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Draft Report

12 Economic Value of Biodiversity Loss: A Study of By-Catch from Marine Fisheries in Andhra Pradesh

THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY-INDIA INITIATIVE

COASTAL AND MARINE ECOSYSTEMS

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- India Business and Biodiversity Initiative (IBBI)
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- Himachal Pradesh Forest Ecosystem Services Project
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Economic Value of Biodiversity Loss: A Study of By-Catch from Marine Fisheries in Andhra Pradesh

Final Report Submitted to the TEEB India Initiative (GIZ Germany and MoEF & CC, Government of India)

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THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY-INDIA INITIATIVE

The Economics of Ecosystems and Biodiversity – India Initiative (TII) aims at making the values of biodiversity and linked ecosystem services explicit for consideration and mainstreaming into developmental planning. TII targets action at the policy making levels, the business decision level and awareness of citizens. TII has prioritized its focus on three ecosystems - forests, inland wetlands, and coastal and marine ecosystems - to ensure that tangible outcomes can be integrated into policy and planning for these ecosystems based on recommendations emerging from TII.

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12 Economic Valuation of Biodiversity Loss: A Study of By-Catch from Marine Fisheries in Andhra Pradesh

KEY MESSAGES

Harmful fishing techniques may result in the loss of marine biodiversity. A large number of unintended bycatch and juvenile fish has been observed in the fishery off the Andhra coast. This is largely due to the increasing number of trawlers. How can fisherfolk be incentivised to reduce bycatch? The economic and ecological value of future biodiversity loss due to bycatch is likely to be much higher than the cost of regulating fishing techniques.

FINDINGS

- Nearly **59.8%** of the biomass is forgone due to juvenile catch, which stifles breeding and creates a future loss.
- With little commercial value, bycatch is sold at just **₹1** (**US$ 0.016**) per kg to fishmeal and poultry feed industries.
- The estimates of the social cost of bycatch and juvenile species loss is **₹2.42 billion** (**US$ 40m**) per year when we multiply the extra effort with the average cost of fishing effort.
- The present value lost due to fishing effort plus future losses amounts to **₹22.72 billion** (**US$ 378m**) per year.

RECOMMENDATIONS

- Fishermen should be made aware of the consequences of unsustainable fishing in terms of livelihood loss and unintended consequences to marine biodiversity.
- To achieve the goal of 'fish better', incentivise the use of technologies that save juvenile fish and other bycatch.
- Provide a subsidy to those trawlers who are willing to adopt bycatch reduction devices. For example, 25 mm diamond shaped nets can be switched to 40 mm square shaped trawl nets.
- Implement fishing holidays or 'no-take zones' to encourage conservation.
- Regulate the use of bycatch in feed mills and encourage fishmeal industries to use sardine and or other adult low-value oil fishes.
- Conservation-friendly initiatives should be promoted.

Photo: Ritesh Sharma

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EXECUTIVE SUMMARY

Economic Value of Biodiversity Loss: A Study of By-Catch from Andhra Pradesh Marine Fisheries

1. Introduction

1.1. Context

The term biological diversity or biodiversity refers to the variety and variability of life forms existing in a given eco-system, namely, genetic, species and ecological diversities. The increasing rate of biodiversity loss is a major global concern today. At the global level, biodiversity management is governed by several international conventions, including the Convention on Biological Diversity (CBD). The CBD framework defines sustainable use as "the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations" (Convention on Biological Diversity, 2015). India is one of the mega biodiversity countries with a coastal line of about 8118 km, an exclusive economic zone of 2.2 million km sq., and with potential to catch 3.9 million tonnes of fish and crustaceans (Goverment of India, 2004). The country is endowed with rich marine biodiversity eco-system areas, such as estuaries,mangroves, coral reefs, sea-grass beds, and oceanic islands. The number of species spread overall sea habitats could be running into several millions, but we know only a fraction of that for certain; so far, around 2456 fish, more than 2934 crustaceans, and 3370 mollusks have been reported in addition to several other phyla (Venkataraman & Wafar, 2005).

The natural stock of fish and crustaceans constitutes an important marine ecosystem service for human consumption, in that they play a crucial role in the human food chain and nutritional security. Thus, it is natural that, millions of people are dependent on marine ecosystems for their livelihoods and employment. On the other hand, marine eco-systems are, at the same time under severe stress mainly due to over fishing; sometimes, even to the extent of leading to a collapse of the fishery resources (Pauly, et al., 2002). Over fishing has been reported as one of the important drivers of marine biodiversity loss (Jennings & Kaiser, 1998). Most of the fish species caught are used for human consumption, while a large number of them end up as discards in the process of exploitation which, in turn, has negative implications for other marine species and species dependent on fish such as sea birds and mammals. This is an unintended consequence of fishing, a cost to be borne by the society. In India, fishery is facing severe stress due to increased fishing effort involving traditional, motorised and mechanised fishing fleets. The introduction of small meshed harvesting gears and many other innovative gears has resulted in the exploitation of juveniles, sub-adults and spawners that form part of many coastal stocks. Many vulnerable species of fish have become endangered or are on the brink of biological extinction (Devraj, 1996). This study,as part of addressing this issue,analyses the social cost of 'by-catch' and tries to find a solution to minimize the cost so that the stock of fish resources and biodiversity is kept as it is, while harvesting it for human consumption. Further there is a need for understanding the economic dimensions of by-catch loss, particularly from the perspective of biodiversity conservation. To put it differently, the by-catch or unintentional catch of fish and other living organisms is an important factor in linking fishing activities to biodiversity loss and, therefore there is a need for understanding its economic

The direct impact of by-catch is a serious concern. Wastage of marine resources from by-catch can adversely affect the regeneration of fish stock, the present and future human consumption of fish, and the maintenance of its ecological role and functions

dimensions in a more rigorous manner.

The direct impact of by-catch in terms of wastage of biological resources before attaining first maturity and suitability for human consumption is a serious concern. The wastage of marine resources in such a manner has far-reaching implications in that it can adversely affect the regeneration of fish stock, the present and future human consumption of fish and the maintenance of its ecological role and functions. The awareness of the magnitude of such a loss is very low for various reasons. The fishers are not aware of it since the cost is implicit in fishing operations. Second, the social cost, a fallout of by-catch, is seldom taken into consideration while compiling the gross state domestic product (GSDP) and, therefore, it never figures in policy discourse. Hence, this study tries to estimate the economic value of by-catch loss, besides aiming to contribute to policy discourse on marine biodiversity conservation by providing evidences with respect to the potential benefits associated with by-catch species reduction. This study was conducted in the state of Andhra Pradesh in India.

1.2. Review of Literature

1.2.1. Ecological and Economic Dimensions

Fishing affects marine biodiversity (Jennings & Kaiser, 1998),in that it has a number of direct effects on marine ecosystems as it is responsible for increasing the mortality of target species and by-catch species as also disturbing marine habitats. The direct effects of fishing have many indirect implications for other species. First, fishers may remove some of the prey that piscivorous fishes, birds and mammals would otherwise consume, or may remove predators that would otherwise control preys populations. Secondly, a reduction in the density of some species may affect competitive interactions besides resulting in the proliferation of non-target species. The activities of fishers also provide food to scavenging species since fishes, benthic organisms and other unwanted by-catch species are often discarded, because a range of species are killed, but not retained, by towed gears (Jennings & Kaiser, 1998). This shows that an economic valuation of biodiversity loss resulting from fishing activities is not an easy empirical exercise. In fact it is a daunting task due to the sensitive nature of marine ecosystems and interdependence of various species. Therefore, this study focuses only on certain aspects of by-catch as part of arriving at a lower bound value of biodiversity loss to the society at large.

A global assessment of fisheries by-catch and discards (FAO Fisheries Technical Paper No. 339) published in 1994 and revised in 2005, shows 8% of the global catch (7.3 million) amounting to discards during 1992-2001 (Kelleher, 2006). Discards represent a significant proportion of global marine catches(species) generally considered as constituting waste, or suboptimal use of fishery resources. This is considered to be one of the most serious problems affecting marine fisheries management because such a level of by-catch loss is said to affect marine biodiversity. It is pervasive in that it extends to a range of marine fauna, including turtles on hooks, juvenile fish in nets and benthic invertebrates in trawls and dredge gears (Kumar & Deepti, 2006) (Harrington, Myers, & Rosenberg, 2006). Moreover there is failure to fully appreciate its impact on marine environment (Davies, Cripps, Nickson, & Porter, 2009).Intensive fishing (e.g., trawl fishing) has a vicious impact on benthic ecology and biodiversity (Dayton, Thrush, Agardy, & RJ, 1995). That means by-catch is an important driver of biodiversity loss. Therefore a clear understanding of the economic value of by-catch loss can help us to devise policies to regulate such a loss so that marine biodiversity is conserved.

Hall (2000) talks of established solutions to the by-catch problem such as closed areas and season, harvest performance criteria, gear modifications and by-catch limits per vessel etc. The first bio-economic specification of by-catch suggests that discarding of fish by commercially operated vessels occurs because retention of the discarded species has a non-market value or valuable species are discarded to allow space for more valuable species (high grading). (Abbott & Wilen, 2009). Ward (1994), Boyce (1996)offer solutions to by-catch problems in the form of regulations like ITQ, taxes, subsidies landing restrictions etc.

In India, more than 250 species of fishes and shellfishes have been identified from trawl landings of which lizard fishes, puffer fishes, stomatopods, threadfin breams and flatheads are the major contributors (Dineshbabu, Thomas, & Radhakrishnan, 2012). The reasons for discarding fishes have been studied by many others (Saila, 1983; Northridge, 1991; Murawski, 1993; Jennings and Kaiser, 1998; Pillai, 1998; Bijukumar & Deepthi, 2006;Gibinkumar et al., 2012). (Gibin Kumar 2012). (Boopendranath, Sabu, Gibinkumar, & Pravin, 2010) (Boopendranath M. , 2007), (Boopendranath M. , 2009)(Boopendranath, Pravin, Gibinkumar, & Sabu, 2008), (Sujatha, 1996)(Zacharia, Krishnakumar, Muthiah, Krishnan, & Durgekar, 2006) (Kizhakudan, Pillai, Gomathy, Thirumulu, & Poovannan, 2013).

1.2.2. Policy Dimension

An important objective of the comprehensive marine fishery policy of India (Goverment of India, 2004)is "to ensure sustainable development of marine fisheries with due concern for ecological integrity and bio–diversity". It underscores the need for a departure from the open access concept in the context of territorial waters and promoting fishery exploitation in the deep sea and oceanic waters for reducing fishing pressure in the traditional fishing areas. An exclusive zonation or restricted areas for small-scale fishing (motorised and non-motorised) is an important feature of India's fish harvest policy. The policy is not intended to promote any additional fish production within the territorial waters, but an incremental production from open sea fishing.

The policy gives a clear harvesting direction,that is, a more stringent regulation in the context of territorial waters, while encouraging an additional production from open seas. The shift is due to ecological and biodiversity concerns in respect of territorial waters within a 50 meters depth zone, which shows symptoms of depletion and in certain belts in the inshore waters, it tends to cross optimum sustainable levels (Goverment of India, 2004). Licensing of fishing units, boat building yards, closed seasons for both the coasts, a strict ban on all types of destructive fishing gears, mesh size regulations, prohibition of juvenile and non targeted species catches through legislation— are some of the distinctive features of India's marine fishery policy.

However, the policy perspective is not explicit with respect to biodiversity conservation while promoting the expansion of technology even beyond a depth of 50 meters. The expansion and intensification of fishery activities is an important driving force of marine biodiversity loss— juveniles, sub-adults and spawners that form part of many coastal stocks. The integration of the value of biodiversity loss into the policy framework is a necessary step towards promoting biodiversity conservation, but remains indirect and silent in the present policy document. Moreover, there is no direct incentive mechanism for fishers to participate in the biodiversity conservation efforts or to regulate the loss of biological diversity.

1.2.3. By-catch Regulation

As far as by-catch regulation is concerned, the preferred rule is usually to 'fish better' (Hall, 2007). In this respect, the first and foremost solution is technological. It includes the modification of gears and attaching by-catch reduction devices to the fishing gear (e.g. square mesh nets, turtle exclusion devices) etc. However,many case studies show that the technological solution suffers due to its inefficiency to retain 100% of targeted species. Improving selectivity both in terms of species targeted and their desired sizes becomes an issue in the technological solution (Valdemarsen & Suuronen, 2003)(Broadhurst, Kennelly, & Gray, 2007). Other reasons attributed to an ineffective implementation of the technological solution include (a) lack of political will; (b) inefficient institutional arrangements; (c) information and knowledge gap between fishers and scientific communities.

In the Indian context, for instance, the government of Andhra Pradesh made a rule to impose a fine on trawlers in the event of their not complying with

The expansion and intensifcation of fishery activities has been important in driving marine biodiversity loss. The integration of a value of biodiversity loss is a necessary step towards biodiversity conversation that remains absent today

Indian fishery policy has not adequately addressed the issue of by-catch from a conservation perspective. The basic objective of this study was to estimate the economic and ecological value of biodiversity loss in terms of by-catch as part of emphasising the need for regulating it

the use of turtle exclusion devices (TED) in trawling; but there is no evidence so far to show how far fishers or officials took the rule seriously. Trawling in Andhra Pradesh has continued without any regulation in respect of by-catch. It seems there is no incentive for fishers or boat owners to adopt TED technology for regulating the loss of turtles.

Increasing of fish production through fuel subsidy is another important Issue. For instance, Andhra Pradesh provides fuel subsidy in the form of sales tax exemption up to a limit of 3000 liters of diesel per mechanised boat in a month. This is an important incentive to fishers for increasing production. Considering that fuel subsidy is a direct benefit to fisher for increasing fish production, it can have an indirect impact on biodiversity in the form of an increased by-catch. Subsidy is part of the social cost borne by the society as a whole,though it is considered an incentive for the fisher.

In short, the literature recognises by-catch as a serious issue having a bearing on marine biodiversity. The Indian fishery policy has not adequately addressed the issue of by-catch from a conservation perspective. Some of the measures taken by the state government to regulate the harvesting of by-catch(though unintended) like technological and mesh size regulations have also failed to address the issue adequately due to non-compliance on the part of fishers. Non-compliance with the existing fishing rules and fuel subsidy are the two major issues that need attention in the whole process of marine biodiversity conservation. Thus the challenge is to understand the social cost in terms of by-catch and to devise an approach to regulating the harvest of by-catch.

1.3. Research Questions

The basic objective of the study was to estimate the economic and ecological value of biodiversity loss in terms of by-catch as part of emphasising the need for regulating it. The study specifically has tried to answer the following questions: (a) what are the socio-ecological characteristics of Andhra Pradesh marine fisheries?;(b) What are the trends observed in marine fish production in Andhra Pradesh during the recent years?;(c) What is the species— wise composition of target catch and by-catch?; (d) What is the proportion and gross value of target catch and by-catch?(e) What is the economic value of by-catch loss and how can it be regulated?; (f) What is the role of fish meal and poultry feed industries in the value addition of by-catch?; (g) What are the measures that can be adopted to regulate by-catch harvest in the study context?

1.4. Methodology

1.4.1. Data and Other Information

This study has made use of secondary data on fish landings from the government of Andhra Pradesh and the Central Marine Fisheries Research Institute for examining the trends and composition of species caught over a period of time in Andhra Pradesh. The biophysical aspects of the marine area have been examined based on data from the government and various other publications. Two primary data sets collected during the period 2013-14 and 2014-15 have been used for estimating the proportion and value of target catch and by-catch .A fishing unit is defined as a combination of craft and gear. Data was collected using a structured survey schedule containing questions related to (a) Species wise output (observed); (b) Landing price ; (c) Input costs (fixed and variable); (d) Question on disposal of fish ; (f) by-catch and (g) socio economic status of boat owners. The second survey was conducted with a greater focus on by-catch. The species-wise data on by-catch was collected from a sample of 20 Kg by-catch landed from each boat. The process of data collection is provided in Figure 1.

1.4.2. Sampling Method

Following the methodology developed by the Central Marine Fisheries Research Institute (Srinath, Somy, & Mini, 2005), we adopted a stratified multistage random sampling technique for data collection and estimation.

Figure 1: Species-wise data collection process adopted for the primary survey

The suggested stratification is based on space and time. Over space, we have taken each maritime district of Andhra Pradesh as a zone. The zone has been further classified into substrata on the basis of intensity of fish landings. The number of landing centers varies across zones. Therefore,a given zone and a calendar month is a space-time stratum with primary stage sampling units being landing center dates.

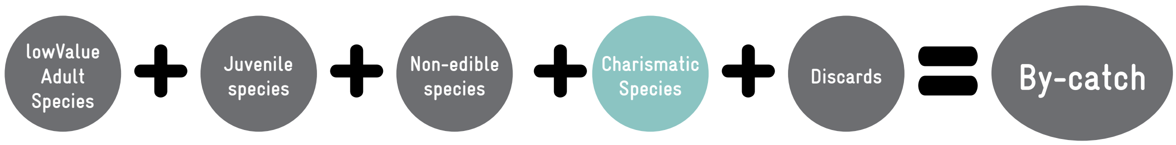
We adopted a time point observation of fish landings in the morning and evening landing of a particular day in a month instead of a continuous observation for a period of one month. Then the total number of trips in a month was collected during the survey to arrive at monthly estimates. The basic assumption is that the catch remains more or less constant for a particular month. The data collection for a particular season was equally spread across all months of the season. In order to capture the seasonal variability, the survey was repeated in all the three seasons and also during the ban period fishing from April 14 to May 31st. We covered a total of 3630 fishing units during the 2013-14 survey and a total of 645 fishing units during second survey i.e.,2014-15. We have already mentioned that the survey was conducted across three

Table 1: Distribution of Sample fishing units across maritime districts of Andhra Pradesh (2013-14)

Scenario	Number of fishing units surveyed	%
Srikakulam	463	13
Vijayanagaram	121	3
Vishakhapatnam	1009	28
East Godavari	706	19
West Godavari	64	2
Krishna	278	8
Guntur	132	4
Prakasam	303	8
Nellore	554	15
Total	3630	100

Source: Based on sample fishing units for the primary survey

Figure 2: Composition of by-catch considered for an economic valuation



seasons (monsoon, winter, summer and fishing holiday season from April 14 to May 31st every year). Overall, the survey covered a total of 3630 fishing units. The distribution of the total number of fishing units covered during the one-year survey across maritime zones (three seasons plus fishing-free holidays) is given in Table 1.

Species are lost when fishers catch anything and everything that they do not intend to catch, including fish, turtles, pieces of coral, sponges, other animals and non-living material, generally treated as by-catch. The Food and Agriculture Organisation of the United Nations (FAO),while providing a detailed scan of the existing literature, says the term "by-catch" has customarily been used to identify (1) species retained and sold; (2) species or sizes and sexes of species discarded as a result of economic, legal, or personal considerations; and (3) non-targeted species retained and sold, plus all discards.In this study, a by-catch (sample) was taken from what fishers segregated as by-catch from the total fish catch. At the harbor, by-catch is always unloaded separately from aboat. As far as juvenile catch is concerned, they were segregated from the by-catch based on length and weight as given in Figure 1. We also found out discarded parts of the by-catch during the survey by asking direct questions. Suppose the length at maturity is 20 cm, we have taken 16 cm as the criterion for classifying juveniles. As far as charismatic species like turtle, dolphin etc., are concerned, no attempt has been made to include the value of these species due to insufficient available information on the occurrence of these species in a by-catch. The value we have arrived at in this report does not include the value of charismatic species.

The low value fishes are those which are not used for direct human consumption, which may be either landed or discarded. These include fish-kind that have a low commercial value by virtue of their low quality, small size or low consumer preference. The low value fish-kind not only include non-commercial species, but also high value commercial species that are below minimum

Figure 3: Catch and By-catch from a Mechanised Trawler

landing size or less profitable species owing to market conditions. The non-commercial non-edible biota consists of starfishes, sea snakes etc. The commercially high value species are also taken as juveniles.

As far as juvenile catch is concerned, they were segregated based on length size and weight. It was done with the help of fishers. Another important category of fish that appear in by-catch are charismatic species such as turtles, dolphins etc. These species are highly valued from an ecological and biodiversity perspective since their status is relatively rare or endangered. However from an operational point of view, this study has considered 'all biological organisms caught from the sea and segregated by fishers as by-catch, whether discarded or landed. Charismatic species like sea turtles and dolphins caught in the fishing gears were taken into consideration while estimating the social cost of by-catch due to information gaps existing on these species during the survey. Therefore, the economic value attributed to biodiversity loss in terms of by-catch is a lower bound value that covers the forgone value of juvenile catch at the current market price of adult species,while value of low value adult fishes and value of non edible species at the average cost of fishing effort.

1.4.3. Analytical Framework

By-catch is an unintended catch while targeting a particular species and is part of a joint output. Biodiversity loss can happen if a joint output is generated in terms of a wrong composition or proportion. By-catch also exhibits characteristics of negative externalities because; it is a welfare reducing output for which limited or no market exists. By-catch externality is generated automatically without producers deciding to allocate resources to them. In other words, no fisherman makes a deliberate effort to catch unwanted fishes and juveniles. It occurs while catching targeted fishes, and therefore, the effort going into by-catch component of the total biomass catch is an implicit cost for fishers. So an enquiry into the implicit cost of fishing can give an estimate of the present value of by-catch(at factor prices) which is considered the real cost of by-catch for the fishers. Besides by-catch is not a source of income for the boat owners. The income they get out of by-catch sold to poultry feed and fish meal industries goes to crew members. Thus,there is an incentive for crew members to bring in maximum by-catch materials to the landing centers. However, very large boats going into deep sea fishing do grading due to space constraints. The second aspect of by-catch value is its future opportunity cost. It is measured in terms of biomass lost due to the catch of commercially important juveniles. The criteria for identifying juveniles is based on the biological definition of juveniles, that is,the quantity of any species found with a length less than the length at first maturity. Some species might attain sexual maturity before attaining a certain length at first maturity. In order to solve this issue, we have subtracted 20% of its length at first maturity from the total length at first maturity across all species. The values estimated for by-catch juveniles and juveniles found in a catch are presented separately in this study. The total future opportunity cost of juveniles (forgone biomass benefit) is a cost to the society. It is added to the current value of by-catch (implicit cost incurred by fishers) for arriving at the total social cost of by-catch.

Another important concern of this study relates to the future dynamics of the by-catch market. We have seen that the entire landed by-catch is sold at throw away prices today in view of an increasing demand for by-catch, particularly in the context of fast growing aquaculture and poultry. Hence, it is important to see the role of fish meal and poultry industries as an emerging driving force of by-catch landings. We have examined the growth of these industries besides providing a future scenario of by-catch production based on the demand for these materials.

1.4.4. Data Analysis

Data was analysed separately for estimating the values of main catch and by-catch. In order to capture the variations in prices, a value-based classification of fish

By-catch is an unintended catch while targeting a particular species. It is a welfare reducing output for which limited or no market exists. In other words, no fisherman makes a deliberate effort to catch unwanted fishes and juveniles

and crustaceans was used as part of presenting estimates with regard to the quantity and value of catch (Table 2). The estimation procedures are discussed in the following subsections of this chapter. The data based on the second survey (2014-15) has been basically used for computing ratios related to by-catch species composition besides applying these ratios to the total by-catch collected for 2013-14 in order to arrive at species-wise by-catch estimates. Therefore, all estimates provided in this report are based on data collected for 2013-14. Experimental data from the central Institute of Fisheries Technology have also been used to build a scenario of potential benefits associated with biodiversity conservation though by-catch regulation.

This study provides estimates for main catch and by-catch of fish landed during the 2013-14 fishing season in the context of Andhra Pradesh. The first step in the estimation process is to get a monthly estimate of the total landings ($\hat{Y}$) for all types of fishing units (craft) and for all species based on the total landing center days. The total number of fishing days of a landing center is calculated by multiplying fishing units under operation with the average number of trips they make for fishing for all types of fishing crafts. Let 'N' be the number of days (fishing days) in a month and 'g' the number of fishing units in dth landing center, then the total number of landing centre days of the d_{th} centre is N_{gd}.

For the sample fishing units, it is n_{gd} or sample landing centre days of the d^{th} centre. Therefore, the total fish species (s) landing (y) of the d^{th} centre is the sum of species-wise landings for all the fishing units in the d_{th} centre ($\sum y_{sgd}$). Therefore, an estimate of total landing of species 's' by unit type 'g' on the 'd^{th}' landing center is given as

$$\ddot{Y}sgd = \frac{Ngd}{Ngd} \sum_{i=1}^{n_{gd}} ysgd$$

Based on an estimate of the total landing of species s by g, the unit for all centres can be obtained as

$$\ddot{Y}sg = \frac{NQ}{n} \sum_{d=1}^{n} \ddot{Y}sgd$$

An estimate of the total landings for a given month over all types of fishing units and for all species for a given zone (district in this study) can be arrived at by summating. The monthly estimates multiplied by the number of months in a given season are considered seasonal estimates. A Summation of all the seasonal estimates across all zones is considered as state level estimate. This is followed for estimating both the main catch and by-catch and the proportion of by-catch to the total landings. The gross value is arrived at by multiplying the total quantity landed with landing price. The gross values of main catch and by-catch at landing prices were presented across zones (districts) and three basic categories of fishing units namely,mechanised, motorised and non-motorised. After presenting an overall picture in terms of gross value, we look into the implications of fish production for biodiversity conservation by analysing the three different categories of by-catch—juveniles, trash and discards. Methods adopted for estimating these three categories are as follows.

1.4.5. Estimates of By-catch

As discussed earlier, the whole by-catch quantity is

Table 2: Classification of Species group based on Market Value

MARINE FISH SPECIES
Pelagic fishes – high value (PHV): Seerfish, Oceanic tunas (yellowfin tuna, skipjack tuna),Large carangids (Caranx sp.), Pomfrets, Pelagic sharks, Mullets
Pelagic fishes – Low value (PLV): Sardines, Mackerel, Anchovies, Bombayduck, Coastal tunas,Scads, Horsemackerel, Barracudas
Demersal Fishes –High Value (DHV): Rock cods, Snappers, Lethrinids, Big-jawed jumper (Lactarius), Threadfins (Polynemids)
Demersal Fishes-low value (DLV): Rays, Silverbellies, Lizard fishes, Catfishes, Goatfishes, Nimipterids,Soles.
Crustaceans – high value (Shrimp): Shrimps, Lobsters
Mollusks and others (Mollusks): Low Value Cephalopods (squids, cuttlefishes and octopus), Mussels, Oysters, Non penaeid prawns, etc.

Source: Kumar (2007)

divided into three main groups, namely juveniles, small low-value adults, and discards and charismatic species. The charismatic species like turtles, dolphins etc., are not revealed by fishers due to legal reasons,as observed during our survey. Therefore, we have used only the first three categories of data for estimating the social cost in the context of by-catch. Using the fishing effort approach, as discussed earlier, we have estimated the implicit cost incurred by fishers. The future value lost in the context of juvenile catch is added to this before arriving at the social cost of by-catch.

Estimating the economic value lost in the make of juvenile catch is straightforward,given the availability of market prices for these species. The future opportunity cost of juveniles(that is the adult biomass lost) through by-catch is calculated using the expected adult price at its first maturity. It is known that the biomass of juveniles will increase positively with their increased growth rates and negatively with their increased mortality rates (Najmudeen & Sathiadhas, 2008). Hence, the first step is to estimate the biomass corresponding to the quantity of juveniles caught,beforecalculating the economic loss. The length–weight relationships of species can be expressed as: W = aLb (where W is the weight of fish, L the length of fish, 'a' the constant and b the exponent). The estimated coefficients (a and b) for different species have been taken from the CMFRI publications and the fish database as given on the web site http://www.fishbase.org. The length-weight table of this database provides values for over 5000 length weight relationships of the form W = aLb pertaining to about 2000 fish species. The unit of length and weight in FishBase is centimeter and gram respectively. The juvenile weight of each species has beenestimated from the average juvenile length reported for each species.

The numbers of juveniles per kilogram of fish have then been estimated and multiplied with an average quantity of adult species to arrive at the total forgone value of 1 kg of juveniles. The economic loss has been calculated separately for each fish group landed since the value of coefficients (a and b) for individual fish species differs from each other. However, in the absence of coefficients, we have taken the value by substituting the value of species for those in the same group.

1.4.6. Estimates of Fishing Effort

The fishing effort is a frequently used measure and is a combination of inputs into the fishing activity, such as the number of hours or days spent fishing, numbers of hooks used (in long-line fishing), kilometers of nets used, etc., (OECD, 1998). We have estimated fishing effort for all categories of fishing units such as mechanised trawlers, mechanised gill neters and other non-mechanised boats. Fishing effort measured in terms of the number of fishing days for a given trip is probably one of the most important decisions for any fisherman (Nguyen & Leung, 2013). Fishing effort is estimated on the basis of boat days. As suggested in the method of calculation (Kurup & Devraj, 2000), a weighted average of catch per unit of effort (CPUE) has been calculated for estimating the total standard effort (SE) in marine fishing in Andhra Pradesh.

SE=Landing/(weighted CPUE) ×1000 (since CPUE in kg)

The estimated value of these species is presented per unit of fishing effort besides showing the importance of regulating these costs for conserving marine biodiversity.

1.5. Fishing Experiments

The data and findings ofa study (Reference) based on an experiment carried out by on-board fishing research vessel CIFTECH-I (15.5m LOA; 122 hp) in the commercial fishing grounds of Visakhapatnam coast (17°40'-17° 42 lat.; 83°21'-83°30 long.), between 40 and 50 m during 2013-14 were used to build a by-catch reduction scenario. In the experiment, a26-meter multi seam demersal trawl fitted with experimental square mesh code ends was used and the overall performance of the code ends during the experimental tows was evaluated. A small mesh cover of 20 mm PE netting, greater than 1.5 times the size of a code end was used for the experiment. 30 hauls of one hour duration were taken and the towing speed maintained at 2.3-2.5 kn. Using catch retention and exclusion data, the study provides an alternative scenario for by-catch reduction that is compared with a business-as-usual scenario. In the business-as-usual scenario, fishers use 25mm code end demand shaped nets, while in the experiment, it was a 40mm code end square mesh net. This experiment was conducted only for mechanised trawls.

1.6. Reporting

This introductory chapter apart, chapter 2 presents trends and composition of fish catch in Andhra Pradesh; chapter 3 provides estimates for main catch and by-catch. The value lost due to juveniles and other by-catch species are also discussed in this chapter. We have also presented an alternative scenario for a by-catch reduction in this chapter using CIFT data; Chapter 4 presents conclusions along with policy recommendations.

2. The Study Area: Andhra Pradesh

Economic Value of Biodiversity Loss: A Study of By-Catch from Andhra Pradesh Marine Fisheries

2.1. Introduction

This chapter provides an overall background for the study,in terms of the characteristics of the study area, trends and composition of marine fish catch and important drivers of marine biodiversity loss. We have alsotried to examine the role of fishing activity in marine biodiversity loss.

2.2. The Study Area

This study was conducted in Andhra Pradesh state (Figure 4), located in the east coast of India. The state is known for its rich biological diversity distributed across 9 agro climatic regions which support 185 families of flora and 108 species of mammals (APSB Board, 2015). The State has a coastal line of 974 kilometers with a relatively narrow continental shelf of 33,227 km2. The diversity of fishes and mollusks is also reported to be rich with 600 species of marine and estuarine fish, 480 fresh water fishes and 180 mollusks (APSB Board, 2015).

Andhra Pradesh has a very rich marine resource base spread over 974 kilometers of coastline. There are 51 reservoirs and 3118 tanks suitable for fresh water fish culture in the state, backed in addition by 62145.5 hectares of fresh water and 15963.65 hectares of brackish water ponds used for aquaculture. These figures indicate a strong marine resource base for Andhra Pradesh fishery.

The state stands first in brackish water shrimp and fresh water prawn production and second in inland fish production in India. The fish and prawn production increased from 9.41 lakh tons in 2006-07 to 16.03 tons by 2011-12, accounting for 2.51% of the GSDP and 11.73% of the agriculture GSDP.

In a recent study, it is noted that the growth potential of marine sector is relatively very less as compared to fresh and brackish water aquaculture, which is evident from the catch data published by the state government (Sathyapalan, 2011).

The growth potential of inland fisheries sector is linked tothe marine sector since most of the raw materials for animal feed in aquaculture aresupplied by marine production. Similarly most of the low value and trash fish areused in aquaculture and poultry feed. In short, there is a high fishing pressure on marine ecosystems due to a high demand for fish for human consumption and as animal feed. The recent trends in fishing also show that growth is very slow in the marine sector, which is a serious concern from the view point of sustainability.

2.3. Marine Fish Landing: Trends and Composition

A large section of the fishers (1.63 lakh marine fishermen families with a total population of 6.05 lakhs) is directly dependent on the marine fishery sector for livelihood. A majority of them are engaged in small-scale fisheries using both traditional fishing crafts and motorised fishing crafts. It is very evident that fish play a significant role in the household income, employment and livelihoods of people in the study area. The sustainability of this resource base depends on how effectively we reduce the social cost involved in resource use.

Data from CMFRI onfish landings during the period 1985 to 2013 reveals that marine production increased from 118541 tonnes in 1985 to 266032

Figure 4: Location of the Study Area (Andhra Pradesh State)

Source: Own map based on (CMFRI, 2010) data.

Trends indicate that fishery is moving towards more valuable species and that its contribution to the economy is quite significant. This is evident in the rate of growth of more economically valuable products like penaeid prawn

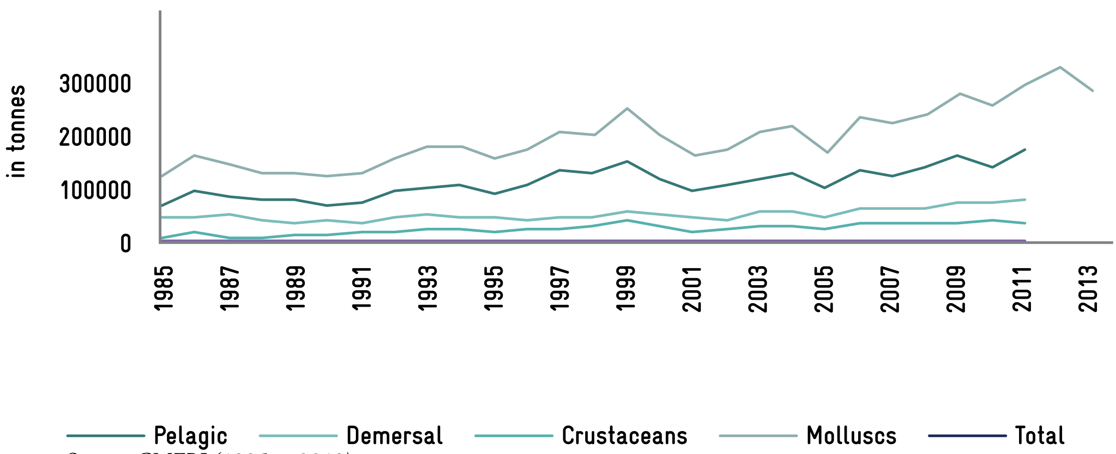
tonnes in 2013 (Annex 1). The contribution of pelagic fishes amounts to around 58% while that of demersal to 27.5% and of crustaceans to 12.3%. Penaeid prawn alone contributes 10.80% to the total production. The growth of total fish landings amounts to 2.7% per annum for the period of 1985 to 2013,of which pelagic fish landing accounts for 2.6%, while demersal fishes for 2.2%. The growth rate of crustaceans and mollusks amounts toaround 4 and 6% respectively. The species wise analysis shows that the production of crustaceans (Penaeid prawns, Non-penaeid prawns, Lobsters, Crabs, and Stomatopods) increased from 29340 tonnes in 2000 to 36973 tonnes in 2013. These trends indicate that fishery is moving towards more valuable species and that its contribution to the economy is quite significant which is evident from the rate of growth of more economically valuable products like penaeid prawn.

The species-wise data indicates that the contribution of Elasmobranchs (Sharks, Skates, Rays, Eels, Catfishes) remained more or less the same i.e., 14910 tonnes in 2000 to 14050 tonnes in 2013, while that of clupeids (Wolf herring, Oil sardine, other sardines, Hilsa shad, Other shads, Anchovies (Coilia, Setipinna, Stolephorus) Thrissina, Thryssa and other clupeids) declined from 62375 tonnes to 45863.6 tonnes. The perches (Rock cods, Snappers, Pig-face breams, Threadfin breams, Other perches) show a high growth from 4979 tonnes in 2000 to 13514 tonnes in 2013.

Other species such as goatfishes, threadfins also show an increasing trend. Croakers, and ribbonfishes growth is quite significant during this period. While ribbonfish landing increased from 13842 tonnes in 2000 to 18800 tonnes in 2013, the landing of croakers increased from 8054 to 13260 tonnes during the same period. While the seer fish landing remained within a range of 5437 tonnes in 2000 and 462 tonnes in 2013, the tuna catch increased many fold from 2899 tonnes in 2000 to 13241 tonnes in 2013.

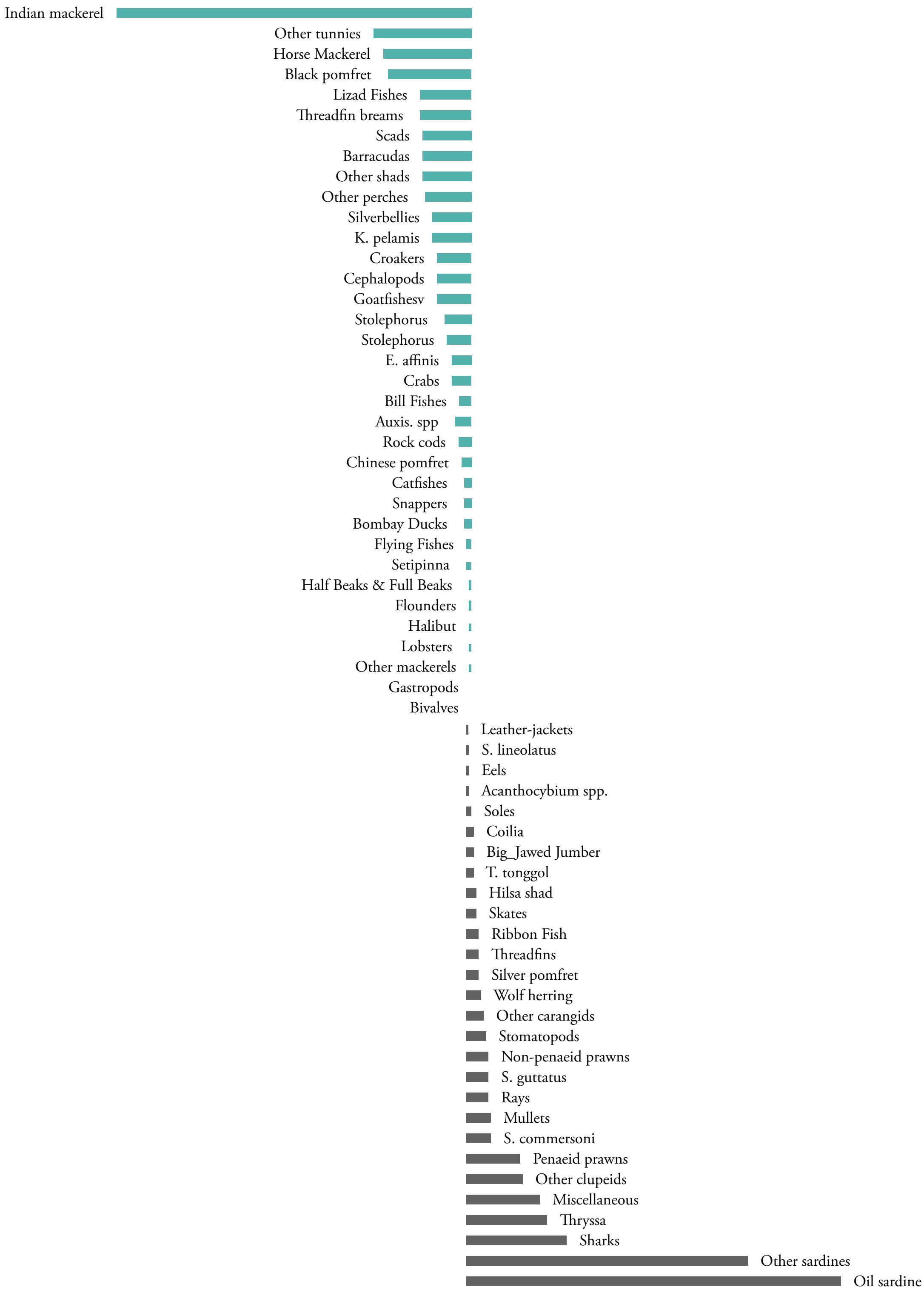
The Indian mackerel also shows acceleration from 9834 to 33716 tonnes during the same period. Indian mackerel is the largest contributor, accounting fora round 12.67% of the production. The growth of pom frets (Black pom fret, Silver pom fret, Chinese pom fret) landing is also quite significant from 5864 tonnes to 12973 tonnes during the period 2000-2013. The contribution of flat fishes (Halibut, Flounders, Soles) is relatively less though it has grown during this period.

Figure 5: Trends in Marine Fisheries landing from 1985 to 2013



Source: CMFRI (1985 to 2013).

Figure 6: Changes in the composition of species caught (in percentages) in 2013 as compared to 1985



Source: CMFRI (1985 to 2013).

Pom fret contributes about 4.81% to the total production. As per 2000 and 2013 fish landing, Pen aid prawns and Indian mackerel stand at the top of the total landed quantity in terms of their contribution,while the miscellaneous category shows with ups and downs for the alternative years. The miscellaneous fishes are generally treated as landed trash and is used as poultry feed and manure. Its contribution comes to only 1.34% to the total production. An important point that is emerging from the secondary data is that the landing of certain species groups like crustaceans, tuna and Indian mackerel has increased, while that of some others has declined over time. The changing species composition is an important indicator of the changing fishery activity (Figure 6).

2.4. Drivers of Biodiversity loss

In order to control the long-term decline of marine biodiversity; it is important to identify the proximate and underlying causes of biodiversity loss. The proximate causes typically include resource use changes, conversion of habitat, pollution, climate change, and invasive alien species etc., while the underlying causes are social, economic, political, cultural, and technological processes, which ultimately define the proximate drivers of biodiversity loss. A few important driving forces of marine biodiversity have been discussed here.

2.4.1. Increasing Fisher Population

Increasing human population and growing demand for fish have to be seen as important driving forces of fishing intensification and the resultant adverse impacts on marine biodiversity. At present, a large section of the fishers in Andhra Pradesh (6.05 lakh) is directly dependent on marine fishery for their livelihoods. The fishers' population constitutes approximately 1.61 lakh families spread across 555 fishing villages of Andhra Pradesh (CMFRI, 2010). It is reported that in 1984, there were 453 marine fishing villages with 280 fish landing centers in the entire coast of Andhra Pradesh. There were about 74000 fishermen families with population of3.30 lakhs.

Also there were about 84,000 fishermen engaged in actual fishing in the nine coastal districts of Andhra Pradesh (Alagaraja, Yohannan, Ammini, & Pavithran, 1987). But today, as per the marine fisheries census 2010, there are approximately 1.50 lakh active sea going fishers. In addition 39,324 people are engaged in marketing, 14082 in production and repairing of nets, 16848 in processing plants, and 2904 in shrimp peeling activates, 64,141 as labors and 2790 in other fishing related activities. Thus the aggregate direct employment in the marine sector comes to around 3,01,956, which shows a high dependency of the coastal fishing population on the marine sector as an important source of income. Therefore, the increasing human settlements, growth of population and increased dependency on fishing as a source of livelihood can be seen as indirect driving forces of marine biodiversity loss.

2.4.2. Technological Changes in the Fishing Sector

The second most important development observed relates to changing fishing practices. Fishers use different types of crafts and gears as part of their fishing activity. The total number of crafts operating in the marine waters of Andhra Pradesh comes to around 31735 as per the CMFRI marine census 2010 ofwhich 17837 crafts are non-motorised and 12557 boats are motorised. The number of mechanised boats works out to approximately 1341 as of 2010 as against 580 in 1984. It is reported that in the districts of Visakhapatnam (204), East Godavari (160), Krishna (52), Guntur (80) and Nellore (84) trawlers were operating in 1984 (Alagaraja, Yohannan, Ammini, & Pavithran, 1987). The maximum number of mechanised crafts observed was in Guntur district followed by East Godavari and Krishna.

There were about 36,000 non-mechanised boats in different districts of the State in 1984 but their number declined to 17837 by2010. These trends indicate that fishing practices have made a switch over from traditional to modern methods that involve an intense resource exploitation. More importantly, much of the shift has happened in respect of trawls and gill nets with a small sized mesh that generates large quantities of by-catch.

Today, mechanised boats are operating mainly in Vishakhapatnam, East Godavari, Krishna and Gundur districts. The mechanised crafts include Trawlers, Gillnetters, Ringseiners and Liners while Catamarams, Dugout canoes, Plankbult boats, Plywood boats, Fibre glass boats, Ferro Cement Boats, Carrier boats, Teppas are used in the motorised sector. In the non-motorised sector mostly Dugout canoes, Catamarams, Plankbult boats, Ferro Cement Boats, Outrigger canoes and Masula Boats are used. Drift/gill nets form the major gear in all the districts of Andhra Pradesh. Trawl nets, fixed bag nets, Hooks & lines boat seines are also used widely in the marine fishing sector. Many fishers in the state use improved technology to find out fishing zones and to receive cyclonic alerts as well. They are now using smart phones equipped with a specially designed

The increasing demand for by-catch materials for industrial purposes is also creating substantial pressure on marine ecosystems. Thus in light of these changes in the fisheries sector, it is important to have a carefully thought out long-term approach towards marine biodiversity conservation

'App' called Fisher Friend Mobile Application (FFMA). The technological innovations in this respect also put additional pressure on fisheries, indirectly affecting the marine diversity.

2.4.3. Subsidy

Subsidy, as an important incentive, also encourages the intensification of fishing activity. The government provides sales tax exemption upto 3000 liters of fuel for mechanised boats and 900 liters for motorised boats as part of encourage fishing. However, the state government is not providing subsidy to new boats entering into fishery. Despite this disincentive, new mechanised boats are being added to the mechanised fleet. The subsidising of the operating cost (fuel cost) of mechanised trawlers as an incentive might put high pressure on the habitat of dimersal species and benthic creatures.

2.4.4. Weak Enforcement of Rules

A weak enforcement of and non-compliance with rules is another important factor affecting the marine resource exploitation. The trend towards mechanisation with an over emphasis on trawling and gill nets in addition to aweak enforcement of regulations related to mesh size and fuel subsidy (fuel sales tax exemption)can lead to an over exploitation of marine resources. However, in the process, a large quantity of waste is also generated in the form of by-catch which in itself is an important driving force of biodiversity loss acrossmarine ecosystems.

2.4.5. Increasing Demand for By-catch

In Andhra Pradesh, poultry and aquaculture are the two fast growing sectors of the economy. These sectors are heavily dependent on animal feed ofwhich fish meal is an important component. Low value fish and by-catch are used in the production of fish meal. There are 11 industries already engaged in the production of fish meal. The decline of oil sardine production has affected these industries with some of them unable to function to their full potential capacity. Dried by-catch materials are also directly mixed with poultry feed instead of adding fish meal. Non-salted dry fish powder is added to aquaculture feeds to minimise the cost of production instead of fish meal. So, the present practice is to add a combination of fish meal and dry fish powder—a potential risk since it can spread diseases through feeds. The different uses of by-catch and low value fishes in the industrial sector can lead to an excessive pressure on marine ecosystems in future. This is to be seen as an important driver of biodiversity decline.

2.4.6. Weak Resource Governance

The present governance structure is hierarchical (fisheries department) with little scope for fishers to contribute to the decision-making process. Lack of co-ordination and interaction among them may result in ineffective resource governance. Finally, the increasing pressure on coastal waters for other non-fishing activities like oil exploration, tourism, military operations etc.forcethe fishers to operate in the same fishing ground. It has been observed during the fieldwork that many boats move into the waters of neighbouring states-Odissa and Tamil Nadu for fishing. Fishers also migrate to Gujarat, Goa, Maharashtra and Andaman as crew members;the main reason for such migration is the non-availability of a sufficient fish stock in Andhra waters. So there is an urgent need to address governance issues related to resource health as part of maintaining a balance between livelihood resources and biodiversity sustenance.

2.5. Conclusions

Ananalysis of secondary data collected from CMFRI and the government shows that there has been a significant change in the composition of fish catch in Andhra Pradesh over the period from 1985-2013. However, at the same time marine fishery is facing increased pressure due to an increase in the number of fisher population, technological advancements, and institutional weaknesses like poor enforcement of rules and non-compliance with rules. The increasing demand for by-catch materials for industrial purposes is also creating substantial pressure on marine ecosystems. Thus in the light of these changes in the fisheries sector, it is important to have a carefully thought out long-term approach towards marine biodiversity conservation.

3. Economic Valuation of By-Catch and Juveniles

Economic valuation of seasonal fishing ban in selected maritime states of India

3.1. Introduction

This chapter provides estimates on the gross value of fish and crustaceans produced in Andhra Pradesh and by-catch at landing price. The disposal of fish and crustaceans to retail, wholesale and processing centers is also discussed. The second part of this chapter provides the economic value lost due to an unintended mortality of fishes, particularly by-catch and juveniles. In order to understand the ecological significance of this value, this chapter presents the diversity and value of juveniles caught. Finally,we discuss how the by-catch can be regulated with fishers' participation and using technological options like adoption of square mesh trawl nets and capacity building programs.

3.2. Gross Value of Fish and Crustaceans

The gross values of catch and by-catch have been estimated using 2013-14 data. The ratios estimated from the composition of by-catch species data collected in 2014-15 are applied to 2013-14 data to arrive at species wise by-catch estimations. The estimated total catch of marine fish and crustaceans,based on primary data for Andhra Pradesh works out to 466810 tonnes .Fish catch alone contributes 402502 tonnes to the total landing which is around 86% of the total production.

Fish production is further classified into high value and low value pelagic and demersal fishes. The high value pelagic amounts to around 61391 tonnes (13.2%) and high value demersal to 30728 (6.6%), where low value pelagic to 146750 tonnes (31.4%) and low value demersal to 163633 tonnes (35.1%). Shrimp contributes around 49580 tonnes, that is 10.6% of the total production and other crustaceans contribute 2.4%. The value of Mollusks and other species works out to a very low amount, that is, around 0.07% of the total production.

As far as the price is concerned, the average landing price per kilogram of different species groups amounts to ₹246 for PHV, ₹67 for PLV, ₹120 for DHV, ₹64 for DLV, ₹305 for shrimp, ₹92 for other crustaceans and ₹126 for Mollusks and others. A simple multiplication of the quantity produced into price provides the gross value of fish and crustaceans for the year 2013-14, that is, around ₹56986.5 million (56.98 billion) per year at landing price (price of first sale).

The flow of 4.66 lakh tonnes of fish to the economy worth rupees 56.98 million per year reveals the significance of the marine sector in Andhra Pradesh. This is an important marine ecosystem provisional service with high implications for food and nutritional

Table 3: Estimated Quantity of Marine Fish Production in Andra Pradesh (in tonnes per year)

Districts	PHV	PLV	DHV	DLV	FISH	SHRIMP	OC	MOLLUSCES	TOTAL
Srikakulam	2967.0	42524.6	4747.9	14748.5	64988.0	1236.9	345.6	26.1	66596.6
Vijayanagaram	2225.7	6467.4	850.2	2842.0	12385.3	853.5	70.4	0.0	13309.2
Vishakhapatnam	17187.6	47025.2	7954.9	79249.0	151416.8	15907.1	2338.7	0.0	169662.7
East Godavari	22697.2	34750.4	4911.0	45972.7	108331.3	15336.0	2141.8	85.4	125894.5
West Godavari	42.9	186.6	82.7	154.6	466.9	115.9	39.6	0.0	622.3
Krishna	6468.2	3995.8	2696.8	5175.7	18336.4	10121.7	1361.0	0.0	29819.1
Guntur	1743.2	1071.8	482.7	6301.9	9599.6	2216.2	1308.3	840.8	13964.9
Prakasam	3406.1	4990.3	8978.9	4657.4	22032.7	1682.4	1848.4	2011.4	27575.0
Nellore	4653.2	5737.6	23.0	4531.2	14945.1	2110.8	1832.8	476.7	19365.4
Total	61391.2	146749.7	30728.2	164000.0	402869.1	49580.5	11286.7	3440.4	466809.6

Source Primary survey

Table 4: Estimated Value of fish and crustaceans (in millions rupees)

Districts	PHV	PLV	DHV	DLV	Total Fish	SHRIMP	OC	MOL	TOTAL
Srikakulam	5850	23160	6712	7946	43669	2177	60.7	2.0	4647.2
Vijayanagaram	5039	3578	1288	1671	11576	2060	10.6	0	1374.1
Vishakhapatnam	38638	28286	11965	53302	132192	58762	214.0	0	19309.3
East Godavari	57912	28969	6783	29368	123032	73993	110.3	5.4	19818.2
West Godavari	75	80	63	67	284	464	1.4	0	76.2
Krishna	17842	2244	2471	2656	25213	11149	159.7	0	3795.8
Guntur	6998	1874	507	5924	15303	5282	209.1	120.5	2388.1
Prakasam	13006	3840	12391	4518	33754	4082	142.5	182.1	4108.2
Nellore	4956	2972	16	1398	9343	4008	104.4	29.9	1469.3
AP	150316	95004	42196	106850	394366	161974	1012.6	339.9	56986.5

Source Primary survey

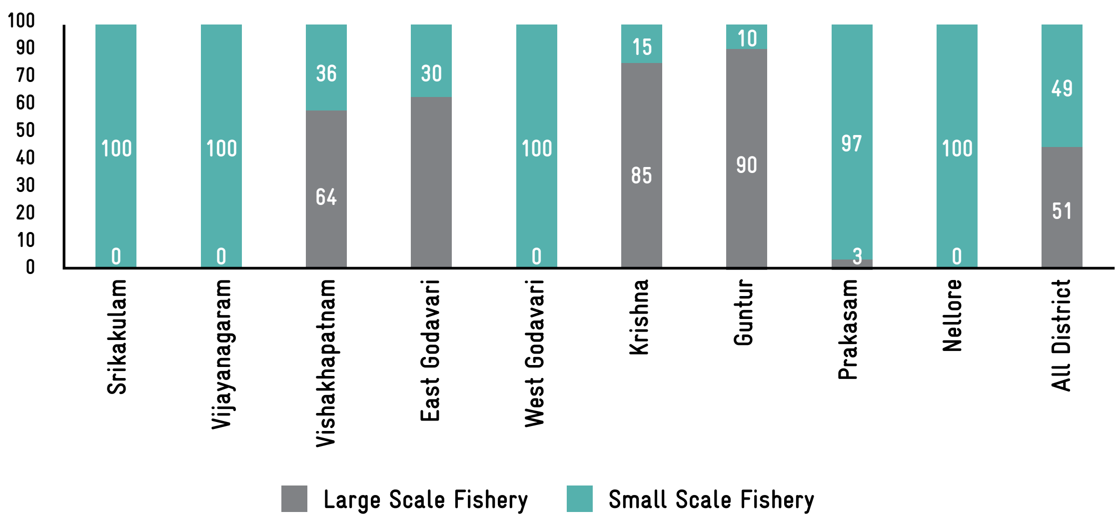
security of the people living in the state. Moreover ,it gives immense scope for value addition activities and foreign exchange earnings.

3.2.1. Distribution of Values Across Fishing Units and Catch Per Unit of Effort

The total landed quantity varies across fishing units depending on the different craft gear combinations,the dominant gears of mechanised sector are trawl nets and gill nets while the non-mechanised (motorised and non-motorised) crafts use widely gill nets. The contribution of the mechanised sector amounts to 236761 tonnes (51%),while it is 142546(31%) for motorised and 87503(19%) tonnes for non-motorised crafts. It is evident from the figures that Vishakhapatnam, East Godavari, Krishna and Gunturdistricts account for a greater share in the fish catch from mechanised boats (large-scale). In respect of all other five districts,the contribution of motorised and non-motorised sectors (small-scale) to the total landing is higher. However, the contribution of large and small-scale fishery to the economy remains more or less close at 51% and 49% respectively for Andhra Pradesh.

The catch per unit of effort has been estimated based on the methodology described in Chapter 1. The estimated per unit effort based on the survey data for the mechanised sector works out to fishing days, 529173 for motorised boats,to 382560 fishing days and for non-motorised sector to 525184 fishing days. The

Figure 7: Contribution (%) of Large and Small Fishing Units to the total Landing across districts



estimated catch per unit of effort for the mechanised sector comes to 441.41 Kg while it is 372.61 kg for motorised and 166.60 kg for non-motorised crafts. The weighted average in respect of CPUE for all boats works out to 371 Kg. The operational expenditures of sona boats with trawl nets for 10 days of voyage range from ₹250000 - 300000 while it is ₹100000 - 150000 in the case of small-mechanised boats for 5 days of voyage,and in respect of non-motorised gill nets from ₹1000–1500 and for non-motorised gill nets, the operational expenditure amounts to ₹500. The estimated average cost per unit of standard fishing effort comes to ₹11525 ranging from ₹500 to 30000, depending up on the fishing unit. That means, there is a high variation in the operating costs across different types of boats. On an average, fishers earn a gross income of ₹5252 to 53830 per unit of fishing effort, depending on the craft and gear they use. The high dispersion in the value of gross benefits and cost is an important limitation involved in arriving at the value of main catch and by-catch.

3.2.2. Disposal and Value Additions of Total Catch

As far as value addition is concerned, the data collected from the local retail market, whole sale market and other value added activities in the sector like salting, drying and processing units shows that 81% of the total catch goes directly to the local and whole sale markets and 16% is shared among processing, drying, salting units,while the remaining 3% is consumed by fisher families. The fishing industry also buys fish from the whole sale market that amounts to around 12%,which means a total of 28% of the total quantity of fish catch goes to value addition activities in the fishing industry of the state. Nearly, 18% of the fish catch is accounted for by the domestic market,while 48% is exported to other states and countries and 3% goes for household home consumption. Nearly 3% of the catch also goes as waste due to various reasons like damage, juveniles etc.

This indicates that the marine fishery plays a significant role in terms of supporting the local economy by providing income, employment and livelihood to many people. It is also a major source of foreign exchange earnings. Nevertheless, high level of fishing also imposes a cost on the society in the form of a juveniles and unwanted species lost in the form of by-catch.

3.3. Gross Value of By-catch and Discards

The total estimated by-catch quantity for a year comes to around 53990 tonnes, whiled is carded quantity to 24136 tonnes in the case of Andhra Pradesh; that means, the total quantity of biomass (catch plus by-catch plus discarded) generated from marine ecosystems works out to 544935 tonnes in a year of which the main catch amounts to 85.66%, by-catch to 9.9% and discarded

Table 5: Quantity of fish and crustaceans disposed of at first and second sales

Districts	Total Fresh fish first sale	Fresh Fish first sale to the local retail market	Fresh fish sale to Agents	Fresh fish second sale to the Domestic Market	Fresh fish second sale to other States	Fresh fish second sale to processing Plants	Fresh Fish first sale to Processing plants	Total sale to Processing Plants
	A=B+C	B	C=D+E+ F+G+K	D	F	G	H	I=G+H let in
Srikakulam	55275	940	54335	30825	23511	0	0	0
Vijayanagaram	11712	141	11572	7026	4546	0	0	0
Vishakhapatnam	128944	3481	125462	13077	83708	18498	0	18498
East Godavari	96939	2811	94128	7564	64634	12614	2518	15132
West Godavari	579	43	536	347	89	55	0	55
Krishna	28626	658	27968	8152	14785	2675	0	2675
Guntur	12149	340	11809	1879	8795	437	0	437
Prakasam	24818	521	24296	12344	9752	1097	0	1097
Nellore	17816	339	17478	4828	12071	191	0	191
Andhra Pradesh	376858	9274	367584	86040	221891	35568	2518	38086

Source Primary survey

Table 6: Gross Value of the total landing and by-catch at market price (first sale)

Items	Quantity (in tonnes)	Value in billions (rupees per year) (Benefits)
Fish and crustaceans landed at market price	466809 (85.66)	56.986
By catch landed at market price	53990 (9.9)	0.08098
By-catch discarded	24136 (4.42)	0.00
Total quantity	544935 (100)	55. 8797

Source: Primary survey

by-catch to 4.42%.

The by-catch ratio for bottom trawlers works out to 4:1, for mid water trawlers to 7:1 and in the case of others varies from 10:1 to 15:1. The by-catch is sold to the market at a price ranging from ₹0.70 to ₹1.5 per Kilogram. The average price is ₹15 per 15 kg basket(₹1 per Kg) that gives a gross benefit of 80.98 million (0.08098 billion) rupees per year at the landing price.

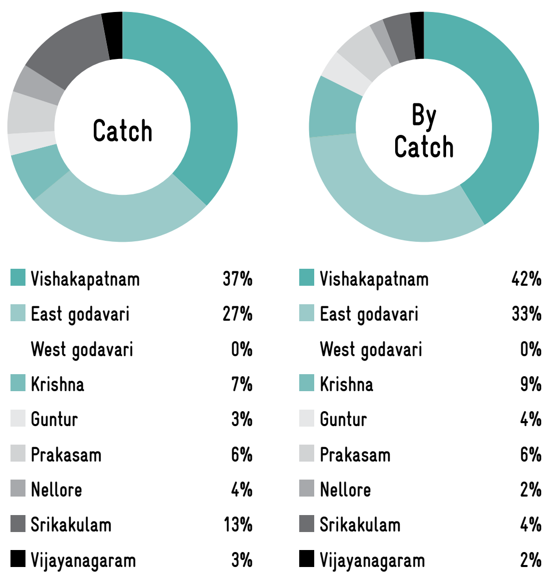
The by-catch value is not a significant contributor to the fishery income though the quantity amounts to around 10% of the total catch. The reason for this can be attributed to the throw away prices. This is a benefit that accurse to the crew members of fishing boats. The landed by-catch flows to fish meal industrial units.

The shares of Visakhapatnam,East Godavari in the by-catch are found to be higher in that of Krishna and Guntur districts,the share of Vishakhapatnam amounts 37% in the total catch, while its share in the by-catch remains higher at 42%. In the case of East Godavari, the share in the total catch amounts to 28%, while its share in the by-catch amounts to 33%. In respect of Krishna and Guntur districts, the share happens to be 9% and 7% respectively. The shares of by-catch in all other districts (Srikakulam Vijayanagaram, Nellore, Prakasam etc.) that are characterised by a small-scale operation are low.

As far as the scale of fishing is concerned, by-catch accounts for around 15.56% in the case of mechanised boats. Among the small scale operations, motorised boats generate 8.0% and non-motorised generate 4.86% of the by-catch as against the total fish catch, while the discards are mainly accounted for by mechanised boats to the extent of around 0.5% of the total catch. This indicates that the promotion of the small scale sector (motorised and non-motorised) is more beneficial to the marine ecosystem.

First sale for Salting	Second sale for salting	Total salting	First sale for sun Drying	Home Con-sumption	Wasted catch
J	K	L Let in	M L Let in	N	O
2664	0	2664	1998	5994	666
0	0	0	399	1198	0
10180	10180	20360	25449	3393	1697
2518	9316	11834	17625	2518	3777
0	44	44	0	44	0
298	2356	2654	596	298	0
279	698	978	419	698	419
827	1103	1930	1655	276	0
0	387	387	968	581	0
16766	24084	40850	49110	14999	6558

Figure 8: Distribution of total catch and by-catch across districts (zones) of Andhra Pradesh



Source: Primary survey

3.3.1. By-catch Value Per Unit of Fishing Effort

We have already seen that the weighted average CPUE for all boats comes to 371 Kgs based on which the estimated total standard fishing effort for the state works out to 1255075 boat days. When we repeat the calculation in respect of the total biomass (catch plus by-catch plus discard) with the same level of weighted CPUE the standard effort works out to 1465127 boat days. That means a difference of 210051 standard boat days is the effort gone into by-catch component of overall fishing. When we multiply the extra effort by the average cost of fishing effort (₹11525), we get a value of 2.42 billion rupees per year in which the contribution of mechanised sector amounts to 1.32 billion rupees, motorised sector to 0.681 billion rupees and non-motorised sector to 0.413 billion rupees. This is an indirect way of arriving at the value of by-catch in terms of the unit cost of fishing which is significantly higher than the value earned from the market through the sale of by-catch. The value of effort lost due to by-catch is much higher than the money earned from it (0.08098 billion),through the sale of by-catch. The boat owners need to be made aware of the loss of effort involved in it while designing any incentive mechanism to regulate by-catch. Also creating awareness among fishers regarding the implicit cost (cost of fishing effort) should be an important strategy towards regulating by-catch.

3.3.2. Disposal and Value Addition of By-catch

The by-catch is disposed of to fish meal and poultry feed units. An important input for fish meal units is by-catch, a low value fish and by products of trimmings made during processing (fish waste or offal) of various seafood products. There is direct linkage between low value fish and fish meal units Fish meal produced from low value fish is an important protein ingredient used in poultry and aqua culture feed sectors. Besides, fish meal is recognised as a valuable animal protein supplement and a source of vitamins, particularly for feed poultry, pigs, and other farm fish. Fish meal is generally manufactured from wild-caught, small marine fish that contain a high percentage of bones and oil. There are estimates available on the amount of wild fish required for producing one kilogram of farm fish. A widely used fish in/fish out ratio is 5:1 that means five, or even more, kilos of wild fish are harvested to produce, via fish meal and fish oil in aqua feed, just one kilo of farm fish (Albert & Marc, 2008). (Rosamond, et al., 2009). These facts indicate that fish meal and feed industrial units can act as an important driving force of by-catch production which, in turn, can affect marine biodiversity.

A study (Ponnusamy, 2012) on fish-meal industrial units finds that fish meal is sold at a price of ₹40 to 50 per kg. On an average, fish meal units earn a profit of 10 to 20% in India. At present sardine and other low value fish are used in fish meal units. There is great scope for these markets to grow in the future since aquaculture, poultry and piggery are fast growing sectors in India. Fish meal produced in India is exported to Australia, China, Egypt, Japan, Middle East countries, South Korea, Saudi Arabia, Pakistan, Spain, South Africa, Thailand, Vietnam and New Zealand (Ponnusamy, 2012).Most of the fish meal units are located in the west coast of India, and are highly dependent on sardine oil. There are a total of 5 industrial units in Andhra Pradesh engaged in the production of fish meal. But these industrial units are not performing well due to the non-availability of sardine oil. It is reported that there is a decline in the production of sardine oil in the east coast. Besides, there is a considerable gap between the demand for and production of fish meal in the state. However, this gap is met with imports from the west coast of India and other countries. The supply-demand gap is also partially met by using dry fish powder in aqua feed production. At present, non-salted or slightly salted dry fish powder is substituted for fish meal in the production of aquaculture feed, particularly for shrimp culture . In an earlier study cited, we have noticed that it could affect the sustainability of the fast growing vennamai culture of the state since many diseases can spread through contaminated feed. The by-catch is also used for making dry fish for poultry feed. The poultry feed units grind dry by-catch with other ingredients to make poultry feed. The state leads the country in the poultry enterprise and hence, there is an increasing demand for by-catch products. In fact, the increasing demand for by-catch products for poultry feed units and aquaculture is to be seen as an important economic driver of by-catch harvest. Therefore, there is every possibility of excessive pressure on the existing fish stock and marine biodiversity which in turn,calls for a long-term precautionary policy approach towards by-catch sustenance.

3.4. Value of Juveniles

Generally, juveniles are found in both main catch and by-catch. Those fish which do not attain a required length at first maturity are treated as juveniles . Calculation of the juvenile biomass lost is made based on the length-weight relationship coefficient as described in chapter

Figure 9: Landing of catch from mechanised trawlers and drying for poultry feed mills

1. In the absence of coefficients for the length-weight relation for any given species, we have used coefficients of the dominant species from within the same group.

3.4.1. Shrimp and Crustaceans

Table 7 shows the average size of juvenile shrimp caught as part of targeted species, while the minimum length is found to be 2 centimeters. The scientifically established coefficient for weight-length relationship is $\text{Log } W=-1.444+2.485 \text{ Log } L$ ($r2 = 91$) (Gopalakrishnan, et al., 2013). Using these coefficients, we have estimated that 757 small shrimps are needed for one kilogram, which is equivalent to 37 kg of adult shrimp as per this relationship. In one trip of a mechanised trawler boat, 13 kilograms of juvenile shrimps have been observed in by-catch, which is equivalent to an average 481 Kg of adult shrimp lost per trip. The estimated per trip loss for sample boats has been extrapolated to the total boats by multiplying with the weights of landing center days,and the results show a loss of 91.28 tonnes per year. That means the lost value of shrimp is approximately ₹41.08 million per year , which is a lower bound value since we have considered only the value of shrimp wasted in by-catch. These shrimps are sometimes picked up and sold in the local market for household consumption.

The main reason behind catching under sized shrimp is the use of a very small sized mesh in trawl nets. It is a diamond shaped mesh, so while dragging no living organism can escape from the net. The diverse species found in by-catch are provided in Table 7. Among other crustaceans, small crabs are found to be in large quantities. The smallest crabs have an average width of 2 centimeters. Using the length-width relations $\text{Log } w = -0.35923+3.140792 \text{ L}$ (Thirunavakkarasu & Shanmugham, 2011), we have arrived at the quantity lost at around 212 tonnes a year, that is worth 19.54 million rupees.

3.4.2. Fish

Among fishes, we have noted that 65% of the sharks and rays caught are under sized juveniles. These are slow growing species. The average size of juveniles for

Table 7: Juvenile Shrimp and crabs considered for value estimation

Scientific Name	Popular English Name	Local Name (Telegu)
1. Penus monodon	giant tiger prawn	pappuroyya
2. Penusindicus	indian white prawn	tellaroyya
3. Penustinyous	small prwan	singodiroyya
4. Metapenacusmonoceres	brown shrimp	chakuroyya
5. Metapenacus dobsoni	pintac shrimp	sankuroyya
6. Metapenacusaffinis	king prwan	bonguroyya
7. Metapenacusbrevacorius	yellow prawn(karikad)	pasupuroyya
8. Parapenacusstylefera	kiddy prawn	gullaroyya
9. solonocera crassicorious	crustal mud prawn	kukkaroyya
10. penacussemisulcates	flower prawn	nuneroyya
11. Stylla serrate	Mud crab	Pacchapeetha
12. Scylaatranquibarica	Green mud crab	Manda peetha
13. portunus sanguindentus	Three spot crab	Muuduchukkalapeetha
14. porulunus pelagicus	Marine swimming crab	Galipeetha
15. Charybdis	Crucifix crab/ gross crab	Jeelagapeetha

Source: Primary survey

sharks is 30 centimeter. Fishers treat these species as sub-adults and sell them in the market. However, a small proportion of these species (3%) goes as trash in the by-catch. Approximately 4988 tonnes are lost due to their juvenile status that is worth 598 million rupees per year. This value also includes the value of sub-adult species in the catch; similarly around 9036 tonnes of juvenile croakers, which is equivalent to 605 million rupees a year.

The other fish species found as juveniles in targeted catch (Table 9) amount to approximately 156435 tonnes per year worth 12.93 billion rupees.

Anchovies (Engraulide) are the most common species found in the by-catch of mechanised vessels. There are 8 different types of anchovies reported as juvenile catch during our survey (Table 10). The reported size of these juveniles varies from 6 to 9 centimeter, while the size at maturity ranges between 12

Table 8: Juvenile Sharks and Rays considered for an economic valuation

Scientific Name	Popular English Name	Local Name (Telegu)
1. rhizaprionodin	mulk sharks	paalasorra
2. carcharlinuslimbatus	grey sharks	sorra
3. carcharlinus melanapterus	black fin reef sharks	kowlasorra
4. galeacerdaarcticus	tiger sharks	pulisorra
5. sphyrenazygaena	hammer head sharks	suthisorra
1. rhinobatusgranulatus	grannlated shower nose shark	ulava
1. nemanturablockerii	whipe tail string ray	tarukuteku
2. manta birostries	gaint devil ray	deyyaputeku
3. narcine	elctric ray	current teku
4. aetobatusnarinari	spotted eagle ray	chukka take
5. rhinopterajavanica	flapnose ray	gadddateku
1. johniusmacropterus	large fin crokers	goraka
2. kathalaaxillarus	kathalacrukaer	pallagoraka
3. jhonicops sina	sin croakers	nallagorka
4. johnieops vogleri	sharp toothed hammer	kacchidi
5. protnibeadiacanthus	spotted croaker	chukkalagoraka

Source: Primary survey

Table 9: Juvenile Fishes considered for valuation.

Category	Scientific Name	Popular English Name	Local Name (Telegu)
Sphyaaenidae (barracudas)	1. sphyraena obtusata	Oftse barracuda	Seelapothu
	2. Sphyraenajella	Barracuda	Seelapothu
Polynemidae(thredfinbaen)	1. Eleutheroenema/ tetradactylum	Indian solaman/ six thredfin	Maagalau
	2. Polynemusindicus	Indian thredfin	Boddenmaaga
Trichiuridae (ribbon fish)	1. Lepaturaconthussavala	Small head ribbon fish	Chinnathalachavida
	2. thichiurus lepturus	Large nose ribbon fish	Nallchavida
	3. E pleurogramusimermidius	Inshore hairtai ribbon fish	Tall chavida
Scombridae (tunas	1. Euthyunusaffinis	Little tuna	Chukkalatura
	2. Katsuwonuspelamis	Shipjock tuna	Nehuru tuna
Seer fish	1. Scomberomorouscommerson	Narrow barred seer fish	Konem
	2. scomberomorousguttalus	spotted seerfish	marjoram
	3. scomberomorouslineolatus	streated seer fish	vanjaram
Lutjanidae (snapper)	1. Lutijanusargentimaculatus	Mangrove red snapper	Yerrakachdi
	2. Lutjanusjohni	Johns snapper/ golden snapper	Rangukachidi
Stromatfidae (pomfrets)	1. pompus argenteus	silver pomfret/white pomfretes	tellachnaduva
	2. stromateousniger	black pomfrets	nallachanduva
	3. pampuschinensis	chinesepomfrtes	chaineschanduva
Psettodidae (halibat)	1. psettoduserumai	indianhalibat	tamburotta/yeddunalika
	2. psettdorhombusarrius	large thootedlounder	namminalika
Cynoglossidae (toungsole)	1. cynoglossusarel	large scale toung sole	podavuthamburotta
	2. cynoglossusdubias	toung sole	nallathamburotta
cephalopods sephdae (cuttle fish)	1. sepia pharaonis	cuttle fish	charalkandavai
	2. sepiallainermis	cuttle fish/ spinellesscuttle fish	buddakanduvai
sqvids	loligoduvaceli	indian squid	kandvai
Chirocentride (wolf herring)	1. chirocentrus dorat	Wolf herring/ silver bar	Gaggola/ mullavarav
	2. Chirocentrusnudus	White fin wolf herring	Goggola/ vala
Megalopidae (tarpons)	1. Megalopscyprinoides	Indo pasifictarpan	Karringa
Muraenidae (eels)	1. Thyrbrideamacrura	Gaint moray	Peddapamu
	2. congresox talabonoids	Indian pike conger	Tallapamu
	3. uroconger lepture	Conger eel	Paamu
Synodontidae	1. saurida tunbil	Greater lizard fish	Bademarta
	2. S indicus	Indian lizard fish	Bade matta
Harpadontidae	1. Harpadonnehereus	Bombayduck	Kukkchavida
Centropoidae	1. Latescalcarifer	Gaint sea perch	Pandugappa

Contd...

Category	Scientific Name	Popular English Name	Local Name (Telegu)
Searranidae	1. cephalaphots	Sonnerate plate tomnto	Bontha
	2. Epenephelusaredatus	Aredated grouper	Rathibonta
Rachycentridae	1. Rachycentroncanadum	Cobia/block ikng fish	Nallamatta
Carangide (carangoids)	1. Alper para	Golden scad	Pacchakaralu
	2. Alectsindicus	Indian thredfin trevally	Thoka para
	3. Carngigoidesmalbaricus	Malabar trevally	Thalanpara
Carynx	1. Caranxignobils	Yellofin trevally	Pasupupora
	2. Caranxsexfasciatis	Dusky travelly	Karachukkalu

Source: Primary survey

to 21 centimeters.Around 32% of the total anchovies are found juveniles. The estimated average weight loss due to undersized catch comes to around 3840 tonnes, worth 144 million rupees.Anchovies (Engraulide) are the most common species found in the by-catch of mechanised vessels. There are 8 different types of anchovies reported as juvenile catch during our survey (Table 10). The reported size of these juveniles varies from 6 to 9 centimeter, while the size at maturity ranges between 12 to 21 centimeters. Around 32% of the total anchovies are found juveniles. The estimated average weight loss due to undersized catch comes to around 3840 tonnes, worth 144 million rupees.

Another important group found in the by-catch basket is clupeidae, of which 10 species have been reported. Clupeidae (Latin: "sardine") is the name of the fish family of herrings, shads, sardines, hilsa, and menhadens . The juveniles reported in by-catch are given in Table 11. There is substantial variation in the prices of clupeid species. For example, hilsa costs 5 to 6 times more than sardines. The smallest size of clupeidae measures around 6 centimeters. Nearly 11% of by catch species come under the category of clupeid juveniles. It is estimated that around 36914 tonnes of clupeidae are lost due to juvenile catch in a year,at a value loss of 4.87 billion rupees.

Pony fish juveniles are also found in large quantities in the by-catch of mechanised boats. The smallest size is around 5 centimeters. We lose nearly 112803 tonnes of fish in a year due to juvenile catch, worth 10.15 billion rupees.

The proportion of catfish juveniles is also high in by-catch. The catfish mainly live in marine waters in the tropical to warm temperate zones. The family includes about 143 species. We have found 6 different species of catfish juveniles in by-catch with an average size of 12.33 centimeters. The estimated loss amounts to approximately 37% of the present catch due to undersized fishing. The estimated loss is approximately 3544 tonnes, worth ₹177.22 million at the landing price of matured species (₹50 per kg). The other juveniles found in by-catch are yellow goatfish, laying scud, Paste shrimp and Indian mackerel. The estimated quantity of loss of these species comes to around 120860 tonnes, worth ₹3.38 billion.

From the analysis, it is clear that the future loss of

Table 10: Juvenile Anchovies considered for an economic valuation.

Scientific Name	Popular English Name	Local Name (Telegu)
1. Coliadussumoeri	Gold spotted grandieranchavy	Pasuputhokanettalu
2. Setopinnataty	Hairfinanchavy	Thikapariginettalu
3. stolephorus commersoni	Commersoni anchovy	Nettalu
4. stolephorus indicus	Indian anchovy	Nettalu
5. stolephorus wailai	White bait/ spot faced anchovy	Purva chukka
6. thryssa dussumieri	Dussimieri anchovy/tharyssa	Pottiporava
7. Thryssahamiltonil	Hamiltin'sthryssa	Pottiporava
8. thryssa malabarica	Malabar anchovy	Porava

Source: Primary survey

Table 11: Juvenile Clupeide considered for an economic valaution.

Scientific Name	Popular English Name	Local Name (Telegu)
1. Anodantostomachacunda	Chacunda gizzard shad	Mudurlu
2. Dussumieriaacta	Rainbow sardine	Morava
3. escaralosa thoracate	White saradine	Tellakavallu
4. Sardinellalongiceps	Indian oil sardine	Nunikavallu
5. sardinella fimbrate	Fringe scale sardines	Geethakavallu
6. sardinella gibbosa	Gold striped sardiine	Pasupukavullu
7. Ilishamegaloptera	Big eye ilisha	Gudduakurai
8. Tennalosailisha	Hilshailisha/indian shad	Polora
9. Pellonabiligera	Pellona	Channaakurai
10. pellona ditchala	Indian pellona	Morava

Source: Primary survey

Table 12: Juvenile Pony fish considered for an economic valuation.

Scientific Name	Popular English Name	Local Name (Telegu)
1. Lelognathussplendens	Splendid fish	Mullakara
2. Lelognthus bin dus	Orenge fin pony fish	Banda kara
3. Lelognathusdussumieri	Dussumieri pony fish	Chandavakara
4. Lelognthusequalus	Common pony fish	Chanduva fish
5. Leiognthusdaura	Goleden striped pony fish	Dasarakara
6. Liognathusfaciatus	Striped pony fish	Karala chukka
7. Secuctosruconius	Deep pung nose pony fish	Chinnakara chukka

Source: Primary survey

Table 13: Juvenile Catfish and goat fish considered for an economic valuation.

Scientific Name	English Name	Local Name (Telegu)
1. Arius arius	Hamiltaons cat fish	Jella
2. Arius dussumieri	Dussumieri catfish	Tedijela
3. Arius jella small eye catfish	Small eye catfish	Chinnakannujella
4. Arius tenuispinis	Dusky catfish	Peddajella
5. Arius tenuispinis	Days catfish / slendera pined	Nallajella
6. Arius thalassinus	Sea catfish gaint marine cat fish	Tella
1. upendiessulphracus	yellow goat fish	pasupugulimindha
2. upenusvittalus	yellow strpped goat fish	pasupucharalaguliminda
3. parupeneusindicus	indian goat fishes	rathigulimindalu
1. Decaptersmacrosoma	Layangscad/short scad	Pilladugulu
2. Decaptersrusselli	Indian scad / round scad	Rilladugalu
1. Acetusindicus	Paste shrimp	Potturoyya
1.Rastrelliger	Indian Mackerl	Kanagarthalu

Source: Primary survey

juvenile catch is quite high. The amount of loss comes to around 318827 tonnes of biomass per year worth 20.29377 billion rupees. This is the future value lost due to juvenile catch in the present. When we add up the present value lost due to fishing effort (2.42 billion for by-catch), the total loss works out to 22.71377 billion rupees. That means,the society loses 35% of the value of fishery in terms of by catch and juveniles. In terms of quantity, the loss per unit of effort is 221.88 Kg, while the quantity landed per unit of effort is 371 Kg; that means, the loss is 59.8%. The loss in terms of value is less as compared to the loss in terms of quantity because a higher proportion of by-catch and juvenile species constitutes low value species. But from a conservation point of view, it is important to consider the loss in terms of quantity, which is higher, since many species do not fetch any economic value in the market. This cost can be avoided by regulating the excessive fishing effort for by-catch, which is estimated to be 210051 standard fishing days per year. But it is also important to examine what proportion of this cost can be really avoided. Avoiding the entire juvenile catch is not feasible in trawling, since the size of many juveniles found in catch is found to be much bigger than the code end size of the nets. For example, large quantities of juvenile gray shark and black fin shark have been reported with less than 30 cm length. But a certain proportion of the overall cost can be avoided by way of increasing the mesh size and changing its shape. We have examined this aspect with data on catch retention and exclusion experiment conducted by CIFT.

3.5. Catch Retention and Exclusion (experiments)

As per the Central Institute of Fishing Technology, one of the simplest methods of regulating by-catch is using a square mesh of 40mm at the code end of trawlers. Mesh size regulations for trawl gears aim to reduce fish mortality by allowing small sized fishes and juveniles to escape. This experiment was undertaken to study the retention and exclusion characteristics of fish species in respect of trawls attached with a 40 mm square mesh code end in Bay of Bengal. Square mesh code ends of 40 mm were fabricated with 1 mm dia polyethylene (PE) netting. The experiments were carried out on board fishing research vessel CIFTECH-I (15.5m LOA; 122 hp) in the commercial fishing grounds off Visakhapatnam coast (17°40'-17° 42 lat.; 83°21'-83°30 long.), between 40 and 50 m. A 26 m multi seam demersal trawl fitted with an experimental square mesh code end was used and the overall performance of the code ends during the experimental tows evaluated. The covered code end method was used to assess the selectivity of the code ends. A small mesh cover of 20 mm PEnetting greater than 1.5 times the size of code end was used for the experiments. 30 hauls of

Table 14: Catch details with a retention and exclusion rate of mechanised trawling with a 40mm code end square mesh trawl net.

Species	Retained	Escaped	Total catch kg	Exclusion (%)	Catch (%)	Value of Retained	Value of escaped
silver bellies	152.0	80.4	232.4	34.6	49.3	1303	345
Ribbon fish	80.0	11.0	91.0	12.1	6.7	8000	157
Scianids	52.2	3.0	55.2	5.4	1.8	1417	21
Upeniussp	40.0	8.0	48.0	16.7	4.9	2000	103
Puffer fish	43.0	0.0	43.0	0.0	0.0	0	0
Lizard fish	40.0	2.2	42.2	5.1	1.3	4571	28
Nemepterids	30.0	5.0	35.0	14.3	3.1	4286	0
Pomfret (Black)	30.0	0.0	30.0	0.0	0.0	18000	0
Stolephorus	10.0	20.0	30.0	66.7	12.3	1429	1143
Nebeamaculata	18.9	5.8	24.7	23.6	3.6	1080	99
leognathussplendens	22.0	0.0	22.0	0.0	0.0	2514	0

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Species	Retained	Escaped	Total catch kg	Exclusion (%)	Catch (%)	Value of Retained	Value of escaped
Pentaprionsp	12.3	7.0	19.3	36.3	4.3	1406	0
Decapterussp	15.0	2.0	17.0	11.8	1.2	964	29
Squid	11.0	3.8	14.8	25.7	2.3	786	27
Thyssa sp.	10.3	4.4	14.7	30.1	2.7	191	38
Rainbow sardine	13.0	1.0	14.0	7.3	0.6	371	10
Crabs	13.1	0.0	13.1	0.0	0.0	749	0
Cuttle fish	11.0	0.7	11.7	6.1	0.4	2200	3
Squilla	10.0	0.5	10.5	4.8	0.3	0	2
Pomfret (w)	10.0	0.0	10.0	0.0	0.0	6000	0
Skates	10.0	0.0	10.0	0.0	0.0	1000	0
Pomfret (C)	10.0	0.0	10.0	0.0	0.0	12000	0
Lacterias sp.	9.0	0.0	9.0	0.0	0.0	1286	0
Horse mackerel	9.0	0.0	9.0	0.0	0.0	141	0
Barracuda	7.0	0.0	7.0	0.0	0.0	800	0
Gobids	5.8	0.7	6.5	10.8	0.4	0	0
Pssittoduserumi (Flat fish)	6.0	0.1	6.1	1.6	0.1	1800	0
Trachiocephalusmyops	3.0	2.4	5.4	43.9	1.4	129	0
Mackerel	5.0	0.0	5.0	0.0	0.0	357	0
Arriomaindica	5.0	0.0	5.0	0.0	0.0	643	0
Seer fish	5.0	0.0	5.0	0.0	0.0	1250	0
Moon fish	5.0	0.0	5.0	0.0	0.0	500	0
Cynoglossuscynoglossus	3.0	0.3	3.3	9.6	0.2	129	2
Cat fish	6.2	0.3	6.5	4.6	0.2	443	2
J. carutta	3.0	0.2	3.2	4.8	0.1	129	0
Cynoglossuspuncticeps	3.0	0.0	3.0	0.0	0.0	257	0
Polynimidustetradactylus	3.0	0.0	3.0	0.0	0.0	514	0
Eel	3.0	0.0	3.0	0.0	0.0	129	0
Apogonids	2.5	0.4	2.9	14.1	0.3	0	0
Pipefish	2.0	0.6	2.6	23.8	0.4	0	3
Carangids	2.4	0.0	2.4	0.0	0.0	137	0
Octopus	2.0	0.3	2.3	13.0	0.2	0	1
Theraponjarbua	1.6	0.0	1.6	0.0	0.0	34	0
Ray	1.6	0.0	1.6	0.0	0.0	0	0
Total	736.8	160.1	896.9			78944	2012

Source: (Prakash, 2014)

one hour duration were taken with the towing speed maintained at 2.3-2.5 kn. The quantity and size of the fishes retained in the square mesh code end as also those excluded were recorded.

In other words, if we hadused adiamond shaped net with a small size mesh (less 25 mm), it would have generated the same quantity (17.8) or more quantity of by-catch, which is comparable with our estimate of by-catch for mechanised trawlers,that is,15.5%. Another important fact is that excluded fish from a giventrawl net would not fetchmuch value forthe fishers since most of them are juveniles and low value fishes. In value terms, it amounts toonly 2.5% of the total value of a given catch. A comparison of the experimental data on exclusion rate with estimatesof by-catch for mechanised boats reveals that by-catch reduction is possible without affecting the target catch by adopting a square mesh with a 40 mm code end mesh size. However, greater proportion of sub-adults found in the targeted catch is bigger than the size of nets, so only a certain proportion sub-adults can be regulated.

3.6. Conclusion

In this chapter, we found that marine ecosystems contribute significantly to the economy in terms of fish and crustaceans for human consumption, which is estimated to be 4.66 lakh tones, worth ₹55.986 billion per year for Andhra Pradesh State. The estimated catch per standard fishing effort comes to 371 Kg per boat. The flow of fish and crustaceans also creates value addition activities and employment opportunities in the economy. This is a very important serviceprovided by marine ecosystems. On the other hand,high fishing pressure on the system is generating large quantities of by-catch in the form of low value fishes and juveniles. The study estimated the value of a significant part of the present fishing effort used for generating these wastes. The benefit generated out of the by-catch comes to around ₹80.98 million per year through sale. This value is much lower than the present cost incurred by fishers for generating the by-catch that amounts toaround ₹2.42 billion. Further, it is important that fishers are aware of the implicit cost they incur while harvesting by-catch.

In addition, the biomass lost due to juvenile catch comes to around 20.71 billion rupees per year. In value terms, it is a loss to the extent of 35% of the total fish catch and in quantity terms, it is to the extent of 59.98%. Therefore, the study argues for minimising the excessive fishing effort to minimise this component of social cost. Moreover, with the fast growing aquaculture and poultry industries in Andhra Pradesh, there is high likelihood ofincreased demand for by-catch fishes. Therefore, we propose a long-term precautionary policy approach towards addressing the consequences of increasing demand for by-catch in the economy.

4. Conclusion and Recommendations

Economic Value of Biodiversity Loss: A Study of By-Catch from Andhra Pradesh Marine Fisheries

This study focuses on the social cost of by-catch and juveniles in respect of marine fisheries of Andhra Pradesh state in India besides highlighting the need for regulating by-catch harvest. The state has a very rich resource base for fisheries development. A majority of the fishers are engaged in small-scale fishing activities using traditional fishing crafts and motorised fishing crafts. It is very evident that fisheries, as an industry plays a significant role in income, employment and livelihoods of the people in the study area.

However, the marine sector has already reached its maximum production threshold with limited growth potential. The marine sector is facinghigh fishing pressure due to increased demand for fish and crustaceans for human consumption and low value and trash fishes for aquaculture and poultry sectors. This study findsthat the landing of certain species groups like crustaceans, tuna and Indian mackerel has increased over time while that ofothers shows adeclining trend. The changing composition of fish species caught indicates the changing character of marine fish diversity.

The increasing human settlements and growth of population in coastal areas have made fishing an important source of livelihood. Now people use various modern techniques to harvest fish from the seas. The technological trends indicate that fishing practices are making a switch over from traditional to modern methods that involve intensive resource exploitation. Muchof the shift has happened with respect to trawls and gill nets withsmall sized meshes that generate large quantities of by-catch.

A steady subsidy support towards meeting the operational costs(fuel cost) of mechanised trawling is another factor that encourages trawling on a large scale which, in turn,puts high pressure on the habitat of dimersal species and benthic creatures. Therefore, there is a need for rationalising the subsidy regime in the fishing sector.

Weak enforcement and non-compliance with fishing rules is another important factor affecting resource exploitation in Andhra Pradesh. A growing demand for by-catch and low value fish for producing fish-meal, dry fish powder and poultry feed might lead to an excessive landing of by-catch in future. These are the major underlying drivers of the economy with far reaching adverse implications for marine biodiversity. In the light of these developments, it is important to have a long-term precautionary policy approach towards marine biodiversity conservation.

The present governance structure is hierarchical (fisheries department) with little scope for fishers to contribute to the decision-making process. Lack of co-ordination and interaction among them can result in weak resource governance. Finally, the increasing use of coastal waters for other non-fishing activities like oil exploration, tourism, military operations etc tend to push the fishers into operating in the same fishing ground, which in turn, can affect the sustainability of the fish stock in future. Too many vessels on the same ground can also affect biodiversity of the region.

It is observed during the fieldwork that many boats move into the waters of other neighboring states for fishing. Andhra Pradesh fishermen are found fishing in Odissa and Tamil Nadu waters. Fishers also migrate to Gujarat, Goa, Maharashtra and Andaman as crew members. An important push factor underlying such migration is the non-availability of fish stock in Andhra waters. Thus, there is an urgent need foraddressing issues related to marine resource health as part ofmaintaining a balance between for-livelihood resource exploitation and biodiversity sustenance.

At present, marine ecosystems provide 4.66 lakh tonnes of fish and crustaceans to the economy, worth 56.98 billion rupees per year. A steady flow of these services creates immense scope for value addition activities and thereby additional employment in the economy. The fishery sector plays a very significant role in terms of creating income, employment and livelihoods for nearly 6.5 lakh fishermen families and many others depending on the value addition sectors. Nevertheless, the growth potential of the marine sector is found to bevery limited. The sector generates large quantities of by-catch and juveniles as part of overall catch, which is itself a social cost.

The estimates on the value of by-catch in terms of fishing effort lost come to around 2.42 billion rupees in a year. This is an implicit cost incurred by fishers due to unsustainable fishing practices and non-compliance with fishing rules. The fact is that they are not aware of the implicit cost involved in their fishing activities. Therefore, there is need for creating awareness among fishers regarding the implicit cost involved as part of minimising these extra costs and efforts. The harvesting of juveniles through extra efforts and non-compliance with mesh size regulations can also put a future cost on the society in terms of biomass loss. An estimate of juvenile loss and the corresponding future biomass loss has also been made in this study. In terms of value, the loss is around 35% of the total value of fishery sector (20. 71 billion) and in quantity terms, it is around 60% of the total quantity of fish landed per year. This is a huge loss to the society, which needs to be regulated.

There is also a high likelihood of increased demand for by-catch in the future due to the fast growing aquaculture and poultry industries that need fish meal and dry fish powder for feed purposes. Therefore, the study recommends a long-term precautionary policy approach to addressing the potential implications of an increasing demand for by-catch in the economy. In the present institutional context and circumstances, an effective approach towards minimising by-catch could be formulated with fishers' involvement.

4.1. Recommendations

First, Fishers must be made aware of the implicit cost involved in fishing and how it can affect their livelihoods. Awareness regarding the future consequences of unsustainable fishing in terms of livelihood loss and unintended consequences on marine biodiversity needs to be imparted to them on a long-term basis. Tentative solutions might not work in this case since the tendency on the part of fishers to over exploit resources is deep rooted.

It is important to design a long term policy on capacity building with participatory data collection and research activities, so that informed awareness programs can be taken up in the sector towards biodiversity conservation. The interaction between resource users (fishers) and civil societies working on biodiversity conservation needs to be encouraged which is completely absent in the present context. Fishers and fisheries department generally think that conservation is a domain of the Ministry of Environment and Forest and Climate Change.

It is also important to ensure the involvement of all secondary stakeholders like scientists, academicians and students in the long-term programs for building local scenarios of biodiversity loss and conservation through research activities. These studies can be used again for awareness creation and capacity building among resource users. The involvement of all primary

Table 15: Summary of gross values estimated for Andhra Pradesh Marine fisheries.

Categories	Method estimation	Quantity per year in tonnes	Gross Value Earned in billion rupees	Future Quantity lost in tones	Present/ Future Gross Value Lost in billion rupees	Quantity per unit of standard fishing effort
Catch (a)	Market Valuation	466809	55.699	-		371.93
By Catch	Market Valuation					
By-catch and discards	Market and input Valuation at the average cost of fishing effort	53990	0.08098	-	2.42	
Total Quantity		544935	-	-		434.18
Juvenile Catch	Market Value (price of adults)	-	-	448723	20.71	221.88

Source: primary data

and secondary stakeholders can make the programs more interactive.

Second, the study recommends creating incentives for the use of technologies that save juveniles and other by-catch. At present, an important driver of excessive fishing is sales tax exemption upto 3000 litres of fuel in a month for mechanised boats. We propose that the subsidy be made conditional.

(a) Provide subsidy to those trawlers willing to adopt by-catch exclusion devises. For example, square mesh size with a 40 mm code end can be promoted.
(b) Subsidy can be provided or diverted to mechanised boats willing to convert their vessels from bottom trawling to tuna long lining. It is also important to make sure that these conversions adopt by-catch reduction technologies. As per the present estimate, Andhra Pradesh has a plan to convert 20% of the mechanised boats to tuna long lining. It is important to subsidise and encourage by-catch reduction technologies for these purposes.

Thirdly, fishing holidays or no take zones can be identified to encourage conservation may be with limited access to the traditional sector to avoid livelihood loss. It is also important to point out that certain traditional activities that are not conservation-friendly should be taken into account while designing no take zones with limited access to the traditional fishing activity.

Fourth,the by-catch required for animal feed purposes is,at present used as a substitute for fish meal. Dry fish powder and ground dry fish are used in these feeds as part of minimising the overall cost of production of aquaculture and poultry feed. Adulteration of feeds to minimise the cost of production is good neither for marine fisheries nor for aquaculture. This may affect the sustainability of aquaculture by spreading diseases through feeds. Therefore, it is wise to control the use of by-catch in feed mills directly, but it is desirable to encourage fish meal units using sardine or other adult low value oil fishes.

Finally, the government needs to take steps to include by-catch reduction as an important objective of the national fishing policy. The Indian marine fishing policy needs to be rationalised by incorporating biodiversity conservation as an important objective because, unregulated fishing practices can lead to an immense loss of biological wealth in the form of by-catch and discards,not only in the present times, but also in future. Moreover, to achieve the goal of 'fish better', there must be incentives to encourage fishers' cooperation and participation in the process of biodiversity conservation. This is a necessary step because (a) fishers know more about fishing than anybody else;(b) fishers can think of practical solutions; (c) they must be engaged in the process on their own rather than being forced into it. Therefore, the policy challenge should be to provide directions to create incentives for the fishing community to regulate biodiversity loss.

ANNEX 1

Table 16: Trends in the total landing of fish and crustaceans in Andhra Pradesh from 1985 to 2013

Resource/Year->	2000	2001	2002	2003	2004	2005	
ELASMOBRANCHS							
Sharks	4914	3257	1613	1921	2250	1855	
Skates	562	91	55	161	162	60	
Rays	3431	4005	3303	6571	3759	2962	
Eels	1903	1545	1125	1717	2046	1462	
Catfishes	4100	4135	2529	3432	4321	4058	
CLUPEIDS							
Wolf herring	1458	1014	821	2104	1600	789	
Oil sardine	19125	12000	1068	5679	2605	6383	
Other sardines	20230	17741	25950	13536	24134	15453	
Hilsa shad	398	195	93	5921	2732	492	
Other shads	1399	929	1993	1569	1772	3562	
Anchovies							
Coilia	501	417	299	200	319	281	
Setipinna	9	67	70	266	306	201	
Stolephorus	4043	5447	2293	4247	6212	6015	
Thrissina							
Thryssa	6583	3694	3502	4161	3398	3168	
Other clupeids	8629	5219	5887	6560	8073	6487	
BOMBAYDUCK	693	2165	1754	701	2986	1318	
LIZARD FISHES	1062	1243	2047	2014	2651	1678	
HALF BEAKS&FULL BEAKS	78	96	434	304	378	224	
FLYING FISHES	4	39		42		21	
PERCHES							
Rock cods	99	64	26	63	102	124	
Snappers	369	270	252	310	615	656	
Pig-face breams			20				
Threadfin breams	1209	1474	2034	2699	3150	2805	
Other perches	3302	3570	3477	4242	5002	4123	
GOATFISHES	3501	2527	3230	4780	4668	3775	
THREADFINS	1391	718	629	655	891	804	
CROAKERS	8054	5784	5596	9277	10142	7521	
RIBBON FISHES	13842	7278	18372	15565	9995	6398	
CARANGIDS							
Horse Mackerel	1169	724	1306	1684	1645	1549	
Scads	2448	1751	1250	3747	4284	3624	
Leather-jackets	652	491	530	660	620	1398	

	2006	2007	2008	2009	2010	2011	2012	2013
	3806	4434	2194	2737	1263	2068	1385	1319
	246	118	61	69	100	109	149	227
	4849	2314	3495	3183	4395	5873	9971	3522
	2265	2079	2202	2566	1917	2011	2870	2656
	4170	4682	4903	5864	5494	6751	5364	6326
	1148	924	953	861	892	1319	1089	1213
	6933	5702	9540	16839	10465	12159	9062	5849
	24599	11951	30090	26941	23251	33598	25051	12590
	192	272	89	60	10	95	29	6
	6412	3622	2538	2841	1335	2797	4339	4718
	572	284	157	136	153	275	319	355
		126	67	64	63	527	80	355
	11208	9354	7529	7372	14481	4816	10067	7144
	6383	3860	2961	4616	3049	3474	7117	4703
	4751	17076	10436	10911	6987	8684	9757	8931
	1821	1832	688	556	1053	1262	1057	1335
	2122	1766	2422	3366	4231	4547	4774	4422
	711	201	1024	341	148	1443	335	287
	21	4	99	297	97	540	373	365
	405	504	418	587	702	777	785	758
	673	715	493	900	885	954	1012	964
	11			3	31	1		
	3387	3314	4366	4653	5435	5033	5072	4529
	5120	5983	4806	5785	6411	6758	7560	7264
	6135	3908	5151	5559	8030	6750	7382	6807
	1051	1268	1112	1378	1179	1159	1419	1256
	10688	10627	11383	11686	12149	13501	14288	13260
	16522	11449	15960	11895	9363	15348	21777	18800
	2678	2307	1387	2046	2391	3672	4794	6550
	3304	4682	4343	6986	3936	3776	5495	6227
	1140	1346	537	1272	934	1481	1093	914

Contd...

Resource/Year->	2000	2001	2002	2003	2004	2005
Other carangids	5695	4316	5688	6552	5327	3503
SILVERBELLIES	3583	4254	4898	4036	3368	3323
BIG-JAWED JUMPER	584	506	333	372	206	205
POMFRETS						
Black pomfret	2909	2190	1788	3665	3449	2207
Silver pomfret	2715	3152	2704	2652	3030	2690
Chinese pomfret	240	161	136	204	346	493
MACKERELS						
Indian mackerel	9834	9306	14206	22572	20209	17665
Other mackerels						
SEER FISHES						
S. commersoni	3578	4898	3544	2529	4685	3539
S. guttatus	1836	2608	2543	3324	3644	1789
S. lineolatus	2	6				
Acanthocybium spp.	21			3		
TUNNIES						
E. affinis	1542	1241	1480	618	1087	906
Auxis. spp	98	51	325	62	24	108
K. pelamis	273	104	466	234	124	186
T. tonggol	325	28	16	470	2217	1292
Other tunnies	661	261	119	446	453	696
BILL FISHES	1384	767	647	852	4107	1289
BARRACUDAS	696	1050	666	1292	973	671
MULLETS	1057	1009	1667	1005	2376	1678
UNICORN COD						
FLAT FISHES						
Halibut	163	101	138	263	205	157
Flounders	97	150	83	41	45	90
Soles	1302	1048	1234	1869	1316	875
CRUSTACEANS						
Penaeid prawns	22657	16221	16391	17911	17128	13487
Non-penaeid prawns	2685	1455	2987	4445	1777	2620
Lobsters	13	3	16	13	38	26
Crabs	2791	2929	4955	5113	6877	5405
Stomatopods	1194	681	723	900	787	620
MOLLUSCS						
Bivalves			1			
Gastropods						29
Cephalopods	1011	1191	2302	2003	2198	1422
MISCELLANEOUS	5425	5120	3297	3773	4534	3460
Toyal	189529	152757	164911	192007	201348	159677

Source CMFRI 1985-2013 Fish landing for Andhra Pradesh

	2006	2007	2008	2009	2010	2011	2012	2013
	4528	5017	4303	6348	6026	7973	9166	7006
	4921	4510	5531	8484	8091	6158	7484	7281
	529	330	492	448	366	352	506	412
	3128	3827	3738	6224	5008	6432	9267	8771
	3702	5347	3540	3590	2788	2947	4384	3092
	274	523	278	453	430	343	723	931
	13004	7903	18127	23078	19564	22410	28407	33716
		1			3			4
			2					
	5602	8763	3415	5984	4395	3311	4767	3611
	1373	3264	959	3023	2582	2275	2368	1352
		41						
	5	2						
	3948	1856	7730	5244	4176	5366	3550	3563
	18	12	679	1247	1111	1694	497	797
	193	210	613	724	1342	5209	2984	2527
	1376	4313	2315	3306	3885	6276	5857	6355
	1407	2398	756	2640	1550	3626	2465	3000
	2095	1279	930	2039	2329	4339	3991	3752
	1327	1087	478	261	1070	1523	391	176
	312	265	365	345	393	324	358	377
	4	92	99	135	189	211	193	291
	1356	1447	1581	1277	1251	1414	2030	1504
	20951	25053	23412	24980	27404	26380	29758	28744
	1931	2180	1950	1657	2358	1086	2824	2584
	114	21	55	128	145	121	281	49
	6804	5324	4678	6757	6298	5718	7041	5008
	550	665	572	506	717	573	844	588
	168	2						
	2161	2490	1765	2895	3876	3606	4224	3336
	3991	3129	2880	4552	3265	3408	6177	3554
	219095	208051.715	222645.806	258695.304	241441.946	274632.669	304399.151	266031.493

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India a biodiversity hotspot

India is one of the megadiverse countries in the world. It faces unique circumstances as well as challenges in the conservation of its rich biological heritage. With only 2.4% of the world's geographical area, her 1.2 billion people coexist with over 47,000 species of plants and 91,000 species of animals. Several among them are the keystone and charismatic species. In addition, the country supports up to one-sixth of the world's livestock population. The rapid growth of her vibrant economy, as well as conserving natural capital, are both essential to maintaining ecosystem services that support human well-being and prosperity.

To demonstrate her empathy, love and reverence for all forms of life, India has set aside 4.89% of the geographical space as Protected Areas Network. India believes in "वसुधैव कुटुम्बकम" i.e. "the world is one family".

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