For Official Use Only

REPORT OF THE WORKING GROUP FOR REVALIDATING THE POTENTIAL OF FISHERY RESOURCES IN THE INDIAN EEZ

Submitted to the

Department of Animal Husbandry, Dairying & Fisheries
Ministry of Agriculture
NEW DELHI

सत्यमेव जयते

ORT OF THE WORKING GROUP FOR REVALIDATING THE POTENTIAL OF FISHERY RESOURCES IN THE INDIAN EEZ

For Official Use Only

Report of the Working Group for Revalidating the Potential of Fishery Resources in the Indian Exclusive Economic Zone

सत्यमेव जयते

December 2011

Submitted to

The Department of Animal Husbandry, Dairying and Fisheries
Ministry of Agriculture
New Delhi

Preface

The United Nations Convention on the Law of the Sea (UNCLOS) has brought in revolutionary changes in the regime of exploitation of marine resources. The coastal states were bestowed with the right for exploitation and responsibility for management of the fishery resources of their territorial waters and Exclusive Economic Zones (EEZ). Ever since India declared 200 nautical miles EEZ in the year 1976, the judicious exploitation and management of the marine fishery resources assumed priority. The estimation of potential yield of the EEZ has become necessary for evolving the exploitation and management strategies.

In a pioneering attempt made by George *et al.* (1977) the fishery potential of the Indian EEZ was estimated as 4.46 million t for the depth zone up to 200 m and oceanic waters. Subsequently, several attempts were made to estimate the potential using different data sets and for different geographic extents and coastal and oceanic realms. These estimates varied from 2.03 to 5.5 million t. However, a comprehensive exercise analyzing several data sets and consolidating the output could materialise only with the initiative of the Ministry of Agriculture in 1990s.

The Department of Animal Husbandry, Dairying and Fisheries (DAHDF) of Ministry of Agriculture (MoA), Government of India (GoI) has been engaging expert committees (Working Groups) from time to time to revalidate the potential of exploitable fishery resources of the Indian EEZ. The Working Group of Experts constituted in 1991 by the Ministry of Agriculture, examined all the available information on exploited resources, exploratory surveys and other data up to 1987 and arrived at estimated potential of 3.9 million t for the Indian EEZ. The last exercise completed during October 2000 under the leadership of Dr E. G. Silas estimated the potential yield at 3.92 million t, close to the previous estimate.

Rapid changes have taken place in the exploitation scenario during the past one decade. The number of different types of craft and gear have increased manifold in all maritime states and union territories. In order to cope up with increase in fuel price, energy intensive fishing methods such as trawling changed their strategy from single day fishing to multiday fishing. This multiday fishing in turn has resulted in the problem of discards, which by and large goes unreported.

Another significant development was the expansion of the fishing area in the offshore direction. If majority of vessels confined operations within 70 m depth zone in 1990s, they extended their operational range up to about 100 m depth a decade later. (Due to this reason, the current exercise assumed that the landing data collected by CMFRI represent the fishery up to 100 m depth contour).

The expansion of traditional sector was remarkable in the southern states. The ring seine boats in Kerala have defied all norms of classification of 'traditional' craft. The proliferation of traditional crafts along Tamil Nadu coast, especially during the post-tsunami period has resulted in local conflicts in resource sharing and greater challenges to managers. In other places, motorization has become a universal feature with non-motorized boats dwindling in number.

This decade also witnessed the development of tuna fishing using hooks and line and long-line. The fishing sector has become aware of the lucrative avenues in tuna fishing and various schemes were floated by the Government for conversion of trawlers into tuna long-liners. The Ministry of Agriculture also introduced the new scheme of letter of permit (LOP) for enabling Indian companies to acquire foreign fishing vessels for operation in the Indian EEZ.

Apart from these developments there were concerns about the overexploitation of several fish stocks, impact of climate change on the distribution and biology of fishes etc. These circumstances have necessitated a re-look into the estimates of fishery potential from the Indian EEZ. It is for addressing these issues that the DAHDF constituted (vide order No. 21001/7/2009-FY (Ind) dated 17 September 2009) a Committee (Working Group) under the Chairmanship of the Director General, Fishery Survey of India.

The Working Group of Experts looked into the details of the previous exercises and the extent of data generated since then and came to an understanding that the data sets at the disposal of the present committee are much more comprehensive. Therefore the Working Group embarked on a series of analyses to come out with an estimate of fishery potential for the Indian EEZ. One of the unique features of the present exercise is the convergence of the outputs from different analyses using different data sets.

For the first time, the present Working Group was entrusted with an additional task of deciding the optimum fleet size for the different maritime states. The Working Group embarked on using a model which was applied to Kerala fisheries by CMFRI scientists. The model is essentially based on the biological sustainability of the fish populations. However, the exploitation environment is decided by the market and economic parameters, which are seldom captured by the model. As a consequence the fleet size arrived at by this exercise is mostly indicative of the existing over-capacity. In addition, the sanctity of state-wise estimates of fleet size is questionable when the target resources are transboundary stocks and the operational area of fleets overlaps. Therefore the outcome of this exercise must be used as a red signal for arresting the expansion of fleet rather than as prescriptive formula for fleet reduction.

The Working Group has made sincere efforts to make the best use of available database and tools of analysis. Species-wise estimates were made wherever possible to provide an idea about the qualitative aspect of the resources. State-wise splitting of the resource potential was not presented in view of the controversies related to spatial disparities in places of capture and landing.

Any exercise of this magnitude would be forced to make some compromises between the required and possible outcomes. The outcomes of the present exercise may not exactly fit to expectations of certain stakeholders. The compromises were unintentional and were forced on by the limitations of the database as well as tools. The Working Group has felt it appropriate to record various issues for resolving them before another revalidation exercise is embarked in future.

The Working Group experienced tremendous synergy in its business mainly due to the wholehearted involvement of the members. The members of the Working Group are thankful to the Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India for reposing on them the important responsibility of revalidating the fishery potential of the Indian EEZ. The Working Group believes that the outcome of the present revalidation would help the Government to reorient the strategies for resource management in the Indian EEZ.

Mumbai
18 December 2011

Dr K Vijayakumaran
Chairman, Working Group

Acknowledgement

The members of the Working Group wish to express their gratitude to Shri Rudra Gangadharan, Secretary, Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, and Shri Tarun Shridhar, Joint-Secretary (Fy), Department of Animal Husbandry, Dairying and Fisheries, Government of India for the support and encouragement in carrying out the Working Group's business smoothly. The officers of the Fisheries section in the Ministry also helped the Working Group in various ways.

The members provided excellent support and cooperation during the various processes of revalidation as well as preparation of this report. Organizations such as CMFRI, FSI, CMLRE and MPEDA were major sources of data inputs for various analyses. Special thanks to those who worked in the sub-committees, without them the Working Group would have been greatly handicapped.

Except the subgroup meetings, all the meetings of Working Group were held at the Committee Room of CMFRI, Kochi. This was to minimize the travel burden of the members as five experts involved in the Committee's work were from Kochi. The Working Group records its appreciation to the Director, CMFRI for extending all support for the smooth conduct of the meeting and also for addressing the members on a couple of occasions.

There are few nominees of the representative departments who regularly participated in the meetings and took active part in the deliberations. Dr T V Sathianandan and Dr Sunil Mohamed of CMFRI were present at all the meetings and made tremendous contributions to the proceedings. Shri G D Rajeev, MPEDA and Dr M Vijayakumaran, NIOT were the other major contributors. Shri K J Antony, MPEDA, Dr J Jayashankar, CMFRI, Dr Dinesh Kumar, NIO and Shri Ajay Srivastava and Dr C P Juyal, DAHDF also enriched the Working Group's business.

Dr E M Abdussamad, Dr N G K Pillai, and Dr R Sathiadas from CMFRI and Dr B R Smitha and Ms C R Ashadevi from CMLRE participated in the meetings and discussions. The Working Group acknowledges their valuable contributions. The assistance rendered by members of staff and officials of FSI and CMFRI in arranging the meetings, recording the proceedings and assisting in communication and logistics is also acknowledged.

□□□

The Constitution and Terms of Reference

The Working Group

The Department of Animal Husbandry, Dairying and Fisheries, Ministry of agriculture, Government of India, has constituted the Working Group of Experts during September, 2009 (vide Order No.21001/7/2009-FY (Ind) dated 17 September 2009) with the following members and Terms of Reference.

CHAIRMAN

Dr K Vijayakumaran
Director General, Fishery Survey of India, Mumbai

MEMBERS

Dr Madan Mohan
Asst. Director General (Marine Fisheries)
Indian Council of Agricultural Research
New Delhi

Dr E Vivekanandan
Principal Scientist
Central Marine Fisheries Research Institute
Kochi

Dr V N Sanjeevan
Director
Centre for Marine Living Resources & Ecology, Kochi

Dr Z A Ansari
Scientist G
National Institute of Oceanography
Dona Paula, Goa

Dr D V Rao
Scientist- G
Estuarine Biology Regional Centre, ZSI
Gopalpur, Ganjam, Odisha

Dr N R Menon
Emeritus Professor
Cochin University of Science and Technology
Kochi

Dr R Kirubagaran
Scientist-F and Head, OSIT
National Institute of Ocean Technology
Pallikaranai, Chennai

Shri B N Nanda *(Member-Secretary)*
Economic Advisor
DAHD&F, Ministry of Agriculture
New Delhi

The Terms of Reference

1. To revalidate the potential yield estimates of marine fishery resources on the basis of subsequent research, fisheries resources survey and exploratory work conducted in the Indian EEZ.
2. To estimate the additional potential that could be harvested on a sustainable basis from different depth / zones / regions of the Indian EEZ

3. To estimate the number of each category of resource specific vessels / fleet size for sustainable harvest of potential marine fishery resources available in the Indian EEZ for the next five year period, and
4. To give suggestions on conservation of fishery stocks in the Indian EEZ in light of the existing legislation and various global convention(s) / initiatives.

Co-option of Members

The following members were co-opted in the Working Group of Experts after the first meeting:

Dr M E John
Zonal Director
Mormugao Base of FSI
Mormugao

Shri J Ramesh
MPEDA
Panampilly Nagar,
Kochi

Subsequent Changes

The term of the Working Group was extended up to 17.09.2010 (Vide Ministry's Order No.21001/7/2009-FY (Ind) dated 17th July 2010.

The Working Group met five times (26 November 2009, 09 March 2010, 25-26 June, 2010, 12-13 August 2010, and 6-7 September 2010) and held intensive deliberations taking into consideration the data furnished by various organizations and other relevant aspects to prepare the draft report. The subgroups also met several times in their respective offices and deliberated on the data analysis and outputs. Subsequent to the demitting the office by Shri B N Nanda, Economic Advisor, DAHD&F, Ministry of Agriculture as Member –Secretary the Working Group meetings were attended by the present incumbent, Shri Ajay Srivastava, Director (Fy- Economics).

Sub-Groups

The Working Group during its first meeting held on 26-11-2009 formalised three Sub-groups, one each in FSI and CMFRI to analyze the data and work out the potential yield estimates on the basis of the data collected by the respective organizations and another group called *Trophodynamics* Sub-Group comprising experts from various organizations. The compositions of the Sub-Groups are given below:

FSI Sub-Group

Dr K Vijayakumaran, Director General (Convener)
Dr A K Bhargava, Sr. Fish. Scientist
Shri P Chalapati Rao, Statistician
Shri Ch Bhaskar, Programmer
Dr M E John, Zonal Director
Shri D K Gulati, Sr. Fish. Scientist
Shri Ashok S Kadam, Jr. Fish. Scientist
Shri B M Raut, Data Processing Asst.

CMFRI Sub-Group

Dr E Vivekanandan, Head, DFD (Convener)
Dr E V Radhakrishnan, Head, CFD
Dr R Sathiadhas, Head, SEETTD
Dr J Jayashankar, Sr. Scientist
Dr N G K Pillai, Head, PFD
Dr Sunil Mohammed, Head, MFD
Dr T V Sathianandan, Sr. Scientist

Trophodynamics Sub-Group

Dr V N Sanjeevan, CMLRE, (Convener)
Prof (Dr) N R Menon, CUSAT
Dr Dinesh Kumar, NIO
Dr E Vivekanandan, CMFRI
Dr Sunil Mohammed, CMFRI

Contents

1. SUMMARY AND RECOMMENDATIONS

1.1 Introduction

1. The Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India is bestowed with the responsibility of planning the sustainable exploitation of the fishery resources of the Indian EEZ. For achieving this objective, the Department constituted a Working Group to study and revalidate the fishery resource potential of the Indian EEZ vide Order No.21001/7/2009-FY (Ind) dated 17 September 2009.

2. The Working Group convened several meetings and conducted in-depth analysis of the available data and arrived at the revised figures of potential for different resources in the Indian EEZ. The experts used a variety of methods to arrive at the best results from the available databases and other information. The summary of the findings and recommendations are presented in the following sections. Two approaches, one using landing and survey data and the other using productivity data, were adopted for arriving at potential yield. The results of the first approach with finer details are taken as the potential estimates while that of the second approach was presented as gross indicative figure.

1.2. Summary of Potential Yield Estimates

3. The potential yield (PY) of the Indian EEZ is revalidated as 4.41 million t by the present Working Group of Experts. Of this, the pelagic resources account for 2.13 million t, the demersal resources account for 2.07 million t and the oceanic resources would be 0.22 million t. As compared to the previous estimates the current estimate is higher by about 0.5 million t.

4. The potential up to 100 m depth is estimated as 3.8 million t whereas the potential for depth zones between 100-200 m and 200 – 500 m is estimated at 0.26 and 0.11 million t respectively.

5. The estimates for the different depth zones indicated a decrease in the resources from shallow zones to deeper zones. The region within 100 m depth zone is currently almost fully exploited as indicated by the landings (2008-10) of about 3.2 million t.

6. The potential of oceanic resources including tuna, billfishes and allied species, is estimated at 0.22 million t. This comprises yellowfin tuna (80,000 t), skipjack tuna (99,000 t), bigeye tuna (500 t), billfishes (14,400 t), pelagic sharks (20,800 t) and

other species (1,800 t). In the case of yellowfin tuna, out of the projected yield of 80,000 t, the sub-surface component that can be targeted by longline is estimated at 20,000 t.

7. Of the contribution by different groups of pelagic fish, the potential yield of oil sardines was 0.51 million t followed by the ribbonfish (0.23 million t) and the Indian mackerel (0.2 million t). Among the demersal groups, penaeid shrimps topped with a share of 0.24 million t followed by croakers 0.22 million t and non- penaeid shrimps 0.21 million t.

8. An independent estimate using the productivity data (Approach 2) gave the following results. The estimates of fishery potential for Indian EEZ from primary production and secondary production were of 3.605 and 3.322 million t respectively, the average being 3.463 million t. The potential from benthic production was 0.855 million t. Thus the maximum sustainable yield (MSY) of fish from the Indian EEZ works out to 4.318 million t. This figure is closer to the figures arrived at by Approach 1.

9. Silas *et al.* (1986) reported a potential yield of oceanic squids (*Sthenoteuthis oualaniensis)* in Indian EEZ as 20 to 50 thousand t. Globally, the stock of oceanic squid has been assessed as 3-4 million t (Zuyev *et al.*, 2002) and about 1.0 to 1.5 million t of this resource is in the Central Arabian Sea. Since about 10% of the area of abundance lies within the Indian EEZ, the potential yield of this resource from the Indian EEZ could be about 0.1 million t.

10. An estimate of the optimum fleet size based on the best available model indicated that the current fishing fleet is more than the required one for the sustainable exploitation of the resources of the continental shelf. The state-wise break-up of different types of fishing crafts have little significance as the resources are transboundary in nature and harvesting units operate across the state borders. However, it could be taken as indicative guideline for controlling fishing effort.

1.3. Conclusions and Recommendations

11. The Working Group concludes that the present level of exploitation of the fishery resources from the waters up to 100 m depth zone is near optimum and there is no scope for further expansion of the fishing fleet in the shelf region.

12. The present fishing fleet of all categories need reduction to make the fishery economically sustainable and every step must be taken immediately for maintaining the present status and measures must be taken for systematic reduction/relocation of fishing effort to maintain the economic and biological health of the fishery.

13. The majority of resources in the 100-200 m depth zone also form a significant component in the resources within 100 m depth. Therefore, the distribution of these resources could be presumed to spread over a wider area of the shelf from near-shore waters to the shelf edge. Obviously there may not be different stocks for different depth zones. There is no point in introducing further fishing efforts to harvest these resources in deeper waters as the pressure within 100 m zone is likely to be absorbed by the portion of the stocks spread in a deeper area. On the other hand, leaving them underexploited in deeper waters would help the biological sustainability and resilience of the stock to natural and fishing related stress.

14. Except the oceanic resources and deep-sea crustaceans, the resources beyond 200 m zone are generally of low value and their density is also low compared to near-shore regions. Further none of the species has adequate density to support a dedicated fishery. As such, the cost of harvesting, in the present context of escalating fuel prices, would defeat the economic viability of such venture.

15. The oceanic resources are transboundary stocks and excess harvests in one region will have an impact on the fishery in other regions. Further the fisheries of some of these species are subject to fluctuations due to environmental perturbations and changes in oceanic circulation. Therefore any fishery depending on these species must be capable of absorbing the fluctuations in the catch. Fleet planning based on the optimistic figures may end up in overcapacity and diseconomy.

16. Other non-conventional resources such as oceanic squids could be promising only if the commercial viability is proven and entrepreneurs are attracted to it. However, proper control and limit on entry must be ensured while planning such ventures.

17. The need of the hour is to consolidate the current efforts to optimize the yield and bring in economic efficiency and reduce the conflicts among users by reducing overcapitalization. There must also be efforts to protect the coastal habitats such as estuaries, mangroves etc to ensure the health of the system as well as providing sufficient grounds for the nursery of commercially important species.

18. The Working Group after considering the present scenario of the marine fishery in India and taking into account the results of the revalidation exercise, recommends the following actions:

19. The development programmes need a shift from driving growth with continuous supports to healthy practices of natural resource accounting with responsible behaviour, and transparent mechanisms in catch recording and reporting.

20. Strengthening the coordination mechanism between different agencies engaged in generation of data on marine living resources is essential. It would be desirable to have an inter-institutional body of these organizations for planning the data generation for revalidation exercises in future.

21. Establish a mechanism linking the issue of license/permission for fishing with supply of data to the Government. This would help to avoid round about calculations and approximations in arriving at figures of potential for important resources such as oceanic tunas.

22. The concept of territorial boundaries of jurisdiction is inappropriate in the context of overlapping boundaries of the resources. The instruments of resource management have to recognize the distribution boundaries of the resource. The existing legal framework needs a relook to accommodate the distribution of the resources rather than the political boundaries of States.

23. The resource estimates should consider the whole area within the natural boundaries of distribution of the resource. There is a need for a shift in the management of marine fisheries expanding the conventional boundaries and jurisdictions to that of the distribution boundaries of the resources.

24. Right to resource exploitation should be tagged with responsibility of reporting. All supports to the industry must be chalked out with mandatory reporting practices to ensure that the relevant catches and vessels are not categorized as illegal unreported and unregulated (IUU).

25. The prospects of exploitation of oceanic squids have been suggested by several earlier studies. But the technology of harvest and postharvest and prospects of marketing are still grey areas where attention is being paid under an NAIP Project of ICAR. If the results of the project are promising, it could be possible to introduce a few squid jiggers of appropriate size to exploit the oceanic squids of the Arabian Sea.

26. The transboundary nature of resource has to be properly understood when the fleet development and conversion programmes by different agencies are being approved. The inter-sectoral conflicts cannot be avoided if proper limits are not set for the development programmes.

27. An earlier committee had recommended a biannual revalidation, instead of a decadal exercise. This would be quite desirable but would pose some practical problems unless permanent mechanisms are in place for carrying out the exercise on a regular basis. This could be preceded by an arrangement to collect relevant data and create appropriate databases.

28. The exercise has exposed some limitations of the available models in explaining the reality with respect to the fleet structure. There are several factors which the models are unable to capture. There is a strong need for paying attention to the development of appropriate models incorporating economic parameters and population parameters for arriving at the optimum fleet.

29. The quantitative aspects of resources beyond 100 m have been projected for introduction of resource specific vessels. However, valuation of the resources has not been attempted so far for deciding on the number and type of vessels. Economics of exploitation of specific resources has to be worked out before supporting the introduction of any specific vessels and the process must be on case by case basis with expert consultation.

30. The fishing power of the exploitation units has to be taken into account while planning fleet development. The convention of considering numbers, without any regard to the fishing capacity of units, would lead overcapacity in the long-run.

31. When the resources in the EEZ are being optimally exploited, promotion of vessels to go beyond the EEZ seems imperative. The capacity of exceptionally skilled fishermen in certain localities along the coast could be improved with necessary support for venturing into this area. The need for claiming a legitimate share of the transboundary resources of the Indian Ocean has to be mooted in the context of agencies like IOTC evolving a quota system for the oceanic resources based on historic catches.

32. Indian fishery industry has harvested every bit of resource whenever it is profitable. If there is lucrative investment opportunity, fishermen would invest in vessels and venture into fishing. The best strategy would be to regulate the fishery, inculcating responsible behavior providing necessary support to critical areas and small scale sector.

[][][]

2. INTRODUCTION

2.1 Trends in Marine Fisheries

33. Global reported marine fish production has increased from less than 20 million t per year in early 50s to average around 80 million t per year in mid 1990s (the peak figure of 86.8 million t was recorded during 2000). If the unreported and discarded catches are also taken into account, the global catches would have been around 120 million t per year (Zeller *et al.*, 2009).

34. The demand for fish and fish products in the world market has shown an ever increasing trend driving increased fishing pressure in all fisheries with little dividend. The general trend in shortfall from traditional fishing grounds in the EEZs of developed countries is being compensated by the increasing exploitation of resources by developing countries (Pauly and Watson, 2003).

35. From a meagre 0.53 million t in 1950 the marine fish production in India has increased to 2.4 million t in 1999 and peaked around 3.2 million t during 2008-10. The average growth rate during the period 1999 to 2008 was 3.3% per annum. Presently, fisheries and aquaculture contribute 1.07% to the national GDP and 5.3% to the GDP from agriculture and allied activities. The average annual value of production is estimated at about Rs. 68 thousand crore in 2009-10.

36. The marine product export from the country during the year 2010-11 was about eight lakh t valued Rs.12,826 crore. The major commodity of the export basket was frozen shrimp (quantity 19%; value 44%) and frozen fish (quantity 38% and value 21%). Though the growth in shrimp export was significantly contributed by the aquaculture production, the main target of trawl fishery in the marine sector also continued to be shrimps. This also created a situation where by-catch of juveniles and low value fish are unavoidable.

37. The projected demand for fish in the country by 2012 is 9.74 million t, of which 5.34 million t is expected from inland aquaculture and of the remaining from marine fisheries. While the production figures have breached the 3 million t mark after a phase of fluctuation between 2.7 and 2.9 million t, the changing composition of the catch and the catch per unit effort were facts by and large not discussed. Thus the health of the fishery stocks and the environment and the probable 'fishing down the food web' (Pauly *et al.*, 1998, Vivekanandan *et al.*, 2005) need further attention.

38. According to the National Marine Fisheries Census 2005, a total of 243, 939 fishing crafts were in operation in India, comprising of 59,743 mechanized vessels (about 29,000 of them are trawlers) and 76,372 motorized vessels and the remaining non-motorized craft. The traditional crafts and motorized craft are concentrated more in the east coast (73% and 60%) whereas the mechanized vessels are more along the west coast (64%). The post-tsunami flow of funds to support the coastal

communities to recover from the loss from the calamity also helped to add more number of fishing units in the sector, especially in the southern part of the Indian peninsula.

39. Most of the fishing activities of all categories of fishing units (except longliners) are confined to within 100 m depth zone. The increasing number of units and intensity in the fishing grounds resulted in the decline in catch per unit effort (CPUE). In the context of the increasing price of fuel, labour costs and other inputs, the trawl units had to change their fishing strategy from single day to multiday operation. This resulted in increasing bycatch and discard as the fish hold capacity was limited.

40. The fishing capacity has been described in terms of numbers, disregard of the fishing power of the units. The traditional crafts of Kerala have become larger in size and have the power to compete with any mechanized fishing units in the State. Similarly when a fishing unit is decommissioned the replacement vessel introduced is often of a larger capacity, though the number is kept constant.

41. The changes in the fishery environment have become very dynamic and complex for any system to efficiently monitor and manage. Added to that the complete lack of coordination among various development agencies which try to maximize their development targets, is also creating unmanageable situations. Subsidies and supports could distort the market driven economy of production, adding externalities to the system.

2.2. Global Response

42. The UNCLOS has brought in revolutionary changes in the regime of exploitation of marine resources bestowing the coastal states with the right for exploitation and responsibility for management of the fishery resources of their EEZ. Changing trends in the global fisheries has created awareness about the need for management of the resources and resulted in various responses. The FAO promoted the Code of Conduct for Responsible Fisheries (CCRF) for voluntary adoption by the member countries. There were a large number of initiatives by Regional Fisheries Management Organisations (RFMOs) for implementing management regimes in their respective areas of competency.

43. The principle that 'you can manage anything if you can measure it' is well evident in the recent responses in establishing accurate catch data collection systems. The manifestation of this response could be seen in the trade restrictions and control on illegal, unreported and unregulated (IUU) fishing by EU. The Catch Certification and reporting systems have become mandatory for various export markets in the wake of these initiatives.

44. Several species of fishes, reptiles, mammals and birds are being harmed in the process of indiscriminate and non-selective exploitation of fishery resources. Initiatives are undertaken globally to address these issues by adopting suitable conservation measures and reducing by-catch of non-targeted species.

45. Decline in the transboundary migratory species like tuna and allied species has created alarming concerns. For addressing the issues on a multilateral platform regional management institutions were established with an intention to evolve sustainable management practices.

46. The world is moving fast from a less regulated near-open access fisheries towards a more responsible management regime. The need for tuning the fishery to the global standards is assuming importance as more and more national initiatives are to be demonstrated under various international obligations.

2.3. Revalidation of Potential Yield

47. Prior to the declaration of EEZ, several attempts have been made to assess the fishery potential of the Indian Ocean in the seventies (Prasad *et al.*, 1970; Gulland, 1971; Cushing, 1973; Jones and Banerji, 1973; Mitra, 1973). All these attempts were mainly based on primary production and fish production trends. Assuming that the Indian Ocean accounts for about one fifth of the oceanic primary production, Prasad (1970) suggested a potential of 11 to 12 million t of fish from the Indian Ocean.

48. George *et al.* (1977), reviewing the various estimates and analysing the exploratory survey data and fish landing data estimated the potential yield of the Indian EEZ as 4.5 million t. Subsequently several authors worked out the potential of the EEZ ranging between 3.5 to 5.5 million t and FSI estimated the potential as 3.92 million t.

49. This was followed by an initiative from the Government of India to revalidate the potential of the Indian EEZ by constituting Working Groups of Experts from 1990 onwards. The exercise of revalidation of the potential yield of the Indian EEZ has become a periodic stock-taking and various development programmes are fine tuned based on the revalidated estimates.

50. The Working Group constituted in 1990 estimated the total potential of the EEZ as 3.9 million t comprising of 1.689 million t of demersal 1.916 million t of pelagic stocks and 0.246 million t of oceanic resources. In the year 2000 the estimate was revised as 3.93 million t, adding an estimated 2.05 lakh t of bivalves and gastropods and 1.01 lakh t of deep sea fishes to the previous estimates.

51. Unlike the previous exercises, the current revalidation exercise used different sets of databases for arriving at independent estimates of potential for the different

regions. However, the exercise was not a smooth ride and several hurdles in analysis were overcome by manoeuvring suitably, making changes in the approaches.

52. The Working Group agreed on bringing transparency with regard to the methods adopted and acknowledging the contributions of individuals and subgroups with their outputs.

2.4. Report Structure

53. The present report is structured to provide a complete picture of the transactions of the Working Group in carrying out the revalidation process. The report can be broadly divided into three parts namely the body, the support documents and the appendices.

54. The body of the report contains the executive summary in the form of conclusions and recommendations, followed by an introduction, outline of methodology and salient findings of the analysis. There is a chapter on future course of action, primarily touching on the obligations under international regulatory environment.

55. The support documents are the analytical outputs generated by the different sub-groups that worked on the different databases to arrive at the estimation of different components that added up as the output of the Working Group.

56. The appendices provide abbreviations, bibliography, the map of EEZ and general statistics relevant to the report.

3. METHODOLOGY

3.1 Scope

57. The revalidation exercise has considered data and relevant information pertaining to the 200 nautical mile EEZ of India. The period of reference of the information and data is approximately a ten year period between 1998 and 2009.

58. Except those targeting oceanic resources and deep-sea crustaceans, the commercial fishing fleet in the country is presumed to operate within 100 m depth zone and accordingly the data were segregated for analysis and estimation of potential.

3.2. Database

59. Different sets of data were used for the estimation of various components of potential resources of the Indian EEZ. The fish landing data available at the National Marine Living Resource Data Centre (NMLRDC) of Central Marine Fisheries Research Institute (CMFRI) and the survey data generated by the Fishery Survey of India (FSI) vessels formed the basis for most of the estimations.

60. While the landings data from NMLRDC formed the basis for the estimation of potential up to 100 m depth contour, the fishery survey data generated by FSI formed the basis of estimates of potential between 100-500 m depth zones.

61. The estimates of potential of oceanic tuna and allied resources were made based on several sets of data such as hooking rates obtained in longline surveys from FSI vessels, export data, primary productivity data, nominal catch data from the Indian Ocean etc. Published records were used for arriving at the estimates of oceanic squids and few other resources.

62. The data on primary (including remote sensed data), secondary, tertiary and benthic productivity were used by the trophodynamics sub-group for estimation of potential of the Indian EEZ. The details of data sets used are provided in the respective scientific documents prepared by the different sub-groups.

3.3. Methods

63. A wide range of methods were used for the estimation of the potential of different regions and resources. The details of the methods are provided in the respective scientific documents (See *Support Documents* 6.1, 6.2, 6.3 and 6.4).

64. Two approaches were adopted to estimate the potential: Approach 1 using database and statistics of survey and landings and Approach 2 using primary, secondary and benthic productivity as well as remote sensed data. The results of the approach 1 with finer qualitative and distribution details of resources is treated as the potential estimates by the current Working Group. The output of the approach 2 was treated as an independent gross indicative figure. The terminology of Potential Yield and Maximum Sustainable Yield are treated as synonyms.

65. Though it was desired that the Working Group could work on to provide interval estimates to facilitate optimistic and pessimistic scenarios for development planning, it could not materialize due to the compromises made in the selection of methods and types of analysis.

3.4. Limitations

66. The best models available have been used for analysing the data on various fishery resources of the Indian EEZ. However, there is an inherent drawback of assuming biological parameters as the driving factor in the fishery environment. Unless the models capture the economic variables along with the biological variables it would not be possible to explain several features of the fishery sector properly.

67. The data on oceanic species were very limited and some improvisation has been made to evolve a method which would reflect the real situation. However, there is a lot of room for improvement when refinements of data are possible. The term 'oceanic resources' mentioned in this report indicates the resources which straddle beyond the Indian EEZ but are available in the EEZ for exploitation.

[][][]

4. RESULTS AND DISCUSSION

4.1 Potential Yield Estimates

68. The potential yield (by Approach 1) of the Indian EEZ is revalidated as 4.41 million t by the present Working Group of Experts. As compared to the previous estimates the current estimate is about 0.5 million t more. The figure comes closer to the estimate of 4.5 million t made by George *et al.,* (1977). The summary of the potentials in the different realms and depth zones are given below (Table-1.1, 1.2 and 1.3).

Table-1.1.The potential yield for different realms

Realm	Potential (t)
Pelagic	2,128,424
Demersal	2,066,763
Oceanic	216,500
Total	**4,411,687**

Table-1.2. The potential yield for different depth zones

Depth Zone	Potential (t)
up to 100 m	3,821,508
100-200 m	259,039
200-500 m	114,640
Oceanic[1]	216,500
Total	**4,411,687**

Table-1.3.The potential yield of oceanic resources

Oceanic Resources	Potential (t)
Yellowfin tuna	80,000
Skipjack tuna	99,000
Bigeye tuna	500
Billfishes	14,400
Pelagic Sharks	20,800
Other species (Barracuda, Dolphin Fish, Wahoo etc.)	1,800
Total	**216,500**

69. An independent estimate (Approach-2) using productivity data facilitated by the trophodynamics sub-group gave the following results. The estimate of MSY for

[1]The estimated potential of oceanic squids (0.1 million t) not included

pelagic fishery of the Indian EEZ from primary production and secondary production were 3.605 and 3.322 million t respectively, the average being 3.463 million t. The MSY estimate for demersal fishery from benthic production was 0.855 million t. Thus the Maximum Sustainable Yield (MSY) of fish from the Indian EEZ is estimated as 4.318 million t (Table-2).

Table-2: Summary of the potentials (million t) estimated by Approach 2

Ecosystem	MSY-Pelagic		MSY-Demersal	Total MSY (in million t)
	From PP	From SP	From BP	
SEAS	1.359165	1.205825	0.41998	1.702475
NEAS	1.067719	1.001950	0.21132	1.2461545
NWBE	0.581445	0.504810	0.06507	0.608198
SWBE	0.256137	0.229965	0.11562	0.358671
AIE	0.340434	0.380156	0.0425	0.402795
Total	**3.604899**	**3.322706**	**0.8545**	**4.318294**

SEAS: South-east Arabian Sea; NEAS: North-east Arabian Sea; NWBE: North west Bay of Bengal, SWBE: South West Bay of Bengal; AIE:-Andaman Island Ecosystem; PP: Primary production; SP: Secondary production; BP: Benthic production

70. This estimate is close to the potential yield estimates arrived at by the Approach 1 using capture and survey data. The overall agreement indicates the degree of convergence on the estimates by different methods rather than a mere coincidence.

4.2. Comparisons

71. A comparison of the earlier estimate made in the year 2000 with the current outcome would be interesting as depicted below (Table-3). The estimates of pelagic fishes have gone up by 0.45 million t which is about 27 percent increase over the previous estimates of pelagics. There is a small increase of 49,692 t (about 2.5 percent) in the estimates of demersal resources and a decrease in the estimates of oceanic resources by 27,300 t (about 11 percent).

Table-3: Comparison of potential yield estimates of two Working Groups

Realm	WG 2010	WG 2000	Difference
Pelagic	2,128,424	1,673,545	454,879
Demersal	2,066,763	2,017,071	49,692
Oceanic	216,500	243,800	-27,300
Total	**4,411,687**	**3,934,416**	**477,271**

72. The change in the predominance of pelagic in the current estimate is quite interesting as compared to the estimates of year 2000. Barring the oceanic resources, the pelagic and demersal resources contributed respectively 45 and 55 percent in the estimates of year 2000. On the other hand, in the current estimate the pelagic and demersal resources contributed respectively 51 and 49 percent. The pelagics accounted for about 95 percent of the increase in the current estimates.

4.3. Species/Group Composition

73. Among the different species/group which constituted the estimate, oil sardine is the single largest resource accounting for about 12 percent and other sardines formed about three percent of the total. Ribbonfish emerged as the second dominant species with about six percent. Indian mackerel, croakers, penaeid shrimps, and non-penaeid shrimps accounted for about five percent each. Bombay duck, threadfin breams and bulls-eye accounted for four percent each. The estimated potential of important species/group of resources in different depth zone is given below (Table-4).

Table-4:

Summary of potential yield (t) calculated from different depth zones of the Indian EEZ using Approach 1.

Sl.		0-100 m		100-200 m		200-500 m		Oceanic	
No	Name of Group/Species	Demersal	Pelagic	Demersal	Pelagic	Demersal	Pelagic	waters	Total
1	Sharks	48721		239		100		20800	69860
2	Skates	5540		143		4			5687
3	Rays	31621		930		10			32561
4	Wolf herrings		20727		5				20732
5	Oil sardine		510501		12				510513
6	Other sardines		114708		1933				116641
7	Hilsa shad		56985				1		56986
8	Other shads		11339						11339
9	Anchovies		147466		196		33		147695
10	Other clupeids		67531		95				67626
11	Bombay duck		156651						156651
12	Half beaks and full beaks		11624						11624
13	Flying fish		9943		124				10067
14	Ribbon fishes		231862		3056		8292		243210
15	Horse Mackerel		37315						37315
16	Scads		52778						52778
17	Leather-jackets		14501						14501
18	Other carangids		78727						78727
19	Carangids*				42742		6250		48992
20	Indian mackerel		200830		3579		178		204587
21	Other mackerels		9						9

22	Scomberomorous *commerson*		50270						50270
23	*S. guttatus*		24610						24610
24	*S. lineolatus*		90						90
25	Other Seer fish		52		54				106
26	*Euthynnus affinis*		38646						38646
27	*Auxis* spp		15467						15467
28	*Kutsuwonus pelamis*							99000	99000
29	*Thunnus tonggol*		8128						8128
30	Yellowfin tuna							80000	80000
31	Bigeye tuna							500	500
32	Other tunas		18838						18838
33	Bill fishes							14400	14400
34	Barracuda		21941		2139		1681		25761
35	Mullets		18651						18651
36	Unicorn cod		1527						1527
37	Pig face breams	14014		32		2			14048
38	Snappers	7521		15					7536
39	Groupers/ Rock cods	27216		3027		953			31196
40	Threadfin breams	138886		17646		770			157302
41	Bull's eye (*Priacanthids*)	33116		95441		31708			160265
42	Other perches	43548		246		2470			46264
43	Cat fishes	97700		1565		116			99381
44	Eel	14822		63		291			15176
45	Croackers	222312		2609		624			225545
46	White fish (*Lactarius sp*)	11576		111					11687
47	Threadfins(Polynemids)	14643		45					14688
48	Indian drift fish			663		368			1031
49	Silver bellies (*Leiognathids*)	80910		1419		16			82345
50	Goat fishes (*Upenids*)	24413		3775		150			28338
51	Lizard fishes	39388		5666		1278			46332
52	Flat fishes			1497		111			1608
53	Halibut	1661							1661
54	Flounders	149							149
55	Soles	59378							59378
56	Moon fish			10		4			14
57	Silver pomfret	40930							40930
58	Chinese pomfret	4842							4842
59	Black pomfret	22637							22637
60	Pomfrets *			37					37
61	Cobia			113		3			116
62	Trigger fish (Balastids)			167		59			226
63	Black ruff			5246		9582			14828
64	Deep sea shark			93		857			950
65	Green eye			28		5277			5305
66	Sack fish (*Epinnula orientalis*)			373		5070			5443
67	Other deep sea fishes			5253		18140			23393
68	Other oceanic species *							1800	1800

69	Penaeid shrimps	242653							242653
70	Non-penaeid shrimps	207409							207409
71	Deep sea shrimp			1713		7555			9268
72	Crabs	61429		46334		5945			113708
73	Stomatopods	35983							35983
74	Lobsters	2107		50		4			2161
75	Deep sea lobster			9		38			47
76	Squids	60255		3541		2998			66794
77	Cuttlefish	71705		4630		410			76745
78	Octopus	5336		12		319			5667
79	Oyster	16060							16060
80	Clams & cockles	113189							113189
81	Mussels	21494							21494
82	Gastropods	1951							1951
83	Other molluscs					133			133
84	Miscellaneous		74676	2363		2840			79879
	TOTAL	**1825115**	**1996393**	**205104**	**53935**	**98205**	**16435**	**216500**	**4411687**

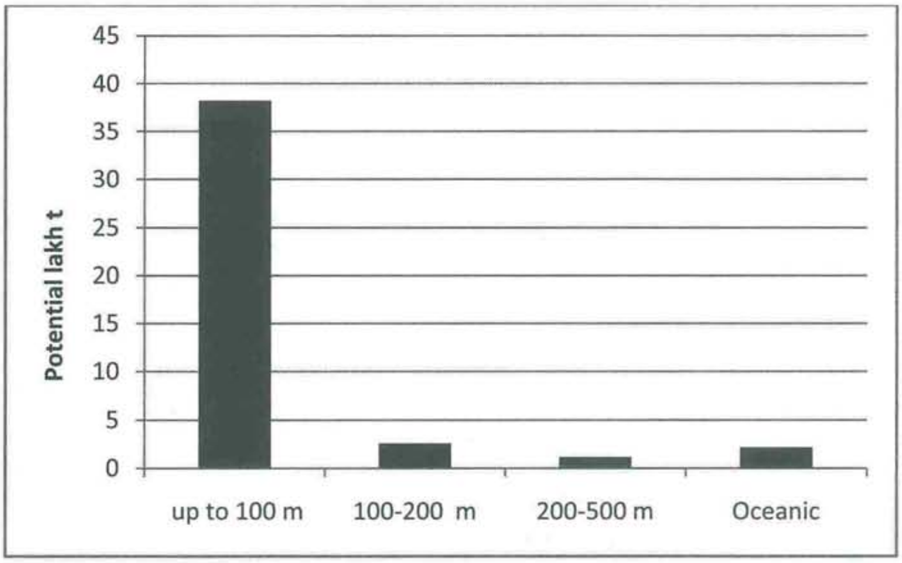
*Unsorted Fish

74. Overall there is an indication that pelagic species in the lower trophic levels are becoming dominant compared to the demersal species. Whereas the apex predators in the oceanic realm are declining. Thus, it could be presumed that 'fishing down the food web' (Pauly *et al.*, 1998; Vivekanandan *et al.*, 2005) is happening in the coastal fisheries of Indian EEZ. However, this subject needs detailed investigation and immediate attention.

4.4. Exploitable Potential

75. The potential for the EEZ up to 100 m depth is estimated at 3.8 million t whereas the landing in recent years amounted to about 3.2 million t. The additional 0.6 million t could eventually be harvested by enhancing the capabilities of the existing fleet of vessels. The potential for depth zones between 100-200 m and 200-500 m had been estimated as 259,039 t and 114,640 t respectively. Since venturing into deeper areas implies incremental costs the possibility of exploitation of these resources is dependent on the incremental revenue.

Figure.1. The Potential resources in the depth zones of Indian EEZ



76. The potential yield estimates for the different depth zones indicated a general decrease distribution of the resources from shallow zones to deeper zones (fig.1). The oceanic groups are migratory in nature and are distributed throughout the EEZ. The potential of the resources in the 100-200 as well as 200-500 m regions is comparatively very low. Further, the mixed multi-species nature of the fishery with heterogeneous size and meat quality would defeat any attempt to organize an industrial processing venture. World over, the industrial fleets are supported by a larger single species fishery of magnitude 0.2 million t (Great yellow croaker) to 13 million t (Peruvian anchovy). An economy of scale and vertical integration is pre-requisite for any such fishery. It could be noticed that except perhaps oil sardine, no other fishery is large enough in Indian waters.

77. A look at the distribution of different species over different depth zones indicate that most of the species/groups are distributed over the entire region. Only a few species/groups are restricted to deeper zones beyond 100 m. This brings in the basic issue of transboundary nature of the resources to prominence. The exploitation of any such species/groups in the deeper waters will have its impact on the abundance and availability of the same species near-shore. Leaving the resources in the deeper waters underexploited would, in one way, help the recovery and replenishment of stock from the excessive fishing pressure near-shore.

78. Another salient feature of the deeper resources is that they are of low value (except perhaps the deep-sea shrimps, lobsters and tuna) compared to the near-shore resources. Thus as the operations move from shallow to deep, the search-time and consequently the cost of operation increases while the revenue decreases, making the fishing operations most unviable. Analysing this relation in the context of promoting deep-sea fishing ventures, Vijayakumaran (1995, 1998) clearly stated that

the prevailing conditions of market and operational economies will force almost all the fishing units to operate near-shore rather than venturing into deeper waters.

4.5. Nonconventional Resources

79. Oceanic squid, *Sthenoteuthis oualaniensis* (Lesson, 1830), is a major resource in the deeper waters of world oceans that offer immense potential for exploitation. Recently, the share of cephalopods in the global marine landings has increased substantially owing to the shift to exploitation of oceanic stocks by other nations. These fast growing short-lived cephalopods are known to withstand high fishing-pressure. However, commercial fishing activity for this resource is non-existent in the country due to inadequate information on its abundance and distribution, lack of a directed approach and lack of skill in squid jigging techniques.

80. A whole body of Russian work during the nineteen eighties indicated that the Arabian Sea is considered as one of the richest regions for these oceanic squids in the Indian Ocean. Oceanic squids live in the open ocean. This species is usually absent over the continental shelves (<200 m) and first appears over continental slopes at depths above 250-300 m (Zuyev *et al.*, 2002). Chesalin *et al.* (1995) termed *S. oualaniensis* as the *Master of the Arabian Sea* due to its high abundance, large size, short life-span, fast growth and near monopoly of the higher trophic niche. The composition of the deep scattering layer (DSL) between 300-500 m depth, mentioned in the earlier report could be partially this species.

81. Globally, the stock of *S. oualaniensis* has been assessed as 3-4 million t (Zuyev *et al.*, 2002) and in Central Arabian Sea, it was assessed as (1.0 to 1.5 million t). Based on a study by Silas *et al.* (1986), the previous Working Group pegged the potential yield of oceanic squids in Indian EEZ as 20,000 to 50,000 t. Since about 10% of the area of abundance lies within the Indian EEZ, the potential yield from the area has been arbitrarily fixed as 0.1 million t. Further resource surveys are essential to establish the facts.

82. Moreover, exploitation of this resource warrants specialized vessels, expert crew, processing techniques and market channels. The outcome of an NAIP project on the subject could help in preparing a roadmap for exploitation of this important resource. Therefore, as matter of prudence, this resource is not included in the total potential in the current exercise.

83. The subject of exploitation of Antarctic krill and finfish resources had figured in the report of earlier Working Groups and a need for developing a suitable exploitation strategy was reiterated. The Department of Ocean development (DOD) sponsored expeditions were intended to attract entrepreneurs to exploitation of resources. The Commission for Conservation of Antarctic Marine Living Resources (CCAMLR) annually decides the catch quotas and total allowable catch (TAC) based on the

requests made by member countries. However, since no Indian entrepreneurs could venture into such risky uncharted areas, the rightful quota of India could not be exploited.

84. Constable (2002) mentioned that the potential of Antarctic krill estimated earlier around 240 million t is not very reliable. The current estimates of abundance of krill in the Southern Ocean, based on acoustic surveys and historical information on the distribution aggregations, fall between 60 and 155 million t. There is still debate on the harvestable potential of Antarctic krill, after accounting for the requirement of consumers like mammals, birds etc.

85. There are no advantages for a new entrant with very limited vertical integration (complete handling capability from capture to market) in exploitation of resources of the Antarctic region. A precautionary approach is necessary in any proposal on investment in these areas. A collaborative partnership with existing players could be a first step in this direction.

4.6. Fleet Optimization

86. Driven by the existing regulatory framework where coastal fishery is a State subject, there is a demand for arriving at the optimum fleet size for each State. Deciding an optimum fleet size is a daunting task in a multi-craft multi-gear multi-species fishery like that in India. The overlapping exploitation regime of a species by several gears renders the optimisation the exploitation by any one gear difficult.

87. However, an attempt made by the CMFRI sub-group in calculating the optimum fleet size is quite impressive (Table-5) and pertains to shelf fishery (The oceanic longline fishery need separate treatment). Though the results (as well as the model) are debatable, they give an indication that the numbers of existing boats are on the higher side. If the actual figures are compared, it could be noticed that the existing fleet size exceeds the optimum recommended by the model. How these units sustain in the fishery when the biological optimum does not permit such large number of units is a tricky question to answer. The easy way to explain the question would be that biological parameters are outside the operational economics of the harvesting units. Economic factors such as market demand, price of inputs and outputs and similar factors are key determinants for the viability of harvesting units.

88. The model used for arriving at the optimum fleet size was based on biological parameters (like MSY) of different species. There is an overwhelming simplification of the situation to fit into the available model. Some important Uts are not included in the exercise. The inherent drawback of the model by virtue of its inability to incorporate economic variables is an area where more attention has to be paid in future. This should be one of the priorities of research and development in the next plan period.

Table-5: Optimum fleet size (number of boats) estimated for the maritime States of India

State / Gear	West Bengal	Odisha	Andhra Pradesh	Tamil Nadu	Pondicherry	Kerala	Karnataka	Goa	Maharashtra	Gujarat	Total
Mechanized M-Day Trawlers	1061	877	1412	927	0	2489	1312	133	883	1462	**10556**
Mechanized S-Day Trawlers	0	121	404	2254	75	1121	729	191	1203	540	**6638**
Mechanized Gillnetters	2826	1752	868	201	13	64	0	4	1676	615	**8019**
Mechanized Hooks & Liners	89	5	46	210	0	34	0	0	20	94	**499**
Other Mechanized Craft	680	0	137	18	0	1347	141	277	3348	571	**6519**
Total Mechanized Craft	4656	2755	2867	3610	88	5055	2182	605	7130	3282	**32231**
Motorized Craft	2192	3464	2906	22455	1567	19105	2330	348	1876	3976	**60218**

M-day: Multi-day operation; S-day: Single day operation

[][][]

5. FUTURE OUTLOOK

5.1 The Global Commitments

89. As the world's largest democracy and a responsible member of the global community, India has a major role to play in almost all global affairs. Being a party to several conventions and treaties, the country needs to comply with several accepted principles and rules for the common good. There are several important global treaties and conventions which are having a direct bearing on the fishery sector of the country (see Box.1).

90. The FAO's Code of Conduct for Responsible Fisheries (CCRF) is very important, though the compliance to the Code is voluntary in nature. The Code prescribes the best practices to be followed in different aspects of fisheries so that the resource can be managed in a sustainable manner. The Monitoring, Control and Surveillance (MCS) using Vessel Monitoring System (VMS) assume great importance.

91. Another issue which would haunt the fishery sector is the Illegal, unreported and unregulated (IUU) fishing. FAO has prepared an International Plan of Action (IPOA-IUU) prescribing the member States to adopt National Plans of Actions (NPOA) before 2004. It has been stated that before a country allows a fishing vessel to be registered and before it allows a vessel to fly the country's flag, the country should make sure that it has the ability to control the fishing activities of the vessel. Though the issue of license is legal right to fish, the catch reporting and regulation of fishing are areas with scope for great improvement in India.

Box-1. India's commitments to international conventions and regulations with respect to fisheries

International agreements and conventions deal with varied subjects from oil pollution to safeguarding migratory species and natural habitats. Living marine resources are protected by many international laws. The conservation of marine resources is based on two strategies, one that protects specific species and the other that protects specific habitats or ecosystems. The Government of India is a party to, and has ratified, a number of conventions related to the marine environment and fisheries. By international obligations the government is required to meet the requirements of those conventions. However, the conventions will gain legal status only when incorporated within the domestic legal framework. The following are some of the international agreements to which India is a party.

INTERNATIONAL CONVENTION	KEY PROVISIONS	COMPLIANCE
UNCLOS III United Nations Convention on the Law of Sea	Concluded in 1982, and came into force in 1994, gave legal provisions for the protection of marine environment. Apart from protection of marine areas, the convention also specifies the mode of prevention of pollution from sea bed activities, dumping, and land based activities. This convention gave the right of exploitation and management of living and non-living marine	In 1976 the Maritime Zones Act had been promulgated whereby a territorial sea of 12 nautical miles, a contiguous zone of 24 nautical miles and exclusive economic zone (EEZ) of 200 nautical miles, from the baseline had been established.

	resources to coastal states under a newly formed Exclusive Economic Zone (EEZ).	
UNFCCC United Nations Framework Convention on Climate Change	This was drafted in New York in 1992 and became active in 1994. The objective of this convention is to stabilize the greenhouse gas concentrations in the atmosphere, an area which was not covered in the Montreal Protocol. It gives a framework for Governments to carry out new policies and programs to fulfill the obligations of the convention. The convention emphasizes the use of a precautionary approach and promotion of sustainable development in order to minimize the causes of climate change due to greenhouse gases.	Specific impacts of climate change on marine resources are as of now not fully understood and focused research programmes are being attempted by many national research organizations . A comprehensive policy on climate change impacts on fisheries is being prepared by the CMFRI.
RAMSAR Convention on Wetlands of International Importance	Was held in 1971 and the provisions were amended by the protocol in 1982. This convention seeks to preserve the fundamental ecology of wetlands. Each party is required to designate suitable wetlands for inclusion in a list of wetlands of international importance.	This Convention is not legally binding as per Indian Laws. Though India is a party to the Convention we do not have a legislation specific to the protection of RAMSAR Wetlands. The Conservation laws in India are more general, dealing with biodiversity and not to specific ecosystems. But several wetlands have been identified as RAMSAR sites
CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora	Was held in Bonn in 1973 and came into force for India in 1976. This Convention lists out three appendices in Article II: • Appendix I: species threatened with extinction and which are or may be, affected by trade • Appendix II: species which may become threatened with extinction, if international trade in them is not regulated and • Appendix III: species which any Party identifies as being subject to regulation within its jurisdiction for the purpose of preventing, or restricting, exploitation and as needing the cooperation of other parties in the control of trade.	The Indian Wildlife (Protection) Act, 1972 and the Wild Life (Protection) Amendment Act, 2002 provides protection through designated schedules to all species of marine mammals, corals, gorgonids and selected species of fishes and molluscs. Re-assessments of densities and abundance have to be made for commercial species by concerned research institutions wherever livelihoods are affected by the ban on capture.

Rio Declaration on Environment and Development	Adopted at the Earth Summit in 1992 this declaration laid down the principles for establishing new and equitable partnership through creation of new levels of cooperation among States, key sectors of the society and people	Need to participate and cooperate towards international agreements for protecting the integrity of the global environment and developmental systems
Agenda 21 of UNCED 1992	Adopted at the Earth Summit in 1992, Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally by organizations of the United Nations System, Governments, and Major Groups in every area in which human impacts on the environment.	A commitment to cooperate and implement programmes for fulfilling the Agenda 21.
FAO Compliance Agreement 1993	The *Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas* was adopted as part of FAO's work on the CCRF and was formally integrated as part of the Code when that instrument was adopted in 1995. It entered into force on 24 April 2003, after acceptance by 25 Parties.	Unlike the other parts of the CCRF, the Compliance Agreement is a legally binding treaty. Commitment to compliance to the responsibilities of flag States, particularly through authorizing fishing vessels to fish on the high seas, and establishing a system of information exchange on high seas fishing activities.
UN Fish Stock Agreement 1995	An agreement for the implementation of the provisions of the united nations convention on the law of the sea of 10 December 1982 relating to the conservation and management of straddling fish stocks and highly migratory fish stocks.	Commitment to participate in the formulation and implementation of conservation and management measures for migratory fish stocks
CBD Convention on Biological Diversity	Concluded in 1992. Its objective is "Conservation of biological diversity, the sustainable use of its component and fair and equitable sharing of benefits". Key provisions include: • Develop, where necessary, guidelines for the selection, establishment and management of protected areas or areas where special measures need to be taken to conserve biological diversity. • Regulate or manage biological resources important for the conservation of biological diversity whether within or outside protected areas, with a view to ensuring their	The National Biodiversity Act, 2002 covers most of the provisions set forth in the CBD. Inventorying of marine biodiversity is being carried out by many maritime states for preparation of baseline information.

	conservation and sustainable use; • Promote the protection of ecosystems, natural habitats and the maintenance or in-situ conservation of viable populations of species in natural surroundings; • Promote environmentally sound and sustainable development in areas adjacent to protected areas. • For marine environments, the Convention stipulates that the parties should follow the rights and obligations of UNCLOS.	
FAO CCRF Food and Agricultural Organisation, Code of Conduct for Responsible Fisheries	This Code of 1995 seeks to lay down a comprehensive set of guidelines and principles to promote responsible fishing and fisheries activities. The Code applies to all fisheries as well as to the capture, processing and trade of fish and fishery products, fishing operations, aquaculture and fisheries research. Article 1(2) of the Code states: "The Code is global in scope, and is directed toward members and non-members of FAO, fishing entities, sub-regional, regional and global organisations , whether governmental or non-governmental, and all persons concerned with the conservation of fishery resources and management and development of fisheries".	Most provisions of the Code are incorporated in the Indian Fisheries Acts, amendments and those currently underway; and also in the Comprehensive Marine Fishing Policy of 2004. However, compliance is poor due to various reasons.
MARPOL The International Convention for Prevention of Pollution from Ships	This was adopted in 1973 and revised in 1978. This Convention replaced the 1954 OILPOL Convention. Besides oil, MARPOL also regulates other type of ship pollution, including noxious liquids, garbage etc. The Convention compels the State to inspect vessels that berth at its ports and to issue International Oil Pollution Prevention Certificate.	The Convention deals with sources of pollution and how to prevent such incidents. It does not deal with the persistent nature of pollutants and its bio-magnification in marine ecosystem.
CCAMLR Commission for Conservation of Antarctic	Came into force in 1982 and India is a member country. The Commission during its annual	No serious attempts have been made to exploit the resources by India. A plan of action is

Marine Living Resources	meeting fixes the annual catch quotas of different resources for each member country	urgently required.
CMS Convention on the Conservation of Migratory Species of Wild Animals	Came into force in 1983 and requires parties to conserve migratory species, with special attention to species with unfavourable conservation status. The Convention calls upon the State to establish a "Scientific Council" to advice on scientific matters relating to conservation of migratory species.	More emphasis has been on terrestrial and aerial animals. The MoEF has to be advised on status of migratory marine animals.
In addition to these convention and agreements, the country is responsible for abiding by the provisions of the following International Plan of Actions: ▪ IPOA for Conservation and Management of Sharks (1998). ▪ IPOA for Management of Fishing Capacity (1998). ▪ IPOA for reducing incidental catch of seabirds in longline fisheries. ▪ IPOA to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (2001). A comprehensive analysis of the of the provisions of these instruments and enumerating the relevant compliance obligations under these instruments is beyond the scope of this report and is desirable to be entrusted to an appropriate group of experts.		

5.2. Obligations under IOTC

92. India is a member of the Indian Ocean Tuna Commission (IOTC), an intergovernmental organization established under Article XIV of the FAO constitution, mandated to manage tuna and tuna-like species in the Indian Ocean and adjacent seas. Since its inception in 1996, the IOTC has adopted several resolutions which are mandatory for the member countries to comply with while recommendations are of voluntary nature for adoption. The important IOTC resolutions and recommendations are given in Box-2.

93. The mechanism of ratifications of these instruments is such that the support by a critical mass of members is sufficient to bring them into effect. Some of these international obligations come into force whether or not the individual countries agree or like the same. There is a lot to be done to achieve compliance in the case of several IOTC resolutions. A cooperative environment where all stakeholders play responsible roles with clear strategy is required to achieve this objective.

Box-2. Important resolutions and recommendations of IOTC and compliance requirements by member countries	
Resolution / Recommendation	**Required Action by CPCs / Indian response**
Resolution 99/01 Management of fishing capacity and on the reduction of the catch of juvenile bigeye tuna	Submission of list of vessels fishing for tropical tunas in the IOTC area
Resolution 99/02 Actions against fishing activities by large scale flag of convenience longline vessels	Ensure that large-scale tuna longline vessels under the country's registry do not engage in IUU fishing activities and should refuse landing and transshipment by FOC vessels which are engaged in fishing activities diminishing the effectiveness of measures adopted by IOTC.
Resolution 00/01 Compliance with mandatory statistical requirements for IOTC members and requesting cooperation with non-contracting parties	Submission of the mandatory data requirements to the commission regularly
Resolution 00/02 Survey of predation of longline caught fish	Collecting data on depredation in the longline caught fish
Resolution 01/02 Relating to control of fishing activities	The vessels are required to carry certificates including: License, permit or authorisation to fish and terms and conditions attached to the license, permit of authorisation ; vessel name; port in which registered and the number(s) under which registered; international call sign; names and addresses of owner(s) and where relevant, the charter; overall length and engine power, these documents are to be verified on a regular basis and at least every year.
Resolution 01/03 Establishing a scheme to promote compliance by non-contracting party vessels with resolutions established by IOTC	Assistance of the Indian Coast Guard, Indian navy, research institutes having ocean going vessels etc need to be sought to find any vessels believed to conduct fishing contrary to IOTC conservation or management measures. MPEDA and Indian Coast Guard need to be entrusted monitor the landing and mid-sea transshipment of catch.
Resolution 01/06 IOTC bigeye tuna statistical document programme	Exports of bigeye tuna must accompany bigeye tuna statistical document or IOTC bigeye tuna re-export certificate validated by a government official in the prescribed format. Sample forms of these documents are to be submitted to the executive secretary of IOTC.
Recommendation 02/07 Concerning measures to prevent the laundering of catches by IUU large-scale tuna longline fishing vessels	CPCs must ensure that licensed large-scale tuna longline fishing vessels have a prior authorization of at sea or in port transshipment and obtain the validated statistical document, whenever possible, prior to the transshipment of their tuna and tuna-like species subject to the statistical document programme. We should also ensure that transshipments are consistent with the reported catch amount of each vessel in validating the statistical document and require the reporting of transshipment.
Resolution 03/01 Limitation of fishing capacity of contracting parties and cooperating non-contracting parties	Fleet Development Plan is to be submitted to the commission with top priority.
Resolution 03/03 Amendment of the forms of the	The bigeye tuna statistical documents submitted along with bigeye tuna exported/imported should be in renewed format.

IOTC statistical documents	
Resolution 05/01 Conservation and management measures for bigeye tuna	Fleet development plan is to be submitted at the earliest
Resolution 05/03 Establishment of an IOTC programme of inspection in port	1. Port inspection programmes to be framed so as to inspect documents, fishing gear and catch on board fishing vessels, when such vessels are voluntarily in the ports or at its offshore terminals. Inspections have to be carried out so that the vessel suffers the minimum interference and inconvenience and that degradation of the quality of the fish is avoided. 2. List of foreign vessels which have landed in our ports tuna and tuna like species caught in the IOTC area in the preceding year has to be submitted to the commission before 1st of July.
Resolution 05/05 Conservation of sharks caught in association with fisheries managed by IOTC	Ensure that the tuna fishing vessels should not have onboard fins that total more than 5 % of the weight of sharks onboard, up to the first point of landing. But in the case of Indian tuna fishing vessels, the sharks are landed in whole, not only fins.
Recommendation 05/07 Management standard for the tuna fishing vessels	While issuing the licenses to authorized fishing vessels, ensure that minimum management measures as per the format provided are met with. An annual report on the measures taken in this regard is to be submitted to the commission in the format given in attachment ii
Recommendation 05/08 On sea turtles	No obligatory action to be taken. But, the commission encourages implementing the guidelines and the necessary measures for vessels fishing for tuna and tuna-like species in the IOTC area, to mitigate the impact of fishing operations on sea turtles.
Recommendation 05/09 Incidental mortality of seabirds	Since the sea bird bycatch is reported mainly in the area south of 15° S latitude, and since there are no reports of Indian tuna vessels fishing in these areas, no action is warranted on this recommendation
Resolution 06/03 Establishing a vessel monitoring system programme	1. Satellite based vessel monitoring system (VMS) for all vessels greater than 15 meters in length overall registered on the IOTC record of vessels which operate in the IOTC area and which fish on the high seas (outside the fisheries jurisdiction of any coastal state) for species covered by the IOTC agreement by 1 July 2007. 2. Until 1 July 2008, tuna fishing vessels larger than 15 m LOA, which are not yet equipped with VMS shall report to fisheries monitoring center (agency to be identified) at least daily by email, facsimile, telex, telephone message or radio. Such reports must include, *inter alia*, information required in paragraph 3 when transmitting the report, to their competent authorities, as well as: A. The geographic position at the beginning of the fishing operation; B. The geographic position at the end of the fishing operation. 3. If we are not in a position to fulfill the obligations as outlined in this resolution we have to report to the IOTC secretariat (i) the systems and infrastructure and capabilities existing with respect to the implementation this resolution, and (ii) the hindrances for implementation of such a system and (iii) requirements for implementation. 4. A report on the progress and implementation of its VMS programme to be furnished to the commission by 30 June each year for which the VMS must be made mandatory for Indian tuna vessels.
Resolution 07/02 Concerning the establishment of an IOTC record of vessels authorized to operate in the IOTC area	Members have to submit, to the IOTC by 1 July 2003 for the vessels larger than 24 meters in length overall, and in case of vessels less than 24 m, those operating in waters outside the economic exclusive zone of the flag state, and that are authorized to fish for tuna and tuna-like species in the IOTC area 2. We have to notify, any deletion from and/or any modification of the

	IOTC record at any time such changes occur.
Resolution 07/03 Catch by fishing vessels in the IOTC area	Log books (electronic or bound) must be made mandatory for the vessels over 24 meters length and those less than 24 meters if they fish outside the EEZ.
Resolution 07/04 Registration and exchange of information on vessels fishing for tunas and swordfish in the IOTC area	We have to submit a list of tuna fishing vessels greater than 24 m LOA and vessels of less than 24 m LOA that have fished for tropical tunas, albacore and swordfish outside of our EEZ during the previous year.
Resolution 08/01 Mandatory statistical requirements for IOTC members and cooperating non-contracting parties	We have to furnish the nominal catch, catch and effort and size data to the commission by 30th June. FSI is regularly furnishing the nominal catch and 5° grid catch and effort data with regard to the exploratory survey by FSI to the commission. Lop vessel data, received by the FSI is compiled and nominal catch is reported since the data reported is not geo-referred, in most of the cases. But, these data furnished is not complete since all the boat owners are not submitting the data in time. With regard to the coastal fisheries data, data received from CMFRI (not geo-referred, only area-wise) for the previous year and the fisheries department, UT of Lakshadweep and A&N Islands are compiled and submitted to the commission. Since India doesn't have tuna purse seiners, we may not have any data to furnish with regard to the purse seine and fad fishing data.
Resolution 08/02 On establishing a programme for transshipment by large-scale fishing vessels	Transshipments should be allowed under the conditions suggested by the IOTC. Observer programme may be implemented at the earliest.
Resolution 08/03 Reducing the incidental bycatch of seabirds in longline fisheries	Since the sea bird bycatch in the longline fishery of Indian ocean is reported mainly from the area south of 15°s, we need not to take any action on this resolution
Resolution 08/04 Recording of catch by longline fishing vessels in the IOTC area	Log books with all the details have to be made mandatory for all the tuna fishing vessels.
Resolution 09/02 Implementation of a limitation of fishing capacity of contracting parties and cooperating non-contracting parties	Policy on limitation on fishing capacity to be formulated. It seems that the IOTC proposes to limit the number of vessels to the level of the year 2006 (for tropical tunas) and of the year 2007 (for swordfish and albacore). What about purse seiners? Our fleet development plan, is to be finalized by 31 December 2009, inter alia, the type, size, gear and origin of the vessels included in the fleet development plans and the programming (precise calendar for the forthcoming 10 years) of their introduction into the fisheries. All future fishing efforts has to be in accordance with such development plans of the concerned CPCs.
Resolution 09/03 Establishing a list of vessels presumed to have carried out illegal, unregulated and unreported fishing in the IOTC area	We may forward names of IOTC authorized vessels to the coast guard who can report if they find any vessels other than those appeared in the IOTC list is fishing for tuna and allied fishing in the Indian ocean area. We also have to make sure that the mandatory statistical data is being furnished by all the vessels to the concerned agencies, so as to avoid the inclusion of such vessels in IOTC list
Resolution 09/04 On a regional observer scheme	We have to ensure that at least 5 % of the number of operations/sets for each gear type by the tuna fleet fishing in the IOTC area of 24 meters overall length and over, and under 24 meters if they fish outside their EEZs is covered by observer scheme. For vessels less than 24 meters if they fish outside their EEZ, the above mentioned coverage should has to be achieved progressively by January 2013.
Resolution 09/05 To prohibit the use of large-scale driftnets on the high seas in the	Banning of gill nets longer than 2.5 km in oceanic waters may be considered.

IOTC area of competence	
Resolution 09/06 On marine turtles	The data on bycatch of sea turtles on board survey vessels of FSI are analysed and presented regularly in the IOTC working party on bycatch. We may address letters to all the tuna fishing vessels requesting to furnish the data on bycatch/incidental catch of sea turtles. It may be made mandatory for the longliners to carry the equipments for appropriate handling, including resuscitation or prompt release of all bycaught or incidentally caught sea turtles like line cutters, scoop nets, etc. Use of turtle friendly gears like circle hooks etc are to be encouraged.
Note: Those resolutions superseded by subsequent resolutions are not mentioned in the list	

5.3. Future Course of Action

94. The exercise of revalidating the estimates of potential yield of the fishery resource of the Indian EEZ has become an established feature for providing vital input for planning of marine fishery development in the country. These decadal exercises are carried out using the available data from various sources and using the best suited models available and amenable to the database at the disposal of the Working Groups.

95. In the course of transaction of the business, the Working Group had encountered several issues and had the opportunity to receive suggestions from different agencies and interests groups. In order to make the best use of the output of the present Working Group and also to make the transactions easier for future Working Groups it was felt that the issues and suggestions need to be documented as points for future action, as is attempted here.

- Action Taken Report: Some Working Group members expressed in the first meeting that a report is complete only if it has resulted in some action. The need for preparing an action taken report which should be made available to the members, if not the public, was stressed.

- Circulation of the Report: A general opinion prevailed against the limited or restricted circulation of the reports of the Working Group. It was suggested that the report may be made available to a wider section of audience.

- Periodicity of Revalidation: Some experts and stakeholders expressed the opinion that the ten-year periodicity of the revalidation exercise was inadequate. This needs examination in view of the rapid changes that are taking place in the fishery environment and the resource endowments for carrying out frequent exercises.

- Constitution of a core Working Group: In order to facilitate the fruitful exercise in future there is a need for continuous dialogue among the organizations collecting and maintaining relevant databases. There can be a core group from key organizations with a provision to co-opt experts and members from other organizations as and when the revalidation exercise is being called for.

- Addressing Data Gaps: The current exercise can certainly boast a significant refinement over the previous ones because of the better databases and methods it could use. However, there were serious data gaps and paucity of data which need to be addressed by the core group so that similar situation does not arise in future.

- Developing Models and Tools: Considering the inadequacy of the some of the models such as those used for arriving oceanic resources as well as optimum fleet size, there is an urgent need for initiating research projects for developing suitable models and tools which would explain adequately the realities and give pragmatic solutions.

[][][]

Support Document 6.1

Potential Yield Estimate for the Depth Zone up to 100 m.

CMFRI Sub-Group

Introduction

Marine fish production in the country has increased from 2.40 million t in 1999 to an all time high of 3.21 million t in 2008. The average growth rate during the period 1999 to 2008 is 3.3 % per annum. As per the 2005 marine fisheries census report there are about 2, 39,000 fishing craft in the country for exploitation of marine fishery resources. Out of this about 59,000 are mechanized craft, 76,000 are motorized and the rest are non-mechanized craft. In the mechanized sector there are about 29,000 trawlers. Fishing by these craft are concentrated in the depth zone up to 100 m. The traditional crafts and motorized crafts are concentrated more in the east coast (73% and 60%) where as the mechanized vessels are more along the west coast (64%).

Methodology

Input data used for estimation of potential yield for the area up to 100 m depth is time series data on species-wise, gear-wise and state-wise catch during 2000 – 2008 period obtained from the National Marine Living Resources Data Centre (NMLRDC) of Central Marine Fisheries Research Institute, Kochi. The time series data on fishing effort used was in hours of operation which was standardized as given below:

Let a given species was caught by *k* gears with $c_1, c_2, \cdots, c_k$ the catch and $f_1, f_2, \cdots, f_k$ the effort so that $u_1, u_2, \cdots, u_k$ are the catch per unit effort (CPUE) where

$$u_i = \frac{c_i}{f_i} \quad \text{for } i = 1, \cdots, k$$

The effective CPUE u_w for the species is then obtained as the weighted average of the CPUE values with proportion of catch by the gears as the weights. The standardized effort for the species is then obtained as

$$f_s = \frac{C}{u_w}$$

Where; *C* is the total catch for the species.

Time series data on catch and standardized effort was used to fit the linear version of Schaefer's surplus production model and the potential yield for the species/group was obtained as the MSY where;

$$MSY = \frac{-a^2}{4b}$$

with a and b the fitted values of the intercept and slope respectively for the linear relationship of CPUE on effort. In cases where the data does not fit well for the linear relationship, the non-linear version of Schaefer's surplus production model was followed and a genetic algorithm approach was used to estimate parameters of the model and MSY (Sathianandan and Jayasankar, 2009). For fitting linear model the module available in Microsoft Excel was used. For fitting the non-linear version of Schaefer's model the software developed by CMFRI based on genetic algorithm approach was used.

For estimation of maximum sustainable fleet size, the potential yield estimated for a state was grouped into three as Demersal, Large Pelagics and Small Pelagics. The gears that catch these groups were then identified from time series data on gear-wise catch and the potential yield was distributed for each of the identified gears. The average catch per unit effort (CPUE) for the gears was calculated using catch and effort in hours during 2006-2008. By dividing the potential corresponding to a gear with its CPUE, the optimum hours of operations required to harvest the potential yield was obtained. Then for each type of gear the maximum sustainable fleet size was obtained by dividing the optimum hours with the product of trips per annum and hours per trip by the gear.

Results

Table-6.1.1. Potential yield (t) estimates of demersal resources along the Indian coast.

Sl.No.	Name of Group/Species	Total	Group Total
	Elasmobranchs (1-3)		85882
1	Sharks	48721	
2	Skates	5540	
3	Rays	31621	
	Perches (4-9)		264301
4	Rock cods	27216	
5	Pig-face breams	14014	
6	Snappers	7521	
7	Threadfin breams	138886	
8	Bull's eye	33116	
9	Other perches	43548	

10	Catfishes	97700	
11	Eels	14822	
12	Croakers	222312	
13	White fish	11576	
14	Threadfins	14643	
15	Silverbellies	80910	
16	Indian drift fish		
17	Goatfish	24413	
18	Lizardfish	39388	
	Flatfishes (19-21)		61188
19	Halibut	1661	
20	Flounders	149	
21	Soles	59378	
22	Moon fish		
	Pomfrets (23- 25)		68409
23	Silver pomfret	40930	
24	Chinese pomfret	4842	
25	Black pomfret	22637	
26	King fish		
27	Trigger fish		
28	Black ruff		
29	Deep sea shark		
30	Green eye		
31	Other deep sea fishes		
32	Other fishes		
	Shrimps (33-34)		
33	Penaeid shrimps	242653	
34	Non-penaeid shrimps	207409	
35	Deep sea shrimps		
36	Crabs	61429	
37	Stomatopods	35983	
38	Lobsters	2107	
39	Deep sea lobsters		
	Cephalopods (40-42)		137296
40	Squids	60255	
41	Cuttlefish	71705	
42	Octopus	5336	
	Bivalves (43-45)		150743
43	Oyster	16060	
44	Clams & cockles	113189	
45	Mussels	21494	
46	Gastropods	1951	
	Total	**1825115**	

Table-6.1.2. Potential yield (t) estimates of pelagic resources along the Indian coast.

Sl.No.	Name of Group/Species	Total	Group Total
	Clupeids (1-11)		929257
1	Wolf herring	20727	
2	Oil sardine	510501	
3	Other sardines	114708	
4	Hilsa shad	56985	
5	Other shads	11339	
6	Stolephorus	65753	
7	Coilia	33472	
8	Setipinna	8817	
9	Thrissina	6	
10	Thryssa	39418	
11	Other clupeids	67531	
12	Bombayduck	156651	
13	Half beaks and full beaks	11624	
14	Flying fishes	9943	
15	Ribbonfishes	231862	
	Carangids (16-19)		183321
16	Horse Mackerel	37315	
17	Scads	52778	
18	Leather-jackets	14501	
19	Other carangids	78727	
20	Indian mackerel	200830	200839
21	Other mackerels	9	
	Seerfishes (22-25)		75022
22	*Scomberomorous commerson*	50270	
23	*Scomberomorous guttatus*	24610	
24	*Scomberomorous lineolatus*	90	
25	*Acanthocybium* spp.	52	
	Tunas (26-30)		89383
26	*Euthynnus affinis*	38646	
27	*Auxis* spp	15467	
28	*Kutsuwonus pelamis*	8304	
29	*Thunnus tonggol*	8128	
30	Other tunas	18838	
31	Bill fishes	7586	
32	Barracudas	21941	
33	Mullets	18651	
34	Unicorn cod	1527	
	Total	**1937607**	
	Miscellaneous	**74676**	
	Grand Total	**3837398**	

Table-6.1.3. Maximum sustainable fleet size estimated for different states

Gear	West Bengal	Odisha	Andhra Pradesh	Tamil Nadu	Pondicherry	Kerala	Karnataka	Goa	Maharashtra	Gujarat	Total
Mechanized Multiday Trawlers	1061	877	1412	927	0	2489	1312	133	883	1462	**10556**
Mechanized Single-day Trawlers	0	121	404	2254	75	1121	729	191	1203	540	**6638**
Mechanized Gillneters	2826	1752	868	201	13	64	0	4	1676	615	**8019**
Other Mechanized craft	680	0	137	18	0	1347	141	277	3348	571	**6519**
Mechanized Hooks & Liners	89	5	46	210	0	34	0	0	20	94	**499**
Total Mechanized craft	4656	2755	2867	3610	88	5055	2182	605	7130	3282	**32231**
Motorized	2192	3464	2906	22455	1567	19105	2330	348	1876	3976	**60218**

Suggestions on conservation of marine fishery stocks in the Indian EEZ.

It is evident that the marine fish catches (3.18 t during 2008 and 2009) within the 100 m depth range is approaching the potential yield estimates (3.8 t). It is imperative that appropriate measures are taken to conserve the marine fisheries and fish stocks. The following measures are suggested:

1. Code of conduct for Responsible Fisheries, which is a comprehensive document on the steps that may be taken to conserve the fisheries and fish stocks, may be followed.

2. Ecosystem Approach to Fisheries, which is a better method relative to single- species management, may be initiated with the participation of fishing communities.

3. Marine Fisheries Regulation Acts (MFRAs), which were formulated more than 25 years ago, may be revised considering recent changes, issues and developments in the sector.

4. National Plan of Action on sharks and fishing fleet capacity may be prepared, as suggested by the FAO.

5. The current fishing restrictive measure i.e., seasonal ban on fishing may be continued. Open access to fisheries may be gradually reduced by following other

restrictive measures such as capping the number of boats, declaring more Marine Protected Areas and No-Fishing Zones and mesh size regulation.

6. India may initiate steps with neighbouring countries to tackle transboundary issues related to straddling fish stocks.

7. India may take steps to fulfill its international obligations such as UNCLOS, CBD and IOTC.

8. A revised deep sea fishing policy may be implemented by taking into account the sustainability issues, related to vulnerability of deep sea resources. This policy may include deep sea demersal resources beyond 100 m depth.

9. As the method of fisheries data collection by CMFRI is proven, the data collection mechanism by the Institute may be strengthened with support from the DAHDF, Maritime states and Union Territories. The improved data from the CMFRI may be declared as the official statistics of marine fisheries of the country.

[][][]

Support Document 6.2.

Demersal Fishery Potential in 100-500 m depth zone of the Indian EEZ

FSI Sub-Group

Introduction

Fishery Survey of India (FSI) carries out demersal trawl survey in the EEZ round the year using different types of trawl gear. The surveys were conducted using standard gear and following stratified random sampling with reference to depth and area.

The *Working Group for Revalidation of the Potential Yield in the Indian EEZ,* in its first meeting came to a conclusion that the present fishery exploitation is from within 100 m depth contour and is well reflected in the landing data collected by the Fishery Resource Assessment Division (FRAD) of CMFRI. Therefore, it was decided that Fishery Survey of India analyse the trawl data from the depth strata 100-200 m and 200-500m for four regions.

Database

Since the previous committee has used data for decade up to 1996, the data from January 1997 to December 2008 was taken for the current analysis. FSI deployed eleven survey vessels for demersal resources surveys during the period and operated around 29100 hauls in the depth range 20-500 m. 4721(16 % of total operated hauls) valid hauls available in the depth range 100-500 m were used for the present analysis. The data segregated and processed for the depth zones 100-200 m and 200-500 m for the four regions separately. The regions followed are:

North-west Coast:	Latitude	$15^0 - 23^0$ N
South-west Coast:	Latitude	$07^0 - 15^0$ N
South-east Coast:	Latitude	$10^0 - 15^0$ N
North-east Coast:	Latitude	$15^0 - 22^0$ N

Method

The trawl hauls operated by both fish trawl and shrimp trawl were grouped together for respective region /depth stratum and processed for species-wise CPUE. The *swept area method* as detailed below was used in estimation of biomass (B) of the species.

$$B = \left\{\frac{CPUE}{(a \times X_1)}\right\} \times A$$

Where, A is the area of given depth / region in square km,
a is swept area, and
X_1 is the proportion of the fish caught in the net which is assumed as 0.50

Swept area **a** is estimated from the following equation:

$$a = t \times v \times h \times X_2$$

Where, t is the duration of trawling (h)
v is trawling speed (km per h)
h is the length (m) of the head rope (for multiple gears operated in the given depth region the same is arrived by combined mean of head rope lengths)
X_2 is the ratio representing the effective opening of the head rope length, assumed as 40%

Note: The trawling speed was worked out using actual distance from shooting and hauling positions and the haul duration. The average trawl speed worked out to be 2.5 kt for 100-200 m depth and 2 kt for 200-500 m depth.

On arriving at the biomass (B), Maximum sustainable yield is calculated by using the following formula:

1) For virgin stock $MSY = 0.5 \times M \times B$

2) For exploited stock: $MSY = 0.5(Y + MB)$

Where, M is the natural mortality rate of the species
B is biomass of the species and
Y is average production

Note: Natural mortality (M) is taken from published literature wherever available (both from CMFRI and FSI), otherwise M = 1.

Table-6.2.1. The distribution of number of hauls, effort and area in different regions/zones

Depth (m)	Region / Parameter	North-west $15^0 - 23^0$ N	South-west $7^0 - 15^0$ N	South-east $10^0 - 15^0$ N	North-east $15^0 - 22^0$ N	Total
100-200	Area (km^2)	16445	13140	3305	15780	48670
	Hauls	1798	1193	409	350	3750
	Effort (h)	2659	1801	578	514	5552
200-500	Area (km^2)	7690	11795	1765	3875	25125
	Hauls	74	290	458	149	971
	Effort (h)	72	415	616	215	1318

Results

The density, biomass and MSY estimated for two depth zones in different regions are depicted in tables below.

Table-6.2.2. Distribution of stock density, and MSY in different regions/depth zones

Region	NW	SW	SE	NE	Total (t)
Latitude	15-23	7-15	10-15	15-22	
STOCK DENSITY (t / km^2)					
100-200	3.03	3.16	5.93	3.28	-
200-500	2.80	2.66	4.69	4.30	
MSY					
100-200	81689	67959	32503	76886	259037
200-500	34057	55059	10414	15112	114642
Total	**115746**	**123018**	**42917**	**91998**	**373679**
NW: North-west; SW: South-west; SE: South-east; NE: North-east					

Table-6.2.3. The MSY (t) of different species in 100-200 m depth zone in different regions

a. Demersal resources

	Depth	100-200 m				
	Region (Lat range °N)	NW (15-23)	SW (7-15)	SE (10-15)	NE (15-22)	Total
Sl.No	species/group					
	Elasmobranchs					
1	Sharks	94	71	43	32	239
2	Skates	15	118	5	5	143
3	Rays	157	637	78	58	930
	Perches					
4	Groupers	1701	1287	6	32	3027
5	Pigface breams	15	12	5	0	32
6	Red snapper	13	2	0	0	15
7	Threadfin breams (*Nemipterus spp*)	7568	6230	376	3471	17646
8	Bull's eye (*Priacanthus spp*)	30208	18291	11965	34977	95441
9	Other perches	96	57	5	88	246
10	Cat fishes	1443	34	0	88	1565
11	Eel	20	12	12	19	63
12	Croackers	845	8	222	1534	2609
13	White fish (*Lactarius sp*)	111	0	0	0	111
14	Threadfins(Polynemids)	45	0	0	0	45
15	Silver bellies (Leiognathids)	61	0	36	1322	1419
16	Indian drift fish (*Ariomma indica*)	106	48	43	466	663
17	Goat fishes (Upenids)	788	17	451	2520	3775
18	Lizard fishes	3699	1606	179	183	5666

19	Flat fishes	21	189	407	880	1497
20	Moon fish	5	0	0	5	10
21	Pomfrets	0	0	0	37	37
22	King fish (Elacate)	55	58	0	0	113
23	Trigger fish (Balastids)	83	84	0	0	167
24	Black ruff (*Psenopsis cyaena*)	320	1042	2530	1354	5246
25	Deep sea shark	0	4	6	83	93
26	Green eye	0	20	8	0	28
27	Sack fish (*Epinnula orientalis*)	0	373	0	0	373
28	Other deep sea fishes	180	114	465	4494	5253
29	Other fishes	492	397	122	906	1917
30	Shrimps	32	68	0	0	100
31	Deep sea shrimp	53	857	74	628	1613
32	Crabs	127	22124	10478	13605	46334
33	Rock lobster	2	48	0	0	50
34	Deep sea lobster	0	9	0	0	9
	Cephalopods					
35	Squids	2411	1029	18	84	3541
36	Cuttlefish	3883	425	67	255	4630
37	Octopus	0	12	0	0	12
38	Bivalves	0	0	0	0	0
39	Others	36	20	88	302	446
	Sub-total 1	54685	55303	27690	67424	205101

b. Pelagic resources

	Depth	100-200 m				
	Region (Lat range °N)	NW (15-23)	SW (7-15)	SE (10-15)	NE (15-22)	Total
Sl. No	species/group					
1	*Chirocentrus* spp	5	0	0	0	5
2	Oil sardines	12	0	0	0	12
3	Other sardines	416	8	0	1509	1934
4	Hilsa shad	-	-	-	-	-
5	Other shad	-	-	-	-	-
6	Bombay duck	0	0	0	0	0
7	Anchovies	152	10	0	34	168
8	Other clupeoids	83	0	0	11	95
9	Ribbon fishes	749	2197	93	18	3056
10	Carangids	20676	9777	4692	7598	42742
11	Mackerel	3446	49	2	82	3579
12	Seer fish	35	6	0	13	54
13	Coastal tunas	-	-	-	-	-

14	Barracuda	1425	491	27	197	2139
15	Mullets	-	-	-	-	-
16	Beak fish	-	-	-	-	-
17	Flying fish	10	114	-	-	124
	Sub-total 2	27004	12657	4813	9462	53936
	Grand total	81689	67959	32503	76886	259037

Table-6.2.4. The MSY (t) of different species in 200-500 m depth zone in different regions

a. Demersal resources

Sl. No	Depth	200-500 m				
	Region (Lat range °N)	NW (15-23)	SW (7-15)	SE (10-15)	NE (15-22)	Total
	species/group					
	Elasmobranchs					
1	Sharks	33	0	50	18	100
2	Skates	0	4	0	0	4
3	Rays	0	8	2	0	10
	Perches					
4	Groupers	69	884	0	0	953
5	Pig face breams	0	0	2	0	2
6	Red snapper	0	0	0	0	0
7	Threadfin breams	742	4	11	12	770
8	Bull's eye	21684	919	2543	6561	31708
9	Other perches	0	2468	2	0	2470
10	Cat fishes	116	0	0	0	116
11	Eel	3	103	46	138	291
12	Croackers	587	0	17	21	624
13	White fish (*Lactarius sp*)	0	0	0	0	0
14	Threadfins(Polynemids)	0	0	0	0	0
15	Silver bellies (Leiognathids)	16	0	0	0	16
16	Indian drift fish (*Ariomma indica*)	0	31	0	337	368
17	Goat fishes (Upenids)	150	0	0	0	150
18	Lizard fishes	882	388	5	2	1278
19	Flat fishes	0	0	45	66	111
20	Moon fish	0	4	0	0	4
21	Pomfrets	0	0	0	0	0
22	King fish (Elacate)	3	0	0	0	3
23	Trigger fish (Balastids)	0	59	0	0	59
24	Black ruff (Psenopsis cyaena)	0	6381	2476	725	9582
25	Deep sea shark	0	621	229	8	857
26	Green eye	0	4757	520	0	5277
27	Sack fish (*Epinnula orientalis*)	0	5067	3	0	5070

28	Other deep sea fishes	408	12359	1715	3657	18140
29	Other fishes	66	1473	139	248	1925
30	Shrimps	72	449	2	0	523
31	Deep sea shrimp	78	4174	877	1904	7032
32	Crabs	202	3012	1471	1260	5945
33	Rock lobster	0	4	0	0	4
34	Deep sea lobster	0	28	10	0	38
	Cephalopods					
35	Squids	484	2508	3	3	2998
36	Cuttlefish	403	0	7	0	410
37	Octopus	0	303	17	0	319
38	Bivalves	0	0	18	115	133
39	Others	48	653	183	31	915
	Sub-total 1	26048	46660	10393	15105	98206

b. Pelagic resources

Sl.No.	Depth	200-500 m				
	Region (Lat range °N)	NW (15-23)	SW (7-15)	SE (10-15)	NE (15-22)	Total
	species/group					
1	Wolf herrings	0	0	0	0	0
2	Oil sardines	0	0	0	0	0
3	Other sardines	0	0	0	0	0
4	Hilsa shad	0	0	1	0	1
5	Other shad					
6	Bombay duck	0	0	0	0	0
7	Anchovies	33	0	0	0	33
8	Other clupeids	0	0	0	0	0
9	Ribbon fishes	65	8211	16	0	8292
10	Carangids	6055	188	0	7	6250
11	Mackerel	174	0	4	0	178
12	Seer fish	0	0	0	0	0
13	Coastal tunas					
14	Barracuda	1681	0	0	0	1681
15	Mullets					
16	Beak fish	0	0	0	0	0
17	Flying fish	0	0	0	0	0
	Sub-total 2	8009	8399	20	7	16436
	Grand total	34057	55059	10414	15112	114642

Support Document 6.3.

Assessment of oceanic tunas and allied resources in the Indian EEZ

Dr M E John (with inputs from various sources)

Introduction

Oceanic tunas are among the resources that offer scope for further development in the Indian EEZ. The species occurring are yellowfin tuna (*Thunnus albacares*), skipjack tuna (*Katsuwonus pelamis*) and bigeye tuna (*Thunnus obesus*). Besides, billfishes and oceanic sharks are the important co-existing larger pelagics. The oceanic tunas are highly migratory, with their distribution covering the entire Indian Ocean except the southern latitudes. Results of the recent Indian Ocean Tuna Tagging Programme (IOTTP) undertaken by the Indian Ocean Tuna Commission (IOTC) have shown that the average distance covered by tagged yellowfin after one month of release is over 600 n miles (IOTC, 2009). In the IOTC-FSI small scale tagging conducted during 2005-2006 tagged fish released from Lakshadweep has been recaptured from Seychelles / Mauritius waters. As the oceanic tunas exhibit such large-scale migratory behaviour, estimation of Maximum Sustainable Yield of these stocks from the EEZ of any coastal nation cannot be realistic. Only regional approaches will give valid estimates. Nevertheless, to enable policy formulation and development planning, some approximation of a target yield from the Indian EEZ is worked out with reference to the overall potential / production in the Indian Ocean.

The tuna fishery in the Indian Ocean is fully developed, with several coastal countries as well as distant water fishing nations participating in the fishery. The Scientific Committee of the IOTC in its recent session (December 2009) has assessed the stock status of the tropical tunas and billfishes as follows:

- Yellowfin tuna: The stock size is close to or has possibly entered an overfished state recently. Fishing pressure has been too high in recent years resulting in decline of the population to levels below the optimal. Catch and fishing pressure should not exceed MSY levels (300,000 t).

- Skipjack tuna: It is a highly productive species and robust to overfishing. Catches have increased with increasing fishing pressure, but the trend of some indicators suggests that the stock status should be closely monitored. Stock size and fishing pressure are considered to be within acceptable limits.

- Bigeye tuna: Stock and fishing pressure are close to the optimal indicating that the stock is fully utilized. Stock size indicators have gradually declined since 1970s. Catches should not exceed the MSY level (110,000 t).

- Billfishes: Among billfishes, stock status has been assessed only for swordfish. The overall stock size and fishing pressure are estimated to be within acceptable limits. MSY is estimated to be 33,000 t. In case of marlins and sailfish no quantitative stock assessment is available and the stock status is uncertain.

Database

Data from the following three sources are used in the estimation process.

a) Nominal catch of oceanic tunas and allied species from the Indian Ocean during the last 10 years (1999-2008) derived from the IOTC data base and the latest assessment of MSY by the Scientific Committee of the IOTC (Table-6.3.1).

b) Satellite derived data on primary production from the Indian EEZ and the Indian Ocean during the period 2006-2008 obtained from the CMLRE (MoES), Cochin (Table-6.3.2).

c) CPUE obtained in tuna longline survey conducted by FSI vessels in the Indian EEZ including Andaman & Nicobar waters during 1989 – 2008 (Table-6.3.3). The survey covered operation of 3.27 million hooks by multifilament as well as monofilament longline systems.

Table-6.3.1. Nominal catch and MSY of oceanic tunas and allied species in the Indian Ocean (unit: 1000 t)

Species	Highest Catch	10-yr average (99-2008)	5-yr average (2004-08)	Highest moving average (5-year)	Latest year (2008)	MSY (IOTC, 2009)
Yellowfin tuna	516 (2004)	388	411	443 (02-06)	318	300
Bigeye tuna	151 (1999)	128	122	140 (96-00)	107	110

Skipjack tuna	613 (2006)	480	500	519 (02-06)	447	NA
Bill fishes	83 (2004)	70	72	76 (02-06)	58	NA *

(Source: IOTC) * Estimate available only for swordfish (33,000 t)

Table- 6.3.2. Estimated Primary Production in the Indian EEZ and Indian Ocean

Region / latitude	Area ($10^6 km^2$)	Total PP (10^6t.C/yr)	PP (t C/yr/ km^2)
Indian EEZ	2.02	323.9993	160.3960
Indian Ocean (20°S-24°N)	23.21	2846.5138	122.6417
Indian Ocean (30°S-24°N)	32.82	3817.5040	116.3164

(Source: CMLRE, Cochin)

Table-6.3.3. CPUE recorded in longline survey by FSI fleet :1989 – 2008

Species	Hooking rate (No./100 hooks)	Catch rate Kg./100 hooks)
Total	*1.298*	*33.290*
Yellowfin tuna	0.429	11.265
Bigeye tuna	0.003	0.114
Skipjack tuna	0.053	0.295
Swordfish	0.014	0.407
Marlin	0.040	1.661
Sailfish	0.112	2.985
Sharks	0.527	15.632

(Source: FSI)

Methodology and assumptions

1.On the basis of the production / MSY from the Indian Ocean, an estimate of Management Yield (MY), defined as a reference point at which restrictive management function may have to be put in place in the Indian Ocean, is assumed as follows.

- Yellowfin tuna: The MSY of 300,000 t assessed by the IOTC is based on a single model (*Multifan – CL*). While considering the historical catch record (Table 1), and further that the tuna landings of India and possibly some other coastal countries are not fully reflected in the IOTC database, the estimate may be on the lower side. Considering that the last 10-year average catch is closer to the MSY and as a matter of precaution, 90% of the 10-year average, that is about 350,000 t, is assumed as the Management yield.

- Bigeye tuna: The MSY estimate of 110,000 t by the IOTC was the output from five analytical models, which gave more or less consistent values. Hence the same figure is taken as the Management yield.

- Skipjack tuna: Considering the shorter life span, 5-year average seems to be reasonable. As the stock is highly productive and robust to overfishing, and the fishing pressure is assumed to be within acceptable limits, the precautionary reduction may not be necessary. Hence 500,000 t is considered as the Management yield.

- Billfishes: MSY estimate is available only for swordfish (33,000 t) while in case of other stocks the status is reported to be uncertain. Last 10-year average is taken as the Management yield.

2) From the Management yield projected for the Indian Ocean, the target yield from the EEZ is apportioned taking into account of three factors, *viz.*, primary production (Table-6.3.2), extent of distributional area of the stock and CPUE obtained in longline fishing (Table-6.3. 3), using the following expression.

$$TY_{eez} = MY_{io} \times \frac{P_{eez}}{P_{io}} \times \frac{A_{eez}}{A_{io}} \times \frac{CPUE_{eez}}{CPUE_{io}}$$

where, TY, MY, PP, A and CPUE represent the Target yield, Management yield, Primary production per unit area, extent of the area of distribution of the stock and catch per unit effort (Hooking rate = No. of fish / 100 hooks) obtained in longline fishing from the Indian EEZ / Indian Ocean.

3) The distribution of yellowfin tuna and skipjack in the Indian Ocean is mainly north of 20°S whereas bigeye tuna and billfishes occur in areas north of lat. 30°S. While the former two species are available throughout the EEZ, the occurrence of bigeye tuna is mostly in the latitudes south of lat. 10° N (Sudarsan *et al.*, 1988).

4) The average hooking rate of yellowfin tuna obtained in longline survey in the EEZ is 0.429% (Table-6.3.3).

5) The average hooking rate of yellowfin tuna by the Taiwanese longline fleet in the Indian Ocean hovers around 0.5% for the last two decades (IOTC, 2009). The hooking rate by the Indonesian longline vessels is also about 0.5% (Uktolseja, 1998).

6) As the commercial fishery always tends to concentrate in areas and seasons of high CPUE, in contrast to the survey objective involving systematic coverage of areas / seasons, the CPUE from the commercial fishery can be expected to be 2-3 times the CPUE obtained in the survey. The CPUE realized by 9 converted vessels (20-24 m OAL) during 2005-2007 was >2%.

7) In the Indian Ocean the proportion of yellowfin tuna occurring in longline and other gears targeting the surface swimming component is 25:75 (last 10 years). The same proportion is considered to be valid for the Indian EEZ.

8) The relative proportion of yellowfin and skipjack in the Indian Ocean is 1:1.24 (last 10 years). The same ratio is considered to be valid for the EEZ.

9) The ratio in the catch rate of yellowfin tuna and bigeye tuna recorded in the survey was 1:0.018. While bigeye tuna inhabits the deeper layers of thermocline, the gear used in the survey was targeting yellowfin tuna occurring in the shallow region of thermocline. It is assumed that by deploying deep longline and by concentrating effort in areas south of lat. 10°N, the catch rate of bigeye tuna can be increased 2-3 times.

10) The ratio of yellowfin tuna and sharks recorded in the survey was 1:1.387, based on which the Target yield of pelagic sharks was estimated. Nevertheless, considering the sharp decline reported in the CPUE of sharks in longline surveys (John and Varghese, 2009) and further considering the biological characteristics, namely, low natural mortality, long lifespan and low fecundity of sharks and in view of the FAO's International Plan of Action for

Conservation and Management of shark fisheries (IPOA – Sharks) and the recent IOTC Resolution 10/12 which prohibits catching, retaining or landing of thresher sharks (Fam. Alopiidae) by vessels in the IOTC's record, as a precautionary approach, only 75% of the estimate is considered as the target yield.

11) The relative proportion of catch of yellowfin tuna and billfishes in the Indian ocean is 1:0.18 (last 10 years). The same ratio is considered to be valid for the EEZ.

Target yield estimates

The target yield of the tunas and other larger pelagics from the Indian EEZ estimated on the basis of the above methodology is 216,500 t (Table-6.3.4).

Table- 6.3.4. Target yield of oceanic tunas and allied species from the Indian EEZ.

Sl. No.	Species	Target yield (t)
1	Yellowfin tuna	80,000
2	Skipjack tuna	99,000
3	Bigeye tuna	500
4	Billfishes	14,400
5	Pelagic sharks	20,800
6	Other species (Barracuda, Dolphin fish, Wahoo etc.)	1,800
	TOTAL	**216,500**

In the case of yellowfin tuna, out of the projected yield of 80,000 t, the sub-surface component that can be targeted by longlining is estimated to be 20,000 t.

As CPUE indicators from resources survey are not available for skipjack, apportioning based on two factors, *viz.*, the extent of area and primary production, gave a result of 57,900 t. whereas based on the relative proportion of yellowfin and skipjack in the Indian Ocean (1:1.24), the Target yield worked out to 99,000 t. While considering the annual average (2004-2008) catch of skipjack reported by some of the neighboring countries, *viz.*, Maldives (110,600 t), Sri Lanka (71,400 t) and Iran (68,400 t), the latter figure estimated for the Indian EEZ appears reasonable.

Comparison with earlier estimates

Variation of the target yield from the MSY assessed in the earlier revalidations (Table 5) is of high magnitude in case of yellowfin tuna, bigeye tuna and pelagic sharks.

In case of yellowfin tuna, the reduced assessment is a reflection of the recent finding of the IOTC Scientific Committee that the fishing pressure on the stock has been too high in recent years resulting in decline of the population to levels below the optimal and that the population may not be able to sustain the 1992 – 2002 level of catches.

Table-6.3.5. Comparison of the Target yield with estimates of MSY in earlier assessments

	Species	Revalidation 1991	Revalidation 2000	Revalidation 2011
1	Yellowfin tuna	108,900	114,800	80,000
2	Skipjack tuna	100,200	85,200	99,000
3	Bigeye tuna	300	12,500	500
4	Billfishes	3,800	5,100	14,400
5	Pelagic sharks	31,600	26,200	20,800
6	Other species	1,200	NA	1,800
	TOTAL	**246,000**	**243,800**	**216,500**

As regards bigeye tuna, the assumption in the earlier revalidation (2000) that the proportion of catch of the species in the Indian Ocean is valid for the Indian EEZ is erroneous as the main area of occurrence of the stock is south of lat.5°N. The target yield of pelagic sharks is reduced in line with the global approach on conservation of shark resources.

[][][]

Support Document 6.4.

Revalidation of Potential Yield from Indian EEZ – A Trophodynamic approach.

V.N.Sanjeevan*,Smitha B.R, Asha devi C.R , Abdul Jaleel K.U & Jayalakshmi K.J.
*Centre for Marine Living Resources and Ecology, Ministry of Earth Sciences, Kochi-37.

1. Introduction

Estimation of potential fishery yield (PFY) from the Indian EEZ is worked out on the basis of carbon transfer efficiencies which are considered to vary with the ecosystem. PFY from the Indian EEZ is represented as the cumulative production potential from the 5 ecosystems encompassing the Indian EEZ; viz; North East Arabian Sea Ecosystem (NEASE), South East Arabian Sea Ecosystem (SEASE), Andaman Island Ecosystem (AIE), South West Bay of Bengal Ecosystem (SWBE) and North West Bay of Bengal Ecosystem (NWBE) which have distinct physical and biological attributes. Potential yield for each ecosystem is estimated separately for coastal (<200m depth) and offshore (>200m depth) areas (Figure 6.4.1) covering the summer monsoon (June to September), Fall Inter Monsoon (October), Winter Monsoon (November to February) and Spring Inter Monsoon (March to May) seasons.

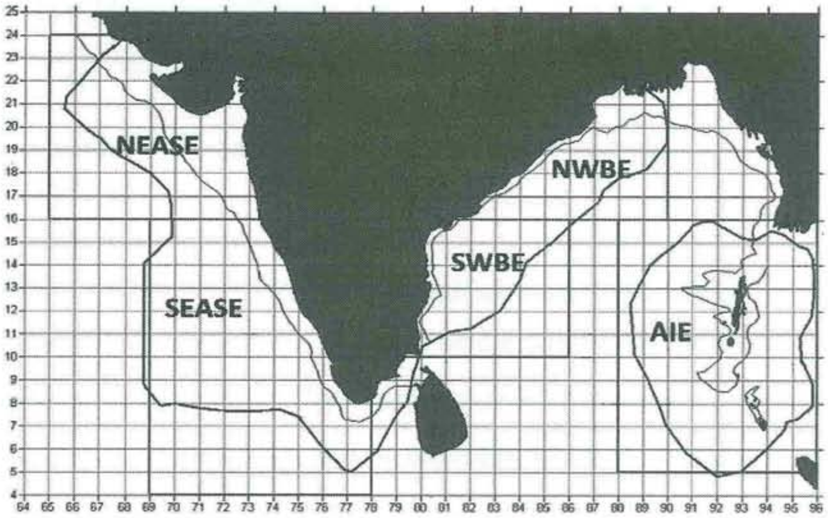


Figure 6.4.1. Ecosystems of Indian EEZ.

2. Methods and Materials: Yield estimates for pelagic fishery are derived from primary production and secondary production and for demersal fishery from benthic production after cross verification with in situ data from the various cruises of Fishery Oceanographic Research Vessel Sagar Sampada (FORVSS) through the years 2002-2009.

2.1. Vertically Generalised Production Model (VGPM) of Behrenfield and Falkowski (1997) is used to describe the relationship between the surface chlorophyll from satellite data and depth integrated primary production. The VGPM is a chlorophyll based model that estimates Net Primary Production (NPP) from chlorophyll using a temperature dependent description of chlorophyll specific photosynthetic efficiency. In the VGPM, NPP is a function of chlorophyll, available light and photosynthetic efficiency. The core equation describing the relationship is expressed as:

$$PP_{eu} = 0.66125 \times P^{B}_{opt} \times \frac{E_0}{E_0 + 4.1} \times C_{SAT} \times Z_{eu} \times D_{IRR}$$

Where; C_{SAT} is Satellite surface chlorophyll concentration as derived from measurements of water leaving radiance (mg Chl/m^3). VGPM calculations of global primary production were based on monthly average C_{SAT}.

D_{IRR} is daily photoperiod (in decimal hours) calculated for the middle of the month for each pixel

E_0 is Sea surface daily PAR (mol quanta/m^2/d)

Z_{eu} is physical depth (m) of the euphotic zone defined as the penetration depth of 1% surface irradiance based on the Beer-Lambert law.

Z_{eu} is calculated from C_{SAT} following Morel and Berthon, 1989.

$$Z_{eu} = \begin{cases} 568.2(C_{TOT})^{-0.746} & if\ Z_{eu} < 102 \\ 200.0(C_{TOT})^{-0.293} & if\ Z_{eu} > 102 \end{cases}$$

Where;

$$C_{TOT} = \begin{cases} 38.0(C_{SAT})^{0.425} & if\ C_{SAT} < 1.0 \\ 40.2(C_{SAT})^{0.507} & if\ C_{SAT} \geq 1.0 \end{cases}$$

P^{B}_{opt} is the optimal rate of daily carbon fixation within a water column [mg C (mg Chl)$^{-1}$ h^{-1}].

P^{B}_{opt} can be modeled according to various temperature-dependent relations hips.

$$P^B_{opt} = \begin{cases} 1.13 & if\, T < -1.0 \\ 4.00 & if\, T > 28.5 \\ P^{B'}_{opt} & Otherwise \end{cases}$$

$$P^{B'}_{opt} = 1.2956 + 2.749 \times 10^{-1}\, T + 6.17 \times 10^{-2}\, T^2 - 2.05 \times 10^{-2}\, T^3 + 2.462 \times 10^{-3}\, T^4 - 1.348 \times 10^{-4}\, T^5 + 3.4132 \times 10^{-6}\, T^6 - 3.27 \times 10^{-8}\, T^7$$

The PP_{eu} is daily carbon fixation integrated from the surface to Z_{eu} , (mg C/m^2)

Depth integrated monthly composite chlorophyll. a data for the Indian EEZ covering SM, WM, FIM and SIM seasons were generated on 9°X9° Km spatial resolution using Ocean color data(chl a) from SeaWiFS and MODIS AQUA. Photosynthetically active radiation (PAR) from SeaWiFS and SST from AVHRR and MODIS AQUA data covering the years 2003 (below normal SEAS upwelling), 2005 (prolonged upwelling along SEAS), 2009 (below normal upwelling along SEAS). Daily photoperiod (in decimal hours) are calculated for the middle of the month for different latitudes from (Meeus Jeans, 1991) astronomical algorithms.

2.2. Direct estimate of pelagic fishery potential from secondary production (zooplankton) are based on 220 MPN (Multiple Plankton Net) collections of *FORV Sagar Sampada* covering the 5 ecosystems in the Indian EEZ. Biovolume (Bv) of zooplankton is estimated as DV/VWF where DV is the displacement volume in ml and VWF is the volume of water filtered. VWF = depth of Mixed Layer x Mouth area of net ($0.25m^2$).

2.3 Estimate of demersal fishery resources from benthic production are based on 529 grab samples from 81 stations along the east coast and 522 grabs samples from 121 stations along the west coast representing 30, 50, 100, 150, 200, 250, 500 and 1000m depths along identified transects. Smith McIntyre grab of 0.1 and 0.2 m^2 were used for the survey.

3. Results and discussions:

3.1 Estimate on Potential Yield of Pelagic fishery from PP: Satellite derived chl a where validated with corresponding in situ data on chl.a collected through FORV Sagar Sampada (168 stations) covering the SM 2009, WM 2000 and SIM 1999 following the procedures of Strickland and Parsons (1972) (Figure 6.4.2a-c).

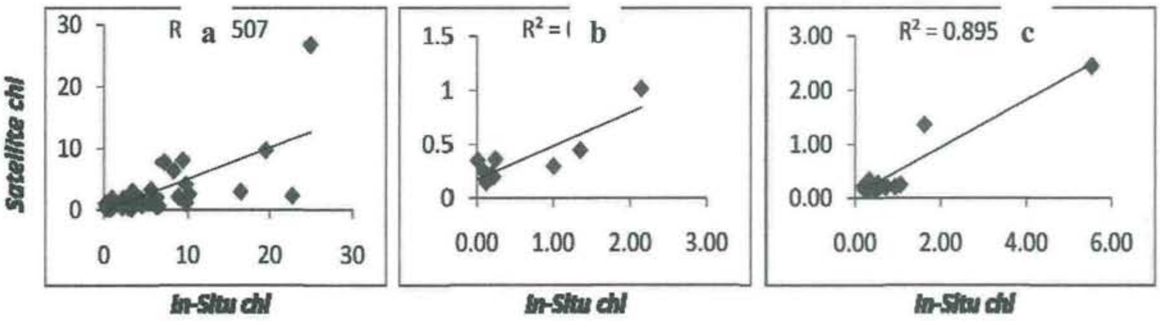


Figure 6.4.2a-c. Validation of satellite chl a against in-situ chl during a) SM, b)WM and c)SIM

While the fit was found to be good for WM and SIM (r^2=0.757 and r^2=0.895 respectively), the relationship was weak for SM probably due to the poor satellite coverage of the area due to cloud cover. SM data sets from SeaWiFS were calibrated using a factor (0.491). Similarly a factor of 0.54 have been used to calibrate the satellite derived PP for subsurface chlorophyll maxima, observed during FIM in the Arabian Sea. Calculated values were then utilized in the further computations of primary productivity (PP) (Table-6.4.1).

Table-6.4.1. Estimated PP from Satellite data

Ecosystem	Component	Area ($x10^6 km^2$)	Average PP in Ton C/Km^2/d				Total PP (m Ton C/yr)
			SIM	SM	FIM	WM	
SEAS	Coast	0.1025	0.4183	1.2520	0.9290	0.2718	25.89471
	Offshore	0.5755	0.3190	0.5263	0.5385	0.2090	77.86195
NEAS	Coast	0.1781	0.5580	1.0691	1.2934	0.8234	57.11224
	Offshore	0.1015	0.4480	0.7978	0.5466	0.6726	23.97749
SWBE	Coast	0.0272	0.4280	1.0446	0.6272	0.4094	6.402694
	Offshore	0.1797	0.2670	0.5730	0.4015	0.3266	26.25507
NWBE	Coast	0.06353	0.4170	1.2100	0.6622	0.5426	17.25638
	Offshore	0.2048	0.3150	0.8740	0.4510	0.3711	39.75664
Andaman	Coast	0.0909	0.2270	0.2412	0.2106	0.1924	7.265003
	Offshore	0.5008	0.2490	0.2390	0.2832	0.1955	42.2171

Validation of VGPM based estimates of PP with in situ PP by C^{14} technique (UNESCO, 1994) from 78 stations of FORV-SS gave R^2 of 0.757 indicating good correlation between the 2 measurements (Figure 6.4.3).

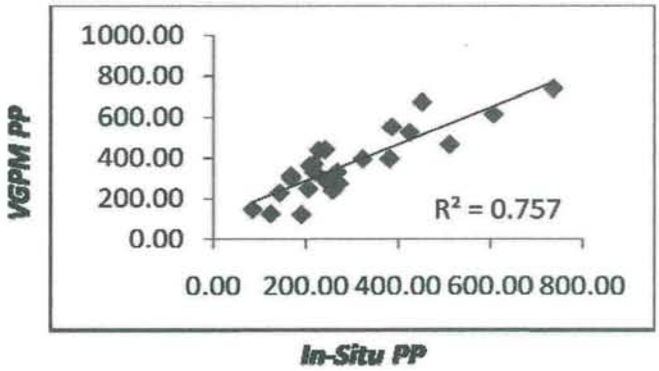


Figure 6.4.3. Validation of VGPM based PP against *in situ* PP

Transfer Efficiency (TE) from trophic level-1 (producers) to trophic level-2 (Primary consumers) for each ecosystem and season is taken as the percentage secondary production to the PP in units of carbon [representing Consumption Efficiency (CE) and Assimilation Efficiency (AE)] multiplied by Production Efficiency (PE) which is considered to decrease proportionally with depth ($PE=10/(D)^{1/2}$) due to increase in respiratory heat loss. (Colin R.Townsend *et al.*, 2008). Thus TE = CE× AE ×PE. Total carbon production at secondary level is derived by applying the TE's to the satellite derived PP values (Table-6.4.2).

Table 6.4.2. Estimate of SP from average annual TE's

Ecosystem	Component	Total PP (mt Cy-1)	Transfer efficiencies					SP (mt Cy-1)
			SIM	SM	FIM	WM	Ann. Avg.TE	
SEAS	Coastal	25.895	26.285	25.387	5.86847	28.9483	18.1627	4.75904
	Off	77.861	29.193	18.089	21.2366	15.5661	8.6187	6.71262
NEAS	Coastal	57.112	8.9704	24.861	2.14147	12.2494	10.1267	5.8522
	Off	23.977	33.585	16.216	11.8051	8.73533	7.2101	1.7286
SWBE	Coastal	6.4027	6.0507	27.7186	2.56792	17.199	11.242	0.72833
	Off	26.255	14.871	12.5886	18.3425	20.3799	6.7836	1.5476
NWBE	Coastal	17.256	5.6247	38.9246	1.83256	11.9879	12.257	2.14029
	Off	39.7566	10.635	7.77251	13.5762	25.5321	5.8953	2.69656
Andaman	Coastal	7.265	-	-	-	-	11.004	0.823
	Off	42.2171	-	-	-	-	5.371	2.30017

Transfer of organic carbon from secondary to tertiary level is related to the number of trophic levels in a food chain. In the upwelling systems and coastal waters, food chains are relatively short [phytoplankton → herbivorous fish or Phytoplankton →Zooplankton→fish] whereas in the offshore waters the chain can be long in the form of Phytoplankton→ Micro-zooplankton→ Ciliates→ Ostracodes→ fish → larger fish etc. At each step of the food chain, there is loss of energy. Accordingly, short food chains are assumed to have a TE of 10% and for the longer food chains a TE of 1% is attributed (Ryther, 1969). The coastal waters and upwelling systems of the Indian EEZ have predominantly (70%), the short food chain represented by large populations of juvenile fish and schooling fishes like clupeoids, which are herbivorous or planktonivorous in nature. The remaining 30% may have comparatively long food chain (phytoplankton→microzooplankton→juvenile fish→ adult fish) with low TE (1%). In the offshore waters, microzooplankton food chain is more dominant (Figure 6.4.4). This, together with large sized carnivorous mesozooplankton, fishes of higher age groups and top carnivores may account for 70% of organisms with 1% TE and 30% with 10% TE for the offshore areas.

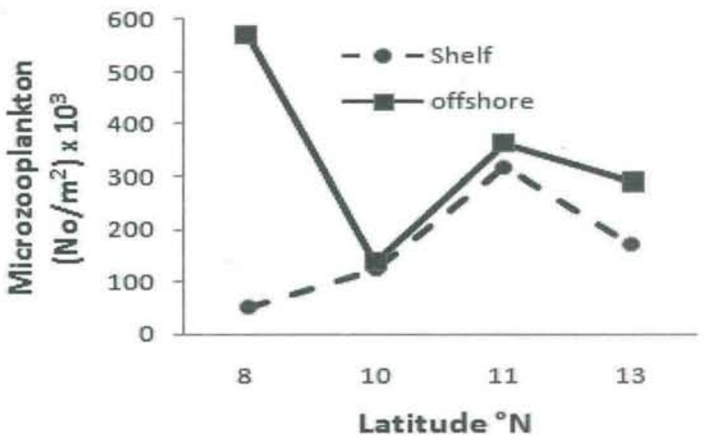


Figure 6.4.4. Microzooplankton is more dominant in the off shore waters

Transfer of carbon from secondary to tertiary levels are estimated using the above TE's and then converted to live weight by multiplying with the factor 10 (Desai and Bhargava, 1998). About 50% of the live weight is assumed to be fishes from which MSY is estimated using the equation, MSY = Bv x M x 0.5 (Gulland), where Bv is the biomass of fish, M the natural mortality coefficient which is taken as 1 for offshore waters and 0.85 for coastal areas. MSY is expressed in million tons (Table-6.4.3).

Table-6.4.3. MSY estimates of Pelagic fishery in Indian EEZ (million tons)

Ecosystem	Component	SP (mt Cy^{-1})	Biomass (mt Cy^{-1})	Live Biomass (mt)	Live Wt. of Fishes (mt)	MSY (mt)
SEAS	Coastal	4.75904	0.34741	3.474103	1.737052	0.738247
	Off	6.71262	0.248367	2.483671	1.241835	0.620918
NEAS	Coastal	5.8522	0.427211	4.272106	2.136053	0.907823
	Off	1.7286	0.063958	0.639584	0.319792	0.159896
SWBE	Coastal	0.72833	0.156241	1.562413	0.781207	0.112983
	Off	1.5476	0.099773	0.997731	0.498865	0.143154
NWBE	Coastal	2.140292	0.053168	0.531684	0.265842	0.332013
	Off	2.69656	0.057261	0.572614	0.286307	0.249433
Andaman	Coastal	0.823	0.060079	0.60079	0.300395	0.127668
	Off	2.300174	0.085106	0.851064	0.425532	0.212766
Total						**3.604899**

3.2. Direct estimate of pelagic fishery potential from secondary production (zooplankton):

Biovolume of zooplankton is estimated as:

$$Bv = \frac{DV}{VWF}$$

Where; DV is the displacement volume in ml and VWF is the volume of water filtered.

VWF = depth of Mixed Layer x Mouth area of net ($0.25m^2$). Average biovolume (BV) for each ecosystem is given in Table-6.4.4.

Table-6.4.4. Average Biovolume (BV) for each echo system (Values in parenthesis changed to positive)

Ecosystem	Component	BV (ml/m^2) SM	FIM	WM	SIM
NEASE	Coastal	11.78 (0.412)	17.82 (0.713)	17.14 (0.381)	10.27 (0.357)
	Offshore	22.57 (0.571)	10.73 (0.285)	13.03 (0.202)	23.27 (0.604)
SEASE	Coastal	17.91 (1.377)	34.66 (1.231)	10.02 (0.191)	16.01 (0.564)
	Offshore	16.61 (0.547)	18.79 (0.546)	5.67 (0.089)	12.03 (0.281)
NWBE	Coastal	23.53 (0.523)	8.19 (0.482)	11.05 (0.623)	6.49 (0.519)
	Offshore	21.63 (0.534)	14.43 (0.78)	16.77 (0.341)	9.79 (0.979)

SWBE	Coastal	12.83 (0.41)	10.36 (0.509)	8.89 (0.147)	6.75 (0.25)
	Offshore	7.77 (0.161)	9.06 (0.492)	14.2 (0.31)	5.58 (0.217)
AIE	Coastal	-	-	10.95 (-0.264)	-
	Offshore	4.82 (-0.075)	-	11.73 (-0.28)	6.39 (-0.169)

BV for each season and ecosystems are converted to standing stock of zooplankton (SS_z) by multiplying with the number of generations of zooplankton (τ/n) represented by 62% copepods.

$$SS_z = \frac{n}{\tau} \times B$$

The generation time (τ) is estimated for copepods using the temperature dependent formula of Harris *et al.*, 2000.

$$\tau = 128.8\, e^{-0.120T}$$

Where T is the SST for the season and n represent the number of days in a season. SS_z is then converted to total carbon (g) using the formula

$$TC = SS_z \times 0.075 \times 0.342$$

Where; 1 ml SS_z has 0.075 g dry weight. Following Madhupratap *et al.*, 1990, dry weight is converted to carbon by multiplying with 0.342 (carbon content is 34.2% of dry weight).

Transfer efficiencies from secondary to tertiary levels are estimated on the same principles described earlier. Carbon at tertiary level is converted to live weight by multiplying by 10 and 50% of the tertiary biomass is considered as fishes, from which MSY is estimated following Gulland;

$$MSY = Bv \times M \times 0.5$$

Table-6.4.5. MSY in different ecosystem in million t

Ecosystem	Component	Total carbon at TP (T/km^2)				Live weight	MSY
		SM	FIM	WM	SIM		
NEASE	Coastal	0.123	0.049	0.139	0.091	4.02	0.857
	Offshore	0.024	0.003	0.010	0.020	0.57	0.145
SEASE	Coastal	0.085	0.056	0.062	0.087	2.9	0.617
	Offshore	0.099	0.030	0.033	0.073	2.35	0.588
NWBE	Coastal	0.078	0.007	0.032	0.015	1.32	0.282
	Offshore	0.040	0.007	0.027	0.013	0.87	0.223
SWBE	Coastal	0.020	0.004	0.014	0.007	0.45	0.099
	Offshore	0.014	0.004	0.026	0.007	0.51	0.131
AIE	Coastal	-	-	0.054	-	0.54	0.115
	Offshore	0.024	-	0.056	0.025	1.05	0.265
Total							**3.322**

3.3.Estimate of demersal fishery resources from benthic production: Contributions from both macro and meiobenthos are considered in the estimation of demersal fishery.

Macrobenthos was separated using 0.5 mm sieve and sorted into four groups namely Polychaets, Crustaceans , Molluscs and other miscellaneous groups. Wet weight of each sample was determined following standard procedures. From this annual macrobenthic production for each ecosystem was estimated by integrating the average production from each depth strata (0-50, 50-100 etc) taking two generations per year as suggested by Sanders (1956). This was converted to organic carbon using the conversion factor of Parulekar *et al.*, (1980) where, dry weight is 22% of wet weight and carbon is 34.5% of dryweight.

Meiobenthos: Average of wet weight of different components of meiofauna viz; Nematodes, Foraminiferans, Haerpacticoid copepods etc. were determined by direct weighing using high precision electronic balance. The biomass of meiobenthic fauna in each depth strata (0-50, 50-100 etc.) were integrated to estimate the total biomass from each ecosystem from which total standing stock was estimated by multiplying with 18.25, the average of the number of generations for nematodes (16.9) Zaika *et al.*, 1979, foraminifera (20 days) Mikael G and Kjell N, 1999, and Herpecticoid copepods (21.6 days) Victor Ugo and M Mistri (1991). Total standing stock was converted to Gram carbon following Gerlach (1978) were dry weight is 25% of wet weight and carbon 50% of dry weight. From the total carbon 10% is expected to be assimilated by the next trophic level which is converted to live weight by multiplying with the factor 10. For coastal waters, 60% of the live weight (Steel 1974) is expected to be fishes and for offshore waters 40% is considered to represent fish. From the available fish biomass MSY is estimated using Gulland formula:

$$\boldsymbol{MSY = Bv \times M \times 0.5}$$

Where Bv stand biomass of fish, M the natural mortality coefficient and 0.5 is the escapement factor. MSY of the demersal fishes (in million tons) is given in the Table-6.4.6.

Table-6.4.6. MSY in different ecosystem in million t

Ecosystem	Component	Total Carbon (Million t)	Assimilated carbon (10%)	Total Biomass (wet weight)	Biomass of fish	MSY
NEASE	Coast	0.6189	0.06189	0.6189	0.3713	0.1578
	Offshore	0.1783	0.01783	0.1783	0.1069	0.0534
SEASE	Coast	0.5197	0.05197	0.5197	0.3118	0.1325
	Offshore	0.9581	0.09581	0.9581	0.5748	0.2874
NWBE	Coast	0.1046	0.01046	0.1046	0.0628	0.0267
	Offshore	0.1279	0.01279	0.1279	0.0767	0.0384
SWBE	Coast	0.0781	0.00781	0.0781	0.0468	0.0199
	Offshore	0.3189	0.03189	0.3189	0.1913	0.0957
AIE	Coast& Offshore	-	-	-	-	0.0425*
Total						**0.8545**

(**Parulekar, 1982*)

The revalidated potential of fishery resources of the different eco-regions of the Indian EEZ is given in Table-6.4.7.

Table-6.4.7.Revalidated Potential Yield (million t) from Indian EEZ

Ecosystem	MSY-Pelagic		MSY-Demersal	Total MSY
	From PP	From SP	From BP	
SEAS	1.359165	1.205825	0.14998	1.432475
NEAS	1.067719	1.00195	0.21132	1.246155
NboB	0.581445	0.50481	0.06507	0.470775
SboB	0.256137	0.229965	0.11562	0.496094
Andaman	0.340434	0.380156	0.0425	0.402795
Total	**3.604899**	**3.322706**	**0.8545**	**4.318484**

4.Conclusion:

Estimate of pelagic fishery for Indian EEZ from primary production and secondary production, provide an MSY of 3.605 and 3.322 million tons respectively, the average being 3.463 million tons. For the demersal fishery, estimates from benthic production give an MSY of 0.855. Thus the revalidated Maximum Sustainable yield (MSY) of fish from the Indian EEZ is 4.318 million tons.

[][][]

Abbreviations

AE	Assimilation Efficiency
AIE	Andaman Island Ecosystem
AVHRR	Advanced Very High Resolution Radiometer
B	Biomass
BP	Benthic Production
BV	Biovolume
CBD	Convention on Biological Diversity
CCAMLR	Commission for Conservation of Antarctic Marine Living Resources
CCRF	Code of Conduct for Responsible Fisheries (of FAO)
CE	Consumption Efficiency
CFD	Crustacean Fisheries Division (of CMFRI)
Chl	Chlorophyll
CITES	Convention on International Trade in Endangered Species
CMFRI	Central Marine Fisheries Research Institute (of ICAR)
CMLRE	Centre for Marine Living Resources and Ecology (of MoES)
CMS	Convention on Migratory Species
CPUE	Catch Per Unit Effort
CUSAT	Cochin University of Science and Technology
DAHDF	Department of Animal Husbandry, Dairying and Fisheries
DFD	Demersal Fisheries Division (of CMFRI)
DOD	Department of Ocean Development (Presently MoES)
DSL	Deep Scattering Layer
EEZ	Exclusive Economic Zone
EU	European Union
FAO	Food and Agriculture Organization (of the United Nations)
FOC	Flag of Convenience
FORVSS	Fishery Oceanographic Research Vessel *Sagar Sampada*
FRAD	Fisheries Resource Assessment Division (of CMFRI)
FSI	Fishery Survey of India
g	Gram
GoI	Government of India
ICAR	Indian Council of Agricultural Research
IOTC	Indian Ocean Tuna Commission
IOTTP	Indian Ocean Tuna Tagging Programme
IPOA	International Plan of Action
IUU	Illegal, Unreported and Unregulated (fish catch)
kg	Kilogram
kt	Knots
LOP	Letter of Permission
m	Meter
M	Natural mortality
MARPOL	International Convention for the Prevention of Pollution from Ships
MCS	Monitoring, Control and Surveillance
MFD	Molluscan Fisheries Division (of CMFRI)
MFRA	Marine Fisheries Regulation Act
mg	Milligram

MoA	Ministry of Agriculture, Government of India
MoES	Ministry of Earth Sciences (formerly DOD)
MPEDA	Marine Products Export Development Authority
MPN	Multiple Plankton Net
MSY	Maximum Sustainable Yield
MY	Management Yield
NAIP	National Agricultural Innovation Project (of ICAR)
NEAS	North East Arabian Sea
NEASE	North East Arabian Sea Ecosystem
NIO	National Institute of Oceanography
NIOT	National Institute of Ocean Technology
NMLRDC	National Marine Living Resources Data Centre (of CMFRI)
NPOA	National Plan of Action
NPP	Net Primary Production
NWBE	North West Bay of Bengal Ecosystem
OAL	Overall Length (also LOA: Length overall)
PAR	Photosynthetically Active Radiation
PE	Production Efficiency
PFD	Pelagic Fisheries Division (of CMFRI)
PFY	Potential Fishery Yield
PP	Primary Production
PY	Potential Yield
RFMO	Regional Fisheries Management Organisation
SEAS	South East Arabian Sea
SEASE	South East Arabian Sea Ecosystem
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SEETTD	Socioeconomic Evaluation & Technology Transfer Division (of CMFRI)
SP	Secondary Production
SST	Sea Surface Temperature
SWBE	South West Bay of Bengal Ecosystem
t	Tonne
TAC	Total Allowable Catch
TE	Transfer Efficiency
UNFCCC	United Nations Framework Convention on Climate Change
UNCLOS	The United Nations Convention on the Law of the Sea
VGPM	Vertically Generalized Production Model
VMS	Vessel Monitoring System
WG	Working Group
ZSI	Zoological Survey of India

Bibliography

Alagaraja, K. 1984. Simple methods for estimation of parameters for assessing exploited fish stocks. *Indian J. Fish.*, **31**(2): 177-208

Alagaraja, K. 1989. A brief appraisal of marine fisheries in India. *CMFRI Bulletin* No. 44, Part I: 36-41.

Anon, 1972. Wildlife (Protection), Act, 1972, Government of India.

Anon, 1996. *Report of the Committee to Review Deep- sea Fishing Policy.*

Behrenfield, M. J.and P.G. Falkowski 1997. Photosynthetic rates derived from satellite-based chlorophyll concentration. Limnology and Oceanography, 42, 1-20.

Chesalin, M.V., G.V.Zuyev and V.N.Nikolsky, 1995. Squid *Sthenoteuthis oualaniensis* (Cephalopoda: Ommastrephidae) is the 'master' of the Arabian Sea. In: A.Guerra, E.Rolan and F. Rochi, Eds, 12th International Malacological Congress, Vito, Italy.

CMFRI, 2000. *Annual Report 1999-2000.* Central Marine Fisheries Research Institute, Cochin. 161 p.

Constable, A.J., 2002. The Status of Antarctic Fisheries Research in: Jabour-Green, J. & Haward, M. (Eds). *The Antarctic: Past, Present and Future.* Antarctic CRC Research Report #28. Hobart, pp.71-84.

Cushing, D.H. 1973. Production in the Indian Ocean and the transfer from primary to the secondary level. *In: The Biology of the Indian Ocean.* Bernt Zeitzschel (Ed.) Springer-Verlag, Berlin, 475-486

Dalal, S.G. and A.H. Parulekar, 1980. *Oceanography of the Indian Ocean*, B.N.Desai (Ed). 227-237.

Desai, B.N., R.M.S. Bhargava and J.S. Sarupria, 1990. Estimates of fishery potentials of the EEZ of India. *Estuary, Coastal Shelf Science*, **30**: 635-639.

Desai, B.N. and R.M.S. Bhargava 1998. The biological production and fishery potential of the exclusive economic zone of Indian EEZ, in: Shermann, K., Okemwa, N.E., and Ntiba (Eds.), *Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability and Management.* Blackwell Science. 394 p.

George, P.C., B.T. Antony Raja and K.C. George, 1977. Fishery Resources of the Indian Economic Zone, *Souv. Integrated Fisheries Project Silver Jubilee Celebration*: 70-120

GOI, 2000. *Report of the Working Group for revalidating the potential of fishery resources in the Indian EEZ,* DAHDF, MoA, New Delhi, 43p.

Gulland, J.A. (Ed.) 1971. *The Fish Resources of the Ocean*, Fishing News (Books) Ltd., England, 255p.

Gulland, J. A. 1971. Ecological aspects of fishery research. *Adv. Ecol. Res.* 7: 115-176.

IOTC, 2009. Report of the 12th Session of the Scientific Committee. Victoria, Seychelles, 30 November – 4 December 2009. *IOTC–2009–SC–R(E)* : 190 pp.

James, P.S.B.R., K. Alagarswami, K.V. Narayana Rao, M.S Muthu, M.S. Rajagopalan, K. Alagaraja and C. Mukundan. 1989. Potential Marine Fishery Resources of India. Seminar Potential Marine Fishery Resources, Cochin, April 23, 1986; *CMFRI Spl. Pub. 30.*

James, P.S.B.R., T. Jacob, K.C. George, V. Narayana Pillai, C.J. Mathew, M.S. Rajagopalan. 1989. National strategy for exploitation and utilisation of potential marine fishery resources of India- A projection *CMFRI Bulletin* No.44: 111-136

James, P.S.B.R. and V. Narayana Pillai. 1990. Fishable concentration of fishes and crustaceans in the offshore and deep sea areas of Indian EEZ based on observations made on board FORV Sagar Sampada. *Proc.1st Workshop Sci. Research. FORV Sagar Sampada*, 201 - 203

Jones, S. and S.K. Banerji. 1973. A Review of the living resources of the Central Indian Ocean. *Proc. Symp. Living Res. Of Sea Around India*. CMFRI Spl. Pub.: 1-17.

John, M. E. and B. C.Varghese, 2009. Decline in CPUE of oceanic sharks in the Indian EEZ: urgent need for precautionary approach. IOTC Working Party on Ecosystems and Bycatch, Mombasa, Kenya, 12-14 October 2009.

Joseph, K.M.1985. Marine Fishery Resources of India, In: E.R. Kulkarni & U.K. Srivastava(Eds.) A system frame work of marine food industry in India, 90-149 p.

Joseph, K.M.1987. The fish resources of the Indian Exclusive Economic Zone. National Seminar Planning Export Strategy for Indian Marine Fisheries, New Delhi, March 11, 1987

Madhupratap, M and P.Haridas, 1990. Zooplankton especially calanoid copepods in the upper 1000m of the southeast Arabian Sea. *Journal of Plankton Research*, **12**: 305-321.

Mathew, K.J., T.S Naomi, Geeta Antony, D. Vincent, R. Anil Kumar and K. Solomon. 1990. Studies on Zooplankton biomass and secondary tertiary production of the EEZ of India. *Proc. First Workshop Scientific Result* FORV Sagar Sampada, 5-7 June, 1989: 59-69.

Ministry of Agriculture 1996. Hand book of Fisheries Statistics.

Ministry of Agriculture/ Government of India/ July 2000. Report of the National Level Review Committee to assess the area wise requirements of different categories of fishing vessels below 20m OAL.

Mitra, G.N. 1973. Method of estimation of fish abundance in the Indian Ocean and steps to be taken for management of the commercial fisheries. *Proc. Symp. Living Res. Of Seas Around India, Spl. Pub.* CMFRI: 145-154

Morel, A. and J.A. Berthon 1989. Surface pigments, algal biomass profiles and potential production of the euphotic layer: Relationships reinvestigated in view of remote-sensing applications. *Limnology and Oceanography*, **34**(8): 1545-1562.

Murty, V.S. R. and P. Vedavyasa Rao. 1996. Marine fishery resources of India- Present status and management concerns. In: N.G. Menon and C.S.G Pillai (Eds.) Marine Biodiversity conservation and management, CMFRI, Cochin, 103-125p.

Nair, P.V.R and V.K. Pillai. 1985. Productivity of Indian Seas. *J. mar. biol. Ass. India* **25**(1& 2): 41-50.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R and Torres, F, 1998. Fishing down the marine food webs. *Science*, **279**: 860-863.

Pauly, D and Watson, R.2003. Counting the last fish. *Scientific American,* 2003 (July): 42-47

Pillai, N.N., 1995. Fish resources in Indian EEZ and deep sea fishing *Proceedings of National Workshop on fish resources in Indian EEZ and Deep sea fishing* held on 24.06.1995 at C.I.F.T., Cochin. Sponsored by Marine Resources Protection Committee (August, 1995).

Prasad, R. R, S. K. Banerji and P. V. Ramachandran Nair. 1970. A quantitative assessment of the potential fishery resources of the Indian Ocean and Adjacent Seas. *Indian J. Anim. Sci.,* 40 (1): 73:98.

Silas, E.G., 1972. Investigations on the Deep Scattering layers in the Laccadive Sea. In: *Proceedings of the Symposium on Corals & Coral Reefs. Mar. biol. Ass. India*, 257-274 p.

Silas,E.G., 1986. Cephalopod fisheries of India - An introduction to the subject with methodologies adopted for the study. In: (E.G.Silas, Ed) Cephalopod bionomics, fisheries and resources of the EEZ of India. *Bull. Cent. Mar. Fish. Res. Inst.*, **37**: 1-4.

Ryther, J.H., 1969. Photosynthesis and fish production in the sea. *Science*, **166**: 72-76.

Sathianandan, T.V. and J. Jayasankar. 2009. Managing the fishery in Kerala through simulation using surplus production model, genetic algorithm and spectral methods. *Indian J. Fish.*, **56**(3): 163-168

Silas, E. G., 1986. The whale Shark (*Rhinodon typus*, Smith) in Indian Coastal Waters: Is the species endangered or vulnerable? *Mar. Fish. Infor. Serve. T. & E.* No. 66.

Silas, E.G., 1986. Cephalopod resources prospective, priorities and targets for 2000 A.D. In: (E.G. Silas Ed.) Cephalopod bionomics, fisheries and resources of EEZ of India: *Bull. Cent. Mar. Fish. Res. Inst.*, **37**:172-183.

Silas, E. G. and P.P. Pillai. 1982. Resources of tunas and related species and their fisheries in the Indian Ocean. *Bull. Cent. Mar. Res. Inst*. 32, 174 pp.

Sparre, P. and S. C. Venema, 1998. Introduction to tropical fish stock assessment. Part-I. Manual. *FAO Fisheries Technical Paper. 306.1, Rev. 2*, FAO, Rome. 407 pp.

Steele, J.H., 1974. *The Structure of Marine Ecosystems*. Cambridge, Mass, Harvard University Press, 128 pp.

Sudarsan, D., T.E. Sivaprakasam, V.S. Somvanshi, M.E. John, K.N.V. Nair and Antony Joseph. 1988. An appraisal of the marine fishery resources of the Indian Exclusive Economic Zone. *Bull. Fish. Surv. India*, 18, 81 pp.

Sudarsan, D., T.E. Sivaprakasam, V.S. Somvanshi and M.E. John. 1989. Assessment of oceanic tuna and allied fish resources in Indian EEZ. *National Conference on Tunas*, Cochin, 21-22 April, 1989.

Sudarsan, D., M.E. John, A. K. Bhargava and S.M. Patil. 1990. Tuna longline fishery *in India, IPTP in Expert Consultation on stock assessment of tuna in the Indian Ocean Bangkok,* 2-6 July, 1990.

Sudarsan, D., V. S. Somvanshi and M. E. John, 1988. Atlas of tunas, billfishes and sharks in the Indian EEZ and adjacent oceanic regions. *FSI / FC(FA) /2 /88*: 57 pp.

Sudarsan, D., M.E. John and V. S. Somvanshi, 1990. Marine fishery resources potential in the Indian Exclusive Economic Zone – An Update. *Bull. Fish. Surv. India*, **20**: 27 pp.

Trownsend, C.R., M.Begon, and J.L. Harper, 2008.Essentials of Ecology, Third Edition, Blackwell Publishing, 367 pp.

Ugo, V.C. and M. Mistri, 1991. Production of the meiobenthic harpacticoid copepod *Canuella perplexa. Marine Ecology Progress Series,* **68**: 225-234.

Uktolseja, J. C. B., 1998. Monthly average distribution of fishing effort and catch per unit effort of yellowfin tuna and bigeye tuna in Indonesian waters of the Indian Ocean, 1978 – 1990. IOTC Expert Consultation on Indian Ocean Tunas, Victoria, Seychelles, 9-14 November 1998.

UNESCO, 1994. Joint Global Ocean Flux studies, 1994, 155 pp.

Vijayakumaran, K., 1998. On the externalities sustainability and rationality of exploitation of the fishery resources of the Indian EEZ. *In*: M.S. Hameed and B.M. Kurup (Eds.) *Technological Advancement in Fisheries*. Publication No.1- School of Indl. Fish., Cochin University of Science and Technology, Cochin: 234-242.

Vijayakumaran, K. 1999. A study of the Problems and Prospects of the deep-sea fishing industry in India. *MBA Project dissertation submitted to Indira Gandhi National Open University*, New Delhi.

Vivekanandan, E and Srinath, M and Kuriakose, Somy, 2005. Fishing the marine food web along the Indian coast. *Fisheries Research*, **72** (2-3): 241-252.

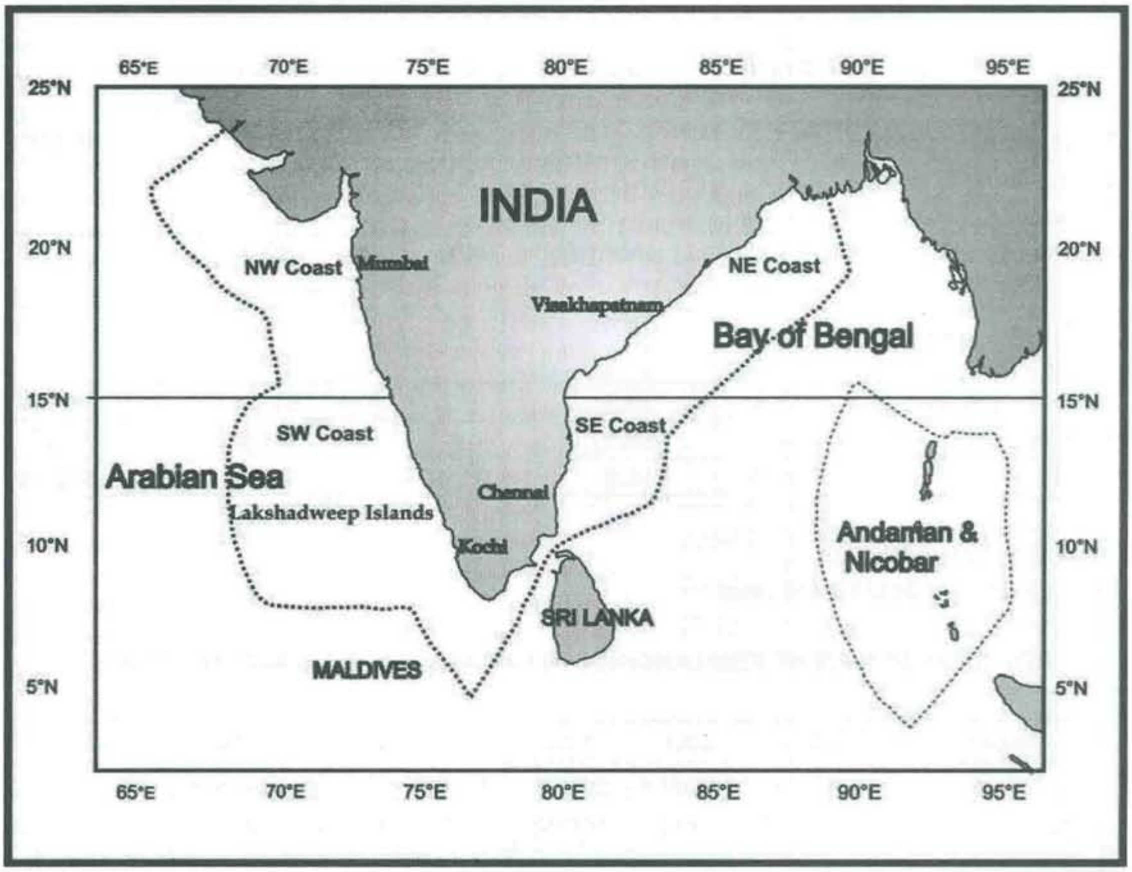
Zaika, V.E. and N.P.Makarova, 1979. Specific Production of Free-Living Marine Nematodes. *Marine Ecology Progress Series*, **1**: 153-159.

Zeller, D., W. Cheung, C. Close and D. Pauly 2009. Trends in Global marine Fisheries- A critical review, in: *Fisheries, Sustainability and Development*, Royal Swedish Academy of Agriculture and Forestry, Stockholm, 478 p.

Zuyev, G., C. Nigmatullin, M. Chesalin and K. Nesis. 2002. Main results of long-term worldwide studies on tropical nektonic oceanic squid genus *Sthenoteuthis*: an overview of the Soviet investigations. *Bull. Mar. Sci.* **71**(2), 1019–1060.

[][][]

Appendices



Map of EEZ of India (the outer margin of the EEZ is only provisional and without prejudice to agreements reached or to be reached with the concerned countries)

EEZ area	- 2.017 million Km^2
West	- 859992 Km^2
East	- 561388 Km^2
A&N Islands	- 596554 Km^2

THE DEPTH AND REGION - WISE AREA UNDER INDIAN EEZ

Region/Latitude	Depth zone (m)				
	0-100	100-200	200-500	Total upto 500	Total for EEZ
South west coast (8°-15°N)	58.6	10.2	10.1	78.9	
North west coast (15°N23°N)	196.9	16.5	7.7	221.1	
Total for west coast	**255.5**	**26.7**	**17.8**	**300**	**860.0***
Wadge Bank & Gulf Mannar $	16.8	5.8	3.3	25.9	
South east coast (10°-15°N)	33.8	4.8	1.8	40.4	
North east coast (15°-21°N)	56.6	14.5	3.9	75	
Total for east coast	**90.4**	**19.3**	**5.7**	**115.4**	**561.4**
A&N Islands	**24.8**	**10.1**	**9**	**43.9**	**596.5**
Total	**387.5**	**61.9**	**35.8**	**485.2**	**2017.9**

* including Lakshadweep
$ Included in the South west coast

REGION-WISE MARINE FISH LANDINGS IN INDIA FROM 2000-2007 (IN TONNES)

Region	2000	2001	2002	2003	2004	2005	2006	2007
NE Coast	295434	298667.4	304675	304775	281667	282448	287958	316340
SE Coast	594169.3	565841.8	647752	646383	661563	599770	607971	651503
Sub-total (West coast)	889603.3	864509.2	952427	951158	943230	882218	895929	967843
SW Coast	751739.9	722947.2	769691	806432	760665	733880	809710	750933
NW Coast	1106229	1160497	1204229	1114326	1120039	1210482	1314929	1308733
Sub-total (West coast)	1857968	1883444	1973920	1920758	1880704	1944362	2124639	2059666
A & N Islands	30339	27173	25488	30636	30636	8635	24096	28005
Lakshadweep	10082.21	12700.54	9149	9149.07	9149	11035	11751	11400
GRAND TOTAL	**2787993**	**2787827**	**2960984**	**2911701**	**2863719**	**2846250**	**3056415**	**3066914**

Source: MOA, 2008
NE Coast - West Bengal and Orissa
SE Coast - Andhra Pradesh,Tamil Nadu and Puducherry
SW Coast - Kerala and Karnataka
NW Coast - Goa, Maharashtra, Gujarat and Daman & Diu

ANNUAL AVERAGE MARINE FISH LANDINGS DURING 1985-89, 1995-99 AND 2005-09 (IN TONNES)

Name of fish/group	1985-89	1995-99	2005-2009
Sharks	54027[a]	42936	27534
Skates		2793	3272
Rays		23132	18065
Eels	6317	8317	10963
Catfishes	50630	43762	73446
Wolf herring		16067	18208
Oil sardine	141831	167123	417163
Other sardines	76541	116458	94084
Hilsa shad		20255	46641
Other shads		11818	8312
Anchovies	68630	138080	126504
Other clupeoids	132626	51868	59945
Bombay duck	93185	99714	114076
Lizard fishes	20557	25262	40263
Threadfin breams		77541	110103
Other perches	90083[b]	74936	92148
Goat fishes		13477	20445
Threadfins		9483	9626
Croakers	102934	169643	156436
Ribbon fishes	78384	122805	152977
Carangids	111040	151601	146112
Silverbellies	60766	60641	66598
Pomfrets	37356	41891	48492
Mackerels	123832	212633	158503
Seer fishes	35171	45059	51918
Tunas	34185	42786	62114
Barracudas		15717	19055
Mullets		659	7043
Flat fishes	29612	44975	40417
Penaeid prawns	143073	192571	199729
Non-penaeid prawns	48057	130789	157293
Lobsters		2409	1624
Crabs		33289	46452
Stomatopods		70758	26956
Cephalopods	39799	107439	122229
Others	203386	102755	106773
TOTAL	**1598113**	**2497342**	**2861519**

a: All elasmobranchs

b: All perches including threadfin bream