Chapter 8
Summary & Conclusions

This study on the impact of fishing on the marine fished taxa biodiversity of Karnataka used secondary data on species-wise fish catches during a 37-year (1971-2008) period and also biological data on key resources from the NMLRDC database. Various types of statistical and biological analysis were carried out to bring out the impact of fishing. The summary and conclusions drawn from the study are presented below as numbered bullets.

1. The taxonomic trees of Arthropoda, Mollusca and Chordata revealed 579 species which was the total fished taxa biodiversity for Karnataka. These belonged to 10 classes, 41 orders, 148 families and 312 genera.

2. The fished taxa biodiversity of arthropoda was 38% of the total marine arthropoda diversity in Karnataka and 7.15% of the total marine arthropod diversity of India. The fished shrimps and prawns form 56% of the total shrimp diversity in India and lobsters form 27% of the total lobster diversity in India. The fished marine brachyuran crabs was 10% of the total brachyuran crab diversity in Karnataka and 4% of the total crab diversity in India.

3. The fished taxa biodiversity of mollusca was 9% of the total marine mollusca diversity in Karnataka and 0.65% of the total marine mollusca diversity of India.

4. The most species rich phyla was phylum chordata and the fished taxa biodiversity of chordata was 19% of the total marine species diversity in India and 10% of the total chordata diversity of India.

5. The class Actinopterygii was the most diverse in the chordate phyla of which order Perciformis had the highest diversity having 55 families and 255 species.

6. *Chelonia mydas* and *Eretmochelys sp.* of family Cheloniidae were the 2 species of reptiles recorded in the present study forming 67% of the total turtle diversity of Karnataka and 5.71% of the total Indian marine reptile species.
7. Mammals were represented by 5 species belonging to 4 families which were accidentally caught along Karnataka coast forming 16% of the total marine mammal diversity from India. The most common species being *Delphinus delphis* of the family Delphinidae followed by *Neophocaena phocaenoides* of family Phocoenidae.

8. Fishing zone MAN followed by MLP had the highest alpha diversity values because of highly mechanized fishing in deeper areas prevalent in these zones. The high beta diversity values in MAN and MLP zones also brings to focus the uniqueness of the fished taxa in these zones and the mechanized fishing as well as the deeper depth of operation of vessels undertaking fishing from these zones.

9. Relatively low alpha and beta diversity values were observed for KES–KAL, GAN, THE–MAN, KSD, BKI, PAV–SHE, TAD, KWR and MUL–PAD zones and this is attributed to the predominantly non-mechanized and outboard engine gears operated in these zones.

10. MAN zone had higher turnover rates indicating that the regional species pool is larger when compared with other regions due to competitive exclusion. The next zone with higher turnover rate was MLP zone, which was also a zone having higher alpha and beta values.

11. The gamma diversity in Karnataka was estimated as 579.

12. Alpha diversity of different gears operated in Karnataka indicated that mechanized trawl net brought in maximum number of species. The next highest alpha diversity value was noted for the non-mechanized gears amongst which the shoreseine net which is a traditional gear of the state is a main gear.

13. The study revealed that taxonomic distinctness indices such as $\Delta^+$ and $\Lambda^+$ are sensitive to detect impact of fishing on the fished taxa biodiversity. The indices were earlier used to evaluate stress in polluted habitats and ecosystems.

14. Fishing impact was observed in all fishing zones using the taxonomic distinctness indices $\Delta^+$ and $\Lambda^+$. Highest values were observed for MAN, BEN-KUN, MLP, KSD and TAD zones and low values were observed in TAL-SAS, BKI, PAV-SHE and KES-KAL zones.
15. All years and decades showed fishing impact and the values of $\Delta^+$ and $\Lambda^+$ were observed to be lower during the early decades of 1970s and 1980s and relatively higher values were observed during the 2000s.

16. Cluster and ordination methods showed maximum species similarity between KSD and TAD followed by MAN and MLP showing similarity of exploited species between these zones. North Karnataka zones and the south Karnataka zones were grouped separately showing that the habitat preference of species is different and the environment also slightly different. Clear distinction was observed between the years and decades showing more dissimilarity between 1970s and 2000s indicating the growth of mechanization of fishing in the state.

17. The number of species grouped under the trophic level $<3.5$ comprised of 44% of the total and those that were from higher trophic level $>3.5$ formed 56%.

18. Mean Trophic Level of the catch for the entire period was estimated as 3.34 and it showed a positive trend for Karnataka State implying that species of all trophic levels were being exploited. Overall the MTL was increasing at the rate of 0.0016/year and 0.0140/decade.

19. The rate of change in TL $<3.5$ and TL $>3.5$ was negative (-0.0010/year and -0.0092/decade for TL $<3.5$ species and -0.0012/year and -0.0082/decade for TL $>3.5$ species) showing that the mainstay of the present fisheries mainly comprises of the lower trophic level species as compared to the prior years.

20. The FiB index was observed to have an increasing trend with the exploitation increasing over the years due to expansion of fishing to new fishing grounds but it was difficult to predict the change in trophic levels of the species.

21. The higher trophic level species were mainly being exploited by the mechanised bag net (MBN) and mechanised gillnet/hook and line (MGN/HL) gears whereas the lower trophic level species mainly exploited by mechanised ring seine (MRS) and mechanised trawl net (MTN).

22. Zonal comparisons showed that as catch was increasing the trophic levels were decreasing in many zones. However, zones such as THE-MAN, BKL, PAV-SHE, TAD and BEL-BAH show an increasing rate for the TL $>3.5$ species indicating that
these are the main zones for exploitation of higher trophic level species. Zones such as TAL-SAS, MAN, MUL-PAD and PAV-SHE showed a positive rate of change for species with TL <3.5 showing that there is increasing exploitation of lower trophic level species in these zones.

23. In zones such as TAL-SAS, MUL-PAD, BEN-KUN, KES-KAL, THE-MAN and KSD where the main gear is artisanal, FiB index showed a decreasing trend implying that the catch is not compensating for the decrease in the MTL.

24. When the MTLs were compared gearwise it was observed that the artisanal gears mainly exploited the higher trophic level species whereas the seine nets and other mechanized gears mainly exploited the lower trophic species.

25. Out of the 579 species fished in Karnataka, maximum number of species were observed under the very rare (37%), 23% in rare category, 31% in less common category, and only 9% of species were in the common category.

26. The hooktooth shark (*Chaenogaleus macrostoma*) is the only vulnerable species (as per IUCN) recorded in the present study which has not occurred in the fishery for the past 9 years and hence there is need to conserve this species by classifying it as endangered.

27. Two very rare species exploited in Karnataka which were near threatened according to the IUCN status were the Leopard coral grouper (*Plectropomus leopardus*) and Winghead shark (*Eusphyra* sp.) and these have not occurred in the fishery for the past 24 and 14 years respectively and there is need for making conservation plans and to classify it as endangered.

28. The Indian threadfin *Leptomelanosoma indicum* (*Polydactylus indicus*) is known as a highly vulnerable species according to the Sea Around Us database and has not been observed in the Karnataka fishery since 1975 (for the past 33 years) and the species needs to be conserved and classified as endangered in the region.

29. Ten species (13%) have not occurred in fishery for past 20–29 years, 24 (32%) have not occurred for past 10–19 years. In the present study 23% of the species caught were observed to occur only once in the entire period 1971–2008.
30. Amongst the most common species in the fishery the Indian mackerel (*Rastrelliger kanagurta*) occurred in the maximum number of months (424 out of 444 months).

31. A fishery catch fluctuation index (FFI) was developed to identify and classify species which undergo fluctuations in catch. Oil sardine and mackerel were observed to have high FFI, mantis shrimp and threadfin bream had medium FFI and remaining 43 species had low FFI indicating that most species in the ecosystem were fairly stable in their abundance.

32. The stock status analysis showed that the maximum number of species were in the declining group (53%) followed by the abundant and less abundant which formed 37%.

33. The depleted stocks were the white sardine (*Escualosa thoracata*) and the tiger prawn (*Penaeus monodon*) and the collapsed stocks were 3 species namely, the flathead (*Sunagocia* sp.), catfish (*Arius* sp.) and the blacktip shark (*Carcharhinus* sp.).

34. Studies on the recovery of species after collapse showed that 66% of the species were capable of fast recovery within 1-5 years and 22% recovered within 6-10 years whereas 9% of the species were slow to recover.

35. The blacktip shark has shown signs of recovering after 25 years of collapse and the catfish has also started recovering after 20 years of collapse as indicated by the improvement in their catch and ranking.

36. The depleted and declining stocks (particularly those close to the threshold of depleted status) needs to be carefully monitored and its conservation and rebuilding plans need to be made. However in the case of large and long-lived species such as the catfish, it is more than 20 years since the species has collapsed. The catfish stocks are improving in recent years with ranks climbing from 104 to 34, and care must be taken such that recruitment overfishing is not allowed to happen again by restricting its capture during the breeding season by seiners.

37. Of the 2 major fisheries in the state, the ranks of mackerel remains steady between 1 and 3 from 1950-2008, on the other hand, the ranks of oil sardine show wide fluctuations between 1 and 28 within the same period.
38. Only 3 species are observed to have held the number 1 rank and will continue to hold it in the future. Markov Chain analysis indicates that Oil sardine and Mackerel are likely to continue and dominate the catches in future also, although oil sardine has higher probability to be at Rank 1 position.

39. Markov Chain analysis shows that most exploited species were predicted to retain their status in the future whereas 6 species (Trichiurus sp., Saurida sp., Scomberomorus commerson, S. guttatus, Mugil cephalus and Anodontostoma chacunda) were predicted to have a probability of deteriorating their catch and ranks.

40. Evaluation of SBI showed that for the pelagic oil sardine and Indian mackerel, the $L_{\text{mean}}$, $L_{\text{min}}$, $L_{\text{max}}$ and $L_{\text{range}}$ indicators did not show any significant relationship with catch. The poor relationship could be due to the fact that these species have relatively short life span, fast growth rate and continuous recruitment and also because of the presence of multiple broods in the population. For the demersal species Malabar tonguesole (Cynoglossus macrostomus) the SBI, $L_{\text{mean}}$ and $L_{\text{min}}$, had a significant negative relationship with catch.

41. The SBIs were not good predictors of stock health in the case of pelagic stocks such as oil sardine and mackerel but a good predictor in case of demersal stocks such as Malabar tonguesole.

42. BKL (Bhatkal) zone was identified as a biodiversity stressed zone with respect to taxonomic distinctness and combined with the fact that this zone had low alpha and beta diversity, and MTL values were declining at the rate of 0.0006/year, this zone was identified for creation of a MPA. The zone is also unique due to the presence of a coral reef close to the fishing grounds.