Chapter 10

SUMMARY AND CONCLUSION

The present investigation is an endeavour to provide an insight on the ecology of the Maranchery Kole wetland and is an appraisal of the qualitative and quantitative distribution as well as biocenosis of macrophytes and macroinvertebrates. The International Convention of Wetlands designated the Vembanad-Kole, in Kerala as Ramsar sites, for their long term conservation and restoration of the biological diversity and wise use. The Kole wetlands of Kerala are known to be indispensable habitat to a variety of biologically and economically important resident aquatic flora, fauna especially certain migratory birds. Kole wetlands are submerged for almost half of the year and under paddy cultivation for the other half. The shift from water body to paddy field involves a series of processes. Paddy cultivation (Punja Krishi*) is practiced from January to May every year. The agriculture related activities made the area behave as four different phases during the study period such as normal water bodies (wet phase), paddy fields (paddy phase) and narrow strips of water bodies

* The terms are of regional language Malayalam
(channel phase). Some of the water body remained stable throughout the study period (stable phase). This thesis embodies a comprehensive analysis of the environmental parameters influencing the productivity pattern, distribution, abundance and community structure of macrophytes and macroinvertebrates based on the spatial variations.

Physico-chemical parameters showed clear spatial variations in phase wise studies. Depth was the most variable physical parameter in this study. Due to spatial variations it led to profound changes in the ecosystem functions as well as macrophyte growth. Temperature of the surface water ranged between 24.5°C to 35°C. Water pH remained neutral mostly or was otherwise acidic in nature. During the early growth stages of rice plants pH showed alkaline nature due to application of fertilizers and wood ashes. Low turbidity during wet phase was noticed. Macrophytes helped to reduce the turbidity by trapping suspended sediments from the water column. Increasing conductivity during channel phase in Maranchery wetland might be due to evaporation of water leading to increase in major ionic concentration which released the decomposing organic materials from plant matter. TDS were higher during paddy phase. Primary sources for TDS in Kole lands are agricultural and residential runoff, leaching of soil and application of several organic and inorganic fertilizers. Hardness of the wetland did not show any noticeable spatial variations. Dissolved oxygen and BOD showed wide variations in different phases but with in permissible limits. Alkalinity of the wetland was moderate indicating that the condition of the wetland was suitable for fish culture operations. Due to the different phases, nutrient concentration was deferred in Maranchery wetland. Higher values of PO₄-P during paddy and channel phases were related to increased decomposition of macrophytes at higher temperature, release of nutrients.
and various agricultural activities like tillage, addition of fertilizers whereas lower values could be attributed to its utilization by macrophytes for their growth in wet and stable phases. Increase in NO₃-N concentration during channel phase might be due to leaching of autochthonous materials (macrophyte litter). Compared to other nutrients NO₂-N was in trace amount in this Kole land. Diverse community of macrophytes utilize for their growth and fruiting period take more NO₂-N that could be one reason for decreased level of NO₂-N. Application of fertilizers contributes to increase in ammonia-nitrogen concentration during paddy phase. Inorganic nutrients were lower during wet phase. Hydrological regimes lead to variation in chemical parameters. Prolific growth of macrophytes acts as a biofilter and decreasing the values of environmental characteristics. Apart from the different kinds of vegetations affecting nutrient distribution in wetlands, the cattle and bird excreta was also suspected to have impacted the nutrient levels in shallow phases like channels and paddy phase.

Phase wise analysis shows that spatial variations significantly alter the productivity of these ecosystem. Primary production was having wide variation throughout the study period. In phase wise analysis channel phase shows higher gross primary productivity (GPP) and net primary productivity (NPP). GPP and NPP showed a strong positive correlation significant at 5% level (P<0.05). Chlorophyll a shows positive correlation with dissolved oxygen, macrophyte biomass, nitrate-nitrogen, phosphate-phosphorus and silicate-silica. NPP showed a positive correlation with algal biomass at 1% level of significance (P<0.01). The luxurious growth of aquatic macrophytes in this wetland may be contributed to the higher Chl. a content that influence the productivity pattern.
A total of 21 aquatic and semi aquatic macrophytes belonging to 21 genera and 16 families, were recorded. The Angiosperms were represented by 12 families and the Pteridophytes or water ferns by 3 families were identified from this wetland. Maximum species were represented by Poaceae (4 species) and water ferns (3 species) followed by Convolvulaceae and Pontederiaceae (2 species). Among the 21 species two species are categorized by exotic plants. In the present study, it was noted that *Eichhornia crassipes*, *Salvinia molesta*, *Nymphaea pubescens*, *Nymphoides indicum*, *Hydrilla verticillata*, *Utricularia aurea*, *Ludwigia adscendens* and *Limnophila heterophylla* are found to form monospecific communities in this area. Other macrophytes that are observed or found in association with dominant macrophytes that were *Rotala* sp., *Ipomea pes-capre*, *Convolvulus* sp., *Sagittaria* sp., *Sacciolepis* sp., and *Lemna perpusilla*. Diversity of macrophytes was significantly varied in different phases. Wet and stable phases were characterized by more diversity of macrophytes as the increased habitable area and undisturbed substrate increases the abundance. Channel and paddy phases were showed a reduced diversity. Same pattern was followed in biomass of macrophytes. Frequency of macrophytes was higher in Station 1 to 5. Manual removal of macrophytes during channel and paddy phases observed as well as agricultural related activities disturbed the growth of macrophytes. This leads to decrease in diversity and biomass in these phases. Growth forms of the aquatic plants were encountered during the present investigation, of which 7 numbers are emergent plants and free floating hydrophytes was second highest growth form in this wetland. The other growth forms observed were submerged- anchored hydrophytes, anchored hydrophytes with floating leaves, emergent-anchored with floating shoot and anchored hydrophytes with floating shoot. Exotic invasive species like *E. crassipes* and *S. molesta* were abundant in station 7 and 8 that seems
to constitute a major threat to wetland biodiversity. Intense anthropogenic activities were found in these stations. The aggressive alien plants in water bodies appeared to pose a threat to the indigenous medicinal macrophytes. Submerged species like *H. verticillata, U. aurea* was wide spread and present throughout the study period. Stagnant nature of this wetland water column protects delicate species like *H. verticillata* and *U. aurea*. Diversity Index $H'$ showed that Station 4 had the highest diversity (3.29) and Station 1 ranked the least with 2.1. Dominance plot shows that wet phase having higher dominance and agreeing with Margalef’s index $(d)$ of 3.03. Abundance, biomass and diversity was found decreased in disturbed paddy and channel phases. Natural hydrological regime of the wetland influenced the macrophyte growth to a great extent. From the results, it is evident that the ecological conditions as well as the stagnant nature of water body support a rich macrophytic vascular plant diversity. The poor representation of macrophytes in channels may be due to the lack of proper substratum.

A definite spatial and temporal variation in the macroinvertebrate abundance was obvious in association with different macrophytes. The phase wise variation in macroinvertebrate assemblage could be related to monsoonal influence, macrophyte species structure and growth pattern and agricultural activities. Total macroinvertebrate abundance were higher during wet phase whereas insect fauna showed higher abundance during paddy phase. In station wise evaluation station 6 shows less abundance of insect entomofauna. Total abundance of macroinvertebrates varied largely due to the presence or absence of insect fauna in this wetland. Station wise study reveals that higher abundance of aquatic insects (4192 No./m$^2$), was associated with *H. verticillata* in Station 1, which were submerged during sampling period also this plant having long dissected leaves that leads to
higher abundance. In Station 5, *N. pubescens* plant contributed least number of insects (2496 No./m²). The floating, undissected leaves harboured the lowest abundance of entomofauna. Mollusca, Branchiopoda, and Arachnida shows higher abundance in association with *Eichhornia crassipes* in station 6. Insect abundance was comparatively less in station 6. Detailed study of aquatic insects abundance shows that each Order of insect fauna was differentiated in different macrophytes. Ephemeroptera were associated with the macrophyte *L. heterophylla*; odonates with *N. indicum*; Hemiptera and Trichoptera with *U. aurea*; Lepidoptera, Coleoptera with *S. molesta*, and Diptera with *H. verticillata*. The study reveals that abundance pattern was closely related with the macrophyte sps. mainly due to different feeding habits.

The macrophyte associated invertebrate community in this wetland varies widely on a phase wise and station wise scale. It comprised of 11 classes belonging to Insecta, Nematoda, Oligochaeta, Euhrudinea, Mollusca, Ostracoda, Branchiopoda, Isopoda, Decapoda, Arachnida, and Pisces. The insects fauna were found dominating during the study period (64.2%) in all the stations and also during phase wise evaluations. Its maximum percentage was contributed in paddy phase (80%), followed by channels (62.1%) wet (38.7 %) and stable phase (32.6%). In station wise analysis 55% and above was contributed by insect fauna in all the eight stations. The percentage contribution of Branchiopoda, Arachnida, Euhrudinea, Mollusca, Decapoda and Ostracoda were in the order 9.8%, 6.8%, 6.5%, 5.8%, 3.3% and 2% respectively. Nematoda, Oligochaeta, Isopoda and Pisces contributed on an average less than 1% in the study stations.
The aquatic insects belonged to 7 orders, 30 families and 58 genera/species. Among the class insecta, Diptera were the most dominant order in all the stations except in station 7, where order Coleoptera dominated. Mean percentage composition of insect fauna entirely varied in four phases. In channel and stable phases, Coleoptera contributed 49.2% and 47.8% respectively. In paddy phase order Dipterans had 40.9% and that in wet period Odonata contributed about 34.9%. Among insect fauna collected, Coleoptera was diverse in number of genera (18sp.) comprising 20% of insect fauna which includes adults and larval forms. It was represented by 10 families Viz., Dytiscidae, Noteridae, Hydrophilidae, Curculionidae, Chrysomelidae, Hydraenidae, Carabidae, Staphylinidae, Dryopidae and Histeridae. Family Dytiscidae was the most predominant species of *Hydrovatus confertus* and wide spread in eight stations whereas family Noteridae species of *Canthydrus luctuosus* was contributed 4.3% in total coleopterans. Hydrophilidae family was mainly represented by *Enochrus esuriens* and *Berosus indicus*. The other species mainly found in association with hydrophytes were *Helichus* sp., *Bagous* sp., *Cassida* sp., *Henicocerus* sp., *Chlaenius* sp., *Paederus* sp. and *Platylomalus* sp. among the aquatic coleopterans. Ephemeroptera was represented in Maranchery Kole lands by the three families Ephemerellidae, Caenidae and Baetidae. The family Ephemerellidae was contributed by *Ephemerella* sp. The family Caenidae and Baetidae similarly contributed one species each, representing *Caenis nigropunctata* and *Centroptilum* sp. The Odonata was represented by the families Libellulidae, Gomphidae and Coenagrionidae. The important members of family Libellulidae was *Nannophya pygmaea*, and the other nymph species that were mainly found in association with macrophytes were *Crocothemis servilia*, *Hydrobasileus croceus*, *Ictinogomphus rapax*, *Agriocnemis lacteola*, *Ischnura senegalensis* and *Pseudagrion* sp. Hemipera
was categorized under 6 families viz., Nepidae, Belostomatidae, Pleidae, Corixidae, Hebridae and Gerridae. Of these, Belostomatidae was the most common family among Hemiptera in eight stations constituted by two species *Diplonychus rusticus* and *Diplonychus annulatum*. Trichoptera or caddisflies were contributed by three species of *Neureclipsis* sp., *Hydropsyche* sp., and *Himalopsycye phryganea*. Among the Trichoptera taxa, *Neureclipsis* sp. of family Polycentropodidae was common throughout the study period. Order dipterans were one of the tolerant group that represented biting and non biting midges. The families contributed were by Chironomidae, Chaoboridae, Culicidae and Ceratopogonidae. The family Chironomidae was represented by 13 species. Among which *Chironomus major*, *Polypedilum leei*, *Polypedilum nubifer*, *Tanypus carinatus* and *Ablabesmyia annulata* were commonly found with different species of macrophytes. The species such as *Bezzia* sp., *Chironomid major*, *Ephemerella* sp., *Nannophya* sp., *Canthydrus luctuosus* were the most abundant species during the study period. The transformation from one phase to another in the wet, paddy and channel phases were through a series of steps which made the death and decaying of macrophytes resulting in habitat loss, habitat isolation and habitat fragmentation for aquatic organisms for some period. Changes in the physical structure of the study area due to human activities could affect the macrophyte composition and abundance, which would intern have a negative influences on the macroinvertebrate population in the wetland. There are studies which states that changes in the landscape has caused reduction in the area and connectivity of natural habitat. Fragmentation of wetlands is one of the main problem related to the diversity and distribution pattern of entomofauna. In certain extreme cases insect fauna survive by metamorphosis like diapausing eggs, resistant cysts enclosing young, adults or fragments of
individuals. Macroinvertebrates like Hirudinea creates mucus coatings, gastropods formed a protective apiphragm of dried mucus across shell opening in the case of adults and young ones survived in moist soil or stream bed. The present study reveals that there are not any egg cases and cysts present with macrophytes. But migration of aquatic insects and larvae into the available macrophyte bed were observed and this might be one reason for decreased diversity and abundance. Diversity indices of macroinvertebrates as well as insects fauna were noticed. In the case of macroinvertebrates richness was compared among different phases and maximum was noticed in stable phase whereas richness of aquatic insects showed a maximum in paddy phase. The abundance also depicted same pattern in both the cases. The results proved that macroinvertebrates other than the aquatic insects the water level fluctuations can cause severe impacts as the fauna is stressed by harsher environmental conditions caused by the drying out process whereas in stable environments, the fauna are less adapted to fluctuations. This may be due to the insect fauna having a wide range of tolerance level and extensive feeding habit.

Macrophyte associated macroinvertebrate assemblage and its environmental relationship also accounted on the ecological quality status of the Maranchery wetland using biomonitoring index of aquatic insects. The indices such as Taxa richness, percentage of intolerant taxa and tolerant taxa, percentage EPT (Ephemeroptera, Plecoptera and Trichoptera ratios), percentage of predators, functional feeding groups (%), biomonitoring working party score (BMWP) and average score per taxon (ASPT) have been used to measure the ecological quality status of aquatic insects fauna of this Kole land, impacted with various types of stress from changing land use pattern, organic enrichment, eutrophication, agriculture runoff and pollution.
problems. In phase wise matrices of aquatic insect fauna it shows that, percentage EPT taxa was higher in wet phase. Percentage of tolerant taxa formed higher in paddy phase whereas percentage of intolerant taxa was higher in channel phase. Percentage of predators was highest in paddy phase followed by channels, wet and stable phases. Dominant taxa in paddy phase was found to be family Caenidae, in channels (family Noteridae), in wet (family Libellulidae) and in stable period (family Staphylanidae). Biomonitoring scores like, BMWP score denoted that pollution tolerant families are higher in paddy phase. ASPT Score of paddy phase was less compared to wet phase and stable phases. Generally a high ASPT usually characterizes clean sites, disturbed sites generally have low ASPT values. Over all ecological status of different phases showed paddy phase was in disturbed condition. Correlation between environmental parameters, macrophyte biomass with aquatic insects showed that a group of parameters such as depth, pH, alkalinity and nutrients as well as macrophyte biomass were showing a week correlation due to the spatial heterogeneity of the study area. Similar to environmental characteristics certain biotic factors play a key role to structuring the community pattern of this wetland. It could be the habitable patch, with hydrological stability, length of hydroperiod, habitat duration, life history strategy, macrophyte structure and diversity, proximity and size of the neighbouring habitat, intensity of disturbance, competition, predation, etc.

From the present study it was found that the abundance and richness of macroinvertebrates are not distributed homogeneously among aquatic macrophytes which differ in complexity and growth forms that they occupy in the wetland. Since the greatest abundances of invertebrates biocenosis was associated with the most structurally complex macrophyte species.
From this study, it is understood and necessary to maintain water levels sufficient to keep macrophytes. However, to maximise biodiversity, it is not as simple as it is regarded. As water levels and other environmental conditions get changed, the species of macrophyte supporting the highest taxonomic richness also changes. It is vital for water managers or farmers to be aware that aquatic macrophytes support a diverse array of invertebrates and that a rich macrophyte flora will undoubtedly equate to a rich invertebrate fauna. Water allocations for farming activities must therefore be commensurate with the requirements of all species of macrophytes. It may be that by maintaining the heterogeneity of this type of habitat, a major step in managing both biodiversity and wetland health are achieved.

Based on the results of this study some management options are suggested here.

- Increasing public awareness for halting the environmental degradation is now necessitated for environmental appraisal of all projects and natural ecosystems such as wetlands on cost benefit ratio, in terms not just of ecology and environment but also on the socio-economic scale. The socio-economic survey of the population living around the wetland, is mainly dependent on the ecosystem for fishing activities, rice farming and allied activities. Fishing appears to be a more lucrative profession compared to agricultural practices for the Kole land communities. Further, several of the farming communities in the area have switched over to other avocations that can benefit more economic benefits. This has also led to large scale reclamation of these productive lands for other developmental works destroying the ecology and health of the Kole wetlands.
The uniqueness of the Kole wetland is the cycle of phases (dry, wet, flooding, channel) on a seasonal basis, that undergoes, for maintaining the hydrology and life support in the system. The paddy cultivation and fishing activities are all linked to the different phases for livelihood measures. The global climate change with its probable regional effects also had its measure of impact on the traditional agricultural practices, when most of wetland has been converted to commercially viable practices like, application of pesticides and chemical fertilizers in the paddy fields. The indiscriminate application of these chemicals in the Kole fields has led to the decrease in diversity of macrophytes and macroinvertebrates as well, that has brought about livelihood changes. Further modification in the seasonal cycle linked to the phases in the Kole lands has propagated invasive water weeds and tolerant organisms like noxious midges affecting the productivity of the region. The low productivity from agriculture and other forms of farming practices has also created barren lands possibly getting reclaimed for developmental objectives. All these lead to mass collapse of the biocenosis of communities like macrophytes and invertebrates as discussed elaborately in this thesis. However, Maranchery wetland offers an excellent example of macrophyte diversity, density and offering a rich variety of food, shelter, nesting and roosting site for migratory birds, fishes and insect communities. The wetland is suitable for enhanced fish farming operations to propagate the native resources. Integrated paddy cum fish farming practice has to be encouraged depending on the various phases and seasonal cycles. The Kerala State Biodiversity Board and other Governmental and
non-Governmental organizations should commence effective action in this direction.

- In the past, special relationship existed not only at the political and cultural levels, but also in the areas of agriculture and food security. Rice biopark concept will go a long way in revitalising its paddy farming in Kole wetlands and also help to get a good income generation for the stake holders. So these Kole lands are to be conserved as bioreserves for food security and livelihood sustainability.

- Aquatic insect biodiversity is of considerable interest to society because these animals are so important in the diets of many fish species, including species that are commonly consumed by humans for food. A high diversity of these insects in Maranchery wetland, each with its own specific emergence time, assures that food is available to the fish through much of the year. The application of pesticides and herbicides in the agricultural fields of these wetlands causes rapid changes in the water quality, leading to the decline in diversity and abundance of insect fauna. Thus the usage of fertilizers and pesticides can be reduced and promoting organic farming for cost effective and economical paddy cultivation.

- The senescence of the macrophytic vegetation in the wetland needs further investigation, and this decomposed organic matter is often exploited by the local population for different usages like cattle fodder and organic fertilizer. Several identified macrophyte species are medicinal varieties, collection and preservation of these plants
often is a good scope for income generation for the local people. This wetland observed different water weeds such as, *Eichhornia crassipes*, *Lemna pepusilla* and *Salvinia molesta*. Use of traditional knowledge for better use of weeds as mineral recycling agents and conversion of weeds into compost would help to generate revenue. Moreover the magnificent beauty of flowering macrophytes and presence of numerous native and migratory birds could be explored for ecotourism purposes without disturbing the ecosystem. Therefore, Maranchery Kole wetland conservation has to be taken up as a crusade at state level for the welfare of present and future generations.

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*Dynamics of biocenosis and its spatio-temporal variability in Maranchery Kole wetland, Kerala*