population by virtue of their micro habitat use, prey selection, polyphagy and obligate predatory feeding strategies (Young and Edwards, 1990; Marc and Canard, 1997; Marc *et al.,* 1999; Nyffeler and Sunderland, 2003). Bristowe (1941) reported that the availability of spiders in any locality depends on the occurrence of the number of insects in that area. Because of their abundance and predominantly insectivorous feeding habits, spiders are suspected to play an important predatory role in agro ecosystems, woodlands and other terrestrial ecosystems (Nyffeler, 1999).

Even though, the populations of spiders in agricultural fields were found to vary depending upon the agricultural practices as well (Hummel *et al.,* 2002). A large number of reports are available on the variations in spider density with reference to the agricultural practices *viz.,* organic regime (Cardenas *et al.,* 2006) and pesticide use Marc *et al.,* 1999; Holland *et al.,* 2000; Amalin *et al.,* 2001; Hummel *et al.,* 2002). Negative effects of applications of inorganic fertilizer and pesticides in the crop field are of great concerns in recent times. Cardenas *et al.* (2006) reported that spider abundance proved significantly higher in organic regime than in conventional regime in olive trees. Similarly intensive application of insecticides during the growing seasons might also eliminate most arthropods including spiders. The agricultural fields that were frequently sprayed with pesticides often had lower spider populations (Holland *et al.,* 2000; Amalin *et al.,* 2001).

In addition to that continuous use of a wide range of pesticides and inorganic fertilizes to intensify agriculture has caused many side effects, including loss of biodiversity, the problem of secondary pests, insecticide resistance, the resurgence of insect pests, residual toxicity and environmental pollution. Policies during the last decades have been working towards improving production methods with reduction in these negative effects. The use of biological control agents like spiders in the greenhouse environment had been shown to be a viable alternative to pesticide use from both environmental and economic perspectives (van Lenteren, 2000). In spite of several applied values mentioned above, spiders have received cursory attention. So far there was no record for the effect of insecticides on the spiders in the store house (godown). Hence, this study was analysed the density, diversity and evaluate the effect of insecticide and fumigation on the spiders in the store house.

2. MATERIALS AND METHODS

The extensive survey were carried out to document the various species spiders, their density, diversity and the effect of insecticide and fumigation on them in the paddy godown and grocery godown (stored cereals, pulses and sugar) situated in the village Sitharkadu, Mayiladuthurai Taluk of Nagapattinum District, Tamil Nadu, India between December 2011and March 2012. The survey was carried out on 0.3 acre of each godown using six random plots, measuring 1 X 1m with weekly interval. The populations of different species of spiders were estimated by direct count method (Sebastian *et al.,* 2005). The density assessment of spider was reported as number / m^2. The diversity of spiders across godowns were analyzed by widely used indices like the Shannon – Wiener index (H^1) (Shannon and wiener, 1949), species richness, evenness index and index of dominance. The effect of insecticides and fumigation were assessed by comparing the density of four selected spiders between before and after the applications of insecticides and fumigations with 24 hours interval. The same procedure was repeated thrice during the study period. Basic statistics *viz.,* arithmetic mean, and standard error were calculated for all the replicate variables and are given as $\bar{X} \pm$ 1SE. Mainly parametric tests *viz.,*'t' test was used to test the hypothesis for insecticidal and fumigation effects.

3. RESULTS AND DISCUSSION

Nine species of spiders *viz., Crossopriza lyoni, Pholcus phalongioides, Plexippus paykuli, Plexippus petersi, Lycosa tista, Cyrtophora cicatrosa, Achearanea mundula, Priitha* species and *Heteropoda venatoria* belonging to seven families were recorded with varied densities in two godowns. This result indicated that both godowns might be provided the same microclimatic conditions (Canard, 1990) or the availability of prey (Sigsgaard, 2000), they have been attributed to be responsible for variations in the richness and composition of spider species in the study area. All the nine species of spiders were recorded in both the godown, eventhough *C. lyoni* and *P. phalongioides* belonging to Pholcidae family were the predominant species in both godowns studied (Fig. 1). Studies on the biology of spiders by

Sebastian and Peter (2009) indicated that Pholcidae prefer buildings, stones and dark places. In paddy godown, Shannon-Wiener diversity (1.3856) and Evenness index (0.6306) were higher compared to grocery godown, while Species Richness (1.1484) and Dominance Index (0.4149) were higher in the grocery godown (Table 1). The variation in population and composition of spiders in different godowns might be directly related to the availability of insects in the godown. In the present study the availability of insect pests in the godown was not studied, thus further studies need to fulfill this lacuna.

Comparison of density estimated, based on selected spiders, for both before and after the applications of insecticide and fumigation revealed that the density decreased significantly after the applications ('t' test; $p<0.05$) (Table 2). This indicates the detrimental effects of these chemicals on spiders, which act as potential predators of insect pest in the godowns. This result was coincided with many works in agro ecosystems. Many studies had also shown that the use of chemicals to decrease the diversity of spiders, in orchards (Specht and Dondale, 1960; of China (Zhao *et al*., 1980), in the cereal fields of France (Fischer, 1987) and in paddy (Lee *et al.,* 1993a, b). Successful management of insect pests in godown is possible when proper storage practices are implemented. Insecticides and fumigants should be viewed as supplements to limits insect pests in stored grains, Loganathan and Singaravadivel (2004) were experimentally proved the application of insecticides and fumigation reduced 80% of grain lice population in paddy storage godown. Even though the insects were develop the resistance to certain insecticides (Weinzierl and Higgins, 2008). More over the usage of insecticides and fumigation is increased manifold. This would cause certain problems to the health of the consumers (live-stock or humans) by treated grain or grain products. The management efforts must be limited to "nonchemical" methods of control, such as cultural practices (sanitation, adequate drying, cleaning, aeration and annual rotation of the commodity) and release beneficial insects (Weinzierl and Higgins, 2008). Thus, more studies are necessary to assess the effects of noted chemical substances commonly used in godowns that might affect the spiders and measures to be taken to minimize the usage of such chemicals and maintain the spiders in the godown so as to maintain hygienic food and environment.

Figure 1. Mean density (number/m^2) of various species of spiders in two godowns.

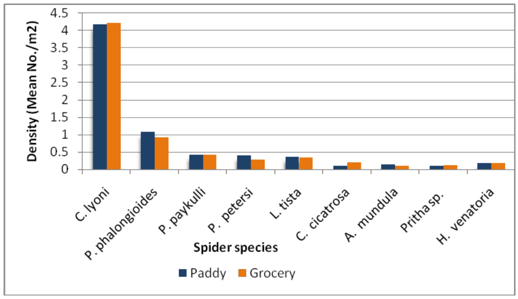

Table 1. Diversity of spider species in two godowns.

Diversity Indices	Paddy godown	Grocery godown
Shannon –Wiener Index	1.3856	1.3592
Species Richness	1.1433	1.1484
Evenness Index	0.6306	0.6186
Index of dominance	0.3921	0.4149

Table 2. Effect of insecticide and fumigation on the spiders density (Mean ± 1 SE; 't' test, $p < 0.001$)

Name of the Spiders	Paddy Godown		Grocery Godown		t	p
	Before Application	After Application	Before Application	After Application		
Crossopriza lyoni	5.17 ± 0.54	2.67 ± 0.36	5.99 ± 0.35	2.46 ± 0.22	9.059	0.000
Pholcus phalongioides	1.69 ± 0.42	0.83 ± 0.27	1.35 ± 0.27	0.50 ± 0.12	3.288	0.000
Plexippus paykulli	0.74 ± 0.26	0.24 ± 0.10	0.61 ± 0.17	0.13 ± 0.05	3.644	0.000
Plexippus petersi	0.45 ± 0.18	0.17 ± 0.08	0.46 ± 0.12	0.08 ± 0.03	3.272	0.000

REFERENCES

Amalin, D.M., Pena, J.E., Yu, S.J. and Mc Sorley, R. 2000. Selective toxicity of some pestisides to *Hibana velox* (Araneae: Anyphaenidae), A predator of Citrus Leafminer. *Florida Entomol.,* 83 (3): 254-262.

Amalin, D.M., Pena, J.E., Mc Sorley, R., Browning, H.W. and Crane, J.H. 2001. Comparison of different sampling methods and effect of pesticide application on spider populations in lime orchards in South Florida. *Environ. Entomol*., 30: 1021-1027.

Bogya, S. and Marko, V. 1999. Effect of pest management systems on ground-dwelling spider assemblages in an apple orchard in Hungary. *Agric. Ecosyst. Environ*., 73: 7-18.

Bristowe, W.S. 1941. *The Comity of Spiders*. Vol. II. London: Ray Sec. London, p. 560.

Canard, A. 1990. Heathland spider communities : a functional group study. *In:* Proc. 11th Int. congr. of Arachnology, Turku, Finland, *Acta Zool. Fenn.* 190 : 45-50.

Cardenas, M., Ruano, F., Garcia, P., Pascual, F. and Campos, M. 2006. Impact of agricultural management on spider populations in the canopy of Olive trees. *Biol. Control,* 38: 188-195.

Fischer, L. 1987. Etude compare de l' incidence de trios insecticides deltamethrines, dimethoate, phosalone sur la fauna des Arthropodes epiges des agrosystem cerealiers. Cas d'un de' ble d'hiver. These de 3eme cycle. University of Paris. 11 :p 325.

Holland, J.M., Winder, L. and Perry, J.N. 2000. The impact of dimethoate on the spatial distribution of beneficial arthropods in winter wheat. *Ann. Appl. Biol*., 136: 93-105.

Hummel, R.L., Walgenbach, J.F., Hoyt, G.D and Kennedy, G.G. 2002. Effects of vegetable production system on epigeal arthropod populations. *Agric. Ecosyst. Environ*., 93: 177-188.

Lee, H.P., Kim, J.P. and Jun, J.R. 1993a. Utilization of insect natural enemies and spiders for the biological control in rice paddy field, community structure of insect pest and spiders, suppress effect on insect pest by natural enemies, and their over wintering habitats in rice paddy field. RDA. *J.Agric. Sci. (Agric. Inst. Coop)* 35 : 261-274.

Lee, H.P., Kim, J.P. and Jun, J.R. 1993b. Influence of the insecticidal application on the natural enemies and spider community. *J.Indus. Tech.Grad. Sch. Dongguk. Univ.,* 1 : 295-307.

Loganathan, M and Singaravadivel, K. 2004. Evaluation of Insecticides for the Control of Grain Lice, *Liposcelis* sp. *Pest. Res.J.* 16(1): 33-34.

Marc, P. and Canard, A. 1997. Maintaining spider biodiversity in agroecosystems as a tool in pest control. *Agric. Ecosyst. Environ*., 62: 229-235.

Marc, P., Canard, A. and Ysnel, F. 1999. Spiders (Araneae) useful for pest limitation and bioindication. *Agric. Ecosyst. Environ.,* 74: 229-273.

Nyffeler, M. 1999. Prey selection of spiders in the field. *J. Arachnol*., 27:317-324.

Nyffeler, M. and Sunderland, K.D. 2003. Composition, abundance and pest control potential of spider communities in agroecosystems: a comparison of European and US studies. *Agric. Ecosyst. Environ*., 95: 579-612.

Sebastian, P.A., Mathew, M.J., Pathummal Beevi, S., Joseph, J. and Biju, C.R. 2005. The spider fauna of the irrigated rice ecosystem in Central Kerala, India, Across different elevational ranges. *J. Arachnol*., 33: 247-255.

Sebastian, P.A. and Peter, K.V. 2009. *Spiders of India*. Universities Press (India) Hyderabad, India. 395.

Shannon, C.E. and Wiener, W. 1949. *The Mathematical Theory of communication.* Illinois University Press. Urban, 111.

Sigsgaard, L. 2000. Early season natural biological control of insect pest in rice by spiders – and some factors in the management of the cropping system that may affect this control. *In :* Toft, S and Scharff, N (Eds), Proc. 19th European colloquium of Arachnology, Arhus, *Eur. Arachnol*. p. 57-64.

Specht, H.B. and Dondale, C.D. 1960. Spider populations in New Jersey apple orchards. *J. Econ. Entomol*., 53: 810-814.

Tanaka, K., Endo, S. and Kazano, H. 2000. Toxicity of insecticides to predators of rice planthoppers: Spiders, the mired bug and the dryinid wasp. *Appl. Entomol. Zool*., 35: 177-187.

Van Lenteren, J.C. 2000. Measures of success in biological control of arthropods by augmentation of natural enemies. *In :* Gurr, G. and Wratten. S (Eds), *Measures of success in Biological control.* Khewer Academic Publishers. Dordrecht. p. 77-103.

Weinzierl,R. and Higgins, R. 2008. Insect Pest management for stored grain. http://ipm/illinois.edu/pubsliamph/05chapter.pdf. dt.11.08.2011.

Young, O.P. and Edwards, G.B. 1990. Spiders in United States field crops and their potential effect on crop pests. *J. Arachnol*., 18 : 1-27.

Young, O.P. and Lockley, T.C. 1994. Spiders of an old field habitat in the delta of Mississippi. *J. Arachnol.,* 22: 114-130.

Zhao, J., Liu, F. and Chen, W. 1980. Preliminary studies of the life history of *Misumenops tricuspidatus* and its control of cotton pests. *Acta Zool. Sin.,* 26 (3) : 255-261.

APPLICATION OF STANDARD MODELS TO EVALUATE GLOBAL WARMING POTENTIALS OF GREEN HOUSE GASES IN INDIA

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ABSTRACT

In India it is observed that more than 90% of Municipal Solid Waste (MSW) is disposed on land without taking any specific precautions. Methane emission from landfills amount to 6 to 020% of total methane emission from the anthropogenic sources. It is highly imperative to assess the landfill methane (CH_4) and Nitrous oxide emission from such sources. Application of models for inventorying and replicating the methane emission to the wide area is crucial and critical for determination of the management practices required to be followed to mitigate global warming. Different models *viz*., IPCC, Theoretical First Order Decay model (FOD) and USEPA regression models were available for assessment. The scope for the IPCC model used here may be extrapolated extensively to the other areas. Unlike the methane emission models, nitrous oxide emission is enumerated by seasonal integration of flux

Keywords*: Landfill, MSW, Methane emission, IPCC*

1. INTRODUCTION

Methane influences the background photochemical system and also affects the earth's thermal budget by absorbing infrared radiation around 8µm. At the current rate of increase by the middle of the next century the greenhouse emission of methane is expected to be nearly 25% as that arising from increasing co_2 concentrations (Dickinson *et al.,* 1986). To control these emissions, it is necessary to identify the various processes contributing to increase in atmospheric methane concentration. Methane released to the atmosphere by biogenic and abiogenic processes. IPCC (1992) estimated global anthropogenic sources to emit a total methane emissions of 352 - 360 Tg/yr, out of which landfills expected to contribute 20 - 70 Tg/yr representing 6 to 20 % of the total.

2. MATERIALS AND METHODS

In the calculation by Bingemer and Crutzen (1987), it was assumed that the ratio of organic matter in land filled waste corresponded to a certain amount of methane. The models of today are also developed from this approach. The IPCC model for estimation of national methane budgets for landfills (IPCC 1996) has become the common standard (Froiland Jensen *et al.,* 1999). The landfill methane emission at specified time domain is estimated by the use of static chambers. They have been placed on the landfill surface with an open part attached to the surface and the accumulated methane concentration in the closed volume has been measured.

Method I : In this method proposed by IPCC/OECD, the theoretical calculations for CH_4 release potential are based on a mass balance approach developed by Bingemer and Crutzen (1987). It is assumed that the release of CH_4 to atmosphere is instantaneous and in the same year the refuse is land filled. It is also assumes that all the waste decomposes anaerobically and the produced methane escapes to atmosphere and no oxidation occurs.

CH_4 emission = Total MSW generated (Tg/yr) X MSW land filled (%) X DOC in MSW (%) X
Fraction dissimilated DOC (%) X 0.5 g CH_4/g C X Conversion factor (16 g CH_4/12 g C)-recovered – CH_4 (Tg/yr)

Where DOC is the Degradable organic carbon;

Method II: This method is based on the theoretical first order decay model is also sometimes used for CH_4 emissions from landfills. It can be applied to a country or region. The model as applied in Netherland states.

$$A=0.8\,k\,P_O\,e^{-kt}$$

Where A is the production of biogas in meter cube /tonne refuse per year; P_0 the conc. of degradable organic carbon in kg/tone refuse; 0.8 is the part of P_0 that is actually degrading: k is the degradation rate coefficient = 0.1 (half of the P_0 is degraded in 7 years and t the time after land filling).

3. RESULTS AND DISCUSSION

Organic matter in waste deposited in landfills creates an anaerobic environment, generating landfill gas (LFG).Among the potential hazards with LFG are: 1) Fires and explosions; 2) Odours and toxicity; 3) Damage to vegetation, 4) Climate effects (greenhouse and smog); water pollution. LFG normally consists of > 50% methane, which is a serious greenhouse gas, but also an energy source. Due to the energy burden in the atmosphere, there is a need to know the methane emission from the landfills. Based on IPCC model the theoretical value arrived is 0.0097 Tg/yr, as such compounded growth rate of population and per capita waste generation is applied. The value is having closest relationship with that established by seasonal integration and it is obtained as 0.00817 Tg/yr.

4. CONCLUSION

Precise inventorying the methane emission from different sources is of immense use and interest for Environmentalists, Climatologists and most importantly for Agricultural scientists. Among the different sources of methane emission landfill alone contributes 6-20% of the other anthropogenic sources. Previous years due to lack of data and systematic handling of Municipal Solid Wastes, there exist a problem of precise measurement.

REFERENCES

Bingemer, H.G and Crutzen, P.J. 1987. The production of methane from solid waste" *Journal of geophysical Research,* V92, no. D2 Feb 1987, p 2181-2187.

Dickinson, R.E. and Cicerone, R.J. 1986. Future global warming from atmospheric trace gases, *Nature*, 319, 109-115, 1986.

Froil and Jensen, J.E. 1999. Beregnings modell for *utslipp av metangass fra norske deponier-historiske og framtide utslippsmengder*. (In Norwegian) Report 99:16, Statens forurensn ingstilsyn,Oslo,Norway.85 pp.

IPCC, 1992. Climate change. The scientific basis contribution of working groups assessment report of the IPCC, Cambridge University Press, Cambridge p.885.

IPCC, 1996. Climate change. The scientific basis contribution of working groups assessment report of the IPCC, Cambridge University Press, Cambridge p.612..

CLIMATE CHANGE AND CONSERVATION OF GREEN ENVIRONMENT WITH SPECIAL REFERENCE TO GREY WATER USE FOR AGRICULTURAL PURPOSES

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ABSTRACT

Climate change occurs due to temperature and weather patterns in the environment at regional level. Water is one of the outstanding problems in the world for irrigation and drinking purposes due to insufficient of rainfall now a day. So some alternative techniques are essential one to save water all over the world. Every day resources like water got wasted because of our life style. People use a lot of water at the kitchen, sink-cooking, washing dishes. This then went to waste. At present a method is essentially required to remove impurities present in daily use water. The impurity water should be removed without spending too much money. The method should be implemented in ordinary households. Hence, the M.Sc., Zoology students of Nehru Memorial College (Autonomous) (N11° 03.845'; E078° 41.007'), Puthanampatti, Trichy district, Tamil Nadu, India has started a project on Grey water use for irrigation purposes within the college campus. A plot which has 25x10 feet area was selected, and various plants such as white radish, merchi, tomato were planted in two areas viz grey water irrigation plot and fresh water irrigation plot. At present lush growth of saplings are recorded both the plots. However slight changes are recorded in plant growth. The mean plant growth is 15.12±1.36 cm in Grey water irrigation plot and 13.12±1.85 cm in fresh water irrigation plot of white radish. The day hour's temperature is around 32±0.85 °C in the plot area. The fresh water pH is around 8.62±0.20 and the grey water pH is around 9.58±0.12. The control plot soil pH is 7.39±0.19 and the experiment plot soil pH is 7.43±0.19. We are taking the other parameter and are in pipeline and to be analysed for thesis preparation during April 2017. Hence, this kind of project should reach all over the districts that are our aim of this project. Various purification process of grey water has been discussed detailed in this paper. The lab to land techniques is successfully implemented in Puthanampatti village.

Key words: Climate change, conservation of environment, Greywater use for agricultural purposes.

1. INTRODUCTION

Climate change occurs due to temperature and weather patterns in the environment at regional level. Generally, climate change occurs every 1000 years once or 40,000 years once or more at global level. Man made activities plays an important role and causes climate change in any part of a region at any time. Next few 100 mil years-resulting in evaporation of the oceans may occur due to climate change. Hence, conservation of green environment is required at present in most possible ways. It involves Socio-Economic Development of the society on the one hand and maintenance of 'Environmental Quality' on the other hand. Various NGOs and Governmental bodies doing fine on it. National Green Tribunal doing good role on it. San Francisco becomes the first city in the world to ban the sale of bottled water, every citizen should have an own bottle and can fill bottle in free water service points.

Every day 2.7 lakh trees are flushed down to the toilet throughout the world. If green banking implemented throughout the world, it would save 6.5 mil trees every year. In United States paperless billing process implemented. All banks monthly paper statement big problem. Malabar Botanical Garden and Institute for Plant Sciences (MBGIPS) Kozhikodu has Isolated 6 strains of bacteria – capable of breaking down plastics into biodegradable polymers. The bacteria produce Polyhydroxyalkanoater (PHAS) which degrade plastic. India 5th largest producer of e-waste and 2nd largest mobile market which discarding 18.5 lakh tonnes of e-waste every year. Telecom equipment alone accounts for 12% of the e-waste and 100 crore mobile phone in circulation of which nearly 25% end up as e-waste. This can be reduced by phased manner. Further, people go open toilet most of the areas which hamper the green environment and human health. 54,257 toilets likely to be constructed in the Tamilnadu state, of which – 30,726 toilets under the clean India Campaign in rural areas. 23,534 toilets under Mahatma Gandhi National Rural Employment Guarantee Scheme.

Recently 90 Educational Institutions get electric incinerators. BHEL (Bharat Heavy Electrical Limited – Trichy) issued the device to Trichy area during July 2016. Hygienic Disposal of Sanitary Napkins WISH and NSS of Bharathidasan University helped on it. Waste is the main cause for rise in stray dogs' population and rabies in the country. Kerala has 2.5 lakh of stray dogs which feed lavishly on the wastes and garbage dumps across cities and towns, as many as one lakh people have been bitten (2015-16). We need great awareness programme to stop the climate change and safe guard the green environment as quickly as possible. Water is one of the outstanding problems in the world for irrigation and drinking purposes due to insufficient of rainfall now a days. So some alternative techniques is essential one to save water all over the world. So the Nehru Memorial College (Autonomous) (N11° 03.845'; E078° 41.007'), II M.Sc., Zoology students started a project on Grey water use for irrigation purposes from November 2016 onwards. It is a model that has to be displayed to the farmers and public to implement the project all over the villages.

1.1 Grey water use

Changing scenario with the economic development of the society towards large-scale urbanization and industrialization is leading to production of huge quantities of effluent in India. Industrial and domestic effluents are either used or disposed off on land for irrigation purposes that create both opportunities and problems. Opportunities exist as sewage effluents from municipal origin are rich in organic matter and also contain appreciable amounts of major and micronutrients (Pescod, 1992; Brar *et al.,* 2000). Accordingly nutrient levels of soils are expected to improve considerably with continuous irrigation with sewage (Brar *et al.,* 2000).

Every day resources like water got wasted because of our life style. People use a lot of water at the kitchen, sink-cooking, washing dishes. This then went to waste. At present a method is essentially required to remove impurities present in daily use water. The impurity water should be removed without spending too much money. The method should be implemented in ordinary households. The average home maker should be able to carry out the process easily.

Generally kitchen sink has organic (food) material from the dishes as well oil, grease, soap and other related debris. It also contains phosphates from the detergents used to clean the vessels.

2. METHODOLOGY

2.1 Grey water use for drinking and agricultural purposes.

Step 1: First trap the kitchen water in a tank (use filter to remove food debris). Remove the oil that floats occasionally. Introduce Algae in the water. Now the water is oxygenated using a small aquarium bubbler that allows the growth of algae. While algae growth it uses some of the phosphates from the kitchen water. The microorganism present in the water taken by algae or killed in the sun light. So 80% of the impurities are gone.

Step 2: Filter the water to remove algae and pass it through sand filter containing 'Vettiver' to get rid of the rest of the phosphates and to allow 95% purification. This water is used for Gardening or use the water for fish tank. The fishes eat the mosquito larvae and other harmful microbes. Other wise use the water in a Rainwater harvesting tank to recharge ground water. Then clean water and pass it into a reverse-osmosis (RO) unit to get clean drinking water (treat it using ozone to disinfect) and again use it for drinking purposes. The major by-product for this process is the algae. Use it as manure or put it in an anaerobic digester and produce methane. Use solar energy to run digester. So make the whole process green without making the environment harmful.

2.2 Other methods: (Tube filter method)

The grey water and the kitchen waste water may be allowed in narrow pipe line which has three important materials in a layer form. The first layer is made up of small gravels of 10 cm pack, the second layer is made of charcoal pieces about 10 cm pack and the third layer is made up of river sand with 10 cm pack. Now the different layers almost filter the debris, soap, oil etc and allow fine water of 85% good water in the outlet. This can be allowed to a small tank which has water lotus or algae which such the heavy metals from the water the sunlight destroys the microbes. Then the water is allowed for filter and is used for drinking or irrigation purposes.

2.3 Experiment

The present experiment has just started first time in the district at Nehru Memorial College (Autonomous), Puthanampatti, Trichy district, Tamilnadu, India. The project has been carried out from November 2016 to April 2017. Within the college campus a small area of 25x10 feet was selected. This was generously supported by the college management. This plot is divided into two equal parts. In the first half plot the vegetations like White radish, tomato and chilly has been planted similarly during the month of January 2017, similarly in the second half plot the same plant species have been planted with similar number. The first plot acting as control plot where the fresh water is allowed for growth once in two days and in second plot the grey water is allowed for once in two days. The plant growth and other parameter like fresh water pH, grey water pH, soil pH, soil temperature, ambient temperature, moisture contents of soil, humidity and mineral contents of soil are being taken. The sun light is good enough for the plant growth. The lux unity of the plot also being taken. To avoid insect attach insecticide is sprayed over the leaves of small saplings. The differentiation of grey water irrigation plant growth, yield and toxicity effect will be recorded. At present lush growth of saplings are recorded both the plots. Display boards are exhibited to the public and students observation.

3. RESULTS AND DISCUSSION

The present study revealed that the plant growth is good in status of both in grey water irrigation plot and in fresh water irrigation plot. However slight changes are recorded in plant growth. The mean plant growth is 15.12±1.36 cm in Grey water irrigation plot and 13.12±1.85 cm in fresh water irrigation plot of white radish. Similarly the tomato and chilly plants are as such in the fresh water plot in young plants (9 cm) growing stage. They may likely introduce into the grey water plot after getting 20 cm of growth. That is the appropriate height for growth, and planting in other place is good one.

The day hour's temperature is around 32±0.85 °C in the plot area. The fresh water pH is around 8.62±0.20 and the grey water pH is around 9.58±0.12. The control plot soil pH is 7.39±0.19 and the experiment plot soil pH is 7.43±0.19. We are taking the other parameter and are in pipeline and are to be analysed for thesis preparation during April 2017. The fullest results will be gathered during April 2017. The growth rate and yield in both the plots will be gathered and compared for further analysis. Nutrient supply and toxicity assay, chemical profile will be done. Graywater can usually be treated on-site with simple technologies, because it is lower in nitrogen levels, fecal material, and organic content than municipal wastewater (Eriksson *et al.,* 2002). Similarly, deterioration of rawgraywater quality was reported in several other studies that found an increase in water contamination parameters such as dissolved oxygen, ammonia, nitrogen, and suspended solids after 24 to 48 hrs of storage (March and Gual, 2009).

4. CONCLUSION

It is concluded that large amount of grey water and kitchen waste water is being dumped in a particular area; as a result the area gets destroyed. So it is suggested that the grey water and house hold kitchen wasted water to be used for many other purposes. Thus, the efficient use of such grey water and domestic kitchen waste water can effectively increase water resource for irrigation and may prove to be a boon for agricultural production. However, traces of some of the toxic ions like Ni, Cd and Pb may be found in plants and that NO3 in some well waters should be a matter of concern and indicate the need for continued monitoring or treatment of grey water and kitchen waste water before it is let into disposal channel for irrigation. The set up is exhibited for public so as to enable them follow the same in their houses. The local people are visiting our garden and asked several questions how to set up such kind of system at low cost. We explain the model to them. Hence, this kind of project should reach all over the districts, states. That is our aim of this project.

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REFERENCES

Brar, M.S., Mahli, S.S., Singh, A.P., Arora, C.L. and Gill, K.S. 2000. Sewer water irrigation effects on some potentially toxic trace elements in soil and potato plants in northwestern India. *Can J Soil Sci.* 80:465–71.

Pescod, M.B.1992. Wastewater treatment and use in agriculture. *Bull FAO*. 47:125.

POPULATION STATUS AND MILK QUALITY AMONG THE GENUS *BOS* IN THE SELECTED VILLAGES OF THIRUVARUR DISTRICT, TAMIL NADU, SOUTH INDIA.

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ABSTRACT

The indigenous cattle species of India, Tamil Nadu is *Bos indicus* and its milk is medicated substance. In the present study abundance and maintenance of present status of indigenous cattle *Bos indicus*, among the Genus *Bos* were assessed in five agriculture villages viz. Sethalapathy, Kovilpathu, Koothanur, Poonthotam and Uthragangai in and around Cauvery delta region of Thiruvarur District, Southern India. In these villages the maintenance of cattles of *Bos indicus* was not common. The abundance of *Bos indicus* ranged from 4% to 9% villages. Among the milk samples of genus *Bos*, the *Bos indicus* milk was high quality than the *Bos taurus indicus* and *Bos taurus*. Among the three species fewer number of *B. indicus* died between 2012 and 2014 whereas *B.taurus* hard death all the years and *B.taurus indicus* died during 2013 and 2014.

Keywords: Abundance, Milk methylene blue reduction test, Genus *Bos*.

1. INTRODUCTION

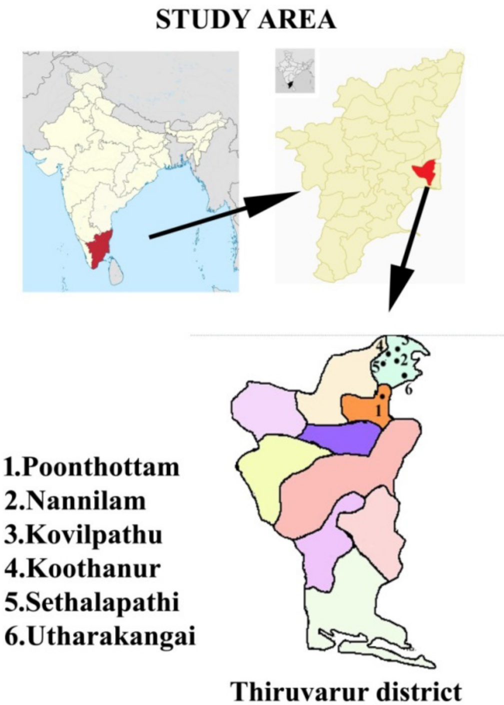
Cattle products such as, milk, meat and dung are essential in developing countries. Different rural Indian people use cattle product, either in medicine, agricultural and religious purpose (Vaseeharan *et al.,* 2012). In developing nation particularly in Indian villages people are mostly depend on cattle for various purposes such as religious, agricultural work, milk, curd, ghee, dung, urine, etc. (Jain, *et al.*, 2010; Panicker *et al,* 2012). The researches in cow excretion were used for identification of putative pheromones in related to estrus detection (Sankar and Archunan, 2008). Since thousands of years, Indian people have been using cow urine for medicinal value related to physical and mental health (Shah, 1997). The Indian traditional practices of indigenous cow excretion of dung and urine and cow production of milk, curd and ghee were mixed to prepare anti-biotic health drugs of “Panchagavya”, “Jeevamirtham” which are very good natural medicine for cure many disease of human, domestic animals and agricultural plants. Cow is worshipped as God who fulfills all the desires (Jarald *et al.,* 2008). In India, indigenous cow *Bos indicus* is having high physical resistance against different environmental changes. The common indigenous species of (*Bos indicus*) in Tamil Nadu state cow species such as Attura, Kidayamadu, Pondymadu and Therkuthimadu not knows in the present generation of people in Tamil Nadu and no study of research in till date. The Indian indigenous cattle products are having medicinal property, especially in ayurvedic and siddha medicine. The Indian indigenous cattles have long life span than the other genus of *Bos.* The indigenous cow *Bos indicus* genetically shrub feeding and mostly consume small plants and grass species which are having medicinal values. The Indian indigenous cow’s maintenance is easy for any of the economic level of people in India. In Tamil Nadu, common existing indigenous cattle species such as Kangayam, Umbalachery, Manaparai, are maintained very few numbers in and around Trichirapalli district, Tamilnadu, Southern India (Thiagarajan and Thangaraju, 2011). The present study evaluated abundance and milk quality among the genus *Bos* in selected five villages of Thiruvarur District, Tamil Nadu, India.

2. MATERILS AND METHEDS:

2.1 Study area

The present study was assessed cattle maintenance in the villages in and around Sethalapathi, Kovilpathu, Koonthanur, Poonthottam and Uthragangai, an area lies in the Thiruvarur district, covering an area of 2161sq km. The area south east part of Nagapattinam and is bounded west by Thanjavur, District (Fig.1). The entire area of Nannilam Taluk, Thiruvarur District is agricultural belt of Cauvery delta region, Tamil Nadu, South India. The average annual rainfall of this area is 25.40 mm. The average annual temperature of this area is 37 ° C to 40° C.

Figure 1. Map showing the villages of Thiruvarur district where the study was undertaken



2.2 Population study

In the present study cattle abundance was recorded from January to March 2015. The cattle abundance of *Bos indicus, Bos Taurus indicus,* and *Bos taurus* in Nannilam Taluk, Thiruvarur District, Tamilnadu, Southern India was evaluated (Fig. 2,3,4). The primary study species Umbalachery, *Bos indicus* cow status was recorded from Cauvery delta region using the methods of Thangaraju *et al.* (2001).

Figure 2. Indigenous species of *Bos indicus* (Umbalchery cow) inTamil Nadu, Southern India.

Figure 3. Cross breed species *Bos taurus indicus* in Tamil Nadu, Southern India.

Figure 4. Hybrid species of *Bos taurus* in Tamil Nadu, Southern India.

2.3 Methylene blue reduction test (MBRT)

MBRT test may be utilized for grading of milk which may be useful for the quality to take a decision on further research as per BIS 1479 (Part 3): 1977 criterion for grading of raw milk based on MBRT is as follows five hours and above time taken for reduction of colour is being considered as very good. If colour changed up to the three to four hours is being considered as good whereas one to two hours is fair quality and less than 30 minutes considered as very poor quality. The test has to be done under sterile conditions. Take 10 ml milk sample (each) in sterile MBRT test tube. Add one ml MBRT dye solution (dye concentration 0.005%). Stopper the tubes with sterilized rubber stopper and carefully place them in a test tube stand dipped in a serological water bath maintained at 37±1°C. Record this time as the beginning of the incubation period and decolorization is considered complete when only a faint blue ring (about 5mm) persists at the top.

2.4 Examination of death rate of cattle

Cattle death rate was recorded from Sethalapathi, Kovilpathu, Koothanoor, Poonthottam, and Uthragangai, Nannilam Taluka, Thiruvarur District. The death rates of genus *Bos* were recorded through Dr. Gowry, Government Veterinary Assistant in Poonthottam, Government Veterinary Centre. Tamil Nadu, Southern India.

3. RESULTS AND DISCUSSION

Abundance of different species of genus *Bos* in selected five villages resulted that, *Bos taurs* was highest in Uthragangai and lowest in Kovilpathu. The *Bos indicus* and *B. taurus indicus* were prominently lower then *B. indicus* in all the villages. The *B.taurus indicus* was higher than *B. indicus* in all the villages except Koothanur (Fig. 5). The methylene blue reductase test indicates that, the *B.indicus* took longest time for reduction followed by *B.taurus indicus* in all the villages. The *B. taurus* took shortest time for reduction in all the villages and it was consistent also (Fig. 6). Among the three species fewer number of *B. indicus* died between 2012 and 2014 whereas *B.taurus* hard death all the years and *B.taurus indicus* died during 2013 and 2014 (Fig. 7).

Figure 5. Abundance of different species of genus *Bos* in selected five villages of Thiruvarur district, Tamil Nadu.

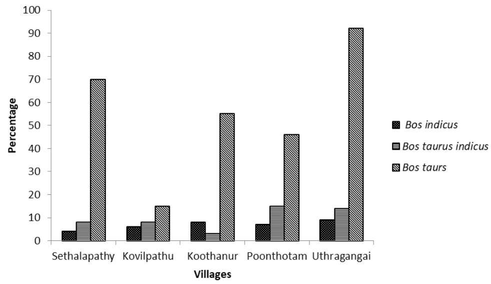


Figure 6. Time taken in methylene blue reduction test of milk samples of genus *Bos* from in and around sethalapathi villages, Thiruvarur district.

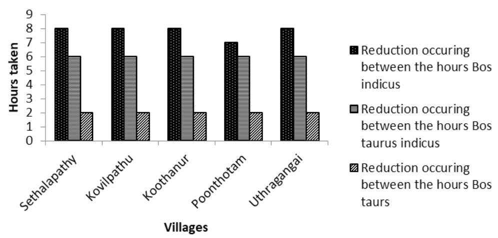
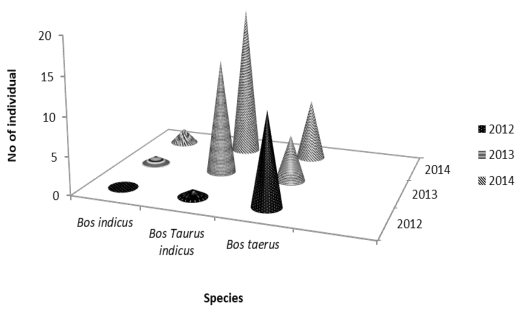


Figure 7. Death rate of three species of cattle from five villages of Thiruvarur district.



The maintenance of higher number of *Bos taurus* could be for daily cash income through milk production. Earlier studies indicated that *B.taurus* was preserved due to increased milk production over the last several years of worldwide (Lucy, 2001; Royal *et al*., 2000; Wiley and Weinheim, 2002). The cattle abundance has been declining in villages which could be due to; (i) people are feeling burden of cattle maintenance of all through the years and periodical exclusion of cost of cattle feed (ii) the cattle maintenance is practiced only village former who are poor (iii) trying to maintenance without knowledge and strategy of cattle maintenance technology (iv) Spreading of communicable and non- communicable diseases (v) lack of anti- biotic vaccination for cattles (vi) disposal to cattles for meat. Ganapathi *et al.,* (2009) have been reported the above reason is similar finding in which population status and distribution of Bargur cattle.

The methylene blue reductase test indicates that, the *B.indicus* took longest time for reduction followed by *B.taurus indicus* in all the villages. The *B. taurus* took shortest time for reduction in all the villages and it was consistent also. It indirectly the showed the microbial composition in the samples collected from the genus Bos. The lowest time taken of methylene blue reductase test indicates that highest number of microbes occupied in the milk and vice versa. This is suggested that earlier study in which cattle used in bio-medical examination (Clough, 1982; Fox, 1995; Ellie and Sharon, 2013). Because the availability of pocket milk is home delivered, daily from rural and urban area. The similar finding has been reported in which rural India, milk is home delivered, daily, by local milk man (Greew, 2005). The present study death rate was noted, in and around Sethalapathi village. The marked death rate was recorded in *Bos taurus* and *Bos taurus indicus* from all five villages of 2012 to 2014 (Fig.4). The reason for marked death rate is (i) *Bos taurus, Bos Taurus indicus* is not resistant in hot environment and cause communicable diseases (ii) Late diagnosing from infective disease (iii) Poor administration of preventive measure (iv) Lack of cattle maintenance strategy. The above fact are suggested that earlier study of cattle morbidity pattern in Tamil Nadu (Palanivel *et al*., 2007). Effect of heat Stress and detection of hoplotypes associated with prenatal death in dairy cattle (Sebastien *et al.,* 2013; Cook *et al.,* 2007**).**

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REFERENCES

Clough, G. 1982.Environment Effects on Animal Used in Biomedical Research. *Biological Reviews Cambridge philosophical Soci*. 57:487-523.

Cook, N.B., Mentink, R.K., Bennett, T.B. and Burgi, K. 2007. The Effect of Heat Stress and Lameness on Time Budgets of Lactating Dairy Cows. *Jr of Dairy Sci.* 90: 1674-1682.

Ellie, R. and Sharon, R. 2013.Only a relatively small percentage (above 30 percent) of the people in the world retain enough lactose to digest and absorb lactose efficiently throughout adult life" in Whitney. *Understanding nutrition.* 103.

Fox, P.F. 1995. *Advanced dairy chemistry* ,vol3 :Lactose, water, salts and vitamins 2nd ed Chapman and Hall, New York.

Ganapathi, P., Rajendran, R. and Subramanian, A. 2009. Distribution and Population Status of Bargur cattle. *The Indian Vet Jr.* 86: 971-972.

Greew, J. 2005. Cassel's Dictionary of slang Weidenfeld and Nicholson. p943.

Jain, N.K., Gupta, V.B., Garg, R. and Silawat, N. 2010. Efficancy of cow urine therapy on various cancer patients in Mandsaur District ,India-A survey *. Int. Jr. Green pharm.* 4:29-35.

Jarald, E., Edwin, S., Tiwari, V., Garg, R. and Toppo, E. 2008. Antioxidant and Antimicrobial activity of cow urine. *Glob J. of pharm.* 2: 20-22.

Lucy, M.C. 2001. Reproductive loss in high-producing dairycatttle : where will it end. *J. Dairy sci.* 84: 1277-1293.

Palanivel, K.M., Vijalingam, T.A., Selvasubramanian, S. and Mohanraj, M. 2007. A retrospective study on cattle morbidity and mortality pattern in Tamil nadu. *Indian J.of field Veteri.*,3(1):41-43.

Panicker, A., Trivedi, M., Shark, R.K., Kumar, N. and Patel. 2012. A effect of cow urine ark and aloe vera extract on sera biochemical parameter in vitro leghorn chicken. *An international journal of pharmaceutical science* : 3163-3170.

Royal, M.D., Darwash, A.O., Flint, A.P., Webb, R., Woolliaams, J.A. and Lamming, G.E. 2000. Declining fertility in dairy cattle : changes in traditional and endocrine parameters of fertility. *Ani.sci* .70: 487 -502.

Sankar, R. and Archunan, G. 2008. Identification of putative pheromones in bovine (*Bos taurus*) faeces in related to estrus detection, *Animal Repro .Sci* .103:149-153.

Sebastien, F., Aurelien, C., Anis, D., Sabrina, CR., Anne, B., Aurelia, B., Cecile, G., Bernard, W., Mekki, B., Diance, I., Christophe, K., Dominique, R. and Didier, B. 2013. Detection of hoplotypes associated with prenatal death in dairy cattle and identification of deleterious mutation in GART,SHBG and SLC37A2.*Jrs*. Plos. Org/Plosone/article:ID=10.1371/ *Jr.Pone*.0065550.

Thangaraju, P., Magalinga, N. and Rajendran, R. 2001. Umblachery-Renowned Draught Cattle of Tamilnadu Status paper Presented at the Oorkshop on Indigenous Cattle and their role in the New Millennium, Organised by TANUVAS, IDA and NDRI on 24 -25 March,2001 at Erode,Tamilnadu,India,TN-13-19.

Thiagarajan. R. and Thangaraju, P. 2011. Molecular characterization of Kangayam cattle by identifying DNA markers using microsatellites, *Int Jr Food Agri & Vet Sci* ISSN:2277:1(1):27-31.

Vaseeharan, B.S.P., Sonibarathi, N.M., Prabhu, R., Manikandan, M., Esakkirajan and Srinivasan, P. 2012. Surveillance and antibacterial activity of commercial antibiotics against *vibrio sp*. *Int. Jr.curr. sci* 4:44-49.

Wiley, V.C.H. and Weinheim, R.J. 2002. Rolf jost"milk and dairy product "*ullmainis Encyclopedia of industrial chemistry* Doi:10:1002/14356007,a16-589 pups.

AVOIDANCE BEHAVIOURAL TEST ON OECD SOIL WITH *EISENIA FETIDA* EXPOSED TO SUPERPHOSPHATE

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ABSTRACT

The Avoidance Behavioural Test (ABT) is one of the simplest and basic ecotoxicological test performed using Eisenia foetida as the test organism with OECD artificial soil as the substrate. Since now many tests have been performed using various chemicals like insecticides, pesticides, etc.. But studies relating the effect of chemical fertilizers were not yet performed. Thus this study was aimed to monitor the effect of the chemical fertilizer, Superphosphate (SP) on the earthworm, *Eisenia fetida*. Another important indirect effect especially of SP fertilization is soil acidification, with considerable negative effects on earthworms. The avoidance behaviour of earthworms regarding SP was tested in the OECD soil under temperate condition in the range of concentrations from 330.40 to 5442.5mg/kg. The results indicate a significant reaction of earthworms to the lower concentrations of SP in OECD soil. The EC_{50} values with 95% confidence limit and LOEC and NOEC values were 1307.7 [95% CL – n.d.], 348.0 and 73.3mg/kg. Extension of this study to other types of soil with other fertilizers would improve the understanding of toxicity to earthworms.

Keywords: Avoidance Behavioural Test, *Eisenia foetida,* Superphosphate, OECD Soil, Temperate condition

1. INTRODUCTION

In nature, the soil is one of the key elements that enable the life on earth. It plays a central role in all terrestrial ecosystems, functions as habitat for many organisms and as a filter and buffer, allowing clean groundwater storage. The main ecological soil functions are those related to organic matter breakdown and nutrient mineralization by soil invertebrates and microbes. The soil dwelling organisms play a crucial role in the ecosystem by mediating the geochemical cycling of elements and nutrient supplies to plants thus maintaining soil fertility through detrivore and microbivore feeding activities and through physical alteration of soil aggregates (Kavdir and Ilay, 2011; Lemtiri *et al.,* 2014).

Among the soil organisms, Earthworms play a significant role in soil formation, aeration, and nutrient cycling (Six *et al.,* 2000; Wolf and Wagner, 2005) in almost all terrestrial ecosystems. Simply by crawling through soil, forming tunnels, and consuming detritus they help to aerate soils. Some species dwell in the surface litter layer, others deeper in the soil, and others move vertically among soil layers (Coleman and Crossley, 1996). The latter group has pronounced effects on soil mixing. Earthworms improve water infiltration rates, neutralize soil pH and stimulate microbial population growth (Doube and Brown, 1998; Reinecke and Reinecke, 1998). Clumping of particles occurs as soil passes through worm digestive tracts, increasing water infiltration rates. Larger particles produce larger spaces, thus allowing more water to infiltrate, and coincidentally, allowing more fertilizers and chemicals to pass into the water table. Because of these functions, earthworms are considered as "ecosystem engineers" (Anderson, 1995).

The technological advances in agriculture have led to an increased production and emission of chemical substances, especially the chemical fertilizers which end up in the soil. The soil constituents, like the clay and organic matter, have a great capacity to retain chemicals. Therefore, the soil is a net sink for all kinds of chemicals, and its concentrations are often considerably higher than in any other environmental compartment (Verhoef and Van Gestel, 1995). The impact of chemical fertilizers on soil fauna diversity and soil functions has become an issue of great concern in recent days. Chemical fertilizers are applied in the environment to fulfil a specific purpose, but at the same time may cause damage to the soil biota, decreasing its diversity, growth or reproduction, and consequently organic matter decomposition and soil fertility. Therefore, there is an increasing need for appropriate methods to assess the side effects of these chemicals on soil ecosystems.

Soil toxicity and bioaccumulation tests can be important tools for decision makers, whether in approving registration requests or in assessing contaminated sites and remedial action plans. Soil toxicity test can also be used for long term monitoring programs or to assess the success of clean-up projects. Registration of chemicals usually includes assessment of the ecotoxicity of the active ingredient and its degradation products, its persistence in the environment and its mobility in water and soil (Brown, 1988; Lynch, 1995). As in the risk assessment of all chemicals, evaluation of ecotoxicity is mostly directed towards targets in the aquatic environment, such as fish, crustaceans and algae (Van Leeuwen and Hermens, 1995). In the terrestrial environment, risk assessment is concerned with the possible effects on birds and small mammals (Moriarty, 1972; Shore and Douben, 1994) and on arthropod species that are valued for their potential to suppress pests (Barrett *et al.,* 1994; Hassan, 1985). For soil organisms, experimental procedures include tests for earthworm survival and reproduction, population development of Collembola, plant germination and microbial activity such as nitrification (Wrage *et al.,* 2001). The results from these tests may be used for decision making in various chemical evaluation procedures, e.g., initial registration, labeling, post registration monitoring, integrated pest management (IPM), Growth promoting products and plant protecting products (PPP).

The ability of organisms to detect and avoid contaminated soil indicates the stress potential of a particular soil (Stephenson *et al.*, 1998 and Hund-Rinke and Wiechering, 2001) and it is ecologically relevant due to the direct relationships with soil biodiversity and its quality as habitat for those organisms. Avoidance of contaminants has been studied for some time in aquatic toxicity (Kravitz *et al.,* 1999; Exley, 2000), but only in recent years have avoidance tests been developed for soils with different chemical substances (Yeardley *et al.,* 1996, Stephenson *et al.,* 1998, Hund-Rinke and Wiechering, 2001; Heupel, 2002). Most of these bioassays were performed using laboratory-contaminated artificial or natural soils using collembolans, earthworms, and enchytraeids as test organisms.

In this project, the avoidance behaviour of earthworm, *Eisenia fetida* was observed against the commonly used NPK fertilizer, Superphosphate under temperate condition i.e. 20ºC. The OECD (Organization for Economic co-operation and Development) recommended artificial soil was utilized as substrate.

2. MATERIALS AND METHODS

2.1. Test Substrate

The soil substrate (artificial soil) was prepared by mixing sand, kaolin clay and sphagnum peat in the proportion 70%: 20%: 10% and made upto 500mg (dry weight basis). The temperature of the soil was maintained at 20ºC as the sphagnum peat will start emitting the hydrogen ions making the substrate acidic if the temperature is raised. The pH was maintained at 6.8. The components of artificial soil, quartz sand, kaolin clay and Sphagnum peat were purchased from the local building contractor, Himedia chemical Laboratories, Bengalure and from a nursery, Coimbatore respectively. The sphagnum peat was shade dried, grounded and sieved through 2mm mesh and then used.

2.2. Test Chemical

Since NPK fertilizers were familiar in almost all the countries, also, the toxic effects of the fertilizers on earthworms were not yet studied so far, one of the NPK fertilizer, Superphosphate was purchased from the preliminary Agricultural Co-operative Bank, Annamalai nagar, India. The preparation of test solutions for each concentration was done by weighing and dissolving the amount of Superphosphate in 1 litre of deionized water. Prepared concentrations were mixed with the artificial soils prepared separately and the final soil moisture was adjusted to 35 ± 5% dw. Using a small mixer, the substrate was completely mixed with the chemical solution until the test substance was homogeneously distributed. The test solution was spiked in the soil only once, at the beginning of the experiment. As the LC_{50} value of Superphosphate was pre-determined by Abbiramy and Ronald Ross (2013), the test concentrations were determined as 330.40, 680.31, 1360.62, 2721.25 to 5442.5mg/kg.

2.3. Test organism

For this work, the required test organism, i.e. the earthworm *Eisenia fetida* was procured from the vermicomposting unit, Annamalai University, Annamalainagar.

2.4. Avoidance tests

The habitat function of soils is often assessed using different earthworm tests with either acute or chronic endpoints in order to obtain information on environmental effects. However, there is a high need for a short and easy-to-perform screening test. Since earthworms have many high chemoreceptors in their body wall (especially in the anterior segments of the body) they show sensitivity to chemicals in their environment (Edwards and Bohlen, 1996). This sensitivity, coupled with their locomotory abilities, enables them to avoid contaminated areas (Stephenson, *et al*. 1998). Therefore, the avoidance test, an alternative for the rapid toxicity assessment based on the behavioral responses of earthworms, has been proposed by Yeardley *et al*. (1996), Slimak (1997), Stephenson *et al*. (1998), Hund-Rinke and Wiechering (2001) and Hund-Rinke *et al*. (2003).

The principle of this test is that the earthworms in one test vial were simultaneously exposed to the soil sample to be evaluated and to a control soil. After a short test period, (48 hours) the location of the animals was determined. In the present study, avoidance tests were performed with *Eisenia fetida* using the Superphosphate at different concentrations in OECD soil under temperate condition. Each treatment consists of 4 replicates. Glass vessels of 30 x 15cm area and 15 cm height was filled with soil up to a height of about 4 to 5cm (about 500g soil, dry weight). Using a piece of plastic fitted transversally in the vessel, one half of the vessel was filled with Superphosphate-spiked soil, the other filled with control soil, without chemical. Then the plastic separator was removed and 10 adults of *Eisenia fetida* (weight: 250 - 400 mg) was placed on the separating line of each test vessel. The test vessels were exposed to the light in the laboratory until all earthworms had entered into the substrate. Then, the vessels were closed with transparent and perforated lids and were kept in the dark at 20 ± 2ºC for 48 h in order to avoid lateral effects of light in the vessels. The animals were not fed during the test. Soil moisture and pH was recorded. At the end of the test period, the control and the Superphosphate-spiked soil sections were carefully separated and the number of earthworms was determined for both sections of the vessels. Individuals found between the sections (on the separating line) was counted according to the direction they were moving, i.e., considered in the section where the anterior part of body was. The dead earthworms were classified as escaped animals.

Computation of avoidance response

For each replicate, the net response (NR) (expressed as percentage) was calculated as following:

$$NR = ((C - T)/10) \times 100$$

where: C = sum of earthworms observed in control soil

T = sum of earthworms observed in treated soil

10 = total number of earthworms per replicate

A positive (+) net response indicates avoidance of, and a negative net response (-) indicates a non-response (or attraction) to the chemical tested in given concentration. For the test results, the value of EC_{50} (including 95%-confidence limits) was calculated and graphics created showing the values of the mean net avoidance response.

3. RESULT AND DISCUSSION

The avoidance behaviour of earthworms regarding SP was tested in the artificial soil in the range of concentrations from 330.40 to 5442.5mg/kg. The results indicate a significant reaction of earthworms to the lower concentrations of SP in OECD soil. A positive net response of earthworms was observed in the lower concentration (Table 1) and the EC_{50} value with 95% confidence limit and LOEC and NOEC values were estimated and presented in Table 2. But no confidence limit was estimated for the test conducted. It indicates the significant reactions of earthworms to the higher concentrations of Superphosphate in OECD soil. The earthworms clearly avoided all the Superphosphate concentrations in test conducted under temperate condition from the lower concentration onwards. Thus this test prove the fact that the commonly used Superphosphate fertilizer affect the earthworm population even in a very low concentration i.e. even at sublethal concentrations. Though this is a lab-based result, this may alter or may have different influence when tested at field level.

Table 1: Avoidance behaviour test with *Eisenia foetida* in SP-dosed OECD soil under temperate condition

SP Concentrations in mg/kg	Frequency distribution of earthworms (%)		Mean Net Response ± SE (%)	pH at beginning	pH at end
	Section A	Section B			
340.15	70.00	30.00	40±16.3*	6.7	6.8
680.31	85.00	15.00	70±12.9	6.5	6.9
1360.62	85.00	15.00	70±12.9	6.8	6.7
2721.25	90.00	10.00	80±14.1**	7.0	6.6
5442.5	100	0	100±0.0**	6.4	6.6

* (P= 0.05); ** (P= 0.01) significant at 't' test

The graphical representation of the mean net response of earthworms with standard error bars against the Superphosphate-spiked concentrations in the OECD soil was presented in Fig. 1. No non-avoidance behaviour (i.e. negative net response) of earthworms was observed in any of the concentrations. This may be due to the acidic effect of the Superphosphate fertilizer. The EC_{50} value with 95% confidence limit and LOEC and NOEC values were given in Table 2. Though many experiments on the determination of EC_{50} value against pesticides exists (Slimak, 1997; Garcia *et al.,* 2008), no work on fertilizers have been done. Though fertilizers are used inevitably on agricultural fields by farmers than pesticides, the effect of fertilizers on earthworm was rarely studied. Thus this study has made a clear idea on the effect of fertilizers on earthworms which could be used as a primary source during the monitoring of environmental risk assessment of soil.

Figure 1. Avoidance during the exposure of ***Eisenia fetida*** to SP concentrations OECD soil under temperate condition (mean net response and standard error bars).

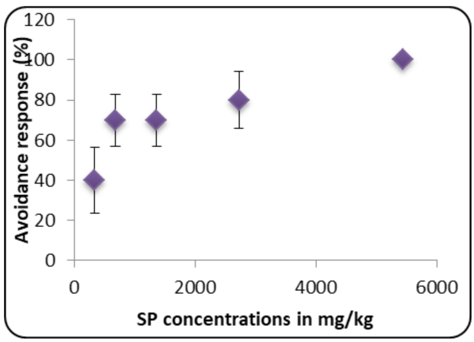

Table 2: Avoidance response of *Eisenia fetida* in superphosphate -dosed substrate under temperate condition: EC50 and its 95%-confidence limits, LOEC and NOEC (values in mg/kg).

Effective Concentrations	OECD soil
EC_{50}	1307.7 [95% CL – n.d.]
LOEC	348.0
NOEC	73.3

n.d. – not determined

Based on the EC_{50} value, it is determined that the avoidance behaviour of earthworm starts from the 130.7mg/kg concentration itself. No effect concentration was determined as 73.3mg/kg and the lower concentration that affects the earthworm population were determined as 348mg/kg. These results reveal the observations of the tests conducted in OECD soil under temperate condition, as the draft of OECD confess the condition. But when the need for the test under tropical condition required, these results may produce an erroneous suggestion. Thus tests under tropical condition must be conducted to confirm the impact assessment. No experiments were performed with fertilizers to compare the results and interpret.

CONCLUSION

The results from the experiment confirm the avoidance behaviour of earthworm population against the effect of Superphosphate fertilizer. Thus usage of over dosage of Superphosphate fertilizer in the agriculture fields must be avoided by the farmers. Many awareness programs on the restricted usage of Superphosphate fertilizer that are artificially synthesized must be conducted by the government. Also the alternate and safe path of organic farming must be enhanced to sustain the soil fertility.

REFERENCES

Abbiramy, K. S. and Ronald Ross, P. 2013. Validation of tropical artificial soil by ecotoxicological studies on *Eisenia fetida* against combined NPK fertilizers. International Journal of Innovative Research and Studies, 2: 212-227.

Anderson, J. 1995. Soil organisms as engineers: microsite modulation of macroscale processes. In: Jones, C. and Lawton, J. (Eds.,) Linking species and ecosystems. Chapman and Hall. London. 94-106.

Coleman, D. C. and Crossley, D. A. Jr. 1996. Fundamentals of Soil Ecology. Academic Press, San Diego.

Doube, B. M. and Brown, G. G. 1998. Life in a complex community: functional interactions between earthworms, organic matter, microorganisms, and plants. In: Edwards, C. A. (Ed.,) *Earthworm Ecology*. St. Lucie Press, Boca Raton. 179-212.

Edwards, C. A. and Bohlen, P. J. 1996. Earthworm ecology and biology. Chapman and Hall, London.

Exley, C. 2000. Avoidance of aluminum by rainbow trout. *Environ Toxicol Chem.,* 19: 1934–1934.

Garcia, M., Rombke, J., De Brito, M. T. and Scheffczyk, A. 2008. Effects of three pesticides on the avoidance behavior of earthworms in laboratory tests performed under temperate and tropical conditions. *Environ. Pollut.,* 153: 450–456.

Heupel, K. 2002. Avoidance response of different collembolan species to Betanal. *Eur J Soil Biol.,* 38: 273–276.

Hund-Rinke, K. and Wiechering, H. 2001. Earthworm avoidance test for soil assessment. *Journal of Soils and Sediments.,* 1: 15–20.

Hund-Rinke, K., Achazi, R., Rombke, J. and Warnecke, D. 2003. Earthworm avoidance test: Results of a laboratory comparison tests. *J. Soil Sediments.,* 3: 7–12.

Kavdir, Y. and Ilay, R. 2011. Earthworms and Soil Structure. In: Karaca, A. (Eds.,) *Biology of Earthworms*. Soil Biology, vol 24. Springer. Berlin. Heidelberg. 45-67

Kravitz, M. J., Lamberson, J. O., Ferraro, S. P. and Swartz, R. C. 1999. Avoidance response of the estuarine amphipod *Eohaustorius estuaries* to polycyclic aromatic hydrocarbon–contaminated field-collected sediments. *Environ Toxicol Chem.,* 18: 1232 – 1235.

Lemtiri, A., Colinet, G., Alabi, T., Cluzeau, D., Zirbes, L., Haubruge, E. and Francis, F. 2014.

Impacts of earthworms on soil components and dynamics. A review. *Biotechnol Agron Soc Environ.,* 18: 121-133.

Reinecke, A. J. and Reinecke, S. A. 1998. The use of earthworms in ecotoxicological evaluation and risk assessment: new approaches. In: Edwards, C. A. (Ed.,) *Earthworm Ecology*. St. Lucie Press. Boca Raton. FL. 273-293.

Six, J., Elliott, E. and Paustian, K. 2000. Soil macroaggregate turnover and microaggregate formation: a mechanism for C sequestration under no-tillage agriculture. *Soil Biol. Biochem.,* 32: 2099-2103.

Slimak, K. M. 1997. Avoidance response as a sublethal effect of pesticides on *Lumbricus terrestris. Soil Biol Biochem.,* 29: 713 – 715.

Stephenson, G. L., Kaushik, A., Kaushik, N. K., Solomon, K. R., Steele, T. and Scroggins, R. P. 1998. Use of an avoidance-response test to assess the toxicity of contaminated soils to earthworms. In: Sheppard, S. C., Bembridge, J. D., Holmstrup, M., Posthuma, L. (Eds.,) *Advances in Earthworm Ecotoxicology.* SETAC, Pensacola, FL. USA. 67–81.

Verhoef, H. A. and Van Gestel, C. A. M. 1995. Methods to assess the effects of chemicals on soils. In: Linthurst, R. A., Bourdeau, P. and Tardiff, R. G. (Eds.,) *Methods to Assess the Effects of Chemicals on Ecosystems*. John Wiley and Sons Ltd. New York. 223-257.

Wolf, D. and Wagner, G. 2005. Carbon transformations and soil organic matter formation. In: Sylvia, D., Fuhrmann, J., Hartel, P. and Zuberer, D. (Eds.,) *Principles and applications of soil microbiology*. Upper Saddle River. NJ. Pearson Prentice Hall. USA. 285-332.

Wrage, N., Velthof, G.L., Van Beusichem, M. L. and Oenema, O. 2001. Role of nitrifier denitrification in the production of nitrous oxide. *Soil Biol. Biochem.,* 33: 1723- 1732.

Yeardley, R. B., Lazorchak, J. M. and Gast, L. C. 1996. The potential of an earthworm avoidance test for evaluation of hazardous waste sites. *Environ Toxicol Chem.,* 15: 1532 –1537.

DIVERSITY OF EARTHWORM SPECIES FROM VARIOUS HABITATS OF ERODE DISTRICT, TAMIL NADU

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ABSTRACT

The comparative abundance of the earthworms in different localities viz., river bank, forest region and cultivated soil were studied from January to December 2009 in Erode District, Tamil Nadu. The earthworm species of four families, five genera and 14 species were taken into account for the present investigation. The percentage of earthworm families were Megascolecidae (50.4%), Eudrilidae (25.4%), Lumbricidae (17.1%) and Moniligastridae (0.05%). Among them, Megascolecidae and Eudrilidae were the most abundant than other families. The findings exhibited great fluctuations in earthworm population over the months. Earthworms conserve the fertility of the soil in the natural way and could replace inorganic fertilizers that make the soil barren in long run. Hence, it is the high time to promote more research on earthworm to improve soil fertility and sustained agricultural development, not only in the study area but also elsewhere in India. Considering the above facts, the paper intends to communicate the importance of earthworm biodiversity conservation and its management, to prevent the declining of the biodiversity of earthworm.

Keywords: Abundance, Diversity, Earthworm, River Bank, Forest Region

1. INTRODUCTION

India is one of the important mega-biodiversity countries and only 11.1% earthworm diversity is available out of total global earthworm diversity. It is estimated that nearly 4200 species of Oligochetes listed so far. The distribution of earthworms throughout the nations was documented by Bhadauria *et al.* (2000) and Julka and Paliwal, (2005). The diversity of Earthworms are greatly influenced by the soil climatic factors (Sinha, 2009). Industrial pollutions like man made disturbances also interfere with the growth and development of the earthworms of a particular area. Crop cultivation practices involve the application of artificial fertilizers and pesticides have a deadly impact on the earthworm biomass (Joshi and Aga, 2009). The biological diversity generally contributes to the natural productivity of agricultural systems. Soil communities represent the major part of natural agricultural systems and thereby play a vital role in maintaining the ecosystem services for the benefit of mankind. Earthworms, the members of the class Oligochaeta under the phylum Annelida are very important soil creatures as they make up a large portion of the total biomass of invertebrates present in the soil. Earthworms constitute more than 80% of total soil invertebrate biomass in subtropical, tropical and temperate regions. Approximately 3,627 earthworm species are known worldwide. The existing diversity of earthworm population is distributed in different cultivable soil, river bank and forestry area of Tamil Nadu especially Erode District. The present investigation focused on a survey of earthworm diversity in different localities of Erode District, Tamil Nadu, India.

2. MATERIALS AND METHODS

The sampling plot was subdivided into many subplots of equal size and periodically a fixed number of samples were taken from subplots using the random numbers. The earthworm samples were collected in river bank, forest region and cultivated soil in Erode District. The sampling unit of 25x25x30 to 40 cm is recommended in different soil types (Satchell, 1971). Hand – sorting method was adopted for earthworm collection outlined by Julka (1988). Collected worms were gently washed in fresh water and stored in test tubes in the field. After anesthetizing in 10% alcohol for 20-60 seconds, the specimens were washed with tap water and kept in 10% formalin for 24 hrs. Then these specimens were permanently kept in 5% formalin solution. The preserved earthworms will be identified based on the methods suggested by Julka (1988).

3. RESULTS

A total of 496 earthworm specimens were collected from all three localities during the study period, represented by 4 families, 5 genera and 14 species of earthworms. The diversity and distribution pattern of earthworms at the ground level were determined. Out of total specimens recorded, Megascolecidae accounted for 50.4% consisting of the species *Lampito mauritii* and *Perionyx excavatus.* Eudrilidae accounted for 25.4% which were the most active earthworms comprising of the species *Eudrilus eugeniae*. The moderately active earthworms of the family Lumbricidae contributed to 17.1% including the species *Eisenia fetida* and Moniligastridae of 0.05% (Table 1). Among them, Megascolecidae and Eudrilidae were the most abundant and active at all sites during the month of July and November, whereas their activity was reduced in April and May. The relative abundance was at peak in October but declined to minimum in March.

Table 1. Number (Mean ± SD) of families, genera, species, number of earthworm specimens and their percentages

S.No.	Families of Earthworms	Number of specimen	Percentage %	Number of Genera	Number of species
1	Megascolecidae	250±8.1	50.4	2±0.02	6.2± 0.9
2	Eudrilidae	136±4.2	25.4	1±0.01	4.1±0.9
3	Lumbricidae	85±2.1	17.1	1±0.01	2.4±0.5
4	Moniligastridae	25±2.3	0.05	1±0.01	1.3±0.02
	Total	496	92.95	5	14

4. DISCUSSION

Several authors have discussed the significance of the diversity of earthworm. Though, the data on the estimation of species abundance and species richness were scanty. Lewis and Taylor (1968) opined that hand shorting method is the only suitable means for sampling of earthworms and appears to be the best available method to date. The abundance of Megascolecidae and Eudrilidae might be due to the highest moisture content. The finding is also coincides with the work of Edwards *et al.* (1998) in *Perionyx excavatus.* The average soil temperature of the sampling sites recorded was around 26^{o}C. Besides the soil of the sampling sites were rich in organic matter, high to medium soil porosity with slightly acidic to neutral pH. From the observations it could be ascertained that the edaphic factors might had provided the ideal environment for the proliferation of the earthworm species. This view was also supported by Kretzschmar and Bruchous, (1991) who revealed that high moisture content of the soil encourage the growth of earthworms. Many other workers like Wever *et al.* (2001), Perreault and Whalen, (2006), Chang and Chen, (2004, 2005a ;b), Blakemore (2006) and Shuster *et al*. (2003), supported the above concept.

5. CONCLUSION

In conclusion, *Lampito mauritii*, *Perionyx excavatus* and *Eudrilus eugeniae* were the most abundant and active species in different habitats of Erode District during July to October. Further research is essential to learn and extend the method to develop these earthworm species for the enhancement of soil to conserve the soil fertility for the sustained agricultural development.

REFERENCES

Bhadauria, T., Ramakrishnan, P.S. and Srivastava, K.N. 2000. Diversity and distribution of endemic and exotic earthworms in natural and regenerating ecosystems in the central Himalayas, India. *Soil Biol. Biochem.,* 32(14): 2045–2054.

Blakemore, R.J. 2006. Checklist of megadrile Earthworms (Annelida : Oligochaeta) from Tamil Nadu, South India. Doi: www.annelida.net/earthworm/TamilN adu.pdf.

Chang, C.H. and Chen, J.H. 2004. A new species of earthworm belonging to the genus Metaphire Sims and Easton 1972 (Oligochaeta: Megascolecidae) from southern Taiwan. *Taiwania,* 49: 219-224.

Chang, C.H. and Chen, J.H. 2005a. Three new species of octothecate pheretimoid earthworms from Taiwan, with discussion on the biogeography of related species. *J. Nat. Hist.,* 39: 1469-1482.

Chang, C.H. and Chen, J.H. 2005b. Taxonomic status and intraspecific phylogeography of two sibling species of Metaphire (Oligochaeta: Megascolecidae) in Taiwan. *Pedobiologia,* 49: 591-600.

Edwards, C.A., Dominguez, J. and Neuhauser, E.F. 1998. Growth and reproduction of *Perionyx excavates* (Perr.) (Megascolecidae) as factors in organic waste management. *Biology and fertility of soils.* 27 (2): 155-161.

Joshi, N. and Aga, S. 2009. Diversity and distribution of earthworms in a subtropical forest ecosystem in Uttarakhand, India. *NHJCU*, 9(1):21–25.

Julka, J. M. 1988. Fauna of India and the Adjacent Countries: Megadrile Oligochaeta (Earthworms). Haplotaxida: Lumbricina: Megascolecoidea: Octochaetidae. *Zoological Survey of India.*

Julka, J.M. and Paliwal, R. 2005. Checklist of earthworms of Western Himalaya, India. Zoos Print J. 20(9): 1972-1976.

Kretzschmar, A. and Bruchous, C. 1991. Weight response to the soil water potential of earthworms. *Apporectodea longa. Boil. Fertile. Soil.,* 12: 209–12.

Lewis, T. and Taylor, L.R. 1968. Introduction to experimental ecology (London & New York: Academic Press) p. 401.

Perreault, J.M. and Whalen, J.K. 2006. Earthworm burrowing in laboratory microcosms as influenced by soil temperature and moisture. *Pedobiologia,* 50: 397-403.

Satchell, J.E. 1971. Earthworms. In: Philipson J (ed) Methods of study in quantitative soil ecology: population. Production and energy flow. Blackwell Scientific Publications, Oxford, pp 107–127.

Shuster, W.D., Shipitalo, M.J., Subler, S., Aref, S., McCoy, E.L. 2003. Earthworm additions affect leachate production and nitrogen losses in typical Midwestern agroecosystems. *J. Environ. Qual.,* 32: 2132–2139.

Sinha, R. K. 2009. Earthworms: the miracle of nature (Charles Darwin's'unheralded soldiers of mankind & farmer's friends'). Environmentalist 29:339-340.

Wever, L.A., Lysyk, T.J. and Clapperton, M.J. 2001. The influence of soil moisture and temperature on the survival, aestivation, growth and development of juvenile Aporrectodea tuberculata (Eisen) (Lumbricidae). *Pedobiologia,* 45(2): 121 – 133.

SURVEY OF COMMON CULTIVABLE CROPS VARIETIES, PROTECTION OF FOOD GRAINS AND SEEDS IN CAUVERY DELTAIC REGIONS IN TAMIL NADU, INDIA.

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ABSTRACT

Agriculture is an important sector of the Indian economy, accounting for 14% of the nationwide, about 11% of its exports, about half of the population still relies on agriculture as its principal source of income and it is a source of raw material for a large number of industries. Storage and upkeep of agricultural products are very important post harvest activities. In the present study the direct interview questioner method Thanjavur, Thiruvarur and Nagapattinam District, among the three districts revealed that the most of the peoples are cultivated the paddy followed by green gram, black gram and cotton. In Thanjavur, Thiruvarur and Nagapattinam, around 225 respondents in fifteen villages showed equal percentage of the paddy (100%) cultivated, followed by the most production of green gram (62.66%) in Nagapattinam district, In Thiruvarur district(60.88%), and 60.44 % in Thanjavur district. The black gram 25.77% in Nagapattinam district, 15.55% in Thanjavur and 15.11% Thiruvarur were observed. Among the three districts in Nagapattinam 83% of stored grains were paddy variety recorded followed by Thanjavur (70.23%) and Thiruvarur (68.88%). The stored grains are used to next year for the purpose of food and seeds.

Keywords: Paddy, Green gram, Black gram, Thanjavur, Thiruvarur and Nagapattinam Districts

1. INTRODUCTION

Agriculture is the most important sector of Indian Economy, Indian agriculture sector accounts for 18 per cent of India's gross domestic product (GDP) and provides employment to 50% of the countries workforce (Madhusudhan, 2015). According to Ministry of External Affairs (2015) India is the world's largest producer of pulses, rice, wheat, spices and spice products. Storage and upkeep of agricultural products are very important post harvest activities, Considerable amount of food grains is being spoiled after harvest due to lack of sufficient storage and processing facilities (Singh and Sharma, 2003). Food and Agricultural Organization (FAO) estimate of worldwide annual losses in stored produce has been given as 10% of all stored grain. About 13 million tons of grain loss is due to 10 million tons to failure (Wolpert, 1966).

Safe storage of grain is the time during which the grain can be stored safely without any significant loss in its quality and quantity (Karunakaran *et al.,* 2001). The farmer can keep the fresh grain only for a specific period to do post harvest conditioning operations (Sathya *et al.,* 2009).Storage period varies with respect to grain moisture content and the temperature (Karunakaran *et al.,* 2001). Grain storage plays an important role in preventing losses which are caused mainly due to weevils, beetles, moths and rodents (Kartikeyan *et al.,* 2009). It is estimated that 60-70% of food grain produced in the country is stored at home level in indigenous storage structures. The percentage of overall food crop production retained at the farm-level and the period of storage is largely a function of farm-size and yield per acre, family-size, consumption pattern, marketing pattern, form of labor payment, credit availability and future crop expectations (Greeley, 1978). The present study were carried out the questioners survey on current status of common cultivable craps and stored food grains and seed protection at farm, domestic, and commercial levels in Cauvery deltaic region (Thanjavur, Thiruvarur and Nagapattinam) Tamil Nadu, India.

2. MATERIALS AND METHODS

The present study was conducted in Cauvery deltaic region of three districts of Tamil Nadu, India (Thanjavur, Thiruvarur and Nagapattinam). In each district fifteen villages were randomly selected and collected the information about the stored products, pest management strategies from progressive farmers, big farmer's categories, aged farmers, farm laborers, farm woman were involved during the process of data collection. The investigated storage point and warehouse were consulted with agricultural officer and assistant agricultural officer of respective area through direct interviews. Above three investigated districts sites were listed in the Table 1.

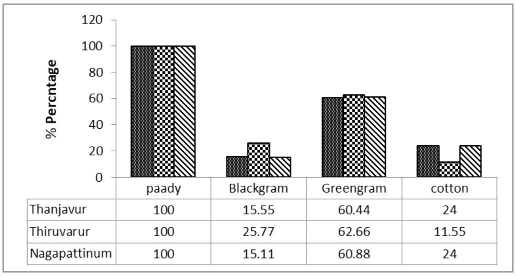
Table.1.Name of the selected villages of study area.

S.No	Districts		
	Thanjore	Thiruvarur	Nagapattinam
1	Pandanallur	Sannanallur	Mannampandal
2	Marathurai	Nannilam	Therazhanthur
3	Kattur	Srivangium	Kelvallur
4	Kurichi	Ammayappan	Kattucherry
5	Thirupanandal	Kavanoor	Killugudi
6	Sozhapuram	Manakkal	Karunkanni
7	Papanasam	Koradacherry	Umabalacherry
8	Ammasamuthiram	Kachanam	Sozhanganallur
9	Aduthurai	Mannargudi	Kottaragudi
10	Vallam	Kattur	Annagudi
11	Ammapet	Kangalancherry	Kovilkadambanur
12	Saliyamangalam	Puthagallur	Neelapadi
13	Poondi	Lakshmangudi	Rathanallur
14	Soorakkottai	Pathurmalkarai	Vedangallur
15	Ponnapur	Mangudi	Sattiyagudi

3. RESULTS

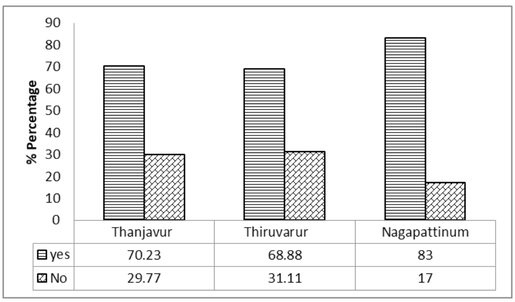
In the present study was conducted questionnaire method to collect the information. Most of the peoples are cultivated the paddy followed by green gram, black gram and cotton. In Thanjavur, Thiruvarur and Nagapattinam, around 225 respondents from fifteen villages showed paddy is being universal (100%) cultivation followed by the green gram (62.66%, 60.88%, 60.44%) in Nagapattinam, Thiruvarur and Thanjavur districts respectively. Respondents from the Nagapattinam district (25.77%) showed highest percentage black gram production followed by the Thanjavore (15.55%) and Thiruvarur (15.11%).

Figure.1 Common cultivable crops verity in Thanjavur, Thiruvarur and Nagapattinam districts (n=225)



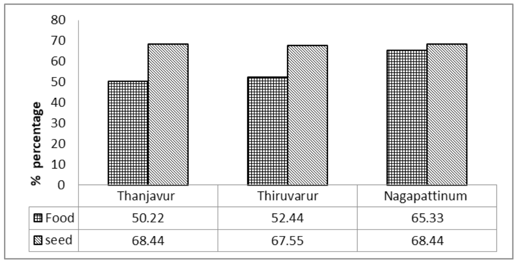
The cotton 24% is being cultivated in Thanjavur and Thiruvarur districts whereas Nagapattinam district 11.5% cultivated by the respondents (Fig.1). Among the three districts, Nagapattinam has highest (83%) stored grains in paddy variety followed by Thanjavur (70.23%) and Thiruvarur (68.88%). Respondents greatly agreed the above stored grain is being used for food and seed of next season (Fig.2).

Figure.2 People perception on storage for grains (n=225)



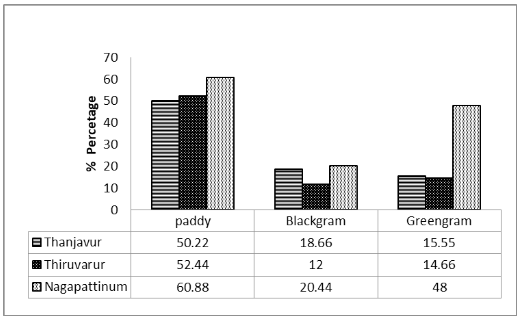
Nagapattinam district showed highest 65.33% followed by 52.44% in Thiruvarur District and 50.22% Thanjavur District respondents agreed to storage for food purpose. The seed purpose of the grains showed Nagapattinam and Thanjavur Districts equal percentage (68.44%) followed by Thiruvarur 67.55% (Fig.3).

Figure.3 Protection of grains and the purpose (n=225)



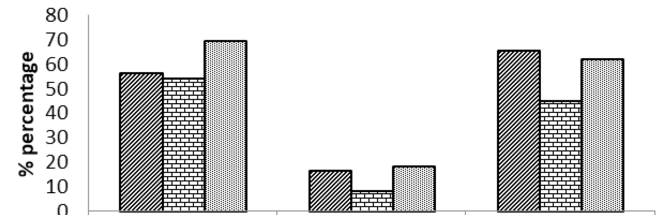
Among the crops, Nagapattinam District showed 60.88% paddy storage followed by Thiruvarur District (52.44%) and Thanjavur District (50.22%). Black gram was stored 20.44% in Nagapattinam followed by the 18.66% of Thanjavur, 12% of Thiruvarur Districts. Likewise, green gram stored 48% in Nagapattinam, 15.55% in Thanjavur and 14.66% in Thiruvarur (Fig.4).

Figure 4. Grains used for the food purpose (n=225)



The storage of the paddy, green gram and black gram for seed purpose showed high in Nagapattinam (69.33%), followed by Thanjavur (56.44%) and Thiruvarur (54.22%). In black gram, 18.22% was found in Nagapattinam followed by 16.44% in Thanjavur and 8% in Thiruvarur District. In green gram, 65.33% in Thanjavur followed by 62.22% of Nagapattinam District and 44.88% in Thiruvarur District (Fig.5).

Figure.5 Grains used for seed purpose (n=225)



	paddy	Blackgram	Greengram
Thanjavur	56.44	16.44	65.33
Thiruvarur	54.22	8	44.88
Nagapattinum	69.33	18.22	62.22

4. DISCUSSION

Indian agriculture sector accounts for 18 per cent of India's gross domestic product (GDP) and provides employment to 50% of the countries workforce. India is the world's largest producer of pulses, rice, wheat, spices and spice products (Madhusudhan, 2015). India people has many areas to choose for business such as dairy, meat, poultry, fisheries and food grains etc., India has emerged as the second largest producer of fruits and vegetables in the world (Ministry of External Affairs, (2015). According to the data provided by Department of Economics and Statics (DES) the production of food grains for the year 2013-2014 is 264 million tons which is increased when compared to (2012-2013) 257 million tons. This is a good symptom for the Indian economy from the agriculture sector (http://www.ccsniam.gov.in/research). Food grains form an important part of the vegetarian Indian diet, Grain production has been steadily increasing due to advancement in production technology, but improper storage results in high losses in grains (Singh, 2010). According to World Bank Report (2008), post-harvest losses in India amount to 12 to 16 million metric tons of food grains each year, an amount that the World Bank stipulates could feed one-third of India's poor. The monetary value of these losses amounts to more than Rs 50,000 crores per year.

Rice (*Oryza sativa* L.) is an important cereal staple food for a large part of the world population in terms of the area cultivated and amount consumed. Globally, more than 90 and 60 % of the global rice is grown and consumed in Asia and south East Asia, respectively (Bua and Ojirot, 2014). The present study revealed that, the respondents of these districts showed importance in rice cultivation and storing for future purposes. Grain storage is a component in the grain marketing supply chain that evens out fluctuations in the supply of grain from one season, usually the harvest season to other seasons, and from one year of abundant supply and releasing to lean years (Mushira, 2000). Grain storage may be at farm, trader, and commercial or at government levels (Mushira, 2000). Most of the Cauvery deltaic regions, especially Thanjavur, Thiruvarur and Nagapattinam Districts people are directly or indirectly, depending on the agriculture. Some are directly attached with the farming and some other people are involved in doing business with these goods. Cauvery deltaic regions, especially Thanjavur, Thiruvarur and Nagapattinam Districts have the capacity to produce the food grains. To achieve targeted mark by the government it needs to provide support in bank loans and other machineries to the small farmers along with the big farmers with this we can expect some of Indian economy improvement through the Cauvery deltaic regions agricultural sources.

REFERENCES

Bua, B. and Ojirot, M. 2014. Assessing the importance of rice as food and income security crop in Puti-Puti Sub-county, Pallisa District, Uganda. *Amer J Exp Agri.,* 4 (5): 532-540.

Greeley, M. 1978. Recent Indian experience with farm-level food grain storage research. *Food Poli.,* 39-49.

Kartikeyan, C., Veeraraghavantham, D., Karpagam, D. and Firdouse, S.A. 2009. Traditional storage practices, *Ind J Tral Know*.;. 8;4: 564-568.

Karunakaran, C., Muir, W.E., Jayas, D.S., White, N.D.G. and Abramson, D. 2001. Safe storage time of high moisture wheat. *J Sto Pro Rese.,* 37:303-312.

Madhusudhan, L. 2015.Agriculture Role on Indian Economy *Bus Eco J* 6;4:1- 4.

Ministry of External Affairs (2015) India in Business. Investment and Technology Promotion Division, Govt. of India pp 127.

Mushira, M.A. 2000. Manual on grain management and equipment maintenance in silos. FAO, Nigeria. 42 p.

Sathya, G., Jayas, D.S. and White, N.D.G. 2010. Safe storage guidelines for canola as the seeds slowly dry, *Cana Bio Engin.,* 51: 329-338.

Singh, P.K.A. 2010. Decentralized and holistic approach for grain management in India. *Cur Sci,.* 99; 10: 1179-1180.

Singh, S. and Sharma, G. 2003. Pulse beetle management through solar energy in stored green gram seeds. *Seed Res.,* 31(1): 89.

Wolpert, V. 1966. Rats in store, India. *Far Eas Eco Rev.,* 53;10: 439.

PHYSICAL CHARACTERISTICS OF ARASALAR RIVER OF KARAIKAL REGION, PUDUCHERRY, INDIA

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ABSTRACT

Water quality assessment is an important part of environmental monitoring. When water quality is poor, it affects not only aquatic life but the surrounding ecosystem as well. Studies on water quality assessment (Physical characters) were conducted in Arasalar River of Karaikal region, Puchucherry Union Territory, India. The study was conducted for four consecutive months of October, November, December (2015) and January (2016). Water samples were collected from six different locations of the Arasalar River of Karaikal region. Physical parameters such as Colour, Temperature, Suspended solids, TDS, Turbidity and Total hardness were analyzed. The colour was brown and the average temperature was 30±2ºC for all the four months. The other parameters such as Suspended solids, TDS, Turbidity and Total hardness were seen increased to about 200 – 250% in all the four months. This may be due to the industrial effluents that are discharges in the River in Karaikal region. Further studies on chemical and biological parameters must be done to determine the pollution level of Arasalar River and the eradication measurements must be followed.

Keywords: Water Quality Assessment, Physical characters, Arasalar River, Karaikal region.

1. INTRODUCTION

With the rapid economic and social development in recent decades, non-point source pollution to the environment from livestock and poultry industry, aquaculture industry, planting industry, and rural domestic sewage to our living space centered on the Earth has drawn much attention to the public and policy-makers. Among various pollutions, water environmental pollution, as a vital threat to human being health, also became the most remarkable issue for the sustainable development. Niemi *et al.* (1990) reported that human activities mainly impact surface water quality through effluent discharges, using of agricultural chemicals, in addition to the increased exploitation of water resources. Many rivers in the developing countries are heavily polluted due to anthropogenic activities (Jonnalagadda and Mgere, 2001), especially in India. The water quality management in India is performed under the provision of Water (Prevention and Control of Pollution) Act, 1974. The basic objective of this Act is to maintain and restore the wholesomeness of national aquatic resources by prevention and control of pollution. The Central Pollution Control Board (CPCB) has tried to define the wholesomeness in terms of protection of human uses, and thus, taken human uses of water as base f or identification of water quality objectives for different water bodies in the country.

It was considered ambitious to maintain or restore all natural water body at pristine level. Planning pollution control activities to attain such a goal is bound to be deterrent to developmental activities and cost prohibitive. Since the natural water bodies have got to be used for various competing as well as conflicting demands, the objective is aimed at restoring and/or maintaining natural water bodies or their parts to such a quality as needed for their best uses. The water pollution in India has become a serious issue to economic, social sustainable development, not only because the imbalance between available scant water resource and dense population, but also the inefficient of water resources regulation and management. According to “Annual Report of CPCB in India, 2011” (Anonymous, 2011), the River Arasalar is heavily polluted. Aiming at evaluating water quality and identifying the potential pollutant, this paper deals with the site observation data of water quality collected from a field campaign conducted within the four consecutive months of October, November, December (2015) and

January (2016) in Arasalar River of Karaikal region, Puchucherry Union Territory.

2. MATERIALS AND METHODS

2.1. Study area

The study area, is located in river Arasalar situated in Karaikal at the latitude 10º 54' 52''N Longitude 79º 51' 09'' E. Arasalar River separates as a tributary of Cauvery at Papanasam, near Kumbakonam. It is a branch of the major river, the Cauvery. At the place near to Pullambadi the River Cauvery is been stopped by Lower dam and from Tiruvaiyaru this Arasalar separates from the River Cauvery. This Arasalar takes its course from Tiruvaiyaru of Tanjore district, covers and travels through Kumbakonam and enters into the Sea, Bay of Bengal at Karaikal. Karaikal once served as a River Port till 19th century where the Yachts and "Marakkalam" ships of Karaikal Marakkayar harbored in and, loaded and unloaded the Goods and materials towards Exports and Imports. Furthermore, no specific permits were required for the study area and the location is not privately owned or protected, and the study studies did not involve endangered or protected species.

2.2. Physical Characteristics of Water

Physical characteristics of water (colour, temperature, etc.) are determined by sense of sight, temperature by thermometer, turbidity by turbidity meter, TDS by TDS monitor and Total Hardness by standardized analytical method.

3. RESULT

Water temperature plays an important role in influencing the quality and ecology of streams and rivers. It affects not only the physical nature of water by changing the viscosity, density and surface tension but also the rate and types of chemical reactions that occur within. Water temperature is thus an important factor that influences that rate of all biological activities. Temperature can therefore be used as a first step in predicting the effects of mans activities on the aquatic ecosystem (Moor *et al.,* 2004). Physico-chemical parameters analyzed by standard method are presented in Table 1.

The observed average temperature during the study period was 30.33±0.48. The minimum temperature level was 30ºC and the maximum temperature was 31.2ºC. The average pH was 6.0±0.37. The minimum of pH 5.7 and the maximum of 6.6 were recorded. The observed turbidity level was -2.58±0.21 and maximum and minimum level was 2.9 and 2.3 respectively. The observed alkalinity level was 244.5±16.82 mg/l. The maximum was noted to be 265 mg/l minimum was 220 mg/l. The observed total hardness was 226.66±13.13 mg/l and the maximum and minimum total hardness observed was 246 mg/l and 210 mg/l respectively. TDS was 992.66±3.94. The maximum and minimum TDS observed was 986 and 998 respectively.

Table: 1 Physico-chemical parameters of water sample

PARAMETERS	MEAN AND SD	MAXIMUM	MINIMUM
Colour	Brown	Dark Brown	Light Brown
Temperature (°C)	30.33± 0.48	31.2	30
Turbidity (NTU)	-2.58±0.21	2.9	2.3
Total hardness (ppm)	226.66 ±13.13	246	210
TDS (ppm)	992.67±3.94	986	998

The water temperature was ranging from 26°C to 32°C during the study period. The minimum water temperature (26°C) was observed in December at S1 and maximum temperature (32°C) was observed in April at S3. The mean value of water temperature observed to be 29±1.58ºC, 28.84±1.62ºC and 29±1.47ºC for S1, S2, and S3 respectively. Water samples collected in the river Arasalar showed lower temperature in the monsoon season. In the summer season it was found to be highest. Similar seasonal variation in water temperature was recorded by [6] in river Cauvery.

4. DISCUSSION

Fishes and many aquatic organisms present in the River are supposed to be a part of a nutritious human diet. Though fishes of various species do not provide the same nutrient profile to their consumers (Takama *et al.,* 1999), and the nutritive value of fish varies with environmental factors (Saoud *et al.,* 2008). Colour in water is primarily a concern of water quality for aesthetic reason. Coloured water gives the appearance of being unfit to drink, even though the water may be perfectly safe for public use. On the other hand, colour can indicate the presence of organic substances, such as algae or humic compounds. More recently, colour has been used as a quantitative assessment of the presence of potentially hazardous or toxic organic materials in water.

The temperature of water affects some of the important physical properties and characteristics of water: thermal capacity, density, specific weight, viscosity, surface tension, specific conductivity, salinity and solubility of dissolved gases and etc. Chemical and biological reaction rates increase with increasing temperature. Reaction rates usually assumed to double for an increase in temperature of 10 °C.

The total solids content of water is defined as the residue remaining after evaporation of the water and drying the residue to a constant weight at 103 °C to 105 °C. The organic fraction (or volatile solids content) is considered to be related to the loss of weight of the residue remaining after evaporation of the water and after ignition of the residue at a temperature of 500 °C. The volatile solids will oxidize at this temperature and will be driven off as gas. The inorganic (or fixed solids) remind as inert ash. Solids are classified as settle able solids, suspended solids and filterable solids. Settle able solids (silt and heavy organic solids) are the one that settle under the influence of gravity. Suspended solids and filterable solids are classified based on particle size and the retention of suspended solids on standard glass-fibre filters. Turbidity is a measure of the light-transmitting properties of water and is comprised of suspended and colloidal material. It is important for health and aesthetic reasons.

5. CONCLUSION

The present study aim is to investigate the physical parameters of water which would affect the fishes and other organisms living in the river Arasalar at karaikal, Tamil Nadu. The study concluded that the river water is physically polluted and unfit for normal usage in the Karaikal region. The polluted nature of river causes not only great reduction in the diversity of aquatic life but also incorporate into humans through food chain. Thus a severe monitoring protocol is essential in maintaining the quality of the River Arasalar.

REFERENCES

Anonymous, 2011. Guidelines for Water Quality Monitoring. MINARS/27/2007-08, Central Pollution Control Board, Delhi. http://cpcb.nic.in/upload/NewItems/NewItem_116_Guidelinesof%20waterqualitymonitoring_31.07.08.pdf.

Saoud, I. P., Batal, M., Ghanawi, J. and Lebbos, N. 2008. Seasonal evaluation of nutritional benefits of two fish species in the eastern Mediterranean Sea. International Journal of Food Science and Technology, 43, 538-542.

Jonnalagadda, S.B. and Mgere, G. 2001. Water quality of the Odzi River in the eastern high lands of Zimbabwe. Water Res. 35(10): 2371–2376.

Moor, N. A., Jewitt, G. P. W. and Weeks, D.C. 2004. Water temperature and fish distribution in the Sobie River system towards the development of an adaptive management tool. WRC Report No 1065/1/04. Water research commission, Pretoria 188.

Niemi, G.J., Devore, P., Detenbeck, N., Taylor, D. and Lima A. 1990. Overview of case studies on recovery of aquatic systems from disturbance. Environmental management. 1990; 14: 571–87.

Sholkovitz, E.R. 1976. Flocculation of dissolved organic and inorganic matter during the mixing of river water and seawater, Geochimica et Cosmochimica Acta. 40, 831–845.

Takama, K., Suzuki, T., Yoshida, K., Arai, H. and Mitsui, T. 1999. Phosphatidylcholine levels and their fatty acid compositions in teleost tissues and squid muscle. Comp. Biochem. Physiol. Part B: Biochem. Mol. Biol, 124, 109-116.

ASSESSMENT OF WATER QUALITY OF COLEROON RIVER, TAMIL NADU, INDIA

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ABSTRACT

The study was conducted in Coleroon River from Upper Anaicut to Lower Anaicut Thanjavur District, Tamilnadu. It is the drainage carrier of Cauvery, branching out near Upper Anaicut. Normally, the entire floodwaters of Cauvery, surplus from Mettur dam are being diverted to Upper Anaicut and Coleroon directly and also through Grand Anaicut. Four stations were selected for collection of water samples and analyzed for water quality parameters. The air temperature varied between 28°C and 38°C during the period of investigation. The conductivity was a factor related to the present study points to its significant relationship with water temperature, phosphate and silicate. During summer, the Dissolved Oxygen level (DO) was reduced because of the decomposition of organic matter, resulting in increased COD and BOD. Sulphate was found to have significant correlation with DO, BOD and COD. Phosphate was found to have significant correlation with silicate, BOD and COD. Similarly, Phosphates was recorded within the suitable range for supporting a productive ecosystem. Silicate had significant correlation with air temperature, conductivity, DO, BOD and COD. The results indicated that Coleroon river water quality as 'Good'. Based upon the results, the existing conservation measures have been reviewed and additional measures are suggested.

Keywords : Water quality parameters, Water quality index, Coleroon River, Temperature.

1. INTRODUCTION

Rivers are the sources of drinking water, irrigation, fishery and energy production. Almost all the freshwater bodies are being polluted by expanding human population and in consequence, industrialization, intensive agricultural practices and discharges of massive amount of wastewater which result in deterioration of water quality. The main pollutants that pose to natural water quality problems are organic wastes, bacteria, nutrients and other chemical substances. There is an intricate relationship between the external and internal factors in aquatic environments. The physio-chemical parameters have major influences on biochemical reactions that occur within the water. Sudden changes of these parameters may be indicative of changing conditions in the water. The physico-chemical parameters of different freshwater systems have been studied by various researchers (Kiran, 2010; Abhas and Singh, 2013; Malviya and Dwivedi, 2015 and Jasmin lena and Maneemegalai, 2015). However, no comprehensive work has been done till yet to explore the seasonal variation in physiochemical parameters on the water quality of Coleroon river. Keeping this in view, our work was done during the period June 2014 to May 2015, to evaluate some of the physiochemical parameters of Coleroon river water in different seasons.

Coleroon river from Upper Anaicut to Lower Anaicut Thanjavur District, Tamilnadu is located at 10.830° N and 78.818° E and 11.138° N 79.451° E. and was is selected for the present study. The river Coleroon is the drainage carrier of Cauvery, branching out near Upper Anaicut. Normally, the entire floodwaters of Cauvery, surplus from Mettur dam are being diverted to Upper Anaicut and Coleroon directly and also through Grand anaicut. The total length of river Coleroon is 257 KM from Upper Anaicut and it flows through the districts of Trichy, Perambalur, Ariyalur, Thanjavur, Cuddalore, and Nagapattinam, finally, mixes into the Bay of Bengal. The study was carried out to assess the seasonal variations in the water quality characteristics.

2. MATERIALS AND METHODS

The present study was carried out over a period of one year from June 2014 to May 2015 in different four stations Water sampling was carried out in early hour of the morning throughout the study period at four stations. Generally two liters of water sample in 2.5 litre polythene can was sufficient for most of the physical and chemical examinations. The water samples were collected from a depth of 0.5m and collected up to the top with the mouth facing slightly upward in the direction of the current. The container was properly labeled and the samples were transported to the laboratory in an ice box to avoid unpredictable changes in physicochemical and biological characteristics. Sampling and analysis were carried out according to standard methods prescribed by APHA (1995). Methods of the determination of various physiochemical parameters are given in table 1.

Table 1. List of physicochemical parameters and their methods

SI. No	Parameters (units)	Method /instrument
1.	Temperature (ºC)	Celsius thermometer
2.	Conductivity (µSie)	Conductivity meter (Henna pen type) made in Portugal
3.	pH	pH meter (Hanna Pen type) made in Portugal
4.	Dissolved oxygen (mg/l)	Winkler's iodometric method
5.	BOD (mg/l)	Winkler's method after incubation for 5 days
6.	COD (mg/l)	Titrimetric method
7.	Sulphate (mg/l)	Turbidimetric at 420nm
8.	Phosphate (mg/l)	Colorimetric (Molybdophosphoric acid method)
9.	Silicate (mg/l)	Colorimetric (Molybosilicate method)

3. RESULTS AND DISCUSSION

Season dependent variations in air temperature of the four stations of the Coleroon River are presented in table 2 and figure 1. It divulges that the patterns of deviation in all the four stations were alike throughout the phase of research. The air temperature varied between 28°C and 38°C during the period of investigation. Seasonal variations of the water temperature in the four stations of Coleroon River are presented in table 2 and figure 2. The maximum water temperature of 34°C was documented during Apr'15 in station III and the lowest water temperature of 23°C during Dec 14 all the stations and were hot during the months from Feb'14 to Jul'14 and Feb'15 to May'15. The temperature dropped gradually in Oct'14 to Dec'14 in all the stations. Variation in the same months may be due to the changes in the weather factors and difference in the time of observation. The variations between the air and water temperature went hand in hand. Further, the water temperature was not parallel with air temperature during Oct'14 to Dec'14. In view of it could be assumed that the cooler water flowing into the river has reduced the water temperature more than the local air temperature. The maximum difference of 6 °C between the air temperature and water temperature was recorded in December'14 at all the stations. The outflow was low and there was only little inflow. The correlation of the air temperature and water temperature of Coleroon river showed positive relationship. A similar correlation between air and water temperature was reported (Sharma and Krimav, 2011; Maya *et el.*, 2013; Ravichandran and Rakesh, 2014). The variations in air and water temperature is similar to other rivers and reservoirs of Tamil Nadu as reported (Bhalero *et al.,* 2012; Garge *et al.,* 2010; Khalik *et al.,* 2015).

Variations in the pH of four stations are presented in table 2 and figure 4. The pH of the four stations was between 7.2 and 8.3. The pH showed changes during the months of the study period in Coleroon River. During Apr'15 to May'15 period, pH was found to increase towards neutral in all the stations. A similar observation was earlier reported (Garge *et al.,* 2010 and Khalik *et al.,* 2015).

According to Srivastava *et al*. (2011) increase in pH is related to increase in production. This synchronizes with observation made in Coleroon River. A minor reduction in pH was observed during the period of Jan'14 to May'14. This reduction is in agreement with the earlier observation in Cauvery river (Ravichandra and Rakesh, 2014). According to Rajagopal *et al.* (2010) the environment from which water drains into the catchment determines its pH. During the above months in flowing water influenced the pH to some extent as the natural rain water is of 7.2 – 7.3. This may be one of the reasons for the low pH during the raining season. Further alkaline nature of the water may be due to the presence of limestone deposits along the bank of the river as Ariyalur formation of cretaceous period lies adjoining to the river.

The electrical conductivity of the four stations ranged from 800 µSie – 1420 µSie are given in table 2 and figure 3. The low electrical conductivity (730 µSie) was observed in the station III in Sep'13 and Oct'13 and the maximum in station II in Jul'14. Conductivity is an index of the amount of water soluble salt presents in water indicating that the salt of mineralization in an aquatic ecosystem. The measurement of dissolved ions having wide bearing on the productivity. Majority of Indian rivers have lower values of conductivity as compared to Coleroon River. The presence of salts and nutrients in the water may be the reason for conductivity. The result of the present study reveals that the conductivity of all the stations seems to be suitable for agriculture and aquaculture practices.

The minimum amount of dissolved oxygen of 8.28 mg/l was recorded in Mar'13 in station II and Jun'14 in the station IV. The maximum amount of DO was observed from station IV (10.85 mg/l) during Dec'13 and Feb'15 and are given in table 2 and figure 5. The dissolved oxygen showed insignificant difference among the different stations studied. Among the chemical parameters dissolved oxygen is one of the very important factors for the existence of plants and animals in an aquatic environment. The amount of dissolved oxygen is an indicator of quality of water and its suitability for aquatic life. The dissolved oxygen content of the water was high in Feb '15 and Mar'15 compared with other months in all the stations. This may be due to high solubility of water with surface water at low temperature. This finding is in agreement with the observations made by Charkhabi and Sakizadesh (2016). According to Ravichandran and Rakesh Sharma (2014) the reduction of dissolved oxygen level implies an index of high productivity. Mahendran (2010) reported that tropical reservoir are characterised by low dissolved oxygen levels in the water regardless of eutrophy or oligotrophy. However, it was observed that the variations are of many reasons other than a sign of productivity. According to Sreenivasan and Kotaiah (2000), the deficit may be either due to the decomposition of submerged vegetation and bottom mud or due to the oxygen being utilized by the benthic organisms for respiration. High photosynthetic group can fix oxygen to the water mass to a greater extent than through diffusion (Pankaj *et al.,* 2015; Jasmin and Maneemegalai, 2015). The result of the present study reveals that the river never suffered from hypoxia or anoxia. The results also reveal its suitability as high productive river and suitability for intensive aquaculture practice.

The aquatic production will be higher if all nutrients are present in optimum concentration. Among the dissolved nutrients, phosphorus in freshwater system is most often found to be a limiting factor. The role of phosphorus in aquatic life has been widely studied and its importance in aquatic ecosystem is well recognized. Accordingly phosphorus concentration was monitored to assess the trophic status of river under investigation. The nutrient flow dynamic and forms the biogeochemical cycles. The high nutrient levels and nutrient dynamics in the form of nutrient turnover are essential for better production characteristics. The results of the present study reveal a significant relationship between nutrients levels of the sediments and the nutrient levels in water. The mathematical models and relationship established also paved way for developing sustainable strategies for water quality management in the river ecosystem.

The results of the present study reveal that there is a wide fluctuation in the biological oxygen demand of station II that showed a maximum of 92 mg/l (Jun'14 in station IV) and a minimum of 29 mg/l in station III during Apr'15 presented in table 2 and figure 6. Seasonal variations in COD reveal the maximum of 72.14 mg/l in station III during Jun'13 and the minimum of 72.14 mg/l in SII Feb'15 presented in table 2 and figure 7.

Table 2. The detailed observations for the fluctuation in all the physio chemical parameters are recorded in Coleron River

Sl. No	Parameter	Station-I	Station-II	Station-III	Station-IV
1	Air temperature (^oC)	30 - 38	31-38	30 - 38	31 - 38
2	Water temperature (^oC)	25 - 33	26 - 33	25 - 34	25 - 31
3	Conductivity (µSie)	830 - 1300	840 - 1420	800- 1200	910 - 1090
4	pH	7.3 – 8.2	7.3 – 8.2	7.2 – 8.3	7.2 – 8.3
5	Dissolved oxygen (mg/l)	9.74- 10.85	9.5- 10.52	8.7 – 10.1	8.28- 10.81
6	BOD (mg/l)	32 - 58	31 - 40	30 - 60	29 - 92
7	COD (mg/l)	32.06- 49.1	42.06– 54.12	30.08 – 72.14	35.54– 67.54
8	Sulphate (mg/l)	5.35- 12.46	5.84- 18.52	4.76-16.06	6.61-26.91
9	Phosphate (mg/l)	0.15- 1.5	0.13-1.25	0.27-2.14	0.12-1.24
10	Silicate (mg/l)	1.15- 2.5	2.13-3.25	2.27-3.14	2.12-3.24

The present investigation revealed that the dissolved phosphate concentration in the river varied widely and it is related to the sediment phosphates. During most of the months the river were characterized by low level of phosphate. Earlier studies revealed such low levels of phosphate content in many of the Indian rivers (Rajagopal *et al.,* 2010; Malviya and Dwivedi, 2015; Jasmin and Maneemegalai, 2015) stated that the amount of nutrients in the river is derived from the catchment area through rain washing depends on the soil types of catchment. In this river phosphate content ranged from 0.012 – 2.14 mg/. In the present study all the stations showed seasonal variation of dissolved phosphate concentration. The values were found high during Oct'14 to Dec' 14 and are shown in figure 8. A similar instance was earlier reported (Pankaj *et al.,*2015; Jasmin and Maneemegalai, 2015) in Narmada river. The high values of dissolved phosphate during monsoon may be due to the rain washings from the catchment through river discharge and flood water as well as seepage from paddy fields. Besides the rain water soil colloids decomposition of aquatic and conversion of insoluble salts appear to show increasing trend in the water column and enrich the water during monsoon (Mathavan and Nambirajan, 2012). The level of phosphates in the river further reveal that it is a water body without eutrophication and optimum production. Proper management strategies will evolve it as a highly productive water body. The minimum sulphate level of 4.76 mg/l was observed in station IV during Aug'13 and Oct'14 and in station III Sep'13, Jan'14, Nov'14 and Mar'15 and the maximum level of 26.91 mg/l was in station IV in Feb'15 and are shown in Figure 9.

Seasonal variations in the silicates of the different stations during the experimental period are shown in figure 10. Silicates in river water exist mainly in the form silicic acid and reactive polymer. The release of silicic acid depends on the availability of carbon-di-oxide or bicarbonates. According to Maya *et al.* (2013) silicate concentration is directly associated with the density of diatom population since diatoms are the main consumers of silicate for the formation of frustules. Nutrient status of the Coleroon River revealed that compared to phosphorus and nitrogen, silicate content was higher in concentration. The silicate concentration was in the range of 1.15 – 3.25 mg/l during the present study. The correlation coefficients of silicate with dissolved oxygen, ammonia, BOD, COD, and dissolved oxygen showed significantly correlated. The observed values are in agreement with the results recorded earlier (Malviya and Dwivedi, 2015; Jasmin and Maneemegalai, 2015; Charkhabi and Sakizadesh, 2016). It was observed that the level of dissolved silicate was higher towards station IV.

Figure1: Seasonal variation of Air temperature (°C) in four stations from June 2014 to May 2015.

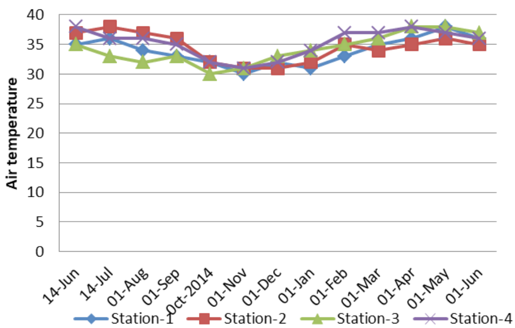


Figure 2: Seasonal variation of Water temperature (°C) in four stations from June 2014 tom May 2015.

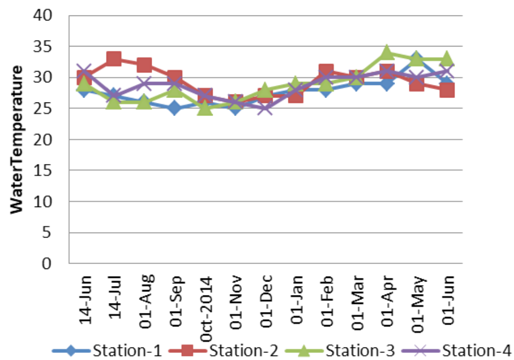


Figure3: Seasonal variation of Conductivity in four stations during the study period.

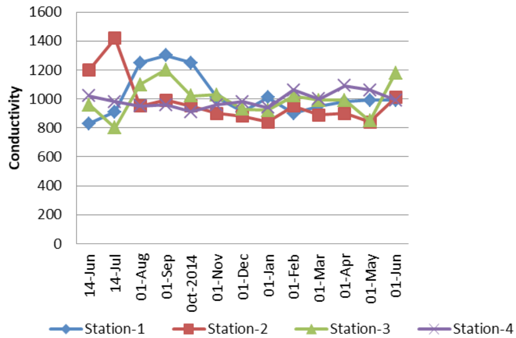


Figure 4: Seasonal variation of pH in four stations during the study period.

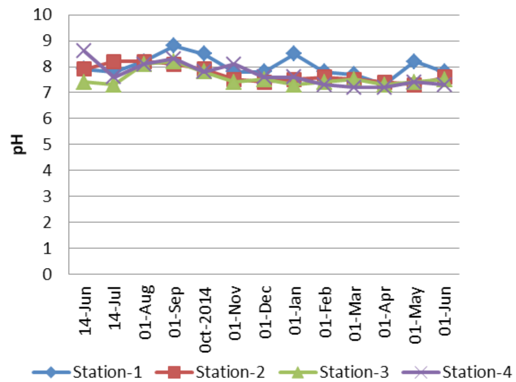


Figure 5: Seasonal variation of dissolved oxygen (mg/L) in four stations.

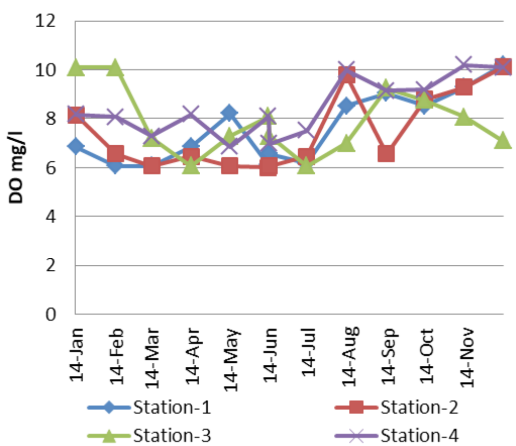


Figure 6: Seasonal variation of BOD (mg/L) in four stations.

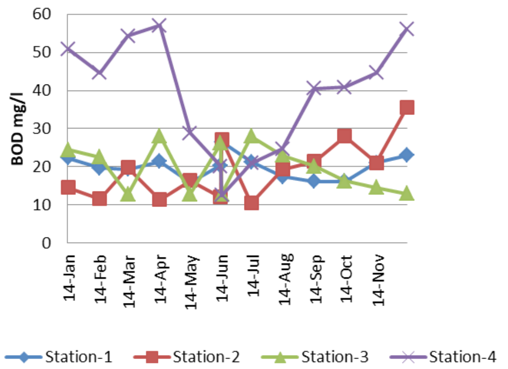


Figure 7: Seasonal variations of COD (mg/L) in four stations during study period.

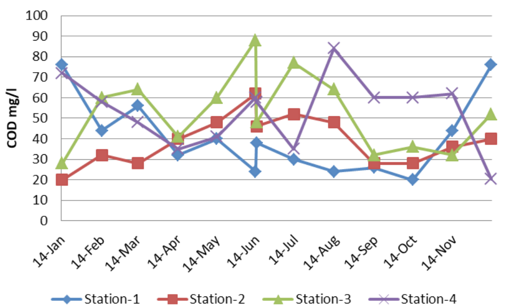


Figure 8: Seasonal variation of Phosphate (mg/L) in four stations.

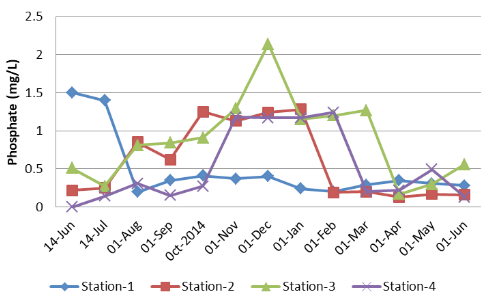


Figure 9: Seasonal variation of Sulphate (mg/L) in four stations.

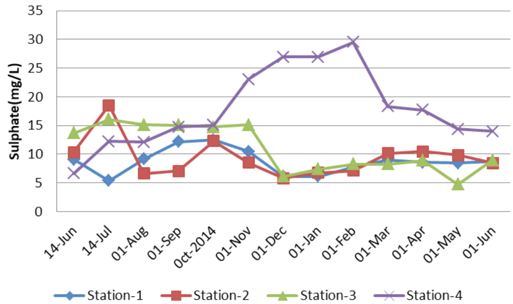
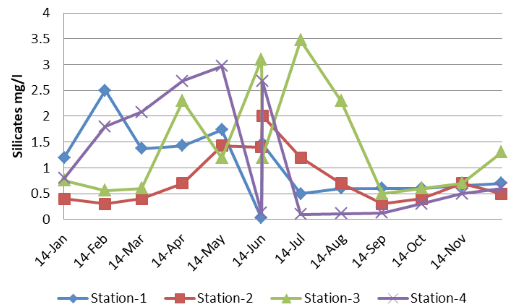


Figure 10: Seasonal variation of Silicates (mg/L) in four stations.



4. CONCLUSION

The results clearly suggest that the dissolved oxygen can be a suitable and easy index to predict air temperature, water temperature, conductivity, pH, BOD, COD, sulphate as well as phosphate of water. Investigations of these nonlinear derivations should be made in different types of ecosystem with different characteristics for deriving a universal nonlinear equation for predicting such parameters. The present study suggested that most of the physical and chemical properties of Coleroon river water were within desirable limits. The quality of water is not stable and it may be changed due to seasonal variations.

REFERENCES

Abhas Jain and Singh, S.K. 2013. Limnological Studies Related to Physico- Chemical Characteristics of Water in Anasagar Lake, Ajmer, Rajasthan *International J. Adve. Res. and Inno.* 1 : 65-72.

APHA 1995. Standard Methods for the estimation of water and waste water, American Public Health Association, American Waste Water Association and Water Pollution Control Federation, Washington.

Bhalerao S.N. 2012. Study of Fish Diversity and Water Quality at Kasar Sai Dam, Hinjewadi, Pune, Madhya Pradesh, India, *International Research Journal of Biological Sciences*, 1(4): 51-55.

Charkhabi A.H. and Sakizadeh M. 2016. Assessment of spatial variation of water quality parameters in the most polluted branch of the Anzali Wetland. Northern Iran, Polish *Journal of Environmental Studies*. 15(3): 395-403.

Garg, R.K., Rao, R.J., Uchchariya, D., Shukla, G. and Saksena, D.N. 2010. Seasonal variations in water quality parameters and major threats it Ramsagar reservoir, *Afr.J.Environ.Sci.,* 4(2): 61-76.

Jasmin lena, P. and Maneemegalai, S. 2015. Water pollution status of Varahanadhi River by physico-chemical Analysis. *International Journal of ChemTech Research* 7(7): 2911-2916.

Kiran, B.R. 2010. Physico-chemical characteristics of Fish ponds of Bhadra Project at Karnataka. *Rasayan J.Chem*, 3(4): 671-676.

Mathavan, N. and Nambirajan, P. 2012. Studies on the physicochemical parameters of Grant Anaicut (Kallanai), Thanjavur District, Tamil Nadu, India, *IJBPS*., 2(4): 32-40.

Maya, K., Remya, S.I., Baburaj, B., Lekshmi, I., Nisha, U.R., Sangeetha, J. and Padmalal, D. 2013. *International Journal of Agricultural Science*, 3(1), 363-372.

Malviya, P. and Dwivedi, A.K. 2015. Physico- chemical parameters of Narmada River Water: A review. *International Journal of Chemical Studies* 3(2): 01-04.

Rajagopal, T., Thangamani, A., Sevarkodiyone, S.P., Sekar, M. and Archunan, G. 2010. Zooplankton diversity and physico-chemical conditions in three perennial ponds of Virudhunagar district. Tamilnadu. *J. Env Biol*., 18: 265-272.

Ravichandran, C. and Rakesh Sharma, T. 2014. Physico-chemical characteristics of sediments in Distributaries of River Cauvery, Tiruchirappalli, Tamilnadu *Sch. Acad. J. Biosci.,* 2(7): 398-403.

Sharma, T. and Krimav, P.S. 2011. Water Quality Index of River Cauvery in Tiruchi District, Tamilnadu, *Arch. Environ.Sci*, 5: 55-61.

Sonawane, S.R., Powar, S.M., Sathe, S.S. and Ganeshwade, R.M. 2009. Hydrobiological studies on two freshwater reservoirs from Satara District (Maharashtra), *India.Ind.J.Envi and Ecoplan*., 16(1):35-40.

Srinivasa, G.S. and Kotaiah, B. 2000. Seasonal variation of water quality in a tropical Kalyani reservoir, near Tirupati. *Indian J. Environmental Protection* 20 (6): 452 – 455.

Srivastav, A. and Srivastava, S. 2011. Assessment of Physio-chemical properties and sewage pollution indicator bacteria in surface water of River Gomti in Uttar Pradesh.*International Journal of Environmental Sciences.* 2(1): 325-336.

Srivastava. P.K., Mukherjee, S., Gupta, M. and Singh, S.K. 2011. Characterizing monsoonal variation on the Water Quality Index of River Mahi in India using Geographical Information System. *Water Quality Expo Health* 2: 193-203.

Wan Mohd Khalik, M. Abdullah, P. and Al-Qaim. F.F. 2015. Chemometric Application on Surface River Water Quality: A Case Study of Linggi River, Malaysia. *Iranica Journal of Energy and Environment* 6(1): 26-33.

CHANGES IN THE POPULATION OF MOLLUSCAN SPECIES IN VEERANAM LAKE, TAMIL NADU, SOUTHERN INDIA

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ABSTRACT

Lake Veeranam is one of the major freshwater bodies in Tamil Nadu, Southern India which provide water source for agricultural and domestic purposes. On the other hand, the lake has ecological significances by supporting wide varieties of biodiversity. Among the aquatic organisms molluscan forms provide primary role in aquatic ecosystems and perform considerable amount of ecosystem services. Hence, the aquatic habitats support enormous molluscan diversity. We assessed the changes in freshwater molluscan population at Veeranam Lake from six selected sampling stations at Kaliyamalai and Koolapadi which were collected from January 2014 to March 2015. We recorded 12 species of freshwater molluscs belonging to 7 families of class Gastropoda and Bivalvia viz., *Villorita carbiculoides* (1344 individuals), *Parreysia khadakvasiwensis* (122), *Lamellidens marginalis* (822), *Corbicula striatella* (593), *Polymesoda bengalensis* (210), *Indoplanorbis exustus* (250), *Bellamya bengalensis* (11913), *Pila globosa* (2130), *Stenothyra blanfordina* (593), and *Thira tuberculota* (62), *Lymnaea biacuminada* (42) and *Cryptozoha semirugata* (39) with overall molluscan number of 9432 and 8724 individuals in Kaliyamalai and Koolapadi respectively. Among species, *Villorita carbiculoides, Lamellidens marginalis, Bellamya bengalensis,* and *Pila globosa* were recorded in all the months in both areas. The relative abundance of *Bellamya bengalensis* was highest in all the months followed by *Pila globosa* and *Villorita carbiculoides*. The molluscan species viz., *Thiara tuberculota, Lymnaea biacuminata* and *Cryptozoha semirugata* were observed occasionally in both areas. The overall species richness of lake Veeranam was 4.8±1.30 and the diversity (H') was 0.306±0.2166 (n=396). The overall richness was 4.89±1.368 and 4.71±1.231 and diversity was 0.308±0.2352 and 0.303±0.1967 (n=198) for Kaliyamalai and Koolapodi respectively. The abundance of molluscan species varied both spatially, monthly and seasonally. The changes viz., reduction in the availability of water, variations in chemical characteristic features of water, predation and invasion of aquatic vegetation seems to cause the changes in the population dynamics of molluscan forms. Furthermore, this study indicated that the lake Veeranam is one of the important areas for molluscan diversity and abundance.

Keywords: Mollusca, Population, Relative abundance, Season, Areas, Diversity, Richness, Veeranam lake

1. INTRODUCTION

Mollusc organisms are animals belonging to invertebrate phylum Mollusca which has six classes of soft body, unsegmented animals usually having a hard shell (Apte, 1998) and also two classes are entirely extinct already. Representatives of this phylum live in a huge range of habitats including marine, freshwater, and terrestrial environments. Molluscs are highly diverse group, in size, in anatomical structure, in behavior and in habitat. They are extremely diverse in tropical and temperate regions but can be found at all latitudes. The gastropods (snails) are by far the most numerous molluscs in terms of classified species, and account for 80% of the total number of classified molluscan species (Oehlmann and Schulte-Oehlmann, 2002). The current estimated number of mollusca could vary from 80,000 species to 1,35,000 species (Abbott, 1989) and the total diversity possibly as high as 2, 00,000 species and second richest phylum with species richness (Strong *et al*., 2008). In marine ecosystem, approximately around 93,000 are recognized which is making it the largest marine phylum with about 23% of all named marine organisms. The global freshwater gastropod fauna is estimated at approximately 4,000 described species, however, the total number is probably 8,000 (Strong *et al*., 2008) with 213 species reported from India (Subba Rao, 1989). They are extremely diverse in tropical and temperate regions and can be found at all latitudes. The gastropods (snails) are by far the most numerous molluscs in terms of classified species, and account for 80% of the total number of classified molluscan species. Molluscs have more varied forms than any other animal phylum– snails and other gastropods, clams and other bivalves, squids and other cephalopods, and other less well-known but similarly distinctive sub-groups. The majority of species still live in the oceans, from the seashores to the abyssal zone, but some are significant members of freshwater and terrestrial ecosystems. Mollusca have the evolutionary and ecological significance and play an important role in the food chain by acting as a predators as well as prey. Apart from this they act as parasite vectors, invasive species passive indicators of environmental degradation, etc. Since most of the bivalves are filter feeders they act as environmental cleaners and often indicate the environmental changes.

Molluscs, especially bivalves such as clams and mussels, have been an important food source for different organisms including man because of their high nutritive values. Mussels and Pila are one of the major prey items of several predators such as crabs *Carcinus* spp. (Creswell and McLay, 1990; McGrorty *et al*., 1990; Hughes and Seed, 1995), starfish *Asterias rubens* (O'Neill *et al*., 1983), and birds such as the Asian open-billed Stork *Anastomus ositians* (Maheswari, 2005), oystercatcher *Haematopus ostralegus*, gulls *Larus* spp., crows *Corvus* spp. (Goss-Custard *et al*., 1982) and eider duck *Somateria mollissima* (Hamilton *et al.,* 1999). Apart from this they act as parasite vectors, invasive species passive indicators of environmental degradation, etc. Since most of the bivalves are filter feeders they act as environmental cleaners and often indicate the environmental changes.

Considerations of water quality are important in molluscan habitat evaluation because a host of interacting physical and chemical factors can influence the level of primary productivity in aquatic systems and thus influence the trophic structure and total biomass throughout the aquatic food web (Wetzel, 1975). Mollusca constitute an important part of ecosystem and play a critical role in maintaining aquatic ecosystem by recycling the nutrients and serve as main food for many aquatic creatures. Hence, their existence is necessary to maintain food web and equilibrium in ecosystem (Subba Rao, 1989). The largest molluscan classes *i.e.,* Gastropoda and Bivalvia had already survived in all continents (Strong *et al.,* 2008). A relationship between water quality and molluscan organisms had already been indicated by several studies (Dhivaharan, 2004). Physiochemical characteristics of the water largely determine the molluscan community of aquatic habitats, primarily by their direct and indirect impact on the availability and abundance of the molluscs' prey (Dhivaharan, 2004). Furthermore, the changes in the water quality influence the quality and quantity of the molluscs (Nagarajan *et al*., 2006; 2008). Therefore, the distribution of molluscs showed spatio-temporal variations in different habitats. As per the Article 7(a) of the UN Convention on Biological Diversity, Identifying components of biological diversity importance for its conservation and sustainable use is the first step for *in-situ* conservation of the species. Hence, we aim to survey the species composition of mollusca in different areas of lake Veeranam of Cuddalore district of Tamil Nadu across the months covering different climatic seasons across the years.

2. STUDY AREA

2.1 Veeranam Lake

Veeranam lake (11.20'10N"; 79.32' 40"E) (formerly called as Veeranaaraayanapuram Lake) is located 14 km south west of Chidambaram in Cuddalore district in the state of Tamil Nadu in south India and 1 km from Sethiyathope. The lake is being used for multipurpose utility such as irrigation, fish catching, washing and bathing. The lake has a catchments area of 25 km^2 (9.7 miles^2) and the maximum length of the lake is 11.2 km and width is 4 km. The lake located 235 km from Chennai, India, is one of the water reservoirs from where the water supply is planned to Chennai. Veeranam lake was created during Chola period in the tenth century, built from 1011 to 1037 AD and is a 16 km (10 mile) long dam in northern Tamil Nadu. Veeranam lake gets water from Kollidam via Vadavar river. Water released from the Mettur dam through Kollidam and Lower Anicut would also bring in sufficient inflow into the Veeranam Lake. The lake received sufficient inflow in April enabling supply to the city for three months with heavy rain in Western Ghats, the lake almost got its storage capacity as it received inflow from the Cauvery tributaries Bhavani and Amaravathi. The lake has a capacity to store about 1,465 mcft of water. Veeranam is second biggest lake of Tamil Nadu. The lake remains dry for the major part of the year. Their water is used for irrigation for about 70,000 acres. It is one of the sources of drinking water to Chennai and source of water for agriculture lands for a part of Cuddalore district. There are many small villages and towns on all sides of the lake. The crops cultivated using the water from the lake are paddy, sugarcane, black gram, green gram, groundnut, etc., The lake area offers a wide variety of microhabitats, which provide suitable substrates for a variety of waterbirds (Balasundaram and Nagarajan, 2010). The Veeranam lake and its watershed are situated in the rain shadow region of south west monsoon (June-August) and receive Northeast monsoon (September-December) only. The climate is subtropical. Hot weather prevails in March to June and the maximum temperature varies from 29°C-37°C.

2.2 Kaliyamalai Area

This is the weed free area and there was no aquatic vegetation. The water spread area can be seen without any surface vegetation. It extends from Kandakumaran to Viruthanganallur and is about 2 km in extent.

2.3 Koolapadi Area

This region is characterized by aquatic vegetation particularly weed invaded area and is dominated by *Ipomoea aquatica, Cyperus* sp., *Acacia* sp., *Prosopis juliflora, Pistia atiotes, Azolla* sp., *Hydrilla* sp., and *Vallisneria* sp. It extends from Thenpathi to Vazhakollai and is about 1.5 km in extent.

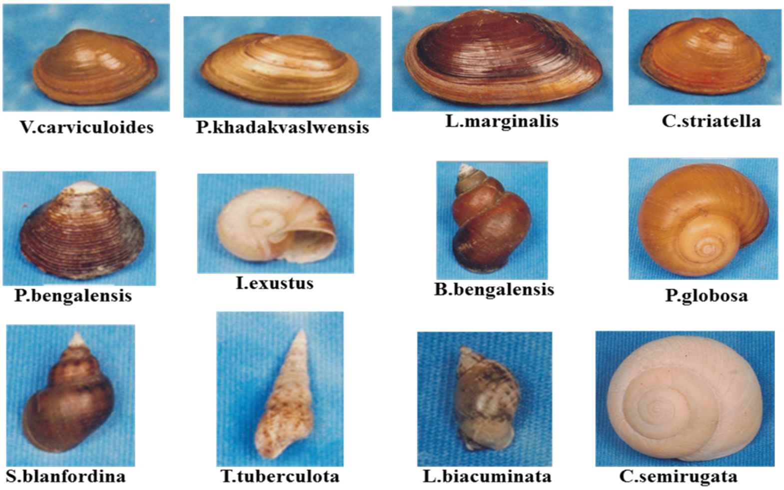
3. MATERIALS AND METHODS

The number of individuals of different species of freshwater mollusca at Veeranam Lake from six selected sampling stations at Kaliyamalai and Koolapadi were evaluated from January 2014 to March 2015. The visual search survey method (Emberton *et al*., 1996) was used mostly in the morning and evening hours and also some time during day hours for assessing the population of molluscs. Collections of mollusc were made by the methods of hand-picking in mostly from the edges and floor of the lake. In addition, the molluscs that were attached in the walls and plants were also collected by hand. Molluscs were preserved with their shells (Sjoberg and Danell, 1981) in 5% formaldehyde (Strin, 1981). The relative abundance of the prey items in two different areas across the months and seasons were estimated and the number of molluscan species were considered as species richness and diversity of mollusca was assessed using Shannon Diversity Index (H') (Shannon and Weiner, 1949). The association of molluscan species between two different areas and across the months and seasons was tested using Chi-square test by using number of molluscan individuals. The significant variations in molluscan species richness and diversity across the months and seasons were tested using two-way analysis of variance without interactions. The statistical inferences were made using Sokal and Rohlf (1995). The values are expressed in the tables and text as mean±SD.

4. RESULTS

Totally, 12 molluscan species viz., *Villorita carbiculoides* (*V.c*)*, Parreysia khadakvaslwensis* (*P.k*), *Lamellidens marginalis* (*L.m*), *Corbicula striatella* (*C.s*), *Polymesoda bengalensis* (*P.b*), *Indoplanorbis exustus* (*I.e*), *Bellamya bengalensis* (*B.b*), *Pila globosa* (*P.g*), *Stenothyra blanfordina* (*S.b*), *Thiara tuberculota* (*T.t*), *Lymnaea biacuminata* (*L.b*) and *Cryptozoha semirugata* (*C.s*) were collected during the study period from two areas namely Kaliyamalai and Koolpadi. They belonged to two classes i.e. Gastropoda and Bivalvia from five different orders viz., veneroida, trigoinoidea, basommitiophora, mesogastropoda and ariophantacea including nine families i.e. corbiculidae, unionoidae, bullininae, viviparoidae, ampullariidae, stenothyridae, thiaridae, lymnaeidae and ariophantidae.

BIVALVES AND GASTROBODS SPECIES OCCURING IN VEERANAM LAKE



Among the 12 species, *Villorita carbiculoides, Lamellidens marginalis, Bellamya bengalensis,* and *Pila globosa* were recorded in all the months in both areas. The relative abundance of *Bellamya bengalensis* was highest in all the months followed by *Pila globosa* and *Villorita carbiculoides*. The molluscan species viz., *Thiara tuberculota, Lymnaea biacuminata* and *Cryptozoha semirugata* were observed occasionally in both areas (Table 1). In both areas, the total numbers of individuals recorded were more than 1000 from January to March and it was lowest during October in both areas.

Table 1: Variations in relative abundance (%), diversity (H':Mean±SD) and richness (R: Mean±SD) of molluscan species collected from two different areas across the period from January 2014 to March 2015 in Lake Veeranam, Cuddalore District of Southern India. Values under month in parenthesis are sample size. Refer table 2 for the complete species name.

Sp	Kaliyamalai (n=198)												Koolapadi (n=198)											
	Jan (24)	Feb (24)	Mar (30)	Apr (12)	May (12)	Jun (12)	Jul (12)	Aug (18)	Sep (12)	Oct (12)	Nov (18)	Dec (12)	Jan (24)	Feb (24)	Mar (30)	Apr (12)	May (12)	Jun (12)	Jul (12)	Aug (18)	Sep (12)	Oct (12)	Nov (18)	Dec (12)
V.c	3	6	6	14	7	7	16	10	2	2	5	2	2	3	9	21	15	18	17	12	1	3	4	2
P.k	0	3	0	0	0	0	0	1	2	0	1	1	0	0	0	0	2	0	0	0	0	1	1	0
L.m	2	1	5	9	8	9	13	12	3	2	3	2	4	4	4	5	4	6	3	5	2	2	2	2
C.t	6	4	2	3	4	3	3	4	1	2	3	0	6	6	2	1	3	2	6	3	1	1	2	2
P.b	0	0	1	1	1	1	3	3	2	2	2	1	0	0	1	2	1	2	3	1	3	2	0	1
I.e	6	1	0	0	0	0	2	1	1	1	4	2	4	1	1	0	0	0	0	0	1	2	2	2
B.b	69	50	69	55	56	62	53	61	81	83	73	82	69	69	65	49	54	51	56	61	76	82	82	82
P.g	8	10	15	17	20	17	6	5	7	5	9	10	11	11	16	20	17	19	11	16	14	5	4	7
S.b	4	24	1	1	1	0	2	1	1	1	0	0	3	5	2	1	3	2	2	1	1	0	1	3
T.t	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1
L.b	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0
C.s	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
R	5.0± 1.45	4.5± 1.32	4.6± 1.17	4.8± 1.32	5.3± 1.23	5.0± 1.13	5.9± 1.24	6.2± 1.22	5.3± 1.22	4.0± 0.85	4.4± 1.29	4.0± 1.28	4.7± 1.44	5.0± 1.12	4.4± 1.16	4.8± 1.14	5.0± 0.85	4.8± 1.14	5.5± 1.45	5.1± 1.51	4.6± 1.17	4.6± 0.90	4.4± 1.38	4.4± 0.87
H'	0.45± 0.39	0.24± 0.07	0.26± 0.09	0.28± 0.23	0.31± 0.08	0.31± 0.11	0.27 ± 0.08	0.29 ± 0.07	0.18 ± 0.06	0.17± 0.07	0.64± 0.40	0.16± 0.04	0.43± 0.33	0.33± 0.29	0.25± 0.09	0.35± 0.05	0.29± 0.09	0.27± 0.11	0.32± 0.05	0.29± 0.06	0.21± 0.09	0.27± 0.22	0.35 ± 0.25	0.18 ± 0.08

The overall richness of lake Veeranam was 4.8±1.30 species (range: 2-8 and mode=5; n=396) and the diversity (H') was 0.306±0.2166 (range: 0.0298-1.6164). The overall richness of Kaliyamalai was 4.89±1.368 species (range: 2-8) and the diversity (H') was 0.308±0.2352 (range: 0.0521-1.3921; n=198). The overall richness of Koolapadi was 4.71±1.231 species (range: 2-8) and the diversity (H') was 0.303±0.1967 (range: 0.0298-1.6164) (Table 2). The mean molluscan species richness ranged between 4.0±1.28 species (December in Kaliyamalai) and 6.2±1.22 species (August in Kaliyamalai) across the months and irrespective areas. On the other hand, the mean species richness ranged from with a mean of 4.4 species in March, November and December to 5.5±1.45 (July). The mean diversity (H') of molluscan species ranged from 0.16±0.04 (December in Kaliyamalai) to 0.65±0.40 (November in Kaliyamalai) whereas the trend was different in Koolapadi i.e. from 0.18±0.08 (December) to 0.43±0.33 (January) (Table 1).

Totally eight molluscan species were recorded in all the seasons in both areas and four species viz., *Parreysia khadakvaslwensis*, *Thiara tuberculota, Lymnaea biacuminata* and *Cryptozoha semirugata* were not noticed in all seasons. The relative abundance of *Bellamya bengalensis* was highest in all the seasons in both areas followed by *Pila globosa* and *Villorita carbiculoides* (Table 2).

The mean molluscan species richness ranged between 4.2±1.17 species (Monsoon in Kaliyamalai) and 5.8±1.29 species (Pre-monsoon in Kaliyamalai) across the months and irrespective of areas. On the other hand, in Koolapadi the species richness was highest during Summer (5.0±1.17 species) and lowest in Monsoon (4.4±1.11 species). The mean diversity (H') of molluscan species ranged from 0.25±0.09 (Pre-monsoon in Kaliyamalai) to 0.37±0.35 (Monsoon in Kaliyamalai) whereas the trend was different in Koolapadi i.e. from 0.26±0.08 (Pre-monsoon) to 0.33±0.26 (Post-monsoon) (Table 2).

Table 2: Variations in relative abundance (%), diversity (H':Mean±SD) and richness (R: Mean±SD) of molluscan species collected from two different areas across the period from January 2014 to March 2015 in Lake Veeranam, Cuddalore District of Southern India. Values under season in parenthesis are sample size.

Species & Season[a]	Kaliyamalai (n=198)				Koolapadi (n=198)			
	PM (n=78)	SU (n=48)	PrM (n=30)	MO (n=42)	PM (n=78)	SU (n=48)	PrM (n=30)	MO (n=42)
Villorita carbiculoides	5.1	11.2	7.4	2.9	5.4	17.9	7.3	3.1
Parreysia khadakvasiwensis	1.2	0.1	1.1	0.9	0.3	0.5	0.2	1.0
Lamellidens marginalis	2.9	9.8	8.8	2.3	3.7	4.7	3.5	2.2
Corbicula striatella	4.0	3.2	3.1	1.8	4.5	2.9	1.9	1.8
Polymesoda bengalensis	0.6	1.6	2.4	1.3	0.5	1.9	2.0	0.6
Indoplanorbis exustus	2.3	0.6	0.9	2.3	1.4	0	0.7	1.7
Bellamya bengalensis	63.5	56.4	68.4	78.6	67.4	52.3	67.2	82.0
Pila globosa	11.2	15.1	5.8	8.2	13.1	17.2	15.0	5.2
Stenothyra blanfordina	8.6	1.1	0.9	0.5	3.1	2.1	0.9	1.3
Thira tuberculota	0.1	0.9	0.2	0.3	0.2	0.4	0.5	0.5

Lymnaea biacuminada	0.1	0.1	0.5	0.5	0.2	0.1	0.4	0.3
Cryptozoha semirugata	0.2	0.1	0.5	0.4	0.1	0	0.5	0.3
Seasonal Richness	4.7± 1.30	5.3± 1.27	5.8± 1.29	4.2± 1.17	4.6± 1.25	5.0± 1.17	4.9± 1.38	4.4± 1.11
Area Richness	4.89±1.368				4.71±1.231			
Seasonal Diversity (H')	0.31± 0.24	0.29± 0.13	0.25± 0.09	0.37± 0.35	0.33± 0.26	0.31± 0.08	0.26± 0.08	0.28± 0.22
Area Diversity (H')	0.308±02352				0.303± 0.1967			

[a]PM=Post monsoon; SU=Summer; PrM=Pre-monsoon; Mo=Monsoon

From the Chi-square analysis, it is confirmed that the changes in the overall population of mollusca in the two areas had significant association with months and seasons. Further, there was an association between area and across the months in the population of all species of mollusc except *Lymnaea biacuminata* and *Cryptozoha semirugata*. On the other hand, the population variations of *Villorita carbiculoides, Parreysia khadakvasiwensis, Lamellidens marginalis, Bellamya bengalensis, Pila globosa* and *Stenothyra blanfordina* in two different areas had association with season (Table 3). The Two-way analysis of variance indicated that the molluscan species richness did not vary significantly between areas whereas varied significantly across the months ($F_{11, 383}$=4.62; P<0.001) and seasons ($F_{11, 391}$=11.29; P<0.001). The molluscan species diversity did not vary between areas and among the seasons but varied significantly across the months ($F_{11, 383}$=7.52; P<0.001).

Table 3: Chi-square test to investigate the association between area and month and area and season in the population of different species of mollusca across the months and different areas of Lake Veeranam, Cuddalore District of Southern India.

Species	Area* Month	P (11 df)	Area* Season	P (3 df)
Villorita carbiculoides	66.00	<0.001	23.34	<0.001
Parreysia khadakvasiwensis	52.49	<0.001	30.62	<0.001
Lamellidens marginalis	46.04	<0.001	53.92	<0.001
Corbicula striatella	39.88	<0.001	7.30	NS
Polymesoda bengalensis	19.69	<0.05	4.35	NS
Indoplanorbis exustus	20.37	<0.05	7.32	NS
Bellamya bengalensis	192.23	<0.001	50.25	<0.001
Pila globosa	38.78	<0.001	31.51	<0.001
Stenothyra blanfordina	139.81	<0.001	71.79	<0.001
Thira tuberculota	21.06	<0.05	4.83	NS
Lymnaea biacuminada	7.33	NS	1.42	NS
Cryptozoha semirugata	2.20	NS	0.64	NS
Overall	133.69	<0.001	49.93	<0.001

DISCUSSION

We recorded 12 species viz, *Villorita carbiculoides, Parreysia khadakvasiwensis*, *Lamellidens marginalis*, *Corbicula striatella*, *Polymesoda bengalensis*, *Indoplanorbis exustus*, *Bellamya bengalensis*, *Pila globosa*, *Stenothyra blanfordina*, *Thira tuberculota*, *Lymnaea biacuminada* and *Cryptozoha semirugata* in both areas i.e. Kaliyamalai and Koolapadi. Among the species, *Villorita carbiculoides*, *Lamellidens marginalis*, *Bellamya bengalensis*, and *Pila globosa* were recorded in all the months in both areas. It is well established that the species of molluscs are cosmopolitan in distribution in all terrestrial, freshwater and marine environments including steppes, desserts, alpine mountains, polar regions, the deep sea (Oehlmann and Schulte-Oehlmann, 2002). The molluscan species have varied food, feeding habits and feeding mechanisms and therefore live in various habitats and such details of these 12 species are given in table 4. The IUCN conservation status indicated that nine species belonged to category 'Least Concern', one species (*Parreysia khadakvasiwensis*) to 'Vulnerable', one species (*Lymnaea biacuminada*) to 'Data Deficient' and one species (*Cryptozoha semirugata*) to 'Not Evaluated'. Among the 12 species, six are omnivorous, five are herbivorous and one is herbivorous/ scavengers and in which five are filter-feeding and seven are raspers. Leal (2002) emphasised that bivalves and gastropods can live in a highly diverse gamut of habitat conditions. Hence, these 12 species would have distributed in both areas and are capable of living all micro-habitats and could be generalist in feeding.

Table 4: Habitat, feeding habits, food, and feeding mechanisms of different of molluscan species recorded in lake Veeranam, Southern India.

S.No	Name of the species & IUCN Status	Habitat	Feeding habit, food & feeding mechanisms
1	*Villorita carbiculoides* (Prashad 1927) Least Concern ver 3.1 (2011)	Bottom dweller of freshwater ponds, rivers and lakes, usually burrows in the mud at the bottom of ponds by large ventral foot.	Omnivorous Suspended algae, bacteria, phytoplankton, micro-zooplankton, detritus, and also on dissolved organic material, such as amino acids and sugars and are regarded as crude suspension-feeders. Filter-feed by gills with their different ciliary tracts.
2	*Parreysia khadakvaslwensis* (Ray 1966) Vulnerable B1ab (iii)+2ab (iii) ver 3.1 (2014)	Inside mud bed of rivers, keeping itself upside down, obliquely upto 1 to 1.5" depth.	Omnivorous Feeds vegetative plants, algae, protozoa, bacteria and riverine sediments. Filter-feed fine particles from the water.
3	*Lamellidens marginalis* (Lamarck 1819) Least Concern ver 3.1 (2010)	Bottom dweller of freshwater ponds, rivers and lakes, usually burrows in the mud at the bottom of ponds by large ventral foot and does not go deep due to the posterior extremities of the valves remain exposed for the inhalant and exhalent respiratory water currents.	Omnivorous Feeds mainly on algae, protozoa, bacteria and riverine sediments. Filter-feed fine particles from the water and possess a ribbon-shaped tongue or radula, covered with rasping teeth.

4	*Corbicula striatella* (Deshayes 1854) Least Concern ver 3.1 (2010)	Inhabits in rivers, lake and streams, where the sand or gravel at the bottom as benthic substratum.	Omnivorous Feeds vegetative plants, algae, protozoa, bacteria and riverine sediments. Filter-feed fine particles from the water
5	*Polymesoda bengalensis* (Lamarck 1818) Least Concern ver 3.1 (2012)	Almost all types of lowland water bodies, mainly stagnant water and low saline water resources such as rivers, streams, lakes, ponds, wetlands, marshes, ditches, fields, etc.,	Omnivorous Littoral vegetation on water basin bank, short grass vegetation, tall grass vegetation, agriculture land, bush vegetation. Filter-feed fine particles from the water.
6	*Indoplanorbis exustus* (Deshayes 1834) Least Concern ver 3.1 (2012)	Common freshwater air-breathing gastropod found in grasslands, ponds and lakes.	Herbivorous *Hydrilla*, algal food and decaying leaves. Raspers of surfaces
7	*Bellamya bengalensis* (Jousseaume 1886) Least Concern ver 3.1 (2010)	Freshwater ponds, rivers, reservoirs, ditches and lakes and rich in macro vegetation and lay eggs specially on *Eichhornia crassipes*	Herbivorous *Hydrilla* leaves, algal materials in soft soil. Rasping plant tissue
8	*Pila globosa* (Swainson 1822) Least Concern ver.3.1 (2010)	Freshwater ponds, lakes, rivers, tanks and quite abundant in water having succulent aquatic vegetation on which it feeds; lives both in aquatic and terrestrial environments.	Herbivorous Succulent aquatic plants like *Vallisneria* and *Pistia.* Rasping plant leaf and stem
9	*Stenothyra blanfordina* (Nevill, 1880) Least Concern ver 3.1 (2010)	Freshwater ponds, lakes, rivers and tanks	Herbivorous Succulent aquatic plants like *Vallisneria* and *Pistia* leaf and stem. Rasping plant leaf and stem.
10	*Thiara tuberculota* (Nevill, 1880) Least Concern ver 3.1 (2016)	Ponds, rivers and other wetlands of swampy nature	Herbivorous *Hydrilla* leaves, algal materials in soft soil. Rasping plant leaf and stem.

11	*Lymnaea biacuminata* (Annandale and Rao, 1925) Data Deficient ver 3.1 (2010)	Large ponds, rivers and lakes in almost all stagnant ditches and long standing marshes.	Omnivorous Feeding on animals as well as plants. Raspers of surfaces
12	*Cryptozona semirugata* (Morch, 1872) Not assessed by IUCN	Colonized wide range of habitats on land, freshwater. Land molluscs mostly ground dwellers and found in parks, gardens, bushes, and vegetation patches of natural forests. Aquatic molluscs, sufficiently shady and moist situation, damp shady corners among vegetation, under fallen leaves, litters, under stones, crevices in wooden logs.	Herbivorous/ Scavengers Land snails generalist feeders subsist on a varied diet, papers, polythene bags, preferring dead or live plant matters, the fungal rich detritus available in bushes and damp soils. Rasping plant tissues

Several physical, chemical and biological factors were found to influence the distribution and abundance of various aquatic organisms (Wetzel, 1975; Nagarajan and Thiyagesan, 1996; 1998) especially the benthic and molluscan organisms (Nagarajan *et al*., 2006). The changes in the water chemistry would cause variations in aquatic organisms quantity (Boalch, 1980; Westerborm *et al*., 2002) and quality (Nagarajan *et al*., 2008). Balasundaram and Nagarajan (2017) assessed the water quality variations between weed invaded and weed free areas of Veeranam lake and found that the atmospheric temperature, turbidity, total hardness and nitrite varied significantly between the areas due to weed invasion. They also suggested that removal of the weeds would maintain the water quality. Hence, water quality would have influenced the variations in molluscan relative abundance, species richness and diversity.

Apart from these physio-chemical variations the biological pressures such as predation would decrease the mollusc population (Goss-Custard, 1996) and invasion of weed (Balasundaram and Nagarajan, 2018) would influence the population of mollusca. Variations in the water quality influence the prey availability to predators (Nagarajan *et al*., 2006; 2008) and Veeranam Lake is one of the major foraging sites for several aquatic birds and most of them prey on the benthic and molluscan forms (Ali and Ripley, 1983). Balasundaram and Nagarajan (2018) evaluated the molluscan diversity in different micro-habitats with reference to aquatic vegetation in Veeranam lake and recorded that aquatic weeds supported the molluscan diversity.

The undesirable changes due to developmental activities such as industrialisation, urbanisation, construction of dams and roads, intensification of agriculture, expansion of aquaculture, over-fishing of molluscs and eco-tourism are the major threats for their diversity and abundance and furthermore such threats alter the habitat utilization and quality of molluscs (Nagarajan *et al*., 2008). Natural populations of freshwater gastropods are severely affected by ecological constrains and fluctuation in the abiotic factors and their survival might be depend upon physiological capacity to tolerate these stress and fluctuations (Kalyoncu, 2009). Gastropods usually play an important role in freshwater ecosystem by providing food for many animals and by grazing on vast amount of algae and detritus (Agudo-Padron, 2011). Freshwater biodiversity patterns are closely associated to local geographic features and physiochemical and habitat structure, in combination with biological effects (Malm *et al*., 2005). Therefore, the spatio-temporal variations of these mollusc species might be due to their food, feeding habits, and feeding mechanisms, habitat characteristic i.e. spread of aquatic vegetation and nature of benthic substratum and variations in the water quality.

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REFERENCES

Abbott, R. T. 1989. *Compendium of Landshells: a Color Guide to more than 2,000 of the World's Terrestrial Shells.* Burlington, MA: American Malacologists.

Ali, A. and Ripley, S.D. 1983. *A Pictorial Guide to the Birds of the Indian Subcontinent*. Washington, D.C.: Smithsonian Institution Press.

Apte, D. A. 1998. *The Book of Indian shells*. Bombay Nat. Hist. Soc. Calcutta: Oxford Univ. Press.

Balasundaram, K. and Nagarajan, R. 2010. Diversity of molluscan species in lake Veeranam. *Mayur* VI: 57-61.

Balasundaram, K. and Nagarajan, R. 2017. Variations in the water quality between weed invaded and weed free areas of Veeranam Lake, Cuddalore District, Tamil Nadu, Southern India. *Research Journal of Biological Sciences* VIII: 3-11.

Balasundaram, K. and Nagarajan, R. 2018. Molluscan diversity in different micro-habitats with reference to aquatic vegetation in Lake Veeranam, Tamilnadu, Southern India. Indo American *Journal of Pharmaceutical Science* 5:688-696.

Boalch G.T. (Ed.). 1980. *Essay on the Exe Estuary*. Exeter: The Devonshire Association.

Creswell, P.D. and McLay, C.L. 1990. Handling times, prey size and species selection by *Cancer novaezelandiae* (Jacquinot, 1853) feeding on molluscan prey. *Journal of Experimental Marine Biology and Ecology* 140: 13–28.

Dhivaharan, V. 2003. *Limnobiotic Profile of Thirumeni Lake, Tamil Nadu, Southern India with Special Emphasis on Molluscan Diversity*. Ph.D. Thesis, AVC College, Mayiladuthurai, Tamil Nadu. submitted to Bharathidasan University, Tiruchirappalli.

Emberton, K.C., Pearce, T.A. and Randalana, R. 1996. Quantitatively sampling land-snail species richness in Madagascan rainforests. *Malacologia* 38: 203-212.

Goss-Custard, J. D. (Ed.). 1996. *The Oystercatchers from Individuals to Populations*. Oxford: Oxford University Press.

Goss-Custard, J.D., Durell, S.E.A. Le V. Dit. and Ens, B.J. 1982. Individual differences in aggressiveness and food stealing among wintering oystercatchers, *Haematopus ostralegus*. L. *Animal Behaviour* 30:917–928.

Hamilton, D.J., Nudds, T.D. and Neate, J. 1999. Size-selective predation of blue mussels (*Mytilus edulis*) by common eiders (*Somateria mollissima*) under controlled field conditions. *Auk* 116: 403–416.

Hughes, R.N. and Seed, R. 1995. Behavioural mechanisms of prey selection in crabs. *Journal of Experimental Marine Biology and Ecology* 193: 225–238.

Kalyoncu, H.M. 2009. Species composition of mollusc in the Aksu river system (Turkey) in relation to water quality. *Fresenius Environmental Bulletin* 18:1446-1451.

Leal, J.H. 2002. Bivalves. In: *The Living Marine Resources of the Western Central Atlantic*. Volume 1, pages 25-98 (Editor Carpenter, K.E.). FAO Identification Guide for Fishery Purposes. The Food and Agriculture Organization of the United Nations, Rome.

Maheswari, A.S. 2005. Population and foraging ecology of Asian openbill stork *Anastomus oscitans*. Ph.D. thesis, Department of Zoology and Division of Wildlife Biology, A.V.C. College, Mayiladuthurai, Southern India.

Malm, B., Nilsson, C. and Jansson, R. 2005. Spatial and temporal patterns of species richness in a riparian landscape. *Journal of Biogeography* 32: 2025-2037.

McGrorty, S., Clarke, R.T. Reading C.J. and Goss-Custard, J.D. 1990. Population dynamics of the mussel *Mytilus edulis*: density changes and regulation of the population in the Exe estuary, Devon. *Marine Ecology Progress Series* 67: 157–169.

Nagarajan, R., Lea, S.E.G. and Goss-Custard, J.D. 2006. Seasonal variations in mussel, *Mytilus edulis* L. shell thickness and strength and their ecological implications. *Journal of Experimental Marine Biology and Ecology* 339:241-250.

Nagarajan, R., Lea, S.E.G. and Goss-Custard, J.D. 2008. Relation between water quality and dorsal thickness of mussel (*Mytilus edulis*) and its ecological implications for wintering Oystercatchers (*Haematopus ostralegus*). *Acta Zoologica Academiae Scientiarum Hungaricae* 54 (Suppl.1): 225–238.

Nagarajan, R. and Thiyagesan, K. 1996. Waterbirds population and substrate quality of Pichavaram Wetlands, Southern India. *Ibis* 138:710-721.

O'Neill, S.M., Sutterlin, A.M. and Aggett, D. 1983. The effects of size-selective feeding by starfish (*Asterias vulgaris*) on the production of mussels (*Mytilus edulis*) cultured on nets. *Aquaculture* 35:211–220.

Oehlmann, J. and U. Schulte-Oehlmann. 2002. Molluscs as bioindicators. In: *Bioindicators and biomonitors*, Pages: 577-635 (Editors, Markert, B.A., Breure, A.M. and Zechmeister, H.G.). London: Elsevier Science.

Sjoberg, K., and Danell, K. 1981. Food availability and utilization by ducks of a shallow brakishwater bay in northern Bothnian Bay. *Annales Zoologici Fennici* 18: 253-261.

Strin, J. 1981. Manual of methods in aquatic environment research. Part 8. Ecological assessment of pollution effects. (Guidelines for the FAO/GFCM/UNEP. Joint coordinated project on pollution in the Mediterranean) FAO *Fish.Tech. Pap*. 209:70.

Shannon, C.E. and Wiener, W. 1949. *The mathematical theory of communication*. Urbana: University of Illions Press.

Sokal, R.R. and Rohlf, F.J. 1995. *Biometry*. New York: W.H. Freeman and Company.

Strong, E.E., Gargominy, O., Ponder, W.F. and Bouchet, P. 2008. Global diversity of gastropods (Gastropoda; Mollusca) in freshwater. *Hydrobiologia* 595: 149-166.

Subba Rao, N.V. 1989. *Handbook of Freshwater Molluscs of India*. Calcutta: Zoological Survey of India.

Westerborm, M., Kilpi, M. and Mustonean, O. 2002. Blue mussels *Mytilus edulis*, at the edge of the range: Population structure, growth, and biomass along a salinity gradient in the north-eastern Baltic Sea. *Marine Biology* 140: 991-999.

Wetzel, R.G. 1975. *Limnology*. Philadelphia, Pa: W.B. Saunders & Co.

BIODIVERSITY RULES

CHAPTER-I

PRELIMINARY

Short title, extent and commencement

1. (*1*) This Act may be called the Biological Diversity Act, 2002.

(*2*) It extends to the whole of India.

(*3*) It shall come into force on such date as the Central Government may, by notification in the Official Gazette, appoint:

Provided that different dates may be appointed for different provisions of this Act and any reference in any such provision to the commencement of this Act shall be construed as a reference to the coming into force of that provision.

Definitions

2. In this Act, unless the context otherwise requires,-

(*a*) "benefit claimers" means the conservers of biological resources, their byproducts, creators and holders of knowledge and information relating to the use of such biological resources, innovations and practices associated with such use and application;

(*b*) "biological diversity" means the variability among living organisms from all sources and the ecological complexes of which they are part and includes diversity within species or between species and of eco-systems;

(*c*) "biological resources" means plants, animals and micro-organisms or parts thereof, their genetic material and by-products (excluding value added products) with actual or potential use or value, but does not include human genetic material;

3. (d) "bio-survey and bio-utilization" means survey or collection of species, subspecies, genes, components and extracts of biological resource for any purpose and includes characterisation, inventorisation and bioassay;

(e) "Chairperson" means the Chairperson of the National Biodiversity Authority or, as the case may be, of the State Biodiversity Board;

(f) "commercial utilization" means end uses of biological resources for commercial utilization such as drugs, industrial enzymes, food flavours, fragrance, cosmetics, emulsifiers, oleoresins, colours, extracts and genes used for improving crops and livestock through genetic intervention, but does not include conventional breeding or traditional practices in use in any agriculture, horticulture, poultry, dairy farming, animal husbandry or bee keeping;

(*g*) “fair and equitable benefit sharing” means sharing of benefits as determined by the National Biodiversity Authority under section 21;

(*h*) “local bodies” means Panchayats and Municipalities, by whatever name called, within the meaning of clause (1) of article 243B and clause (1) of article *243Q* of the Constitution and in the absence of any Panchayats or Municipalities, institutions of self- government constituted under any other provision of the Constitution or any Central Act or State Act;

(*i*) “member” means a member of the National Biodiversity Authority or a State Biodiversity Board and includes the Chairperson;

(*j*) “National Biodiversity Authority” means the National Biodiversity Authority established under section 8;

(*k*) “prescribed” means prescribed by rules made under this Act;

(*l*) “regulations” means regulations made under this Act;

(*m*) “research” means study or systematic investigation of any biological resource or technological application, that uses biological systems, living organisms or derivatives thereof to make or modify products or processes for any use;

(*n*) “State Biodiversity Board” means the State Biodiversity Board established under section 22;

(*o*) “sustainable use” means the use of components of biological diversity in such manner and at such rate that does not lead to the long-term decline of the biological diversity thereby maintaining its potential to meet the needs and aspirations of present and future generations;

(*p*) “value added products” means products which may contain portions or extracts of plants and animals in unrecognizable and physically inseparable form.

CHAPTER - II

REGULATION OF ACCESS TO BIOLOGICAL DIVERSITY

Certain persons not to undertake Biodiversity related activities without approval of National Biodiversity Authority

3. (*1*) No person referred to in sub-section (*2*) shall, without previous approval of the National Biodiversity Authority, obtain any biological resource occurring in India or knowledge associated thereto for research or for commercial utilization or for bio-survey and bio-utilization.

(*2*) The persons who shall be required to take the approval of the National Biodiversity Authority under sub-section (*1*) are the following, namely:-

(*a*) a person who is not a citizen of India;

(*b*) a citizen of India, who is a non-resident as
43 of 1961 defined in clause (*30*) of section 2 of the Income-tax Act, 1961 ;

(*c*) a body corporate, association or organization-

(i) not incorporated or registered in India; or

(ii) incorporated or registered in India under any law for the time being in force which has any non-Indian participation in its share capital or management.

Results ofresearch not to be transferred to certain persons without approval of National Biodiversity Authority.

4. No person shall, without the previous approval of the National Biodiversity Authority, transfer the results of any research relating to any biological resources occurring in, or obtained from, India for monetary consideration or otherwise to any person who is not a citizen of India or citizen of India who is non-resident as defined in clause (*30*) of section 2 of the Income-tax Act, 1961 or a body corporate or organisation which is not registered or incorporated in India or which has any non-Indian participation in its share capital or management.

43 of 1961

Explanation - For the purposes of this section, “transfer” does not include publication of research papers or dissemination of knowledge in any seminar or workshop, if such publication is as per the guidelines issued by the Central Government.

Sections 3 and 4 not to apply to certain collaborative research projects

5. (*1*) The provisions of sections 3 and 4 shall not apply to collaborative research projects involving transfer or exchange of biological resources or information relating thereto between institutions, including Government sponsored institutions of India, and such institutions in other countries, if such collaborative research projects satisfy the conditions specified in sub-section *(3).*

(*2*) All collaborative research projects, other than those referred to in sub-section (*1*) which are based on agreements concluded before the commencement of this Act and in force shall, to the extent the provisions of agreement are inconsistent with the provisions of this Act or any guidelines issued under clause (*a*) of sub-section (*3*), be void.

(*3*) For the purposes of sub-section (*1*), collaborative research projects shall-

(a) conform to the policy guidelines issued by the Central Government in this behalf;

(b) be approved by the Central Government.

Application for intellectual property rights not to be made without approval of National Biodiverisity Authority

6. (*1*) No person shall apply for any intellectual property right, by whatever name called, in or outside India for any invention based on any research or information on a biological resource obtained from India without obtaining the previous approval of the National Biodiversity Authority before making such application.

Provided that if a person applies for a patent, permission of the National Biodiversity Authority may be obtained after the acceptance of the patent but before the sealing of the patent by the patent authority concerned:

Provided further that the National Biodiversity Authority shall dispose of the application for permission made to it within a period of ninety days from the date of receipt thereof.

(*2*) The National Biodiversity Authority may, while granting the approval under this section, impose benefit sharing fee or royalty or both or impose conditions including the sharing of financial

(3) The provisions of this section shall not apply to any right under any law relating to protection of plant varieties enacted by Parliament.

(4) Where any right is granted under law referred to in sub-section (3), the concerned authority granting such right shall endorse a copy of such document granting the right to the National Biodiversity Authority.

Prior intimation to State Biodiversity Board for obtaining biological resource for certain purposes

7. No person, who is a citizen of India or a body corporate, association or organisation which is registered in India, shall obtain any biological resource for commercial utilisation, or bio-survey and bio-utilisation for commercial utilisation except after giving prior intimation to the State Biodiversity Board concerned:

Provided that the provisions of this section shall not apply to the local people and communities of the area, including growers and cultivators of biodiversity, and vaids and hakims, who have been practising indigenous medicine.

CHAPTER - III

NATIONAL BIODIVERSITY AUTHORITY

Establishment of National Biodiversity Authority

8. (1) With effect from such date as the Central Government may, by notification in the Official Gazette, appoint, there shall be established by the Central Government for the purposes of this Act, a body to be called the National Biodiversity Authority.

(*2*) The National Biodiversity Authority shall be a body corporate by the name aforesaid, having perpetual succession and a common seal, with power to acquire, hold and dispose of property, both movable and immovable, and to contract, and shall by the said name sue and be sued.

(*3*) The head office of the National Biodiversity Authority shall be at Chennai and the National Biodiversity Authority may, with the previous approval of the Central Government, establish offices at other places in India.

(*4*) The National Biodiversity Authority shall consist of the following members, namely:-

(*a*) a Chairperson, who shall be an eminent person having adequate knowledge and experience in the conservation and sustainable use of biological diversity and in matters relating to equitable sharing of benefits, to be appointed by the Central Government;

(*b*) three *ex officio* members to be appointed by the Central Government, one representing the Ministry dealing with Tribal Affairs and two representing the Ministry dealing with Environment and Forests of whom one shall be the Additional Director General of Forests or the Director General of Forests;

(*c*) seven *ex officio* members to be appointed by the Central Government to represent respectively the Ministries of the Central Government dealing with -

(i) Agricultural Research and Education;

(ii) Biotechnology;

(iii) Ocean Development;

(iv) Agriculture and Cooperation;

(v) Indian Systems of Medicine and Homeopathy;

(vi) Science and Technology;

(vii) Scientific and Industrial Research;

(d) five non-official members to be appointed from amongst specialists and scientists having special knowledge of, or experience in, matters relating to conservation of biological diversity, sustainable use of biological resources and equitable sharing of benefits arising out of the use of biological resources, representatives of industry, conservers, creators and knowledge-holders of biological resources.

Conditions of service of Chairperson and members.

9. The term of office and conditions of service of the Chairperson and the other members other than ex officio members of the National Biodiversity Authority shall be such as may be prescribed by the Central Government.

Chairperson to be Chief executive of National Biodiversity Authority.

10. The Chairperson shall be the Chief Executive of the National Biodiversity Authority and shall exercise such powers and perform such duties, as may be prescribed.

Removal of members

11. The Central Government may remove from the National Biodiversity Authority any member

who, in its opinion, has _

(a) been adjudged as an insolvent; or

(b) been convicted of an offence which involves moral turpitude; or

(c) become physically or mentally incapable of acting as a member; or

(d) so abused his position as to render his continuance in office detrimental to the public interest; or

(e) acquired such financial or other interest as is likely to affect prejudicially his functions as a member.

Meetings of National Biodiversity Authority

12. (1) The National Biodiversity Authority shall meet at such time and place and shall observe such rules of procedure in regard to the transaction of business at its meetings (including the quorum at its meetings) as may be prescribed.

(2) The Chairperson of the National Biodiversity Authority shall preside at the meetings of the National Biodiversity Authority.

(3) If for any reason the Chairperson is unable to attend any meeting of the National Biodiversity Authority , any member of the National Biodiversity Authority chosen by the members present at the meeting shall preside at the meeting.

(4) All questions which come before any meeting of the National Biodiversity Authority shall be decided by a majority of votes of the members present and voting and in the event of equality of votes, the Chairperson or, in his absence, the person presiding, shall have and exercise a second or casting vote.

(5) Every member who is in any way, whether directly, indirectly or personally, concerned or interested in a matter to be decided at the meeting shall disclose the nature of his concern or interest and after such disclosure, the member concerned or interested shall not attend that meeting.

(*6*) No act or proceeding of the National Biodiversity Authority shall be invalidated merely by reason of :-

(*a*) any vacancy in, or any defect in the constitution of, the National Biodiversity Authority; or

(*b*) any defect in the appointment of a person acting as a member; or

(*c*) any irregularity in the procedure of the National Biodiversity Authority not affecting the merits of the case.

Committees of National Biodiveristy Authoriy

13. (*1*) The National Biodiversity Authority may constitute a committee to deal with agro-biodiversity.

Explanation - For the purposes of this sub-section, “agro-biodiversity” means biological diversity of agriculture related species and their wild relatives.

(*2*) Without prejudice to the provisions of sub-section (*1*), the National Biodiversity Authority may constitute such number of committees as it deems fit for the efficient discharge of its duties and performance of its functions under this Act.

(*3*) A committee constituted under this section shall co-opt such number of persons, who are not the members of the National Biodiversity Authority, as it may think fit and the persons so co-opted shall have the right to attend the meetings of the committee and take part in its proceedings but shall not have the right to vote.

(*4*) The persons appointed as members of the committee under sub-section (2) shall be entitled to receive such allowances or fees for attending the meetings of the committee as may be fixed by the Central Government.

Officers and employees of National Biodiversity Authority

14. (1) The National Biodiversity Authority may appoint such officers and other employees as it considers necessary for the efficient discharge of its functions under this Act.

(2) The terms and conditions of service of such officers and other employees of the National Biodiversity Authority shall be such as may be specified by regulations.

Authentication of orders and decisions of National Biodiversity Authority

15. All orders and decisions of the National Biodiversity Authority shall be authenticated by the signature of the Chairperson or any other member authorized by the National Biodiversity Authority in this behalf and all other instruments executed by the National Biodiversity Authority shall be authenticated by the signature of an officer of the National Biodiversity Authority authorized by it in this behalf.

Delegation of powers

16. The National Biodiversity Authority may, by general or special order in writing, delegate to any member, officer of the National Biodiversity Authority or any other person subject to such conditions, if any, as may be specified in the order, such of the powers and functions under this Act (except the power to prefer an appeal under section 50 and the power to make regulations under section 64) as it may deem necessary.

Expenses of National Biodiversity Authority to be defrayed out of the Consolidated Fund of India

17. The salaries and allowances payable to the members and the administrative expenses of the National Biodiversity Authority including salaries, allowances and pension payable to, or in respect of, the officers and other employees of the National Biodiversity Authority shall be defrayed out of the Consolidated Fund of India.

CHAPTER –IV

FUNCTIONS AND POWERS OF THE NATIONAL BIODIVERSITY AUTHORITY

Functions and powers of National Biodiversity Authority

18. (*1*) It shall be the duty of the National Biodiversity Authority to regulate activities referred to in sections 3, 4 and 6 and by regulations issue guidelines for access to biological resources and for fair and equitable benefit sharing.

(*2*) The National Biodiversity Authority may grant approval for undertaking any activity referred to in sections 3, 4 and 6.

(3) The National Biodiversity Authority may-

(a) advise the Central Government on matters relating to the conservation of biodiversity, sustainable use of its components and equitable sharing of benefits arising out of the utilization of biological resources;

(b) advise the State Governments in the selection of areas of biodiversity importance to be notified under sub-section (1) of section 37 as heritage sites and measures for the management of such heritage sites;

(c) perform such other functions as may be necessary to carry out the provisions of this Act.

(4) The National Biodiversity Authority may, on behalf of the Central Government, take any measures necessary to oppose the grant of intellectual property rights in any country outside India on any biological resource obtained from India or knowledge associated with such biological resource which is derived from **India.**

CHAPTER -V

APPROVAL BY THE NATIONAL BIODIVERSITY AUTHORITY

Approval by National Biodiversity Authority for undertaking certain activities

19. (1) Any person referred. to in sub-section (2) of section 3 who intends to obtain any biological resource occurring in India or knowledge associated thereto for research or for commercial utilization or for bio-survey and bio-utilization or transfer the results of any research relating to biological resources occurring in, or obtained from, India, shall make application in such form and payment of such fees as may be prescribed, to the National Biodiversity Authority.

(2) Any person who intends to apply for a patent or any other form of intellectual property protection whether in India or outside India referred to in sub-section (1) of section 6, may make an application in such form and in such manner as may be prescribed to the National Biodiversity Authority.

(3) On receipt of an application under sub-section (1) or sub-section (2), the National Biodiversity Authority may, after making such enquiries as it may deem fit and if necessary after consulting an expert committee constituted for this purpose, by order, grant approval subject to any regulations made in this behalf and subject to such terms and conditions as it may deem fit, including the imposition of charges by way of royalty or for reasons to be recorded in writing, reject the application:

Provided that no such order for rejection shall be made without giving an opportunity of being heard to the person affected.

(4) The National Biodiversity Authority shall give public notice of every approval granted by it under this section.

Transfer of biological resource or knowledge

20. (*1*) No person who has been granted approval under section 19 shall transfer any biological resource or knowledge associated thereto which is the subject matter of the said approval except with the permission of the National Biodiversity Authority.

(*2*) Any person who intends to transfer any biological resource or knowledge associated thereto referred to in sub-section (*1*) shall make an application in such form and in such manner as may be prescribed to the National Biodiversity Authority.

(*3*) On receipt of an application under sub-section (*2*), the National Biodiversity Authority may, after making such enquiries as it may deem fit and if necessary after consulting an expert committee constituted for this purpose, by order, grant approval subject to such terms and conditions as it may deem fit, including the imposition of charges by way of royalty or for reasons to be recorded in writing, reject the application:

Provided that no such order for rejection shall be made without giving an opportunity of being heard to the person affected.

(*4*) The National Biodiversity Authority shall give public notice of every approval granted by it under this section.

Determination of equitable benefit sharing by National Biodiversity Authority

21. (*1*) The National Biodiversity Authority shall while granting approvals under section 19 or section 20 ensure that the terms and conditions subject to which approval is granted secures equitable sharing of benefits arising out of the use of accessed biological resources, their by-products, innovations and practices associated with their use and applications and knowledge relating thereto in accordance with mutually agreed terms and conditions between the person applying for such approval, local bodies concerned and the benefit claimers.

(2) The National Biodiversity Authority shall, subject to any regulations made in this behalf, determine the benefit sharing which shall be given effect in all or any of the following manner, namely:

(a) grant of joint ownership of intellectual property rights to the National Biodiversity Authority, or where benefit claimers are identified, to such benefit claimers;

(b) transfer of technology;

(c) location of production, research and development units in such areas which will facilitate better living standards to the benefit claimers;

(d) association of Indian scientists, benefit claimers and the local people with research and development in biological resources and bio-survey and bio-utilization;

(e) setting up of venture capital fund for aiding the cause of benefit claimers;

(f) payment of monetary compensation and other non-monetary benefits to the benefit claimers as the National Biodiversity Authority may deem fit.

(3) Where any amount of money is ordered by way of benefit sharing, the National Biodiversity Authority may direct the amount to be deposited in the National Biodiversity Fund:

Provided that where biological resource or knowledge was a result of access from specific individual or group of individuals or organisations, the National Biodiversity Authority may direct that the amount shall be paid directly to such individual or group of individuals or organisations in accordance with the terms of any agreement and in such manner as it deems fit.

(4) For the purposes of this section, the National Biodiversity Authority shall, in consultation with the Central Government, by regulations, frame guidelines.

CHAPTER -VI

STATE BIODIVERSITY BOARD

Establishment of State Biodiversity Board

22. (1) With effect from such date as the State Government may, by notification in the Official Gazette, appoint in this behalf, there shall be established by that Government for the purposes of this Act, a Board for the State to be known as the ____________ (name of the State) Biodiversity Board.

(2) Notwithstanding anything contained in this section, no State Biodiversity Board shall be constituted for a Union territory and in relation to a Union territory, the National Biodiversity Authority shall exercise the powers and perform the functions of a State Biodiversity Board for that Union territory:

Provided that in relation to any Union territory, the National Biodiversity Authority may delegate all or any of its powers or functions under this sub-section to such person or group of persons as the Central Government may specify.

(3) The Board shall be a body corporate by the name aforesaid, having perpetual succession and a common seal, with power to acquire, hold and dispose of property, both movable and immovable, and to contract, and shall by the said name sue and be sued.

(4) The Board shall consist of the following members, namely:-

(a) a Chairperson who shall be an eminent person having adequate knowledge and experience in the conservation and sustainable use of biological diversity and in matters relating to equitable sharing of benefits, to be appointed by the State Government;

(b) not more than five ex officio members to be appointed by the State Government to represent the concerned Departments of the State Government;

(c) not more than five members to be appointed from amongst experts in matters relating to conservation of biological diversity, sustainable use of biological resources and equitable sharing of benefits arising out of the use of biological resources.

(5) The head office of the State Biodiversity Board shall be at such place as the State Government may, by notification in the Official Gazette, specify.

Functions of State Biodiversity Board

23. The functions of the State Biodiversity Board shall be to-

(a) advise the State Government, subject to any guidelines issued by the Central Government, on matters relating to the conservation of biodiversity, sustainable use of its components and equitable sharing of the benefits arising out of the utilisation of biological resources;

(b) regulate by granting of approvals or otherwise requests for commercial utilization or bio-survey and bio-utilization of any biological resource by Indians;

(c) perform such other functions as may be necessary to carry out the provisions of this Act or as may be prescribed by the State Government.

Power of State Biodiversity Board to restrict certain activities violating the objectives of conservation etc.

24. (1) Any citizen of India or a body corporate, organization or association registered in India intending to undertake any activity referred to in section 7 shall give prior intimation in such form as may be prescribed by the State Government to the State Biodiversity Board.

(2) On receipt of an intimation under sub-section (1), the State Biodiversity Board may, in consultation with the local bodies concerned and after making such enquires as it may deem fit, by order, prohibit or restrict any such activity if it is of opinion that such activity is detrimental or contrary to the objectives of conservation and sustainable use of biodiversity or equitable sharing of benefits arising out of such activity:

Provided that no such order shall be made without giving an opportunity of being heard to the person affected.

(3) Any information given in the form referred to in sub-section (1) for prior intimation shall be kept confidential and shall not be disclosed, either intentionally or unintentionally, to any person not concerned thereto.

Provisions of sections 9 to 17 to apply with modifications to State Biodiversity Board

25. The provisions of sections 9 to 17 shall apply to a State Biodiversity Board and shall have effect subject to the following modifications, namely:-

(a) references to the Central Government shall be construed as references to the State Government;

(b) references to the National Biodiversity Authority shall be construed as references to the State Biodiversity Board;

(c) reference to the Consolidated Fund of India shall be construed as reference to the Consolidated Fund of the State.

CHAPTER –VII

FINANCE, ACCOUNTS AND AUDIT OF NATIONAL BIODIVERSITY AUTHORITY

Grants or loans by the Central Government

26. The Central Government may, after due appropriation made by Parliament by law in this behalf, pay to the National Biodiversity Authority by way of grants or loans such sums of money as the Central Government may think fit for being utilized for the purposes of this Act.

Constitution of National Biodiversity Fund

27. (1) There shall be constituted a Fund to be called the National Biodiversity Fund and there shall be credited there to

(a) any grants and loans made to the National Biodiversity Authority under section 26;

(b) all charges and royalties received by the National Biodiversity Authority under this Act; and (c) all sums received by the National Biodiversity Authority from such other sources as may be decided upon by the Central Government.

(2) The Fund shall be applied for _
(a) channeling benefits to the benefit claimers;

(b) conservation and promotion of biological resources and development of areas from where such biological resources or knowledge associated thereto has been accessed;

(c) socio-economic development of areas referred to in clause (b) in consultation with the local bodies concerned.

Annual report of National Biodiversity Authority

28. The National Biodiversity Authority shall prepare, in such form and at such time each financial year as may be prescribed, its annual report, giving a full account of its activities during the previous financial year and furnish, to the Central Government, before such date as may be prescribed, its audited copy of accounts together with auditor’s report thereon.

Budget, accounts and audit

29. (1) The National Biodiversity Authority shall prepare a budget, maintain proper accounts and other relevant records (including the accounts and other relevant records of the National Biodiversity Fund) and prepare an annual statement of account in such form as may be prescribed by the Central Government in consultation with the Comptroller and Auditor-General of India.

(2) The accounts of the National Biodiversity Authority shall be audited by the Comptroller and Auditor-General of India at such intervals as may be specified by him and any expenditure incurred in connection with such audit shall be payable by the National Biodiversity Authority to the Comptroller and Auditor-General of India.

(3) The Comptroller and Auditor-General of India and any other person appointed by him in connection with the audit of the accounts of the National Biodiversity Authority shall have the same rights and privileges and authority in connection with such audit as the Comptroller and Auditor-General generally has in connection with the audit of the Government accounts and, in particular, shall have the right to demand the production of books, accounts, connected vouchers and other documents and papers and to inspect any of the offices of the National Biodiversity Authority .

(4) The accounts of the National Biodiversity Authority as certified by the Comptroller and Auditor-General of India or any other person appointed by him in this behalf together with the audit report thereon shall be forwarded annually to the Central Government.

Annual report to be laid before Parliament

30. The Central Government shall cause the annual report and auditor's report to be laid, as soon as may be after they are received, before each House of Parliament.

CHAPTER -VIII

FINANCE, ACCOUNTS AND AUDIT OF STATE BIODIVERSITY BOARD

Grants of money by State Government to State Biodiversity Board.

31. The State Government may, after due appropriation made by the State Legislature by law in this behalf, pay to the State Biodiversity Board by way of grants or loans such sums of money as the State Government may think fit for being utilized for the purposes of this Act.

Constitution of State Biodiversity Fund.

32. (1) There shall be constituted a Fund to be called the State Biodiversity Fund and there shall be credited thereto-

(a) any grants and loans made to the State Biodiversity Board under section 31 ;

(b) any grants or loans made by the National Biodiversity Authority;

(c) all sums received by the State Biodiversity Board from such other sources as may be decided upon by the State Government.

(2) The State Biodiversity Fund shall be applied for __

(a) the management and conservation of heritage sites;

(b) compensating or rehabilitating any section of the people economically affected by notification under sub-section (1) of section 37;

(c) conservation and promotion of biological resources;

(d) socio-economic development of areas from where such biological resources or knowledge associated thereto has been accessed subject to any order made under section 24, in consultation with the local bodies concerned;

(e) meeting the expenses incurred for the purposes authorised by this Act.

Annual Report of State Biodiversity Board

33. The State Biodiversity Board shall prepare, in such form and at such time in each financial year as may be prescribed, its annual report, giving a full account of its activities during the previous financial year, and submit a copy thereof to the State Government.

34. The accounts of the State Biodiversity Board shall be maintained and audited in such manner as may, in consultation with the Accountant-General of the State, be prescribed and the State Biodiversity Board shall furnish, to the State Government, before such date as may be prescribed, its audited copy of accounts together with auditor's report thereon .

Audit of accounts of a State Biodiversity Board.

Annual report of State Biodiversity Board to be laid before State Legislature

35. The State Government shall cause the annual report and auditor's report to be laid, as soon as may be after they are received, before the House of State Legislature.

CHAPTER -IX

DUTIES OF THE CENTRAL AND THE STATE GOVERNMENTS

Central Government to develop National strategies plans. etc., for conservation, etc., of biological diversity.

36. (1) The Central Government shall develop national strategies, plans, programmes for the conservation and promotion and sustainable use of biological diversity including measures for identification and monitoring of areas rich in biological resources, promotion of in situ, and ex situ, conservation of biological resources, incentives for research, training and public education to increase awareness with respect to biodiversity .

(2) Where the Central Government has reason to believe that any area rich in biological diversity, biological resources and their habitats is being threatened by overuse, abuse or neglect, it shall issue directives to the concerned State Government to take immediate ameliorative measures, offering such State Government any technical and other assistance that is possible to be provided or needed.

(3) The Central Government shall, as far as practicable wherever it deems appropriate, integrate the conservation, promotion and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies.

(4) The Central Government shall undertake measures,__

(i) wherever necessary, for assessment of environmental impact of that project which is likely to have adverse effect on biological diversity, with a view to avoid or minimize such effects and where appropriate provide for public participation in such assessment;

(ii) to regulate, manage or control the risks associated with the use and release of living modified organisms resulting from biotechnology likely to have adverse impact on the conservation and sustainable use of biological diversity and human health.

(5) The Central Government shall endeavour to respect and protect the knowledge of local people relating to biological diversity, as recommended by the National Biodiversity Authority through such measures, which may include registration of such knowledge at the local, State or national levels, and other measures for protection, including sui generis system.

Explanation:-For the purposes of this section,-

(a) "ex situ conservation" means the conservation of components of biological diversity outside their natural habitats;

(b) "in situ conservation" means the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties.

Biodiversity heritage sites.

37. (1) Without prejudice to any other law for the time being in force, the State Government may, from time to time in consultation with the local bodies, notify in the Official Gazette, areas of biodiversity importance as biodiversity heritage sites under this Act.

(*2*) The State Government, in consultation with the Central Government, may frame rules for the management and conservation of all the heritage sites.

(3) The State Government shall frame schemes for compensating or rehabilitating any person or section of people economically affected by such notification.

Power of Central Government to notify threatened species

38. Without prejudice to the provisions of any other law for the time being in force, the Central Government, in consultation with the concerned State Government, may from time to time notify any species which is on the verge of extinction or likely to become extinct in the near future as a threatened species and prohibit or regulate collection thereof for any purpose and take appropriate steps to rehabilitate and preserve those species.

Power of Central Government to designate repositories.

39. (1) The Central Government may, in consultation with the National Biodiversity Authority, designate institutions as repositories under this Act for different categories of biological resources.

(2) The repositories shall keep in safe custody the biological material including voucher specimens deposited with them.

(3) Any new taxon discovered by any person shall be notified to the repositories or any institution designated for this purpose and he shall deposit the voucher specimens with such repository or institution.

Power of Central Government to exempt certain biological resoures.

40. Notwithstanding anything contained in this Act, the Central Government may, in consultation with the National Biodiversity Authority, by notification in the Official Gazette, declare that the provisions of this Act shall not apply to any items, including biological resources normally traded as commodities.

CHAPTER-X

BIODIVERSITY MANAGEMENT COMMITTEES

Constitution of Biodiversity Management Committees.

41. (1) Every local body shall constitute a Biodiversity Management Committee within its area for the purpose of promoting conservation, sustainable use and documentation of biological diversity including preservation of habitats, conservation of land races, folk varieties and cultivars, domesticated stocks and breeds of animals and microorganisms and chronicling of knowledge relating to biological diversity.

Explanation.- For the purposes of this sub-section,-

(a) “cultivar” means a variety of plant that has originated and persisted under cultivation or was specifically bred for the purpose of cultivation;

(b) “folk variety” means a cultivated variety of plant that was developed, grown and exchanged informally among farmers;

(c) “landrace” means primitive cultivar that was grown by ancient farmers and their successors.

(2) The National Biodiversity Authority and the State Biodiversity Boards shall consult the Biodiversity Management Committees while taking any decision relating to the use of biological resources and knowledge associated with such resources occurring within the territorial jurisdiction of the Biodiversity Management Committee.

3) The Biodiversity Management Committees may levy charges by way of collection fees from any person for accessing or collecting any biological resource for commercial purposes from areas falling within its territorial jurisdiction.

CHAPTER - XI

LOCAL BIODIVERSITY FUND

Grants to Local Biodiversity Fund.

42. The State Government may, after due appropriation made by State Legislature by law in this behalf, pay to the Local Biodiversity Funds by way of grants or loans such sums of money as the State Government may think fit for being utilized for the purposes of this Act.

Consititution of Local Biodiveisity Fund.

43. (1) There shall be constituted a Fund to be called the Local Biodiversity Fund at every area notified by the State Government where any institution of self-government is functioning and there shall be credited thereto-

(a) any grants and loans made under section 42;

(b) any grants or loans made by the National Biodiversity Authority;

(c) any grants or loans made by the State Biodiversity Boards;

(d) fees referred to in sub-section (3) of section 41 received by the Biodiversity Management Committees;

(e) all sums received by the Local Biodiversity Fund from such other sources as may be decided upon by the State Government.

Application of Local Biodiversity Fund.

44. (1) Subject to the provisions of sub-section (2), the management and the custody of the Local Biodiversity Fund and the purposes for which such Fund shall be applied, be in the manner as may be prescribed by the State Government.

(2) The Fund shall be used for conservation and promotion of biodiversity in the areas falling within the jurisdiction of the concerned local body and for the benefit of the community in so far such use is consistent with conservation of biodiversity.

Annual Report of Biodiversity Management Committees.

45. The person holding the custody of the Local Biodiversity Fund shall prepare, in such form and during each financial year at such time as may be prescribed, its annual report, giving a full account of its activities during the previous financial year, and submit a copy thereof to the concerned local body.

46. The accounts of the Local Biodiversity Fund shall be maintained and audited in such manner as may, in consultation with the Accountant-General of the State, be prescribed and the person holding the custody of the Local Biodiversity Fund shall furnish, to the concerned local body, before such date as may be prescribed, its audited copy of accounts together with auditor's report thereon.

Audit of accounts of Biodiversity Management Committees.

47. Every local body constituting a Biodiversity Management Committee under sub-section (1) of section 41, shall cause, the annual report and audited copy of accounts together with auditor's report thereon referred to in sections 45 and 46, respectively and relating to such Committee to be submitted to the District Magistrate having jurisdiction over the area of the local body.

Annual report, etc, of the Biodiversity Management Committee to be submitted to District Magistrate.

CHAPTER -XII

MISCELLANEOUS

National Biodiversity Authority to be bound by the directions given by Central Government.

48. (1) Without prejudice to the foregoing provisions of this Act, the National Biodiversity Authority shall, in the discharge of its functions and duties under this Act, be bound by such directions on questions of policy as the Central Government may give in writing to it from time to time:

Provided that the National Biodiversity Authority shall, as far as practicable, be given opportunity to express its views before any direction is given under this sub-section.

(2) The decision of the Central Government whether a question is one of policy or not shall be final.

Power of State Government to give directions

49. (1) Without prejudice to the foregoing provisions of this Act, the State Biodiversity Board shall, in the discharge of its functions and duties under this Act, be bound by such directions on questions of policy as the State Government may give in writing to it from time to time:

Provided that the State Biodiversity Board shall, as far as practicable, be given an opportunity to express its views before any direction is given under this sub-section.

(2) The decision of the State Government whether a question is one of policy or not shall be final.

Settlement of disputes between State Biodiversity Boards.

50. (1) If a dispute arises between the National Biodiversity Authority and a State Biodiversity Board, the said Authority or the Board, as the case may be, may prefer an appeal to the Central Government within such time as may be prescribed.

(2) Every appeal made under sub-section (1) shall be in such form as may be prescribed by the Central Government.

(3) The procedure for disposing of an appeal shall be such as may be prescribed by the Central Government:

Provided that before disposing of an appeal, the parties shall be given a reasonable opportunity of, being heard.

(4) If a dispute arises between the State Biodiversity Boards, the Central Government shall refer the same to the National Biodiversity Authority.

(5) While adjudicating any dispute under sub- section (4), the National Biodiversity Authority shall be guided by the principles of natural justice and shall follow such procedure as may be prescribed by the Central Government.

(6) The National Biodiversity Authority shall have, for the purposes of discharging its functions under this section, the same powers as are vested in a civil court under the Code of Civil Procedure, 1908 in 5 of 1908

respect of the following matters, namely:_

(a) summoning and enforcing the attendance of any person and examining him on oath;

(b) requiring the discovery and production of documents;

(c) receiving evidence on affidavits;

(d) issuing commissions for the examination of witnesses or documents;

(e) reviewing its decisions;

(f) dismissing an application for default or deciding it ex parte;

(g) setting aside any order of dismissal of any application for default or any order passed by it exparte;

(h) any other matter which may be prescribed.

45 of 1860 (7) Every proceeding before the National Biodiversity Authority shall be deemed to be a judicial proceeding within the meaning of sections 193 and 228, and for the purpose of section 196, of the Indian Penal Code and the National Biodiversity Authority shall be deemed to be a civil court for all the purposes of section 195 and Chapter XXV1 of the Code of Criminal Procedure, **2 of 1974** 1973.

[1]Inserted by the National Green Tribunal Act, 2010 (19of 2010) dt. 2.6.2010

45 of 1860

Members, officers, etc., of National Biodiversity Authority and State Biodiversity Board deemed to be public servants.

51. All members, officers and other employees of the National Biodiversity Authority or the State Biodiversity Board shall be deemed, when acting or purporting to act in pursuance of any of the provisions of this Act, to be public servants within the meaning of section 21 of the Indian Penal Code.

Appeal

52. Any person, aggrieved by any determination of benefit sharing or order of the National Biodiversity Authority or a State Biodiversity Board under this Act, may file an appeal to the High Court within thirty days from the date of communication to him, of the determination or order of the National Biodiversity Authority or the State Biodiversity Board, as the case may be:

Provided that the High Court may, if it is satisfied that the appellant was prevented by sufficient cause from filing the appeal-within the said period, allow itto be filed within a further period not exceeding sixty days.

[1][Provided further that nothing contained in this section shall apply on and from the commencement of the National Green Tribunal Act, 2010.

Provided also that any appeal pending before the High Court, before the commencement of the National Green Tribunal Act, 2010, shall continue to be heard and disposed of by the High Court as if the National Green Tribunal had not been established under section 3 of the National Green Tribunal Act,2010.

Appeal to National Green Tribunal

52 A. Any person, aggrieved by any determination of benefit sharing or order of the National Biodiversity Authority or a State Biodiversity Board under this Act,

on or after the commencement of the National Green Tribunal Act, 2010, may file an appeal to the National Green Tribunal established under section 3 of the National Green Tribunal Act, 2010, in accordance with the provisions of that Act]

Executive of determination or order.

53. Every determination of benefit sharing or order made by the National Biodiversity Authority or a State Biodiversity Board under this Act or the order made by the High Court in any appeal against any determination or order of the National Biodiversity Authority or a State Biodiversity Board shall, on a certificate issued by any officer of the National Biodiversity Authority or a State Biodiversity Board or the Registrar of the High Court, as the case may be, be deemed to be decree of the civil court and shall be executable in the same manner as a decree of that court.

Explanation.- For the purposes of this section and section 52, the expression "State Biodiversity Board" includes the person or group of persons to whom the powers or functions under sub-section (*2*) of section 22 have been delegated under the proviso to that sub-section and the certificate relating to such person or group of persons under this section shall be issued by such person or group of persons, as the case maybe.

Protection of action taken in good faith

54. No suit, prosecution or other legal proceedings shall lie against the Central Government or the State Government or any officer of the Central Government or the State Government or any member, officer or employee of the National Biodiversity Authority or the State Biodiversity Board for anything which is in good faith done or intended to be done under this Act or the rules or regulations made thereunder.

Penalties

55. (1) Whoever contravenes or attempts to contravene or abets the contravention of the provisions of section 3 or section 4 or section 6 shall be punishable with imprisonment for a term which may extend to five years, or with fine which may extend to ten lakh rupees and where the damage caused exceeds ten lakh rupees such fine may commensurate with the damage caused, or with both.

(2) Whoever contravenes or attempts to contravene or abets the contravention of the provisions of section 7 or any order made under sub-section (2) of section 24 shall be punishable with imprisonment for a term which may extend to three years, or with fine which may extend to five lakh rupees, or with both.

Penalty for contravention of directions or orders of Central Government, State Government, National Biodiversity Authority and State Biodiversity Boards.

56. If any person contravenes any direction given or order made by the Central Government, the State Government, the National Biodiversity Authority or the State Biodiversity Board for which no punishment has been separately provided under this Act, he shall be punished with a fine which may extend to one lakh rupees and in case of a second or subsequent offence, with fine which may extend to two lakh rupees and in the case of continuous contravention with additional fine which may extend to two lakh rupees everyday during which the default continues.

Offences by Companies

57. (1) Where an offence or contravention under this Act has been committed by a company, every person who at the time the offence or contravention was committed was in charge of, and was responsible to, the company for the conduct of the business of the company, as well as the company, shall be deemed to be guilty of the offence or contravention and shall be liable to be proceeded against and punished accordingly:

Provided that nothing contained in this sub-section shall render any such person liable to any punishment provided in this Act, if he proves that the offence or contravention was committed without his knowledge or that he had exercised all due diligence to prevent the commission of such offence or contravention.

(2) Notwithstanding anything contained in sub-section (1), where an offence or contravention under this Act has been committed by a company and it is proved that the offence or contravention has been committed with the consent or connivance of, or is attributable to, any neglect on the part of any director, manager, secretary or other officer of the company, such director, manager, secretary or other officer shall also be deemed to be guilty of the offence or contravention and shall be liable to be proceeded against and punished accordingly.

Explanation. -For the purposes of this section,__

(a) "company" means any body corporate and includes a firm or other association of individuals; and

(b) "director", in relation to a firm, means a partner in the firm.

58. The offences under this Act shall be cognizable and non-bailable.

Offences to be cognizable and non-bailable.

59. The provisions of this Act shall be in addition to, and not in derogation of, the provisions in any other law, for the time being in force, relating to forests or wildlife.

Act to have effect in addition to other Acts.

60. The Central Government may give directions to any State Government as to the carrying into execution in the State of any of the provisions of this Act or of any rule or regulation or order made thereunder.

Power of Central Government to give directions to State Government.

61. No Court shall take cognizance of any offence under this Act except on a complaint made by _

Cognizance of offences.

(a) the Central Government or any authority or officer authorized in this behalf by that Government; or

(b) any benefit claimer who has given notice of not less than thirty days in the prescribed manner, of such offence and of his intention to make a complaint, to the Central Government or the authority or officer authorized as aforesaid.

Power of Central Government to make rules

62. (1) The Central Government may, by notification in the Official Gazette, make rules for carrying out the purposes of this Act.

(2) In particular, and without prejudice to the generality of the foregoing power, such rules may provide for all or any of the following matters, namely:

(a) terms and conditions of service of the Chairperson and members under section 9;

(b) powers and duties of the Chairperson under section 10;

(c) procedure under sub-section (1) of section 12 in regard to transaction of business at meetings;

(d) form of application and payment of fees for undertaking certain activities under sub-section (1) of section 19;

(e) the form and manner of making an application under sub-section (2) of section 19;

(f) form of application and the manner for transfer of biological resource or knowledge under sub-section (2) of section 20;

(g) form in which, and the time of each financial year at which, the annual report of the National Biodiversity Authority shall be prepared and the date before which its audited copy of accounts together with auditor's report thereon shall be furnished under section 28;

(h) form in which the annual statement of account shall be prepared under subsection (1) of section 29;

(i) the time within which and the form in which, an appeal may be preferred, the procedure for disposing of an appeal and the procedure for adjudication, under section 50;

(j) the additional matter in which the National Biodiversity Authority may exercise powers of the civil court under clause (h) of sub-section (6) of section 50;

(k) the manner of giving notice under clause (b) of section 61;

(l) any other matter which is to be, or may be, prescribed, or in respect of which provision is to be made, by rules.

(3) Every rule made under this section and every regulation made under this Act shall be laid, as soon as may be after it is made, before each House of Parliament, while it is in session for a total period of thirty days which may be comprised in one session or in two or more successive sessions, and if, before the expiry of the session immediately following the session or the successive sessions aforesaid, both Houses agree in making any modification in the rule or regulation or both Houses agree that the rule or regulation should not be made, the rule or regulation shall thereafter have effect only in such modified form or be of no effect, as the case may be; so, however, hat any such modification or annulment shall be without prejudice to the validity of anything previously done under that rule or regulation.

Power of State Government to make rules

63. (1) The State Government may, by notification in the Official Gazette, make rules for carrying out the purposes of this Act.

(2) In particular, and without prejudice to the generality of the foregoing power, such rules may provide for all or any of the following matters, namely:

(a) the other functions to be performed by the State Biodiversity Board under clause (c) of section 23;

(b) the form in which the prior intimation shall be given under sub-section (1) of section 24;

(c) the form in which, and the time of each financial year at which, the annual report shall be prepared under section 33;

(d) the manner of maintaining and auditing the accounts of the State Biodiversity Board and the date before which its audited copy of the accounts together with auditor's report thereon shall be furnished under section 34;

(e) management and conservation of national heritage sites under section 37;

(f) the manner of management and custody of the Local Biodiversity Fund and the purposes for which such Fund shall be applied under sub-section (1) of section 44;

(g) the form of annual report and the time at which such report shall be prepared during each financial year under section 45;

(h) the manner of maintaining and auditing the accounts of the Local Biodiversity Fund and the date before which its audited copy of the accounts together with auditor's report thereon shall be furnished under section 46;

(i) any other matter which is to be, or may be, specified.

(3) Every rule made by the State Government under this section shall be laid, as soon as may be after it is made, before each House of the State Legislature where it consists of two Houses, or where such Legislature consists of one House, before that House.

Power to make regualtions.

64. The National Biodiversity Authority shall, with the previous approval of the Central Government, by notification in the Official Gazette, make regulations for carrying out the purposes of this Act.

Power to remove difficulties.

65. (1) If any difficulty arises in giving effect to the provisions of this Act, the Central Government may, by order, not inconsistent with the provisions of this Act, remove the difficulty:

Provided that no such order shall be made after the expiry of a period of two years from the commencement of this Act.

(2) Every order make under this section shall be laid, as soon as may be, after it is made, before each House of Parliament.

SUBHASH C. JAIN

Secretary to the Government of India

BIOLOGICAL DIVERSITY RULES - 2004

MINISTRY OF ENVIRONMENT AND FORESTS NOTIFICATION

New Delhi, the 15th April, 2004

G.S.R. 261 (E). – In exercise of the powers conferred by Section 62 of the Biological Diversity Act, 2002, and in supersession of the National Biodiversity Authority (salary, Allowances and conditions of service of Chairperson and other Members) Rules, 2003 except as respect to things done or omitted to be done before such supersession, the Central Government hereby makes the following rules namely: -

1. Short title and commencement

(1) These rules may be called the Biological Diversity Rules, 2004.

(2) Thus shall come into force on 15th April, 2004.

2. Definitions

In these rules, unless the context otherwise requires, -

(a) “Act” means the Biological Diversity Act 2002 (18 of 2003);

(b) “Authority” means the National Biodiversity Authority established under sub- section (1) of Section 8,

(c) “Biodiversity Management Committee” means a Biodiversity Management Committee established by a local body under sub-section (1) of Section 41;

(d) “Chairperson” means the chairperson of the National Biodiversity Authority or as the case may be, of the State Biodiversity Board.

(e) “fee” means any fee stipulated in the Schedule;

(f) “Form” means form annexed to these rules;

(g) “ Member” means a member of the National Biodiversity Authority or a State Biodiversity Board and includes the chairperson as the case may be;

(h) “section “ means a section of the Act;

(i) “Secretary” means the full time Secretary of the Authority.

(j) words and expressions used but not defined in these rules and defined in the Act shall have the meaning respectively assigned to them in the Act.

3. Manner of selection and appointment of the Chairperson

The Chairperson of the Authority shall be appointed by the Central Government.

Every appointment of Chairperson under sub-section (1) shall be made either on deputation basis or by selection from outside the Central Government. In case the appointment is through deputation, the applicant should not be below the rank of Additional Secretary to the Government of India.

4. Term of Office of the Chairperson

1. The Chairperson of the Authority shall hold the office for a term of three years' and shall be eligible for re-appointment,
2. Provided that no Chairperson shall hold office as such after he attains the age of sixty five years or his term of office expires which is earlier.
3. The Chairperson may resign from his office by giving at least one month notice in writing to the Central Government.

5. Pay and Allowances of Chairperson :–

1. A Chairperson shall be entitled to a fixed pay of Rs. 26,000/- per month. In case of retired person is appointed as Chairperson, his pay shall be fixed in accordance with the orders of the Central Government as applicable to such persons.
2. A Chairperson shall be entitled to such allowances, leave, pension, provident fund, house and other perquisites etc. to be decided by the Central Government from time to time.

6. Term of Office and Allowances of non- official Members:

1. Every non-official member of the Authority shall hold his office for a term not exceeding three years at a time from the date of publication of his appointment in the official Gazette.
2. Every non- official member attending the meeting of the Authority shall be entitled to sitting allowance, travelling expenses, daily allowance and such other allowances as are applicable to non official member of commissions and committees of the Central Government attending the meeting (s) of such Commissions or Committees.

7. Filling up of vacancies of non- official members

1. A non –official member of the Authority may resign his office at any time by giving in writing under his hand addressed to the Central Government and the seat of that member in the Authority shall become vacant.
2. A casual vacancy of a non – official member in the Authority shall be filled up by a fresh nomination and the person nominated to fill the vacancy shall hold office only for the remainder of the term of the member in whose place he was nominated.

8. Removal of the members of the Authority.

No member of the Authority shall be removed from his office on any ground specified in section 11, without a due and proper enquiry by an officer not below the rank of a Secretary to the Government of India appointed by the Central Government and without giving such member a reasonable opportunity of being heard.

9. Secretary of the Authority

1. The Authority shall appoint a Secretary to it.
2. The terms and conditions of the appointment of the Secretary shall be determined by the Authority by regulation.
3. The Secretary shall be responsible for co-ordinating and convening the meetings of the Authority, maintenance of the records of the proceedings of the Authority and such other matters as may be assigned to him by the Authority.

10. Meetings of the Authority

(1) The Authority shall meet at least four times in a year normally after a period of three months at the Head quarters of the Authority or at such place as may be decided by the Chairperson.

(2) The Chairperson shall, upon a written request from not less than five Members of the Authority or upon a direction of the Central Government, call a special meeting of the Authority.

(3) The members shall be given at least fifteen days' notice for holding an ordinary meeting and at least three days' notice for holding a special meeting specifying the purpose, the time and the place at which such meeting is to be held.

(4) Every meeting shall be presided over by the Chairperson and in his absence, by a presiding officer to be elected by the members present from amongst themselves.

(5) The decision of the Authority at a meeting shall, if necessary, be taken by a simple majority of the Members present and voting and the Chairperson or in his absence, the Member presiding shall have a second or casting vote.

(6) Each member shall have one vote.

(7) The quorum at every meeting of the Authority shall be five.

(8) No Member shall be entitled to bring forward for the consideration of a meeting any matter of which he has not given ten days' notice unless the Chairperson in his discretion permits him to do so.

(9) Notice of the meeting may be given to the Members by delivering the same by messenger or sending it by registered post to his last known place of residence or business or in such other manner as the Secretary of the Authority may, in the circumstances of the case, think fit.

11. Appointment of Expert Committee by the Authority and their entitlements

1. The Authority may constitute any number of Committees for such purposes as it may deem fit consisting wholly of members or wholly of other persons or partly of members or partly of other persons.
2. The members of the Committee other than the members of the Authority shall be paid such fees and allowances for attending the meetings as the Authority may deem fit.

12. General functions of the Authority

The Authority may perform the following functions; namely:-

i. lay down the procedure and guidelines to govern the activities provided under sections 3, 4 and 6;

ii. advise the Central Government on any matter concerning conservation of bio diversity, sustainable use of its components and fair and equitable sharing of benefits arising out of the use of biological resource and knowledge;

iii. coordinate the activities of the State Bio-diversity Boards;

iv. provide technical assistance and guidance to the State Bio-diversity Boards;

v. commission studies and sponsor investigations and research;

vi. engage consultants, for a specific period, not exceeding three years, for providing technical assistance to the Authority in the effective discharge of its functions : Provided that if it is necessary and expedient to engage any consultant beyond the period of three years, the Authority shall seek prior approval of the Central Government for such an engagement.

vii. collect, compile and publish technical and statistical data, manuals, codes or guides relating to conservation of bio diversity, sustainable use of its components and fair and equitable sharing of benefits arising out of the use of biological resource and knowledge;

viii. organise through mass media a comprehensive programme regarding conservation of bio-diversity, sustainable use of its components and fair and equitable sharing of benefits arising out of the use of biological resource and knowledge.

ix. plan and organise training of personnel engaged or likely to be engaged in programmes for the conservation of bio-diversity and sustainable use of its components;

x. prepare the annual Budget of the Authority incorporating its own receipts as also the devaluation from the Central Government provided that the allocation by the Central Government shall be operated in accordance with the budget provisions approved by the Central Government ;

xi. recommend creation of posts to the Central Government, for effective discharge of the functions by the Authority and to create such posts, provided that no such post whether permanent / temporary or of any nature, would be created without prior approval of the Central Government;

xii. approve the method of recruitment to the officers and servants of the Authority;

xiii. take steps to build up data base and to create information and documentation system for biological resources and associated traditional knowledge through bio-diversity registers and electronics data bases, to ensure effective management, promotion and sustainable uses ;

xiv. give directions to State Bio-diversity Boards and the Bio-diversity Management Committees in writing for effective implementation of the Act;

xv. report to the Central Government about the functioning of the Authority and implementation of the Act;

xvi. recommend, modify, collection of benefit sharing fee under sub section of Section 6 or Changes of royalties under sub-section (2) of section 19 in respect of biological resources from time to time;

xvii. sanction grants – in – aid and grants to the State Bio-diversity Board and Bio-diversity Management Committees for specific purposes;

xviii. undertake physical inspection of any area in connection with the implementation of the Act;

xix. take necessary measures including appointment of legal experts to oppose grant of intellectual property right in any country outside India on any biological resource and associated knowledge obtained from India in an illegal manner;

xx. do such other functions as may be assigned or directed by the Central Government from time to time.

13. Powers and duties of Chairperson

1. The Chairperson shall have the overall control of the day - to - day activities of the Authority.
2. Subject to the provisions of Section 10, the Chairperson shall have the powers of general superintendence over the officers and staff of the Authority and he may issue necessary directions for the conduct and management of the affairs of the Authority.
3. The Chairperson shall be in charge of all the confidential papers and records of the Authority and shall be responsible for their safe custody.
4. All orders and instructions to be issued by the Authority shall be under the signature of the Chairperson or of any other officer authorised by the Chairperson in this behalf.
5. The Chairperson, either himself or through an officer of the authority authorised for the purpose, may sanction and disburse all payments against the approved budget.
6. The Chairperson shall have full powers for granting administrative and technical sanction to all estimates.
7. The Chairperson shall convene and preside over all the meetings of the Authority and shall ensure that all decisions taken by the Authority are implemented in proper manner.
8. The Chairperson shall exercise such other powers and perform such other functions as may be delegated to him from time to time by the Authority or the Central Government.

14. Procedure for access to biological resources and associated traditional knowledge

1. Any person seeking approval of the Authority for access to biological resources and associated knowledge for research or for commercial utilization shall make an application in Form I
2. Every application under sub- rule (1) shall be accompanied by a fee of ten thousand rupees in the form of a cheque or demand draft drawn in favour of the Authority.
3. The Authority shall after consultation with the concerned local bodies and collecting such additional information from the applicant and other sources, as it may deem necessary, dispose of the application, as far as possible, within a period of six months from the date of its receipts .
4. On being satisfied with the merit of the application, the Authority may grant the approval for access to biological resources and associated knowledge subject to such term and conditions as it may deem fit to impose.
5. The approval to access shall be in the form of a written agreement duly signed by an authorized officer of the Authority and the applicant.
6. The form of the agreement referred to in sub-rule (5) shall be laid down by the Authority and shall include the following; namely:-

i. general objectives and purpose of the application for seeking approval ;

ii. description of the biological resources and traditional knowledge including accompanying information;

iii. intended uses of the biological resources (research, breeding, commercial utilization etc.)

iv. conditions under which the applicant may seek intellectual property rights;

v. quantum of monetary and other incidental benefits. If need be, a commitment to enter into a fresh agreement particularly in case if the biological material is taken for research purposes and later on sought to be used for commercial purposes, and also in case of any other change in use thereof subsequently.

vi. restriction to transfer the accessed biological resources and the traditional knowledge to any third party without prior approval of Authority ;

vii. to adhere to a limit set by the Authority on the quantity and specification of the quality of the biological resources for which the applicant is seeking access;

viii. guarantee to deposit a reference sample of the biological material sought to be accessed with the repositories identified in Section 39;

ix. submitting to the Authority a regular status report of research and other developments;

x. commitment to abide with the provisions of Act and rules and other related legislations in force in the country;

xi. commitment to facilitate measures for conservation and sustainable use of biological resources accessed;

xii. commitment to minimize environmental impacts of collecting activities;

xiii. legal provisions such as duration of the agreement, notice to terminate the agreement, independent enforceability of individual clauses, provision to the extent that obligations in benefit sharing clauses survive the termination of the agreement, events limiting liability (natural calamities), arbitration, any confidentiality clause.

7. The conditions for access may specifically provide measures for conservation and protection of biological resources to which the access is being granted.

8. The Authority may for reasons to be recorded in writing reject an application if it considers that the request cannot be acceded to.

9. No application shall be rejected unless the applicant is given a reasonable opportunity of being heard.

10. The Authority shall take steps to widely publicize the approvals granted, through print or electronic media and shall periodically monitor compliance of conditions on which the approval was accorded.

15. Revocation of access or approval:-

1. The Authority may either on the basis of any complaint or *suo moto* withdraw the approval granted for access under rule 15 and revoke the written agreement under the following conditions ; namely:-

i. on the basis of reasonable belief that the person to whom the approval was granted has violated any of the provisions of the Act or the condition on which the approval was granted ;

ii. when the person who has been granted approval has failed to comply with the terms of the agreement ;

iii. on failure to comply with any of the conditions of access granted;

iv. on account of overriding public interest or for protection of environment and conservation of biological diversity;

2. The Authority shall send a copy of every order of revocation issued by it to the concerned State Biodiversity Board and the Biodiversity Management Committees for prohibiting the access and also to assess the damage, if any, caused and take steps to recover the damage.

16. Restriction on activities related to access to biological resources

1. The Authority if it deems necessary and appropriate shall take the steps to restrict or prohibit the request for access to biological resources for the following reasons; namely:-

i. the request for access is for any endangered taxa;

ii. the request for access is for any endemic and rare species ;

iii. the request for access may likely to result in adverse effect on the livelihoods of the local people;

iv. the request to access may result in adverse environmental impact which may be difficult to control and mitigate.

v. the request for access may cause genetic erosion or affecting the ecosystem function;

vi. use of resources for purposes contrary to national interest and other related international agreements entered into by India.

17. Procedure for seeking approval for transferring results of research

1. Any person desirous of transferring results of research relating to biological resources obtained from India for monetary consideration to foreign nationals, companies and Non Resident Indians (NRIs), shall make an application to the Authority in the Form II.
2. Every application under sub–rule (1) shall be accompanied by a fee of five thousand rupees in the form of a Bank draft or Cheque drawn in favour of the Authority.
3. Every application under sub-rule (1) shall be decided upon by the Authority, as far as possible within a period of three months from the receipt of the same.
4. On being satisfied that the applicant has fulfilled all the requirements, the Authority may grant the approval for transferring the results of research subject to such terms and conditions as it may deem fit to impose in each case.
5. The approval for transfer shall be granted in the form of a written agreement duly signed by an authorized officer of the Authority and the applicant. The form of the agreement shall be such as may be decided by the Authority.
6. The Authority may for reasons to be recorded in writing reject an application if it considers that the application cannot be allowed; Provided that the application shall be rejected unless the applicant has been given a reasonable opportunity of being heard.

18. Procedure for seeking prior approval before applying for intellectual

property protection.

1. Any person desirous of applying for a patent or any other intellectual property based on research on biological material and knowledge obtained from India shall make an application in Form III.
2. Every application under sub- rule (1) shall be accompanied by paying a fee of five hundred rupees.
3. The Authority after due appraisal of the application and after collecting any additional information, on the basis of merit shall decide on the application, as far as possible within a period of three months of receipt of the same.
4. On being satisfied that the applicant has fulfilled all the necessary requirements, the Authority may grant approval for applying for a patent or any other IPR subject to such terms and conditions as it may deem fit to impose in each case.
5. The approval shall be granted in the form of a written agreement duly signed by an authorized officer of the Authority and the applicant. The form of the agreement may be decided by the Authority.
6. The Authority may reject the application if it considers that the request cannot be acceded to after recording the reasons. Before passing order of rejection, the applicant shall be given an opportunity of hearing.

19. Procedure for third party transfer under sub- section (2) of Section 20.

1. The persons who have been granted approval for access to biological resources and associated knowledge, intend to transfer the accessed biological resource or knowledge to any other person or organization shall make an application to the Authority in Form IV
2. Every application under sub- rule (1) shall be accompanied by a fee of ten thousand rupees in the form of Bank draft or cheque drawn in favour of the Authority.
3. The Authority shall after collecting any additional information, decide upon the application as far as possible within a period of six months of receipt of the same.
4. On being satisfied that the applicant has fulfilled all the necessary requirements, the Authority may grant approval for third party transfer subject to such terms and conditions it may deem fit to impose in each case.
5. The approval as may be granted under sub-rule (4) in the form of a written agreement duly signed by an authorized officer of the Authority and the applicant. The form of the agreement shall be such as may be decided by the Authority.
6. The Authority may for reasons to be recorded in writing reject the application if it considers that the request cannot be acceded to provided that no application shall be rejected unless the applicant has been given an opportunity of being heard.

20. Criteria for equitable benefit sharing (Section 21)

1. The Authority shall by notification in the Official Gazette formulate the guidelines and describe the benefit sharing formula.
2. The guidelines shall provide for monetary and other benefits such as royalty; joint ventures; technology transfer; product development; education and awareness raising activities; institutional capacity building and venture capital fund.
3. The formula for benefit sharing shall be determined on a case-by case basis.
4. The Authority while granting approval to any person for access or for transfer of results of research or applying for patent and IPR or for third party transfer of the accessed biological resource and associated knowledge may impose terms and conditions for ensuring equitable sharing of the benefits arising out of the use of accessed biological material and associated knowledge.
5. The quantum of benefits shall be mutually agreed upon between the persons applying for such approval and the Authority in consultation with the local bodies and benefit claimers and may be decided in due regard to the defined parameters of access, the extent of use, the sustainability aspect, impact and expected outcome levels, including measures ensuring conservation and sustainable use of biological diversity.
6. Depending upon each case, the Authority shall stipulate the time frame for assessing benefit sharing on short, medium and long term benefits.
7. The Authority shall stipulate that benefits shall ensure conservation and sustainable use of biological diversity.
8. Where biological resources or knowledge is accessed from a specific individual or a group of individuals or organizations, the Authority may take steps to ensure that the agreed amount is paid directly to them through the district administration. Where such individuals or group of individuals or organizations cannot be identified, the monetary benefits shall be deposited in the National Biodiversity Fund.
9. Five percent of the assessed benefits shall be earmarked for the Authority or Board as the case may be, towards administrative and service charges.
10. The Authority shall monitor the flow of benefits as determined under sub rule (4) in a manner determined by it.

21. Application of National Biodiversity Fund. -

1. The National Biodiversity Fund shall be operated by the Chairperson or by such other officer of the Authority as may be authorized in this regard
2. The National Biodiversity Fund shall have two separate heads of accounts, one relating to the receipts from the Central Government and the other concerning the fee, licence fee, royalty and other receipts of the Authority.

22. Constitution of Biodiversity Management Committees

1. Every local body shall constitute a Biodiversity Management Committee (BMCs) within its area of jurisdiction.

2. The Biodiversity Management Committee as constituted under Sub– rule shall consist of a Chairperson and not more than six persons nominated by the local body, of whom not less than one third should be women and not less than 18% should belong to the Scheduled Castes/ Scheduled Tribes.
3. The Chairperson of the Biodiversity Management Committee shall be elected from amongst the members of the committee in a meeting to be chaired by the Chairperson of the local body. The Chairperson of the local body shall have the casting votes in case of a tie.
4. The Chairperson of the Biodiversity Management Committee shall have a tenure of three years.
5. The local Member of Legislative Assembly/Member of Legislative Council and Member of Parliament would be special invitees to the meetings of the Committee.
6. The main function of the BMC is to prepare People's Biodiversity Register in consultation with local people. The Register shall contain comprehensive information on availability and knowledge of local biological resources, their medicinal or any other use or any other traditional knowledge associated with them.
7. The other functions of the BMC are to advise on any matter referred to it by the State Biodiversity Board or Authority for granting approval, to maintain data about the local vaids and practitioners using the biological resources.
8. The Authority shall take steps to specify the form of the People's Biodiversity Registers, and the particulars it shall contain and the format for electronic database.
9. The Authority and the State Biodiversity Boards shall provide guidance and technical support to the Biodiversity Management Committees for preparing People's Biodiversity Registers.
10. The People's Biodiversity Registers shall be maintained and validated by the Biodiversity Management Committees.
11. The Committee shall also maintain a Register giving information about the details of the access to biological resources and traditional knowledge granted, details of the collection fee imposed and details of the benefits derived and the mode of their sharing.

23. Appeal for settlement of disputes under Section 50. –

1. If a dispute arises between the Authority or a State Biodiversity Board or between one Board and other Board(s) on account of implementation of any order or direction or on any issue of policy decision, either of the aggrieved parties i.e., Authority or the Board, as the case may be, prefer an appeal to the Central Government under section 50, in Form V to the Secretary, Ministry of Environment and Forests, Government of India.
2. In case the dispute arises between a State Biodiversity Board and another state Biodiversity Board or Boards, the aggrieved Board or Boards, shall prefer the point or points of dispute to the Central Government which shall refer the same to the Authority.

3. The memorandum of appeal shall state the facts of the case, the grounds relied upon by the appellant, for preferring the appeal and the relief sought for.
4. The memorandum of appeal shall be accompanied by an authenticated copy of the order, direction or policy decision, as the case may be, by which the appellant is aggrieved and shall be duly signed by the authorized representative of the appellant.
5. The memorandum of appeal shall be submitted in quadruplicate, either in person or through a registered post with Acknowledgement due, within 30 days from the date of the orders, direction or policy decision, impugned provided that if the Central Government is satisfied that there was good and sufficient reason for the delay in preferring the appeal, it may, for reason to be recorded in writing, allow the appeal to be preferred after the expiry of the aforesaid period of 30 days but before the expiry of 45 days from the date of the orders impugned, direction or policy decision, as the case may be.
6. The notice for hearing of the appeal shall be given in Form VI by a registered post with an acknowledgement due.
7. The Central Government shall, after hearing the appellant and the other parties, dispose of the appeal.
8. In disposing of an appeal it may vary or modify or cancel impugned order, direction or policy, as the case may be.
9. In adjudicating a dispute, the Authority shall be guided by the principles of natural justice and as far as practicable, follow the same procedure which the Central Government is required to follow under this rule.

24. Manner of giving notice under Section 61

1. The manner of giving notice, under clause (b) of section 61, shall be as follows namely:
   (i) The notice shall be in writing in Form VII
   (ii) The person giving the notice may send it to,-

(a) If the alleged offence has taken place in a Union territory, to the Chairperson of the National Bio-diversity Authority; and

(b) If the alleged offence has taken place in a State, to the Chairperson of the State Bio-diversity Board

(2) The notice referred to in sub – rule (1) shall be sent by registered post acknowledgement due; and

(3) The period of thirty days mentioned in clause (b) of section 61 shall be reckoned from the date, the notice is received by the Authorities mentioned in sub – rule (1).

FORM I

(see rule 14)

Application form for access to Biological resources and associated traditional knowledge

Part A

i. Full particulars of the applicant
ii. Name:
iii. Permanent address:
iv. Address of the contact person /agent , if any, in India:
v. Profile of the organization (personal profile in case the applicant is an individual). Please attach relevant documents of authentication):
vi. Nature of business:
vii. Turnover of the organization in US $:

2. Details and specific information about nature of access sought and biological material and associated knowledge to be accessed
a. Identification (scientific name) of biological resources and its traditional use:
b. Geographical location of proposed collection:
c. Description /nature of traditional knowledge (oral/documented):
d. Any identified individual /community holding the traditional knowledge:
e. Quantity of biological resources to be collected (give the schedule):
f. Time span in which the biological resources is proposed to be collected:
g. Name and number of person authorized by the company for making the selection:
h. The purpose for which the access is requested including the type and extent of research, commercial use being derived and expected to be derived from it:
i) Whether any collection of the resource endangers any component of biological diversity and the risks which may arise from the access:

3. Details of any national institution which will participate in the Research and Development activities.
4. Primary destination of accessed resource and identity of the location where the R&D will be carried out.
5. The economic and other benefits including those arriving out of any IPR, patent obtained out of accessed biological resources and knowledge that are intended, or may accrue to the applicant or to the country that he/she belongs
6. The biotechnological, scientific, social or any other benefits obtained out of accessed biological resources and knowledge that are intended, or may accrue to the applicant or to the country that he / she belongs
7. Estimation of benefits, that would flow to India / communities arising out of the use of accessed bioresources and traditional knowledge
8. Proposed mechanism and arrangements for benefit sharing.
9. Any other information considered relevant.

Part B

Declaration

I / we declare that:

l Collection of proposed biological resources shall not adversely affect the sustainability of the resources;

l Collection of proposed biological resources shall not entail any environmental impact;

l Collection of proposed biological resources shall not pose any risk to ecosystems;

l Collection of proposed biological resources shall not adversely affect the local communities;

I/we further declare the Information provided in the application form is true and correct and I /We shall be responsible for any incorrect / wrong information.

Signed

Name

Title

Place

Date

FORM II

(see rule 17)

Application for seeking prior approval of National Biodiversity Authority for transferring the results of research to foreign nationals, companies, NRI's, for commercial purposes.

1. Full particulars of the applicant

    i) Name :

    ii) Address :

    iii) Professional profile :

    iv) Organizational affiliation (Please attach relevant documents of authentication):

2. Details of the results of research conducted

3. Details of the Biological resources and / or associated knowledge used in the research.

4. Geo-graphical location from where the biological resources used in the research are collected

5. Details of any traditional knowledge used in the research and any identified individual / community holding the traditional knowledge

6. Details of institution where R & D activities carried out.

7. Details of the individual / organization to whom the research results are intend to transfer.

8. Details of economic, biotechnological, scientific or any other benefits that are intended, or may accrue to the individual / organization due to commercialization of transferred research results.

9. Details of economic, biotechnological, scientific or any other benefits that are intended, or may accrue to the applicant seeking approval for transfer of results of research.

10. Details of any agreement or MOU between by the proposed recipient and applicant seeking approval for transfer of results of research.

Declaration

I/we declare the information provided in the application form is true and correct and I/We shall be responsible for any incorrect/wrong information.

Signed

Name

Title

Place

Date

FORM III

(See rule 18)

Application for seeking prior approval of National Biodiversity Authority for applying for Intellectual Property Right

1. Full particulars of the applicant

   i) Name :

   ii) Address :

   iii) Professional profile :

   iv) Organizational affiliation (Please attach relevant documents of authentication):

2. Details of the invention on which IPRs sought

3. Details of the Biological resources and / or associated knowledge used in the invention.

4. Geo-graphical location from where the biological resources used in the invention are collected .

5. Details of any traditional knowledge used in the invention and any identified individual/ community holding the traditional knowledge.

6. Details of institution where Research and Development activities carried out.

7. Details of economic, biotechnological, scientific or any other benefits that are intended, or may accrue to the applicant due commercialization of the invention.

Declaration

I/we declare the Information provided in the application form is true and correct and I /We shall be responsible for any incorrect/ wrong information.

Signed

Name

Title

Place

Date

FORM IV

(See rule 19)

Application form for seeking approval of National Biodiversity Authority for third party transfer of the accessed Biological resources and associated traditional knowledge.

1. Full particulars of the applicant

   (i) Name :

   (ii) Address :

   (iii) Professional profile :

   (iv) Organizational affiliation (Please attach relevant documents of authentication)

2. Details of the biological material and traditional knowledge accessed

3. Details of the access contract entered (Copy to be enclosed)

4. Details of the benefits and mechanism/arrangements for benefit sharing already implemented.

5. Full particulars of the third part to whom the accessed material knowledge is intended to transfer.

6. The purpose of the intended third party transfer.

7. Details of economic, social, biotechnological, scientific or any other benefits that are intended, or may accrue to the third party due to transfer of accessed biological material and knowledge.

8. Details of any agreement to be entered between the applicant and the third party.

9. Estimation of benefits that would flow to India/communities arising out of the third party transfer of accessed biological resources and traditional knowledge.

10. Proposed mechanism and arrangements for benefit sharing arising out of the proposed third party transfer.

11. Any other relevant information

Declaration

I/we declare the Information provided in the application form is true and correct and I /We shall be responsible for any incorrect/ wrong information.

Signed

Name

Title

Place

Date

FORM V

(See rule –23 (1)

Form of Memorandum of Appeal

BEFORE THE_____________ MINISTRY OF ENVIRONMENT AND FORESTS, NEW DELHI

OR

NATIONAL BIODIVERSITY AUTHORITY

(as the case may be)

(Memorandum of appeal under Section 50 of the Biological Diversity Act, 2002)

Appeal No.____________________________ of 200

____

___________________ ……… Appellant (s)

Vs.

_________________ ………..Respondent (s)

____

(here mention the designation of the Authority/Board, as the case may be)

The appellant begs to prefer this Memorandum of Appeal against the order dated_____________ passed by the Respondent on the following facts and grounds.

1. FACTS:

(Here briefly mention the facts of the case):

2. GROUND :

(Here mention the grounds on which the appeal is made):

i.)

ii.)

iii.)

3. RELIEF SOUGHT

i.)

ii.)

iii.)

4. PRAYER:

a) In the light of what is stated above, the appellant respectfully prays that the order / decision of the respondent be quashed / set-aside.

b) The policy / guidelines / regulation framed by the Respondent be quashed / modified / annulled to the extent________________________

____

c) ____

Place:_____________

Dated:_____________

Signature of the appellant
with seal
Address:

VERIFICATION

I, the appellant do hereby declare that what is stated above is true to the best of my information and belief.

Verified on ______________day of_______________

Signature of the appellant

with seal

Address

Signature of the Authorised representative of the appellant

Enclosures: 1. Authenticated copy of the order / direction/ policy decision, against which the appeal has been preferred.

FORM VI

(See rule 23 (6))

BEFORE THE ___________________ MINISTRY OF ENVIRONMENT AND FORESTS, NEW DELHI

OR

NATIONAL BIODIVERSITY AUTHORITY

(as the case may be)

Appeal No.________________ of 200

Between:

____

__________________________________ ….. Appellant (s)

Vs.

____

__________________________________ … Respondents (s)

NOTICE

Please take notice that the above appeal filed by the appellant, against the order / direction / policy decision (give details) is fixed for hearing on___________________ at____________________ .

The copies of the appeal memorandum and other annexure filed along with the appeal are sent herewith for your reference.

Please note that if you fails to appear on the said date or other subsequent date of hearing of the appeal, the appeal would be disposed of finally by placing you ex-parte.

Authorised signatory on behalf of the

Appellate Authority (Seal)

Date: __________

Place: __________

FORM VII

FORM OF NOTICE

(See rule 24(1))

By Registered Post / Acknowledgement due

From,

Shri___________________________

____

____

To,

____

____

____

Sub: NOTICE UNDER SECTION 61(b) OF THE BIOLOGICAL DIVERSITY ACT, 2002

Whereas an offence under the Biological Diversity Act, 2002 has been committed/is being committed by _____________________________________

2. I/ we hereby give notice of 30 days under Section 61(b) of the Biological Diversity Act, 2002 of my / our intention to file a complaint in the Court against ________________ ________________________ for violation of the provisions of the Biological Diversity Act, 2002.

3. In support of my /our notice, I am / we are enclosing herewith the following documents as evidence of proof.

Place: ___________

Date: ____________

Signature

EXPLANATION:

(1) In case the notice to be given in the name of a company, documentary evidence authorizing the person to sign the notice on behalf of the company shall be enclosed to the notice.

(2) Give the name and address of the alleged offender. In case of using biological resource/knowledge/research/bio- survey and bio utilization / the intellectual property right/patent, without the approval of the Authority, the details thereof and the commercial utilisation if any, may be furnished.

(3) Documentary evidence shall include photograph, technical report etc., for enabling enquiry into the alleged violation / offence.

[No. J-22018/57/2002-CSC(BC)]

DESH DEEPAK VERMA, Jt. Secy.