CHAPTER-VI

SUMMARY

Our country has a rich and unique biodiversity with a variety of indigenous ornamental fishes. However, most of the ornamental fishes cultured and marketed in India are exotic species. Kerala have started creating a niche of its own in the ornamental fish marketing scenario. But this resource has not been properly exploited. Blessed with heavy monsoon rains and sloping topography from the Western Ghats, the 44 rivers of Kerala are swift flowing with limited bed resources. Studies on indigenous ornamental fishes have gained considerable importance in the context of the escalating ornamental fish trade, which is, no doubt a magic money-spinner, particularly for the tropical countries with their high biodiversity of ornamentals, both marine and freshwater.

The choice of Achencoil River for studies in ornamental fishes has obvious reason. Out of the 41 west flowing rivers of Kerala, the River Achencoil is the 9th largest in terms of catchment area and 6th in terms of length; it is comparatively less polluted and has yet to be explored and studied in detail for ornamental fishes. Here lies the relevance of the present study which is an attempt to explore the fish diversity potential within Achencoil River, especially for ornamental purposes. A few studies had been undertaken by different workers on fishes of Achencoil River. However the ornamental fishery potential is yet to be discussed. Therefore the present study is taken up with a view for appending relevant information to the existing knowledge on the distribution of indigenous ornamental fishes and their biology and maintenance under captive condition.
Three sampling stations were selected at different locations – upstream (at Achencoil), midstream (Vazhamuttam, Pathanamthitta) and downstream (Vazhuvadi kadavu, Thazhakkara, Mavelikara) along the basin. Monthly water collections were made from the three study sites from June 2010 to May 2011. Hydrographical parameters and chemical parameters like temperature, pH, dissolved oxygen, carbon dioxide, phosphate and nitrate were recorded. All data on atmospheric and water temperature and hydrographical parameters were tested for statistically significant differences between sites, between seasons and sites interaction by using ANOVA. Significant differences, if any, in any parameter between pairs of sites/seasons were tested using Student-Newman-Keuls test (SNK). Correlations between various hydrographical parameters were estimated by simple linear correlation and analysis was done using statistiXL software.

The result of the study, presented in this dissertation may be summarised as follows: -

**Hydrographical Studies:**

1) The most important factor that brings about changes in the water quality is monsoon. Accordingly three seasons were recognised- Monsoon (June to September), Post monsoon (October to January) and Pre monsoon (February to May). Study indicated that certain parameter where critical when compared to normal value. The monthly survey for one year was carried out to understand the natural and anthropogenic processes controlling the water chemistry in the Achencoil River provides first hand information about the physicochemical aspects of the river water. The highest rainfall occurred in November, 2010 (601.8
mm) and rainfall was least in December (57.4mm). Monsoon period (June to September) had the maximum rainfall with an average of 309.6mm. The pre-monsoon period showed less rainfall with only 195.4mm.

2) Results of ANOVA showed that atmospheric temperature differed significantly both between sites \( (P < 0.01) \) and between seasons \( (P < 0.01) \). Results of SNK test revealed that the difference in atmospheric temperature between sites I and II and that between sites I and III were highly significant \( (P < 0.01) \). Similarly, atmospheric temperature between monsoon and premonsoon and that between post- and premonsoon were highly significant \( (P < 0.01) \).

3) In site I, pre monsoon period showed a high water temperature where as site II and III showed more or less similar water temperature throughout the season. Pre-monsoon period had comparatively higher water temperature than the other two seasons in all the three sites. It may thus be noted from the summery of ANOVA that water temperature differed significantly both between sites \( (P<0.01) \) and between seasons \( (P<0.01) \). Result of SNK test revealed that the difference in water temperature between sites I and II were highly significant \( (P<0.01) \). Similarly, water temperature between monsoon and premonsoon and that between post monsoon and premonsoon differed significantly \( (P<0.01) \).

4) During monsoon period, pH was found to be in an average of 6.7 in site 1, 6.4 in site 2 and 6.6 in site 3, which in general shows a trend towards the acidic side. The pH value has a highest range 6.9 to 7.1 during the pre monsoon period in all the three sites which is slightly alkaline. During the other periods it is below 7. Results of ANOVA shows that pH differed significantly both between sites \( (P < 0.01) \) and
between seasons \((P < 0.01)\). Results of SNK test revealed that there were no significant difference in pH between the three sites and the three seasons.

5) The value of dissolved oxygen in the Achencoil River during the period of study was found to be all within the desirable range. From the summary of ANOVA, it can be concluded that monthly and seasonal variations in dissolved oxygen at Achencoil river basin showed significant variations between sites \((P < 0.01)\) and across the seasons \((P<0.01)\). SNK test result also supported this result.

6) When the three sites were compared, carbon dioxide level was very low in site I than the other 2 sites and high in Site III. At the downstream pollutions due to human interference were more obvious, which may be the reason for such a high value. It is clear from the summary of ANOVA (Table 6(b)) and results of SNK test that the variations between sites and across the seasons \((P< 0.01)\) were statistically significant. Site I had low carbon dioxide level throughout the year, which proves that the river at the upstream is not at all polluted. When we consider the seasonal variations at the three site monsoon season had a low carbon dioxide level throughout the site, except the post monsoon season in site I, this may be due to the heavy rainfall during this period.

7) Results of ANOVA showed that phosphate differed significantly both between sites \((P < 0.01)\) and between seasons \((P < 0.01)\). But no significant sites/seasons interaction was seen. Results of SNK test revealed that though the difference in atmospheric temperature between I and II and that between I and III were highly significant \((P < 0.01)\). Similarly, atmospheric temperature between monsoon and
premonsoon and that between monsoon and postmonsoon were highly significant \((P < 0.01)\).

8) The annual phosphate level was 0.34 ± 0.33, 1.62 ± 0.98 and 1.69 ± 0.92 respectively in the three sites. In the lower reaches of the river, phosphate content showed considerable increase during the study period. Low phosphate value at site I, indicate non-polluted nature of river origin compared to site II and site III. Site I shows a very low value in all the three seasons. But site II and III show low value in monsoon season and high values in pre-monsoon and post monsoon season.

9) The monthly fluctuations in the concentration of nitrate varied from 0.36µg/l in August in Site I to 6.78 µg/l in March in Site II. The annual mean values were 2.75 ± 2.54, 2.67 ± 1.57 and 2.83 ± 1.08 respectively in the three sites. The seasonal variation \((P<0.01)\) were statistically significant between seasons but, no significant variation was seen between sites. SNK test result revealed that there were significant variations between monsoon and premonsoon \((P<0.01)\) and also between postmonson and premonsoon \((P<0.01)\).

**Biodiversity Studies:**

The present study aimed at analysing local diversity (\(\alpha\)-diversity) of the ornamental fish assemblage of the River Achencoil as a whole. The \(\alpha\)- diversity of the up-, mid- and downstream and of the three seasons were also carried out. The study also envisaged the analysis of the beta-diversity patterns along the longitudinal gradients of the river and along temporal gradients in terms of the seasons. The third
important aspect analysed was the phylogenetic structure and taxonomic diversity of the ornamental fish assemblages of the river.

Monthly collections of fishes were taken from three sites of the river for a period of one year from June 2010 to May 2011. From each site, fishes were collected randomly from different locations covering all possible habitats. Data for each monthly sample of the three sites were pooled to study the overall biodiversity pattern (total 36 samples) of the ornamental fish assemblage of River Achencoil. The same data sets were used to analyse the β-diversity patterns and taxonomic diversity. The result obtained can be summarized as follows:

1) During the present study, 1,157 specimens of ornamental fishes belonging to 46 species coming under 32 genera, 16 families, 6 orders and 2 superorders were collected from the river Achencoil. The family Cyprinidae dominated with 25 species, followed by Ambassidae with 4 species and Balitoridae, Nemachilidae and Bagridae with 2 species each. The rest 11 families were represented by a single species only.

2) The results of the analysis of the structural indices of α-diversity of the ornamental fish community of River Achencoil indicate that the biodiversity of the ornamental fish community of river Achencoil was high, with a richness of 46 species, Shannon index clocking at 3.44 and Simpson Diversity (1-D) at 0.958 and with reasonably even distribution (Evenness index = 0.899), no species being overly dominant.

3) Results of the analysis of true species richness estimated by rarefaction for the ornamental fish data set for River Achencoil using 10 estimators, along with the
corresponding number of individuals and mean numbers of singletons, doubletons, uniques and duplicates were also carried out. The overall conclusions drawn from these results are,

i. The ornamental fish assemblage of the river was well inventoried in the present data set as evident from the species accumulation curves reaching asymptote and leveling off at 46 species indicating that the maximum number of species had been collected by 36 monthly collections from the river and that it is quite unlikely that either more number of samples or more number of individuals would have detected more species of ornamentals in this river; in fact, the curves suggests a lesser number of samples (about 16-17) and individuals (about 460-470) for reaching the asymptote at 46 species.

ii. Though singletons, doubletons and uniques were high initially, they declined drastically and were minimal in individual sample size >1,100 (except duplicates) suggesting that the present sampling was nearly thorough, there being virtually no chance for any rare species having been missed from the collection.

iii. All the plotted 9 estimators of true richness (actual number of species deemed to be present in the community), except MMMeans estimator, stabilized rapidly at about 400 individuals level and were conservative being very close to S(est) (= Sobs = Mao Tau). MMMean estimator stabilized much earlier than the others (at about 70 individuals level) (Fig. 22) and gave the highest species estimate (48.31).

iv. MMRuns estimator, though stabilized at just >200 individuals level and coincided with MMMean estimator immediately thereafter below this level,
this curve was erratic obviously because of chance addition of a richer sample(s) early in the randomization runs during computation of the estimator. Thus, though MMRuns estimator gave a higher species estimate (49.71) than MMMean estimator (48.31), or the present data set, the latter is a better fit than the former and

v. MMFitted estimator model is equally as good as both S(est) and MMMean estimator for the data set.

To conclude, though all estimators, except MMRuns estimator, are good fits and would perform well for the present data set, the MMMean estimator is the best for the ornamental fish community data of River Achencoil.

4) A comparative study of the upstream, midst ream and downstream assemblages of ornamental fishes of River Achencoil was made and the species diversity was found to be highest in the mid stream. This region has not yet been analysed and studied much and is found to be less polluted area than the downstream as can be predicted from the hydrographical studies.

5) Comparison of taxonomic and numeric diversities among the three seasons of ornamental fish assemblage of river Achencoil were also statistically analysed and found to be very similar. Taxonomic and numeric diversities were higher in the pre monsoon assemblage when compared to the other two seasons.

All these results indicate that the ornamental Piscean fauna is distributed more or less evenly during the three seasons. No evidences for over dominance or unhealthy competition were observed which also enhanced the biodiversity of river Achencoil. Cyprinidae dominated all the three seasons showing a marked difference in percentage from all other families. The collected species showed
high relative abundance in all seasons and their assemblages were consistent throughout the year.

6) The same logic has been applied while working out beta-diversity indices and similarity/dissimilarity measures in the context of beta-diversity analysis. Species richness for the data set was estimated by rarefaction using rarefaction curve and nine other estimators using the software EstimateS9. The species composition of ornamental fishes during the three seasons in River Achencoil was strikingly similar. Both $b_{nes}$ and $b_{rich}$ analyses with the present data sets on the upstream, midstream and downstream assemblages of ornamental fishes for understanding $\beta$-diversity patterns of the three possible site pairs gave similar results indicating that the $\beta$-diversity was more because of species replacement than because of species loss or gain. Nevertheless, the noticeably higher values for replacement ($\beta_{sim}/\beta_{sor}$) and lower values for species loss ($b_{nes}/\beta_{sor}$) recorded for all site pairs in Baselga’s scheme than that in Carvalho’s scheme ($\beta_{s3}/\beta_{cc}$ and $b_{rich}/\beta_{cc}$, respectively) supports the theory that $b_{nes}$ seems to underestimate the true loss of species, while $b_{sim}$ appears to overestimate replacement.

7) The same data sets were used for taxonomic diversity studies. From the available information, a taxonomic list of indigenous freshwater ornamental fishes so far reported from Kerala State was compiled, with five taxonomic levels: species, genus, family, order and superorder. A similar list was prepared for the ornamental fish species reported so far from the River Achencoil. The taxonomic diversity patterns of the ornamental fish assemblages of River Achencoil, of the three sites and of the three seasons were analysed. Phylogenetic Diversity ($\phi$) was also calculated. Taxonomic diversity and distinctness of the midstream and
downstream assemblages were also high; $\Delta$, $\Delta^*$ and $\Delta^+$ values were higher for the downstream assemblage than for midstream. In comparison, these values were lower for the upstream assemblage.

8) The fish diversity studies using various indices showed that the midstream of river is characterized by more diverse species due to high productivity in the area. In the present study it is found that midstream near Pathanamthitta region (Site II) is the most diverse area than the upstream and downstream. This region has not yet been analysed and studied except for a few work and is found to be less polluted area than the downstream. Anthropogenic activities are the main cause for alarming decline of fish population especially in the downstream. Unethical means of fishing like dynamiting, fish poisoning etc are rampant in these rivers along with sand extraction and construction of physiological obstructions resulted in habitat destruction of natural spawning and breeding grounds of the fishes. These may be the reason why downstream became less diverse than the midstream.

9) Many of the species endangered are now found mostly in upstream where the river is protected under forest and wildlife jurisdiction. This fact itself clearly indicates the reason for their endangerment. The fishes which are endemic to Kerala, *Puntiuns denisoni*, *Puntins chalakkudiensis*, *Nemacheilus guentheri*, *Nemacheilus triangularis*, *Garra suredranathini*, *Puntins bimaculates* etc are collected form upstream only. *Esomus danricus*, *Hypselobarbus jerdoni*, *Laubuca fasciata*, *Osteobrama bakeri*, *Poecilia reticulate*, *Ambassis gymnocephalus* are collected from Pathanamthitta region only. The exotic fish *Poecilia reticulata* is collected from the midstream which may be due to the intrusion of other inland
water resources to the rivers during flood time and human interventions. The fish can be used as a larvicide of mosquito and hence a blessing. A few species where present only in the downstream like, *Puntins chola, Batasio travancoria, Hyporhamphus xanhopterus, Nandus nandus* and *Glossogobius giuris*. A few fishes endemic to fresh water fish diversity of Kerala was collected. This group includes *Garra surendranathani*, *Puntius chalakkudiensis* and *Puntius denisoni* – all the three from upstream- and *Laubuca fasciata* from the midstream. Two endangered species were collected from midstream and downstream. They are *Osteobrama bakeri* and *Batasio travancoria* respectively. *Glossogobius giuris* of Gobidae is the only estuarine species which is ornamental too, collected from the downstream of the river. Though it is an edible fish, with not much beautiful appearance, its bottom feeding nature, tolerance to salinity and low dissolved oxygen gave the fish an ornamental value.

10) Comparison of taxonomic and numeric diversities, among the three seasons – monsoon, post monsoon & pre monsoon – of ornamental fish assemblage of river Achencoil were also statistically analysed. Out of the 46 species recorded, 45, 46 & 45 respectively, were collected during the three seasons, monsoon, postmonsoon and premonsoon, which were very much similar.

All these results indicate that the ornamental Piscean fauna is distributed more or less evenly during the three seasons. No evidences for over dominance or unhealthy competition were observed which also enhanced the biodiversity of river Achencoil. Number of individuals collected showed a gradual increase from monsoon to pre monsoon. This can be explained by reduction in water level due
to drought during pre monsoon period, which helped in the easy collection of samples.

11) If we consider all the species together, pre monsoon was compositely rich being more productive in terms of number of individuals (445). But species concentration was more or less similar in all the three seasons.

12) Altogether 46 species were collected from the three sites. Upstream had 26 species including 9 (19.6%) species of its own (not shared with the other two sites). 30 species with 6 (13.0%) of its own and 24 species with 7 (15.2%) of its own were recorded from midstream and downstream, respectively. 10 species (21.7%) were common to all three sites. Whereas up- and midstream and mid- and downstream had 7 (15.2%) species each in common, up- and downstream had none. Out of the 46 ornamental fishes reported, 8 species were endemic to Western Ghats.

13) Taxonomic diversity of ornamental fish assemblage of River Achencoil was comparatively high as evident from $\Delta$, $\Delta^*$ and $\Delta^+$ values. Taxonomic diversity and distinctness of the midstream and downstream assemblages were also high; $\Delta$, $\Delta^*$ and $\Delta^+$ values were higher for the downstream assemblage than for midstream. In comparison, these values were low for the upstream assemblage. The upstream assemblage differed significantly ($P < 0.05$) from the other two. The three seasonal assemblages recorded high and almost similar $\Delta$, $\Delta^*$ and $\Delta^+$ values.

14) Usually, upstream areas of rivers are known to support highly diverse fish faunas because of the pristine nature of the habitats due primarily to absence of or only very little anthropogenic interferences, such regions being usually situated quite interior in forests or high up on mountains and, therefore, not easily
accessible. The same has been reported for the Achencoil River. However, the upstream fish assemblage of this river recorded during the present study does not support this generalisation. Though in terms of species richness this assemblage was apparently not much different from either mid- or downstream assemblages, critical analysis of the data revealed that the upstream assemblage had lesser number of higher taxa, than the midstream assemblage.

15) The low biodiversity of ornamentals upstream was caused by the non-representation of quite a few higher taxa (genera) leading to relative over representation of the family Cyprinidae resulting in more variable distribution and consequent lowering of taxonomic distinctness. Non-representation of relatively species-poor higher taxa caused decrease in the taxonomic diversity of upstream. This is because of the poor representation of the superorder Acanthopterygii, with only 2 orders and 4 families, unlike the other two sites where this superorder was well represented. The upstream of Achencoil River during the present study was noted to be represented poorly by species having high taxonomic distinctness. The habitat was apparently not polluted, either visually or in terms of its water quality parameters (pH, DO, CO$_2$, PO$_4$ and NO$_3$). The taxonomic diversity of the upstream assemblage falling below the lower bound of the 95% confidence funnel unequivocally point to some sort of degradation of the habitat, and the taxonomic structure of this assemblage was significantly different from that of a random selection from the regional master list.

16) It is also noticeable that, even though the 95% probability contour of the joint ($\Delta^+$, $\Lambda^+$) distribution for upstream assemblage suggested that as of now, its taxonomic diversity is not significantly different from the expected, the plot indicates high chances of deterioration of the taxonomic diversity of this region;
elimination of one or two more higher taxa of ornamentals from this region is highly likely to push the \((\Delta^+, \Lambda^+)\) distribution of upstream out of its region of experience. While habitat degradation due to factors like pollution/contamination is not the cause for this, quite likely, the continual blast (dynamite) fishing in these regions, as reported by the natives, must be causing this deterioration. This highly destructive fishing practice is sure to cause death of several species than what is needed for human consumption and has devastating effect on developmental stages; it also causes heavy damage to the substratum. Though this fishing practice cannot destroy biological taxa selectively, it causes near holocaust of the surrounding ecosystem. Continual blast fishing over time, might have, by chance, eliminated a few taxa of ornamentals from upstream Achencoil River.

Whether or not blast fishing is the real reason for the observed low biodiversity of ornamental fishes upstream Achencoil River, urgent measures must be initiated to ban this illegal practice that, undoubtedly has devastating effect on ecosystems, both for maintaining the pristineness of the habitat and to protect the biodiversity of this region of the river from further deterioration.

17) The species composition of ornamental fishes during the three seasons (monsoon, postmonsoon and premonsoon) in River Achencoil was strikingly similar. The average taxonomic distinctness for observed assemblage of Achancoil river showed that the assemblage was qualitatively very similar to the master list. Though these values of the mid- and downstream assemblages were well within the 95% probability funnel that of the upstream was just below the lower bound of the funnel and the trend suggests that the taxonomic diversity of the upstream ornamental fish assemblage has a strong tendency to depreciate.
While habitat degradation due to factors like pollution/contamination is not the cause for this, quite likely, the continual blast (dynamite) fishing in these regions, as reported by the natives, must be causing this deterioration.

**Feeding Biology of *Rasbora daniconius* and *Danio aequipinnatus*.**

1) Information on the food and feeding habits of fishes is an essential prerequisite for a rational and sustainable management of the fish stocks. Hence two species of fishes, *Rasbora daniconius* and *Danio aequipinnatus* collected from the river Achencoil were selected and their feeding biology and maintenance in captivity were also studied in detail. Analysis of the gut contents was carried out on 211 *R. daniconius*, ranging from 42mm to 94mm and 135 *D. aequipinnatus* ranging from 38mm to 82mm, for a period of one year from June 2010 to May 2011. Monthly samples of fishes were collected from River Achencoil near Vazhamuttom, Pathanamthitta.

2) Analysis of food items was carried out both qualitatively and quantitatively. Since *R. daniconius* and *D. aequipinnatus* are mostly omnivorous, the points method was adopted in the present study. It was found that these fishes were omnivores, feeding on larvae of insects, crustaceans and terrestrial insects. They seemed to feed on small amounts of algae under certain circumstances, as indicated by their gut contents. This partial shifting of diet from carnivorous to herbivorous nature may be because of the difficulty in the availability of preferred food due to adverse weather conditions, which may help the fishes to adjust easily with the new surroundings and food habits when used as ornamentals.
3) Another important ecological aspect that was noted during the present study is the larvicidal action of the two fishes. Hence these fishes can be used for biological control of mosquitoes and other disease causing insects which have now formed a great threat to people, especially when we grow fishes in open glass tanks or cement tanks, these fishes form a great help in cleaning up the water surface from the larvae of mosquitoes.

4) The result of analysis also shows that the major part of the food of these two fishes is formed of terrestrial coleopterans, dipterans and insects remains. This is a peculiarity not so common among fresh water fishes. Hence they can be easily fed in artificial tanks with both artificial and natural food. This food segregation among these fishes would reduce a possible competition with other fishes in aquariums and glass tanks.

5) In the monsoon season, in June, 58% of food items in \textit{R.daniconius} and 35% in \textit{D. aequipinnatus} consisted of filamentous algae and plant matter. In July the two fishes had 35% and 40% of the food with algae and plant matter respectively. From August to November phyto- planktonic contents were almost absent, but during May, about 50% of food item in \textit{R.daniconius} and 30% in \textit{D. aequipinnatus} were algae and plant materials. Insects remains were present in almost all months of the year in the gut of \textit{D. aequipinnatus} but were absent in September to November in \textit{R. daniconius}. Surprisingly, coleopterans and dipterans were present in all months of the year in both the fishes.

6) Feeding intensities of the two fishes were also analysed and it was found that feeding intensities were high among the two fishes during the pre monsoon period.
due to easy availability of food. Feeding intensity was least during the monsoon period were the percentage of empty guts were very high. This slackening may be because monsoon period is their breeding period also.

7) *R. daniconius* and *D. aequipinnatus* are small peaceful, schooling fish that are well suited for small planted community aquarium. In the wild this fishes found swimming the rivers in schools with hundreds of individuals. It was found that Daphnia, Brine shrimp, and blood worms made excellent choice for live foods. As natural foods cannot be easily provided in an aquarium, the carnivorous tendencies should be well catered to keep them interested in their daily intake. As these fishes are omnivorous, in the absence of food, they were noticed to turn towards the vegetation for food. Hence these fishes can survive normally for one or two weeks without proper food or light.

Along with maintaining fishes in captivity, one should also give equal importance for breeding issues too. Kerala, a beautiful evergreen southernmost state of India is gifted with rich fresh water resources, many of them having great ornamental value. However, culturing of these fishes in the close confines of aquarium is yet to be completely studied. Instead we go for exotic species requiring high capital outlay, which demands intense care for maintaining fish health and welfare. The scientific culture of attractive ornamental fish species is gaining much importance as a potentially viable practice towards self employment.

Though entrepreneurs in the country have shown interest in the utilization of the indigenous ornamental fishes for economic development of the country,
there are many areas of concern in the conservation and utilization of indigenous fishes. Ecofriendly practices like harvesting fresh water fishes, simultaneously conserving their natural habitats, including their breeding grounds is one of the desirable method. Present study is conducted to know the food and feeding habits of *R. daniconius* and *D. aequipinnatus*, so that they can be successfully maintained in the aquarium.

---------------------------------------------