Chapter

05

Zone wise Vulnerability Status of Key Indian Marine Fishes

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Introduction

Climate change is predicted to affect individual organisms during all life stages, thereby affecting populations of a species, communities and the functioning of ecosystems.The vulnerability of a species to climate change is generally considered as the extent to which abundance or productivity of species in a region could be impacted by climate change and decadal variability (Hare *et al.*, 2016). Alterations in the fishery and fishery resource profile in turn affect coastal fishing communities dependent on fishing for their livelihood.

Although fishing remains, by and large, the most dominant driver of population abundance, there is now substantial evidence of the impact of climate change and decadal variability on fish and invertebrate populations, with an increasing number of studies linking population models to climate models and projecting future climate change impacts on fish and invertebrate populations (Hare et al., 2016). Long-term climate change is likely to impact the marine environment and its capacity to sustain fish stocks and exacerbate stress on marine fish stocks.

Background Information for Zone wise Vulnerability Assessment

There is ample evidence of the impacts of global climate change on marine environments. Organisms, however, do not respond to approximated global averages. Regional changes are more relevant in the context of ecological response to climate change. Hence, global-scale climate models may be unable to simulate observed changes in temperature and rainfall or the intensification of coastal upwelling in many areas, but regional-scale models may be able to do this (Clark, 2006).

Against the background of changing climate, which we know is a definite happening event, and the paucity of accurate information on the actual changes that this event induces or can induce in different fish species, there is a large uncertainty hovering over Indian marine fisheries, which already faces the threat of overfishing and pollution impacts. In this context, a detailed study was carried out to assess the vulnerability of key species of fishes and invertebrates likely to impact the fishery in the process of undergoing climate-change induced alterations in phenology, reproductive performance, abundance and distribution.

Vulnerability assessments provide framework for evaluating climate impacts on different species with the aid of existing information and combining the exposure and the sensitivity of a species to a stressor (Hare et al., 2016). Methods for assessing species vulnerability have been described through quantitative approaches developed to examine climate impacts on productivity, abundance and distribution of different species of marine fishes and invertebrates (Hare et al., 2016). The vulnerability study would provide a strong base for evolving strategic fishery management plans for highly vulnerable stocks to counter the likely impacts of a changing climate in the long run.

Assessment of the vulnerability of individual fish and invertebrate species to climate change is a prerequisite to understand or predict changes in the species composition and abundance in a particular region. While it is an established fact that climate change influences the marine environment, distribution and abundance of marine species and their phenology in spatial and temporal scales, the impact of climate change on marine organisms may not be uniform for all species and regions as it depends on the biological and behavioural characteristics of the organisms (Morrison et al., 2015).

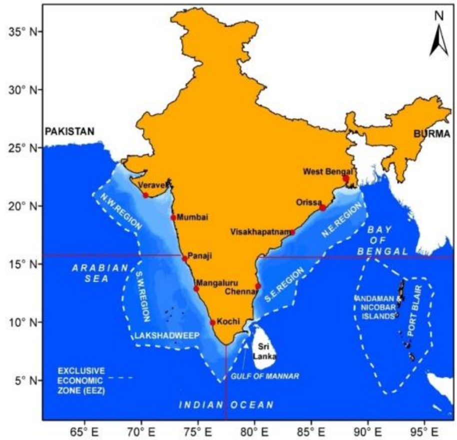
For a tropical country like India with wide variations in environmental parameters and a marine fishery which is characteristically multi-species, multi-gear fishery and multi-ground, the criteria which are developed is insufficient to present a true picture of species vulnerability. Therefore following the methodology described in earlier studies, sets of environmental, biological and fishery-based criteria were developed to suitably define the characteristics of tropical Indian species of fishes and invertebrates and their fishery in the region.

Selection of geographical zones for the study

Peninsular India extends down from the Arabian sea bordering the Gulf of Kutch on the north-west coast upto Cape Comorin overlooking the Indian Ocean at the southern tip of the country and further north along the Coromandel coast bordering the Bay of Bengal, up to the Sunderbans on the north-east coast of India.

The Indian coast exhibits wide diversity in climatic and oceanic conditions, in terms of temperature ranges, precipitation levels, length of seasons, rainfall, riverine flow, wind patterns, current patterns and coastal upwelling. The wide variation in climatic conditions demands evaluation of zone-wise species vulnerability along the coast.

Based on this, the coast was classified into four different geographical zones viz. north-east (NE), north-west (NW), south-west (SW) and south-east (SE) (Figure 1)



Selection of Species

Preliminary analysis of historical data on fishery showed that there is a wide variation in the species composition and biological responses of the species in different geographical zones. Accordingly about 30 to 36 major commercially important finfishes and shell fishes were selected for the study from each zone, with catch-dependant weighted representation of pelagic, demersal, crustacean and molluscan resources. In all, 68 species were selected, of which many were common to two or more zones and some were characteristic to a particular zone. Thirty two species were selected for the NE coast, 36 for the NW coast and 30 each for the SE and SW coasts. Species selection was done based on abundance of a species in a particular zone, its contribution to the fishery, economic importance, growth and reproductive performance and prey-predator interactions (Table1).

Table 1. Species selected for vulnerability study

Sl No	Group	Scientific Name	Sl No	Group	Scientific Name
1	Pelagic	*Chirocentrus dorab*	35	Demersal	*Otolithus biauritus*
2	Pelagic	*Chirocentrus nudus*	36	Demersal	*Pampus argenteus*
3	Pelagic	*Coilia dussumeri*	37	Demersal	*Parastromateus niger*
4	Pelagic	*Coryphaena hippurus*	38	Demersal	*Pennahia anea*
5	Pelagic	*Decapterus russelli*	39	Demersal	*Plicofollis dussumieri*
6	Pelagic	*Encrasicholina devisi*	40	Demersal	*Plicofollis tenuispinis*
7	Pelagic	*Euthynnus affinis*	41	Demersal	*Priacanthus hamrur*
8	Pelagic	*Harpodon nehereus*	42	Demersal	*Protonibea diacanthus*
9	Pelagic	*Katsuwonus pelamis*	43	Demersal	*Saurida undosquamis*
10	Pelagic	*Megalspis cordyla*	44	Demersal	*Saurida tumbil*
11	Pelagic	*Mugil cephalus*	45	Demersal	*Scoliodon laticaudus*
12	Pelagic	*Rastrelliger kanagurta*	46	Demersal	*Sphyrna lewini*
13	Pelagic	*Sardinella fimbriata*	47	Demersal	*Upeneus sulphureus*
14	Pelagic	*Sardinella gibbosa*	48	Demersal	*Upeneus vittatus*
15	Pelagic	*Sardinella longiceps*	49	Crustacean	*Acetes indicus*
16	Pelagic	*Scomberomorus commerson*	50	Crustacean	*Charybdis feriata*
17	Pelagic	*Scomberomorus guttatus*	51	Crustacean	*Feneropenaeus merguiensis*
18	Pelagic	*Sphyraena jello*	52	Crustacean	*Metapenaeopsis stridulans*
19	Pelagic	*Sphyraena obtusata*	53	Crustacean	*Metapenaeus dobsoni*
20	Pelagic	*Stolephorus indicus*	54	Crustacean	*Metapenaeus monoceros*
21	Pelagic	*Tenulosa ilisha*	55	Crustacean	*Metapenenaeus affinis*
22	Pelagic	*Thunnus tonggol*	56	Crustacean	*Panulirus polyphagus*
23	Pelagic	*Thunnus albacares*	57	Crustacean	*Fenneropenaeus indicus*
24	Pelagic	*Trichiurus lepturus*	58	Crustacean	*Penaeus monodon*
25	Demersal	*Carcharhinus limbatus*	59	Crustacean	*Penaeus semisulcatus*
26	Demersal	*Cynoglossus macrostomus*	60	Crustacean	*Penaeus stylifera*
27	Demersal	*Epinephelus diacanthus*	61	Crustacean	*Portunus pelagicus*
28	Demersal	*Himantura imbricata*	62	Crustacean	*Portunus sanguinolentus*
29	Demersal	*Johnius carutta*	63	Crustacean	*Solenocera crassicornis*
30	Demersal	*Lacatrius lactarius*	64	Molluscs	*Perna viridis*
31	Demersal	*Nemipterus japonicus*	65	Molluscs	*Sepia aculeata*

32	Demersal	*Nemipterus randalli*	66	Molluscs	*Sepia pharonis*
33	Demersal	*Otolithes cuvieri*	67	Molluscs	*Sepiella inermis*
34	Demersal	*Otolithes ruber*	68	Molluscs	*U.(L.) duvauceli*

Vulnerability Assessment Design

The primary assumption behind the vulnerability assessment methodology used is that current biological performance indices and expected exposure to climate change can be used to evaluate the relative vulnerability of a species (Chin et al., 2010; Johnson and Welch, 2010; Foden et al., 2013; Pearson, 2014; Pecl et al., 2014). While exposure (E) is the projected magnitude of change in the physical environment due to climate variations, and defines the nature and degree to which a species is exposed to climatic variations, sensitivity (S) indicates the extent to which a species is affected due to its life history traits influenced, either adversely or beneficially, by anthropogenic activities, and, adaptive capacity (A) defines the ability (or potential) of a species to adjust successfully to climate or environmental change. In this study, we chose to represent the three components as separate sets of attributes. Based on the attributes, each component was assigned a score. The Vulnerability (V) was then estimated from the relation:

$$V = (E+S) - A$$

Exposure attributes and their scoring

Exposure attributes used are those climatic variables which could impact the biological or behavioural characteristics of the selected species. Out of several environmental parameters initially considered for inclusion under exposure attributes, 6 environmental parameters viz., sea surface temperature (SST), rainfall, current speed, current direction, upwelling index and chlorophyll concentration, were selected for as exposure attributes.

Sensitivity attributes and their scoring

For sensitivity attributes, the biological characteristics of species that are indicative of their ability or inability to respond to environmental changes and exploitation/fishery related pressures are used. For this study 9 attributes were selected based on time series data for a period 40 years (1975- 2015) on fishery and biology of each species extracted from published information available in CMFRI repository (eprints@cmfri). Data collected through detailed biological study done during 2011-2015 in different zones under the NICRA project was also used. The sensitivity attributes considered were Fecundity, Complexity in early development, Growth coefficient, Trophic level, Longevity/Life span, Lc/Lm, Anomaly in CPUE, Exploitation rate, Price etc. (Table 2)

Table 2. Criteria developed for vulnerability assessment

Environmental criteria	Biological criteria	Fishery related criteria
Sea surface Temperature	Fecundity	Anomaly in CPUE*
Rainfall	Complexity in early development	Exploitation rate
Ocean current Speed	Growth coefficient	Price
Ocean current direction (S to N)*	Trophic level	Gear
Coastal upwelling index	Longevity/Life span	
Chlorophyll concentration	Lc/Lm	
	Horizontal distribution	
	Duration of spawning	
	Prey specificity	

Adaptive Capacity attributes and their scoring

Adaptive capacity attributes used are primarily biological and ecological traits that could help the species to adapt to a fluctuating or changing environment. Four attributes were selected for this study. Based on expert opinion for each attribute the scoring was limited to a scale of 1-3, representing low, medium and high. The adaptive capacity attributes were Horizontal distribution, Vertical Distribution, Duration of spawning, Prey specificity/No. of prey groups/Niche breadth (Fish base) etc.

Vulnerability assessment

The sum of exposure and sensitivity is the impact. For preparation of vulnerability matrix, climatic variables (exposure attributes) were given more weightage as the sensitivity traits are dependent on changes in the climatic variables. Accordingly the following combinations of exposure and sensitivity scores were fixed as binding (Fig 3)

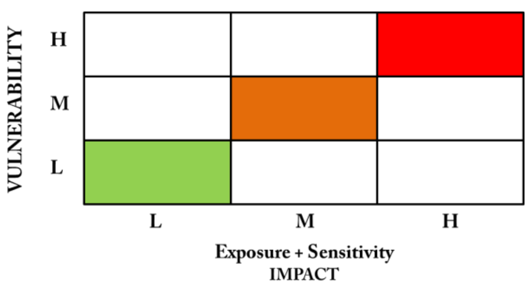


Figure 2. Impact versus vulnerability matrix

Species vulnerable to climate change

Species vulnerability study in relation to climate change was carried out for 68 commercially important shellfishes and finfishes along the coast of India. The species studied belonged to different realms in the water column, and could be classified as pelagic, bentho-pelagic, demersal and benthic. There is considerable variation in the distribution of adults and juveniles of the same species within the water column. The biology of the species was also diverse on many counts. Some species had wide distribution (seerfishes, ribbonfishes, mackerel sardine, lizardfishes, shrimps, cephalopods) and some had restricted distribution (Bombay duck, some species of croakers, and shrimps). Most of the species were broadcast spawners with pelagic eggs and larvae, and occupied a range of trophic levels. Of the 68 species, 3 species are elasmobranchs, 45 are teleosts, 15 crustaceans and 5 molluscs. One of the mollusc species *Perna viridis* is sedentary in nature.

Climate vulnerability

Increasing temperature was the most important driver in climate change. There was zone-wise differentiation in the exposure range for climatic variabilities. Except for the north-east zone the ranking tended towards moderate vulnerability, with a scoring range of 1.33-1.73. In the north-east zone the range was 1.66-2.21. The anomalies of climate variables were high along the north-east and north-west zone, whereas they were moderate in the other zones. Temperature anomalies were high along the north-east and south-east zones. Climate exposure ranking of pelagic species was comparatively higher than that of demersal species.

Impact on the species

Ranking of impact, an additive index of exposure and sensitivity attributes, was classified into high, medium and low for the 68 species assessed for vulnerability. There was zonal variation in the dispersion of species with respect to sensitivity and climatic vulnerability (Exposure). Mean sea surface temperature (SST) anomalies, mean upwelling index, current speed and current direction were considered to be important factors in climatic variability score. The climatic variability score was medium in all the zones. The exposure and sensitivity attributes scored high for some species in north-east.

About 83% of the pelagic fishes studied were highly vulnerable, followed by demersal fishes (66 %), molluscs (60%) and crustaceans (53%).

Table 3 Zone wise list of species which are highly vulnerable

Zone	Species
North-West Zone-11 P- 4, D-5, C-1, M-1	*Coilia dussumeri, Decapterus russelli, Harpodon nehereus, Thunnus tonggol, Epinephelus diacanthus,Otolithus biauritus Pampus argenteus, Parastromateus niger,Protonibea diacanthus,Acetes indicus, Sepia pharonis*
South-West Zone-10 P-1, D-5, C-3, M-1	*Rastrelliger kanagurta, Carcharhinus limbatus, Parastromateus niger Plicofollis tenuispinis,Sphyrna lewini, Upeneus sulphureus, Metapenaeus dobsoni, Metapenaeus monoceros,Fenneropenaeus indicus, Perna viridis*
South- East Zone-23 P-11, D-7, C-4, M-1	*Chirocentrus dorab, Chirocentrus nudus, Decapterus russelli, Euthynnus affinis, Katsuwonus pelamis, Sardinella gibbosa, Scomberomorus commerson, Sphyraena jello,Stolephorus indicus, Thunnus albacares Trichiurus lepturus, Carcharhinus limbatus ,Cynoglossus macrostomus Nemipterus japonicus, Pampus argenteus, Parastromateus niger, Saurida undosquamis, Saurida tumbil, Metapenaeus Monoceros, Penaeus monodon,Portunus pelagicus, Portunus sanguinolentus, U.(L.) duvauceli*
North-East Zone-22 P-11, D-8, C-3	*Coryphaena hippurus, Katsuwonus pelamis, Megalaspis cordyla, Sardinella fimbriata, Sardinella gibbosa, Sardinella longiceps, Scomberomorus commerson,Scomberomorus guttatus, Sphyraena jello, Thunnus albacares Trichiurus lepturus, Nemipterus japonicus, Nemipterus randalli, Otolithes ruber, Plicofollis tenuispinis, Saurida undosquamis, Saurida tumbil, Upeneus sulphureus, Upeneus vittatus, Metapenaeus monoceros, Fenneropenaeus indicus, Penaeus monodon.*

Table 4 - List of species with high vulnerability in two or more zones

Species	Zones	No of zones	Major influencing factor	Major gear
M. monoceros	SW, SE, NE	3	Life history and fishing pressure	Trawl
P. niger	NW, SW, SE	3	Fishing pressure (juvenile)	Trawl
P. tenuispinis	SW, SE, NE	3	Life history and fishing pressure	Trawl
C. limbatus	SW, SE	2	Life history	Trawl
D. russelli	NW,SE	2	Fishing pressure	Trawl
F. indicus	SW,NE	2	Life history and fishing pressure	Trawl
K. pelamis	SE,NE	2	Life history and fishing pressure	
N. japonicus	SE,NE	2	Fishing pressure	Trawl
P. monodon	SE,NE	2	Life history and fishing pressure	Trawl
S. gibbosa	SE,NE	2	Fishing pressure and lack of upwelling	
S. tumbil	SE,NE	2	Fishing pressure	Trawl
S. undosquamis	SE,NE	2	Fishing pressure	Trawl

S. commerson	SE,NE	2	Fishing pressure	
S. jello	SE,NE	2	Fishing pressure	Trawl
T. albacares	SE,NE	2	Life history and fishing pressure	
T. lepturus	SE,NE	2	Fishing pressure	Trawl

Vulnerability assessment of fish stocks to climate change indicates that the finfishes and shellfishes along the Indian coast are highly or moderately vulnerable to climate change. The species composition and exposure of the same species in different zones are variable and the study shows the extent to which abundance or productivity of a species could be impacted by climate change. In contrast to the influence of exposure factors, the influence of sensitivity attributes was more pronounced, indicating the diversity of species composition of the resources exploited along the Indian coast. Changes in species composition of the exploited resources in four different zones have been observed in this study and the changes are likely to continue in the future also.

The present study shows that fishing pressure is plaing a key role in making the species vulnerable in different zones as the climatic variables and sensitivity traits influencing the species could not be changed. The primary approach towards mitigation must consider the vulnerability of a species as dependent on fishing pressure as much as on climate variations. In the context of the present study, mitigation would mean directly managing the fishery of different species, singly, wherever possible, or within the limitations of a mixed fishery, as will be the case in India's marine fishery. Fortunately, several species that contribute in major to the marine fish landings in India are highly resilient with good bounce-back potential due to their inherent reproductive and growth efficiencies. India's oil sardine fishery and threadfin bream fishery are good examples of this. This study was aimed to provide a broad assessment of vulnerability of fishes and shell fishes due to climate change along the Indian coast and the results will act as an effective tool in understanding the species to be prioritized zone wise and the extent to which management must be done.

This assessment will help in adding a climate change perspective to management measures. Furthermore, the assessment of the resources would help the fisheries managers in formulating policy related to the sustainable exploitation of the resources with special attention to the species which are highly vulnerable in each zone. Efforts to reduce the fishing mortalities of the vulnerable species could be initiated. The assessment would contribute to the development of region specific ecosystem based fisheries management and it would be useful for identification of species-specific mitigation measures in relation to climate change. The present vulnerability ranking of the species in different zones will be a handy tool to conserve the species which are ranked as highly vulnerable and also which tend to move to high vulnerability category, through policy level interventions.

Reference

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