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Generalised Fishery Development Model (GFDM) approach for analysis of marine fish landings in India

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Abstract

The time series of estimated landings of major exploited coastal marine fish resources in different areas of exploitation along the Indian coast from 1961-2004 were subjected to trend analysis and segments of the time series were matched to a Generalised Fishery Development Model (GFDM) to indicate the historical and present status of fishery progress. Fifty-one resource-region combinations, termed as 'resources', were used for analysis. These 'resources' were grouped according to the shapes of their landings trends that conform to the different phases of the GFDM. Nearly 90% of the 'resources' were either in mature or senescent stage of development and their landings were found to have reached asymptotic level or have declined.

Keywords: Generalised Fishery Development Model, marine fish landings in India

Introduction

In a multi-species and multi-gear fishery such as in India, compounded by biological and technological interactions, the application of classical stock assessment procedures may be untenable and irrelevant for obvious reasons. However, fishery managers do require some indicators of status of the fishery relevant to chosen reference points. Total catch is an important indicator to monitor and assess the status of the fishery. The decline in the catch is a signal for appropriate interventions from the managers. From the time series of catch it is possible to trace growth of the fishery and identify stages of development. Classification of resources (exploited stocks) to fit into different categories of growth or development was done by Caddy and Gulland (1983). Caddy (1984) and Grainger and Garcia (1996) have indicated that different phases of fishery development that could be broadly classified into four categories: 1) undeveloped, 2) developing, 3) mature and 4) senescent. The growth in fisheries has not been uniform in all the coastal regions of the country. In some regions, the fishery is showing signs of saturation with asymptotic production level. Whereas in other regions, the landings of certain resources are increasing. In this paper an attempt has been made to analyse trends of marine fishery resources off the different coastal regions of exploitation. The study aims to delineate different stages in the growth of major fisheries in the regions since 1961 and indicate the current status of the fisheries.

Materials and methods

Database: The Central Marine Fisheries Research Institute has developed methodology for estimation of marine fish landings in India based on Stratified Multi-stage Random Sampling scheme and has built up a large database of estimates of marine fish landings by species and by different crafts along with the fishing effort expended. The mode of operation of the sampling scheme and the methodology for estimation have been described by Srinath *et al.* (2005). The data on landings from 1961 to 2004 along the four regions, namely, northwest (Gujarat & Maharashtra), southwest (Kerala, Karnataka & Goa, southeast (Tamil Nadu, Pondicherry & Andhra Pradesh) and northeast (West Bengal & Orissa) were considered for analysis. Only the major resource groups in each region were included. A combination of resource-region group is termed as a 'resource' and 51 such combinations (Table 1) were considered for analysis over the 44-year period from 1961 to 2004. These resources together accounted for more than 75% of the total marine fish production in India.

The process of development of a fishery (i.e. the exploitation of a given species with a given gear in a given area) as described by changes in landings with time, often with a "boom and bust" character, has been described by many authors (Caddy, 1984; Welcomme, 1995). This can be represented with a generalised model, which is based loosely on Caddy's (1984) idealised fisheries cycle for an open access resource. In this study, the stages

Table 1. *Resource Groups considered for the study*

Northwest	Southwest	Southeast	Northeast
Elasmobranchs, Catfishes, Croakers, Ribbonfishes, Carangids, Seerfishes, Bombay duck, Perches, Pomfrets, Mackerel, Tunas, Cephalopods, Penaeid shrimps, Non-penaeid shrimps	Elasmobranchs, Catfishes, Whitebaits, Perches, Carangids, Tunas, Cephalopods, Seerfishes, Mackerel, Oil sardine, Other sardines, Croakers, Penaeid shrimps, Ribbonfishes	Perches, Carangids, Mackerels, Seerfishes, Penaeid shrimps, Cephalopods, Ribbonfishes, Whitebaits, Croakers, Silverbellies, Oil sardine, Catfishes, Elasmobranchs, Other sardines	Elasmobranchs, Catfishes, Croakers, Pomfrets, Seerfishes, *Hilsa* shad, Bombay duck, Carangids, Penaeid shrimps

of development process were identified as per the GFDM given in FAO (1996). The 51 resources were grouped by cluster analysis, according to the shape of the trends, irrespective of the magnitude of the landings. The hierarchical clustering technique using Ward's linkage with Pearson distance criterion as in SYSTAT-7 was employed. The average standardized landings of resources in each identified cluster from 1961 were fitted with appropriate curves that were subsequently used for identifying the stages of development as done by Grainger and Garcia (1996). The profiles emerging out from the fitted curves can be considered as constituents of the fishery development model and representing the various phases of growth as mentioned earlier. The overall pattern of phased growth was obtained by dividing each curve into segments corresponding to different phases of the fishery development model and calculating the number of resources in each phase.

A description of the production trends in the fishery is given in the next section in order to understand the nature of fishery in different regions of the country.

Production trends

Characteristic of the tropical seas, the Indian marine fisheries are multispecies comprising over 200 commercially important species of finfishes and shellfishes and multigear with fishing practices varying between different regions depending on the nature of the fishing grounds and the distribution of the fisheries resources. Pelagic fishes (mackerel, sardines, whitebaits, ribbonfishes, carangids, seerfishes, tunas), demersal fishes (croakers, threadfin breams, silverbellies, catfishes, lizardfishes, flatfishes, snappers, breams, groupers, bullseyes, goatfishes), crustaceans (shrimps, crabs, lobsters and stomatopods) and molluscs (gastropods, bivalves and cephalopods) are the major resources exploited. The abundance of these stocks varies between regions, with the large pelagics like tunas being more abundant around the islands and small pelagics like sardines and mackerel supporting a fishery of considerable magnitude along the southwest and southeast coasts. The Bombay duck (*Harpadon nehereus*) and non-penaeid shrimps form a good fishery along the northwest coast. Croakers are important all along the coast, threadfin breams are predominant along west coast, pomfrets along northwest coast and perches (pigface breams, groupers and snappers) are dominant in the southwest and east coasts, especially in the Gulf of Mannar, Palk Bay and Wadge Bank areas. Silverbellies form a major fishery along the southeast coast.

Currently 1,332 traditional landing centres, 33 minor and six major fishing harbours serve as bases for about 104,000 traditional non-motorised crafts, 76,000 small scale beach landing motorised crafts, 58,900 mechanised crafts (mainly bottom trawlers, drift gill netters and purse-seiners) (Marine Fisheries Census 2005 – unpublished report).

The total marine fish production of India (excluding Island territories) increased from 0.68 million tonnes in 1961 to 2.58 million tonnes in 2004, registering a peak

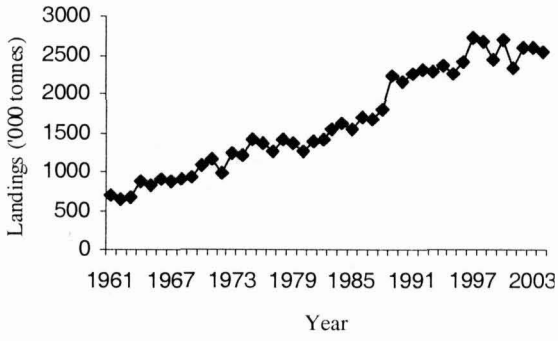

Fig.1. Estimated marine fish landings in India during 1961-2004

The multi-species assemblage harvested by multiplicity of gear is broadly classified into pelagic and demersal resources. The major pelagic resources are oilsardine, lesser sardines, Bombay duck, mackerels, ribbonfishes, carangids and seerfishes. The production from the pelagic fish resources had increased from 4.5 lakh tonnes in 1961 to 13.8 lakh tonnes in 2004 with a peak of 13.9 lakh tonnes in 2003. The major constituents of the pelagic resources such as the oil sardine, mackerel, Bombay duck and lesser sardines fluctuated with high inter-annual variations. The landings of ribbonfishes and carangids have registered a declining trend.

The major constituents of demersal resources are elasmobranchs, catfishes, perches, croakers, pomfrets, silverbellies, flatfishes, penaeid and non-penaied shrimps, crabs and cephalopods. The landings of the demersal resources ranged from 2.3 lakh tonnes in 1961 to 11.5 lakh tonnes in 2004 registering a peak of 13.5 lakh tonnes in 1998. The landings of the resources such as catfishes, elasmobranchs, silverbellies, soles, croakers, silver pomfret, and non-penaeid shrimps have shown declining trend. However, the trend in the aggregated landings of the demersal fish resources registered a decline from 2000.

The general increasing pattern in production discernible at all India level for most of the resources may not truly represent the trends in the resources exploited from different hydro-climatic zones of the country. The overall trends may mask the regional differences in the development of fisheries and variations in resources availability and abundance. Hence the resource trends in each of the four regions namely the northeast, the southeast, the southwest and the northwest are discussed separately (The island territories of Lakshadweep and Andaman & Nicobar were not taken into account in this study). Estimates of Pondicherry pertain to the landings in the region of the Union Territory located in Tamil Nadu. The landings of the other regions of Union Territory in other states are included in the respective state landings.

Northeast

The landings in this region increased from 92,000 tonnes during 1985 to about 2,74,000 tonnes during the year 2004 forming 4.6% and 10.7% of the total all India landings (Fig. 2). Up to the year 1991, the state of Orissa used to be the major contributor to the regional landings. Since 1992, West Bengal emerged as the dominant contributor.

In West Bengal, the contribution of the pelagic and demersal resources was more or less the same until 1988. However, since 1989, there was a quantum leap in the production of pelagic groups, especially the *Hilsa* shad and the Bombay duck and since then the landings of the pelagic groups were about double that of the demersal resources. Contrastingly, in Orissa the landings of the demersal resources were generally higher than that of the pelagic resources. Elasmobranchs (sharks, skates and rays), catfishes, croakers, pomfrets, penaeid shrimps and non-penaeid shrimps are the major contributors to the demersal resources landings in West Bengal. The major constituents of demersal landings in Orissa are catfishes, croakers, pomfrets and penaeid shrimps.

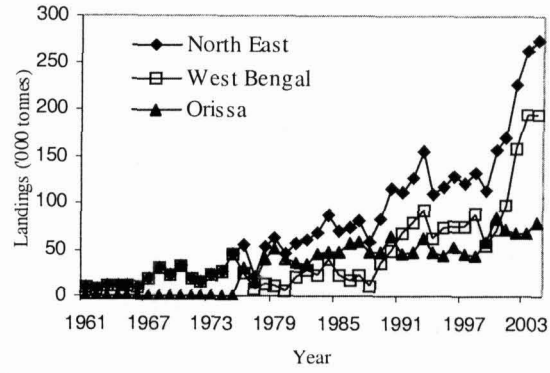

Fig. 2. Estimated marine fish landings in Northeast region during 1961-2004

Southeast

Although the total landings in this region increased from 1.7 lakh tonnes in 1961 to 6.9 lakh tonnes during the year 1997, there has been a decline during 1998 and since then the production has almost leveled off (Fig. 3). The increase was mainly due to spurt in the landings of the small pelagics especially the oil sardine, mackerel and carangids.

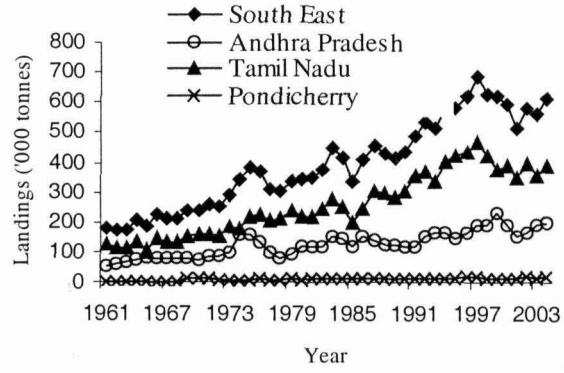

Fig. 3. Estimated marine fish landings in Southeast region during 1961-2004

The main feature of the fisheries of this region is the increased landings of the pelagic resources. Till the year 1985, both the pelagic and demersal resources were increasing with more or less same rate of growth, however from 1986, there was a sudden jump in the pelagic fish landings. A significant development in this region was the emergence of oil sardine as a commercial fishery. Its landings increased from about 19,000 tonnes in 1989 to 110,000 tonnes in 1997. During the years 1997 and 1998, it had been the single largest contributor to the total landings in the states of Andhra Pradesh and Tamil Nadu. The combined landings from these two states were higher than the traditionally high yielding states of Kerala and Karnataka during those years. However, from 1997 the landings have declined. Mackerel landings exhibited very high inter annual variation with a peak of about 26,500 tonnes and 31,000 tonnes in the year 1992, respectively in Andhra Pradesh and Tamil Nadu. Contrary to the trend in other pelagics, the ribbonfish landings are declining along both coasts of the Tamil Nadu and Andhra Pradesh.

The major demersal resources of this region are the sharks, rays, catfishes, perches, croakers, silverbellies, penaeid shrimps, non-penaeid shrimps, crabs and cephalopods. In Andhra Pradesh, sharks formed the bulk of the elasmobranchs landings where as in Tamil Nadu it was the rays. The total demersal landings in Tamil Nadu have shown a declining trend. The landings of sharks and penaeid shrimps have registered decline. In Tamil Nadu, the demersal resources that showed decline are lizardfishes, goatfishes, threadfin breams, silverbellies and penaeid shrimps.

Southwest

The region comprising the states of Kerala, Karnataka and Goa had been the most productive and the largest contributor to the country's total marine fish landings. The landings of the region are characterized by sudden jumps in production after periods of stabilized production. The total landings varied from 2.9 lakh tonnes in 1961 to 8.8 lakh tonnes in 2004 with a peak of 10.18 lakh tonnes during 1989 (Fig.4). Along the coasts of Kerala and Karnataka, the total production was observed to be more or less stagnant during the last five years.

The striking feature of the marine fisheries of the region is the predominance of the pelagic resources and introduction of ring-seines, their proliferation and enhancement of the capacity of ring-seine crafts. A significant event had been the set back to the oil sardine fishery during the year 1994, yielding a meager 3 thousand tonnes along the entire southwest coast. However, the landings recovered and reached an all time high of 3.4 lakh tonnes during 2003. The decline in the landings of sharks, whitebaits, carangids, mackerel and ribbonfishes is causing concern.

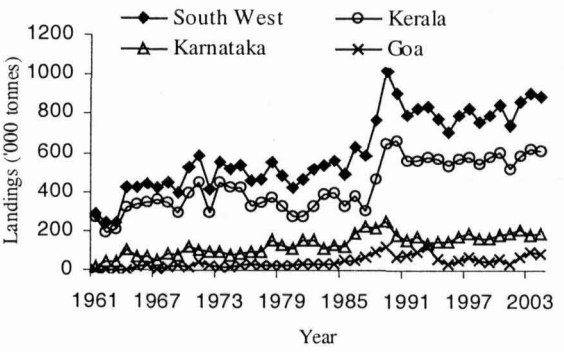

Fig. 4. Estimated marine fish landings in Southwest region during 1961-2004

Unlike the pelagic fish production that had shown high inter annual variations, the demersal fish landings increased steadily. However, the demersal landings along the Kerala coast have been declining. The fall in the landings of catfishes, sharks, croakers and penaeid shrimps demands re-assessment of the potential of the resources in the light of high intensity of fishing. The landings of the crustacean resources attained an all time peak of about 1.6 lakh tonnes in the year 1994 and suddenly slumped to about 90,000 tonnes in 1995. Since then there has been an improvement in the landings. It was observed, however, since 1987, the annual landings fluctuated around an annual average of about 60,000. In Karnataka, the landings exhibited much high inter annual variations. Another economically important resource, namely the cephalopods had been increasing up to 1993, and since then the landings leveled off around 50,000 tonnes annually.

Northwest

There was a spectacular growth of marine fish production of this region from about 0.2 million tonnes in the year 1961 to 0.76 million tonnes in 2004 with a peak of 1.2 million tonnes in 1998, owing primarily to the rapid development of fisheries in the state of Gujarat (Fig. 5).

Differential growth pattern was observed among the constituent states of the region. The pelagic finfish production of the region fluctuated from 1.2 lakh tonnes in 1961 to 2.89 lakh tonnes in 2004 registering a peak of 4.2 lakh tonnes in 1997. Bombay duck, golden anchovy,

ribbonfishes, carangids, mackerel and seerfishes are the major components of the pelagic finfish production. In Maharashtra, the landings of Bombay duck have declined to about 10,000 tonnes in 1996. In Gujarat, the production has increased to 89.5 thousand tonnes in 1989 and subsequently declined to about 40 thousand tonnes in 2004. In both the states the ribbonfish landings had registered high growth rate reaching the peak production in the year 1997. The landings of the carangids leveled off in Maharashtra fluctuating between 10,000-20,000 tonnes, whereas in Gujarat it was still increasing. A similar trend was observed in the landings of seerfishes also. The mackerel landings, the bulk of which was from the lower Maharashtra coast, was quite marginal during 1973 to 1988, but suddenly shot up and since then it was increasing with oscillating trend and reached a peak of about 38,000 tonnes in 1996 and the landings plummeted to 9,600 tonnes in 2004.

Unlike the pelagic landings, the development of demersal fisheries was quite significant and registered an eight-fold increase in the landings from about 0.85 lakh tonnes in 1961 to 7.1 lakh tonnes in 1998. This phenomenal growth was mainly due to increased production from Gujarat. In Maharashtra, the demersal fish production leveled off around 80,000 tonnes since 1985, whereas the production of the crustaceans and cephalopods showed a general increasing trend in both the states. There was differential trend with respect to some of the important demersal resources. In Maharashtra, the production of pomfrets, non-penaeid shrimps and stomatopods declined considerably. In Gujarat, after a steady increase upto 1998, the landings of resources such as catfishes, threadfin breams, croakers, pomfrets, cephalopods, penaeid and non-penaeid shrimps registered decline.

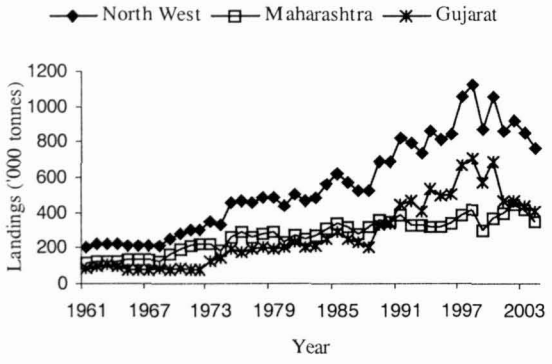

Fig. 5. Estimated marine fish landings in Northwest region during 1961-2004

Results and discussion

The cluster analysis indicated that the 51 resources could be grouped into 9 clusters (Figs. 6-14) based on the trend in their landings over the period of time and constituents of the identified clusters are given in Table 2. The overall pattern of change in the phase composition is shown in Figure 15. It shows the process of increased intensity of fisheries and large proportion of resources was found to indicate declining trend in production. It is quite significant to note that in 2004 nearly 90% of the resources were either in mature or senescent stage. Despite the fact that different fisheries are known to have very different patterns of catch series, and that the implications of these different patterns have profound consequences for management. FAO (1996) examined time

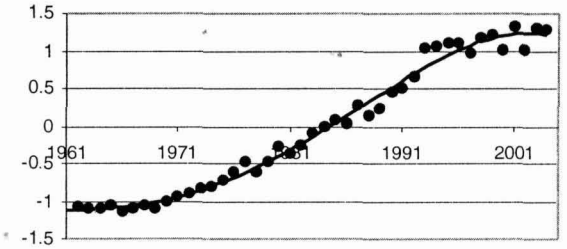

Fig. 6. Trend in average standardised landings of resources in Cluster 1

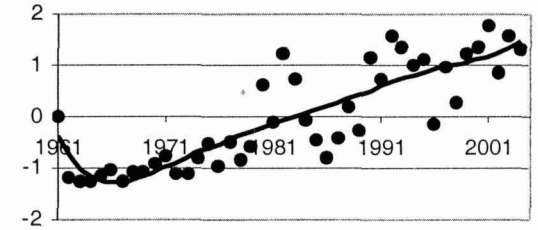

Fig. 7. Trend in average standardised landings of resources in Cluster 2

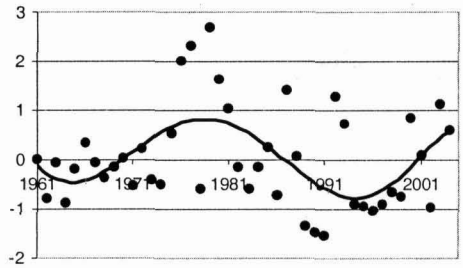

Fig. 8. Trend in average standardised landings of resources in Cluster 3

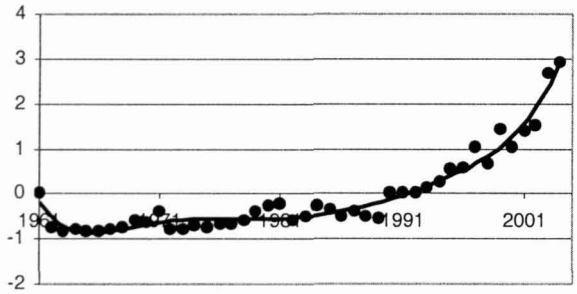

Fig. 9. Trend in average standardised landings of resources in Cluster 4

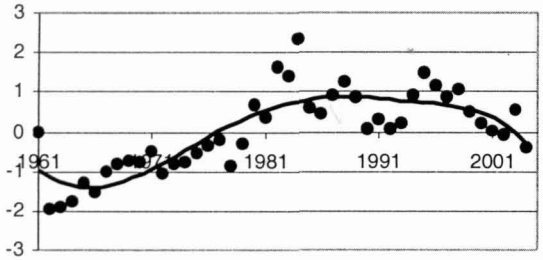

Fig. 10. Trend in average standardised landings of resources in Cluster 5

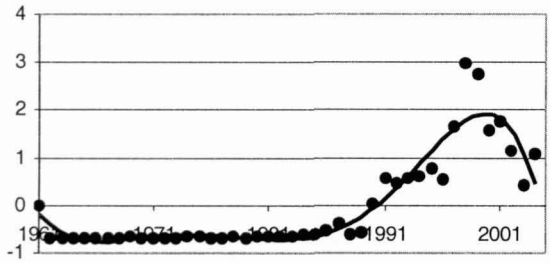

Fig. 11. Trend in average standardised landings of resources in Cluster 6

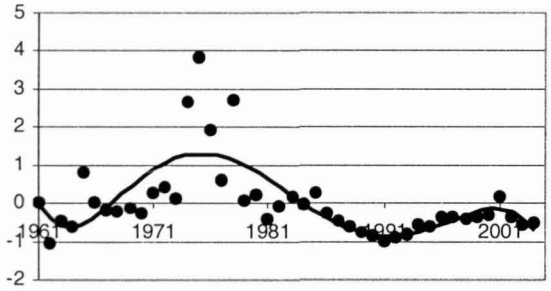

Fig. 12. Trend in average standardised landings of resources in Cluster 7

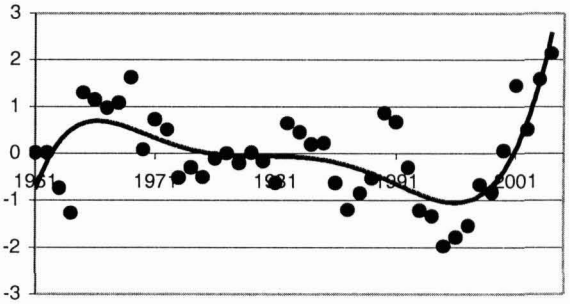

Fig. 13. Trend in average standardised landings of resources in Cluster 8

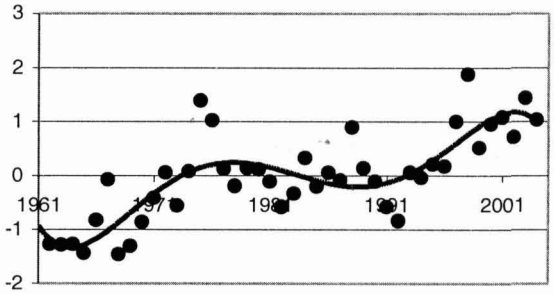

Fig. 14. Trend in average standardised landings of resources in Cluster 9

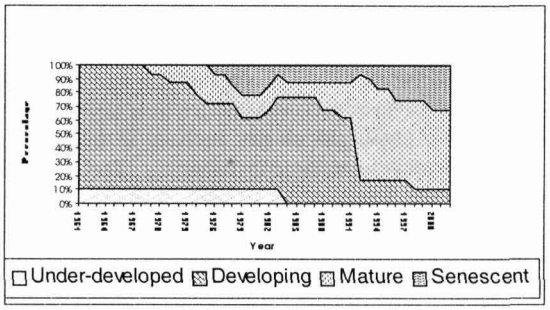

Fig. 15. Trend in phases of development

series landings of 200 major living resources using a generalized fishery development model and showed that the overall development during the period comprised a reduction of fisheries in the undeveloped phase and increase in the proportion of these in mature and senescent phases.

Mathieu *et al.* (2002) used cluster analysis to classify stock into six categories based on the total variability and relative amount of short and long term variations. They concluded that few fish stock biomass or fishery catch time-series correspond to steady-state ideals and could not find any strong statistical evidence for a general corre-

Table 2. *Resource groups in each cluster*

Cluster	Northwest	Southwest	Southeast	Northeast
1	Elasmobranchs, Catfishes, Croakers, Ribbonfishes, Carangids, Seerfishes, Tunas, Penaeid shrimps, Cephalopods	Whitebaits, Perches, Carangids, Tunas, Cephalopods	Perches, Carangids, Mackerel, Seerfishes, Penaeid shrimps, Cephalopods	Elasmobranchs, Catfishes, Croakers, Pomfrets, Seerfishes
2	Bombay Duck		Ribbonfishes	
3	Perches	Seerfishes		*Hilsa* shad, Bombay duck, Carangids, Penaeid shrimps
4	Pomfrets		Whitebaits, Croakers, Silverbellies	
5	Mackerel, Non-penaeid shrimps	Mackerel	Oil sardine	
6		Elasmobranchs, Catfishes	Catfishes	
7		Oil sardine		
8		Other sardines, Croakers, Penaeid shrimps		
9		Ribbonfishes	Elasmobranchs, Other sardines	

spondence between different types of fish and differing patterns and extent of variation in catch time series. Freon *et al.* (2003) employed cluster analysis to investigate remote synchronous pattern in fisheries. Their results indicated some degree of local rather than remote synchrony. This includes identification of dominant pattern in the catch series and common bio-ecological features or ranges of abundance. Alagaraja *et al.* (1982) carried out a macro analysis considering the trend in the landing and the relative contribution of different sectors contributing to the total marine fish production in India. Vivekanandan (2001) opined that the scope for increasing the coastal fish production in India appeared to be limited. Srinath (1989) has analysed the marine fish landings during 1961-85 by dividing the time period into 5 stages from the initial stages of mechanization. It was observed that the rate of growth in marine fish production from the existing fishing grounds had decreased.

Conclusion

The analysis carried out based on the time series of landings from 1961 to 2004 gave a clear insight into the status of the exploited resources in different regions and on an all India basis. Results from the generalized fishery development model revealed that about 90% the resources were either in the mature or senescent stage, assuming the landings do reflect abundance of the resources. This implies that there is less likelihood of increased landings from these resource groups. Even among the groups in the developing phase, the trends indicated possibility of attaining asymptotic levels of production.

In a multi-species, multi-gear fishery system existing in Indian waters application of classical single species models may not yield desirable results owing to their obvious limitations. Of late, ecosystem based approaches are emerging as powerful tools for an integrated analysis of the exploited stocks in relation to the ecosystem and the foodweb. However, these tools are quite data intensive and yet to be implemented for fishery management owing to data constraints. This paper presents an initial analysis of trends in marine resources, which covers the period of the greatest expansion of Indian fisheries. By classifying the resources using cluster analysis according to the pattern of their landings, we attempt to obtain a

useful description of the developments in Indian fisheries at national and regional levels, which can assist in appraising the fisheries potential and aid planning and policy-making for the future.

References

Alagaraja, K., K.Narayana Kurup, M.Srinath and G.Balakrishnan.1982.Analysis of marine fish landings in India – A new approach. *CMFRI Special Publication* No.10: 42pp.

Caddy, J.F. 1984. An alternative to equilibrium theory for management of fisheries. In: *FAO Fisheries Report* No. 289. Supplement 2. Rome. 214pp.

————and J.A. Gulland.1983. Historical patterns of fish stocks. *Marine Policy*, 7: 267-278.

FAO.1996. The State of World Fisheries and Aquaculture (SOFIA). 125pp.

Freon P., C.Mullon, and B.Voisin. 2003. Investigating remote synchronous pattern in fisheries. *Fisheries Oceanography*, 12(4-5), 443-457

Grainger, R.J.R. and S.M. Garcia. 1996. Chronicles of marine fishery landings (1950-1994): Trend analysis and fisheries potential. *FAO Fisheries Technical Paper*, 359, 51 pp.

Matheiu, L.F., E.H. Allison and R.Tinch. 2002. Seeking patterns of population variability from catch and biomass time series. *Final Technical Report* (r7336 prized 336). Fisheries Management Science Programme. Overseas Development Group, University of East Anglia, Norwich NR4 7TJ, United Kingdom (available from http:/dspace.dial .pipex.com/town/green/FTRS/ r7336 .html).

Srinath, M 1989. Trends of the major exploited marine fishery resources of India during 1961-85. In: *Proceedings of National Symposium on Research and Development in Marine Fisheries. Bull.Cent.Mar. Fish.Res.Inst.*, No.49 Part I p. 272-283.

————. 2003. An appraisal of the exploited marine fishery resources of India. *In*: Mohan Joseph M. and Jayaprakash A.A.(Eds.).*Status of exploited marine fishery resources of India.* Central Marine Fisheries Research Institute, Kochi, India. p 1-17.

————, Somy Kuriakose and K.G.Mini. 2005. Methodology for estimation of marine fish landings in India. *CMFRI Special Publication* No. 86. 57pp.

Vivekanandan, E. 2001. Sustainable coastal fisheries for nutritional security. *In*: Pandian, T.J. (Ed.), *Sustainable Indian Fisheries.* National Academy of Agricultural Sciences, New Delhi. p.19-42.

Welcomme, R.L. 1995. Status and trends of global inland fisheries. *In:* Armantrout and W.J. Wolotra.(Eds.) *Conditions of the world's aquatic habitats.* Proceedings of the World Fisheries Congress, Theme 1, p 122-138. Oxford & IBH Publishing Co.

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