	The 2nd Workshop on the Assessment of Fishery Stock Status in the South and Southeast Asia 5-9 October 2009 Jasmine City Hotel, Bangkok, Thailand	WP02h

Status of marine fish stock assessment in India and development of a sustainability index

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Introduction

India has a coastline of 8129 km. Landings by commercial fishing vessels takes place at 1332 centres during day and night by 58,911 mechanized craft, 75,591 motorized (with outboard engine) and 104,270 traditional craft (CMFRI, 2006). Marine fisheries are an important source of food, employment and foreign exchange. About one million people work directly in this sector, producing 3 million tonnes annually valued at about 3 billion US $ at production level (CMFRI, 2007). India earns 1.6 billion US $ by exporting fish and fishery products. India is among the top ten fish producing countries of the world, contributing 3.5% to the total world marine fish production. Concerned about the status of marine fish stocks in the Indian EEZ, the country has put in place appropriate institutional mechanisms to monitor and forecast fishery yields for the last 25 years.

Collection of temporal and spatial data on commercial fish catch and effort

Realizing the importance of a reliable database in fish stock assessment and fisheries management, the Central Marine Fisheries Research Institute, Cochin initiated the process of collection of data on catch and effort of commercial fishing boats along the coastline of mainland based on scientific sampling technique in 1947. Data on marine fishing villages, landing centers, craft and gear were collected that could form a frame for developing an appropriate sampling design. The first attempt in that direction was made in 1948 to collect marine fish catch statistics. Pilot surveys were conducted in different regions of the country between 1950 and 1955 (Banerji and Chakraborty, 1972). Initially the surveys were based on a three-stage stratified sampling. From 1959, the CMFRI is following a multi-stage stratified sampling design along the west coast of India, and a full-fledged sampling along the west and east coasts became operational since 1961. Considering the changing scenario in the fisheries sector, the sampling is periodically updated with enhanced scope and coverage.

The sampling design enables estimation of landings by resource (fish groups/ species) and region (maritime state). In this design, the stratification is over space and time (Srinath *et al.*, 2005). Over space, each maritime state is divided into non-overlapping zones on the basis of fishing intensity and geographical considerations. There are few major fishing harbours/centres, which are classified as single centre zones with extensive coverage. The stratification over time is a calendar month. One zone and one calendar month is a space-time stratum and primary stage sampling units are landing centre days.

The data thus collected are processed. As the first step, codes are applied for major resource groups and commercially important species. A two-digit code for major resource groups and a four-digit code for individual species are assigned (CMFRI, 2000). After coding, the data are computerized and raised to find out monthly landings of each resource group/species by gear in the zone/maritime state. A software has been developed by the Institute for estimation of marine fish landings.

The fishing effort of each craft and gear are recorded. There are separate forms for mechanized and motorized units; and traditional units. The number of fishing units landed on the days of observation, length of craft, type of gear, date and time of departure of units from the landing centre, number of hauls, depth of hauls, duration of actual fishing, manpower employed, weather and sea state are recorded. Thus the fishing efforts in terms of number of units, number of hauls and fishing hours are available, and it is possible to calculate catch rate in terms of number of units and fishing hours. As the observation has spatial and temporal coverage, the catch and effort of directed and non-directed fisheries of all types that are landed along the mainland of India are covered in the database.

Although the taxonomic resolution of the data collected is high, there is considerable data reduction during the data processing to facilitate easier reporting. Consequently the catch data records which have more than 1000 species names were reduced to 83 species groups. To enable the reporting of actual species caught (fished taxa biodiversity), the original data records are being re-entered from the original field data sheets using appropriate software and estimates are made and stored in MS ACCESS by developing an estimation software in C++ and Visual Basic code for exporting data. This database is proposed to be transformed into an Oracle format.

Status of Stock Assessment in India

Assessments for coastal stocks are made from commercial fish catches by CMFRI and for oceanic stocks from exploratory surveys by Fishery Survey of India (FSI). Since 1991 the Department of Animal Husbandry, Dairying and Fisheries (DAHD&F), Ministry of Agriculture is estimating the potential yield of Indian EEZ in collaboration with CMFRI and FSI every 10 years. These organizations are also undertaking marine fishery census periodically and the next census will take place in 2010.

Since its establishment in 1947, the CMFRI is monitoring the biological characteristics of fish resources caught along the Indian coast. In the last 25 years, the focus of capture fisheries research has expanded to stock assessment of commercially important species of small and large pelagics, demersal finfishes, crustaceans and cephalopods. The stocks are continuously monitored through resource, gear and region-based research projects. The technical activities of these projects include monitoring spawning, fecundity, recruitment, diet composition, growth, mortality and status of exploitation to estimate biological reference points, MSY, spawning stock and standing stock biomass and to develop predictive models. The results are consolidated in the institute's Annual Reports and published from time to time in research journals. The findings of the projects are also shared with government fisheries departments to facilitate developing fisheries management policies and acts.

A survey of publications on capture fisheries in the last 25 years shows that 264 records of growth and mortality coefficients and exploitation rates are available for 140 stocks of 98 species. A database on these records has been created in MS ACCESS, but further consolidation is needed as all published information have not been covered. It is noticed that estimates are available for several stocks along SW (southwest), NW (northwest) and SE (southeast) coasts, but there are only a very few records for NE (northeast) coast, Lakshadweep (LAK) Island and Andaman and Nicobar Islands (AN).

We observed that the methodology of stock assessment has remained almost uniform through the time period. As a thumb rule, growth parameters are estimated by length frequency method. Total mortality (Z) is estimated mostly by length converted catch curve method and natural mortality by the empirical relationship derived by Pauly (1980). In recent years, the standing stocks and spawning stock biomass are estimated by length based virtual population analysis (VPA); and prediction models have been developed using Beverton and Holt method (1957) and Thompson and Bell method (1934). Maturity stages of fishes are recorded using standard scales proposed by ICES for finfishes and standard 5-point and 4-point maturity scales for crustaceans and cephalopods, respectively. Fecundity measurements are usually *in-situ* observation and do not indicate annual reproductive potentials. Generally, spawning months with range and peaks are known, but the frequency of spawning is not recorded. Diet compositions have been estimated for several species in the last 5 decades, but most of the earlier records were qualitative. Recently, quantitative diet compositions are recorded for estimating index of relative importance (IRI) for deriving trophic levels. In the last 10 years, trophic models have been developed using ECOPATH with ECOSIM for the SW coast (Vivekanandan et al., 2003) and Karnataka coast (Mohamed et al., 2008) and models are under development for the NW coast and Gulf of Mannar (SE coast).

There is scope to improve the stock assessments by validating growth estimates by reading growth rings in hard parts; by employing acoustic surveys and tagging programmes, and by strengthening the deep sea surveys. In spite of availability of a large amount of data on fish stock estimates and oceanographic parameters (collected by National Institute of Oceanography), only a few models exist to understand the relationship between physical, chemical and biological oceanographic parameters, and fish distribution and abundance. Delineating the impacts of climatic and oceanographic factors and anthropogenic interventions (other than fishing) from fishing impacts remains to be addressed.

Development of Sustainability Index for Indian Marine Fish (siFISH)

Taking advantage of the availability of data on the biological characteristics, exploitation status and population parameters for 98 species of finfish, crustaceans and mollusks from different publications in peer-reviewed journals and grey literature, we initiated development of siFISH. The idea is to rank the species based on 13 attributes under 4 broad categories, viz., biological, exploitation, distribution and habitat productivity. The 13 attributes were derived from the following list of information/ data:

List of attributes and Ranks

Attribute	Description
ISSCAP CODE	FAO code
Species	Species name
Family	Name of the family
SpcID	Four digit species code of CMFRI

StudyLocality	Study Locality
Region	Region to which the study area belongs (one among NE, SE, SW, NW, LAK, IND)
StartYear	Start year of data collection
EndYear	End year of data collection
Gear	Gear from which samples were collected
GScore	Score from gear wise catch using vulnerability score of Bjordal (2002)
GRank	Rank for the gear score
Sex	Sex of the animal (options are M, F and C representing Males, Females and Combined)
K	Annual growth rate, K
KRank	Rank of K scores
M	Natural mortality, M
F	Fishing mortality, F
Z	Total mortality, Z
Tzero	Age at zero length
ExpRate	Exploitation rate (E = F/Z)
ERRank	Rank for the exploitation rate
LenYear1	Length at age 1year
LenYear2	Length at age 2 years
LenYear3	Length at age 3 years
LenYear4	Length at age 4 years
Current Yield	Average landings for 2007-08 in tonnes
Yield	Yield during the study period
FecundityMin	Minimum fecundity
FecundityMax	Maximum fecundity
Fecundity	Average fecundity
FcRank	Rank based on Fecundity
MeanSizeMin	Minimum mean length
MeanSizeMax	Maximum mean length
MeanSize	Mean length
LengthRangeMin	Minimum length in the sample
LengthRangeMax	Maximum length in the sample
Lr	Length at recruitment
Linf	Asymptotic length
LinfRank	Ranked asymptotic length
MeanSizeByLinf	Ratio of Mean size to Linfinity
MeanSizeByLm	Ratio of Mean size to Lm
LrByLinf	Ratio of recruitment length to asymptotic length
LrRank	Rank of Recruitment Vulnerability
LmMin	Minimum length at first maturity
LmMax	Maximum length at first maturity
Lm	Average length at first maturity
LmBL	Ratio of Lm to Linfinity
LmRank	Ranked Reproductive Load
SpawningSeason	Spawing season (months)
NumSpawningMonths	Number of spawning months
NSMRank	Rank based on number of spawning months
Dist	Percentage distribution in continental shelf area
DistRank	Distribution Rank
MTL	Mean Trophic Level
MTLRank	Mean Trophic Level Rank

BDL	Maximum Body Depth Standard Length Ratio
BDLRank	Escapement/Retainment Rank
CPI	Coastal Productivity Index
CPIRank	Rank of Coastal Productivity Index
PriceRank	Target Fishing Rank based on market price
RankTotal	Total of the 13 ranks

Ranking Logic for Attributes

Each attribute was scaled in a rank of 1 to 6 based on the minimum and maximum values. In this ranking, a score of 6 is assigned to highly sustainable species/stock; 5 to sustainable; 4 and 3 to moderately sustainable stocks; 2 to low sustainability and 1 to very low sustainability. The details of the ranking scores for each attribute are given below.

a) Biological

Annual growth coefficient (K)	Rank	Remarks
> 1.5	6	Growth was estimated from length frequency data using FiSAT. The highest sustainability rank was given to species exhibiting higher K values and a frequency table was generated. Source: Publications in journals and reports (n = 264)
1.2 – 1.5	5	
0.9 – 1.19	4	
0.6 – 0.89	3	
0.3 – 0.59	2	
< 0.3	1	

$L_{infinity}$ (mm)	Rank	Remarks
< 200	6	$L_{infinity}$ was estimated from LF data using FiSAT. The highest rank was given to species of small size and a frequency table was generated. Source: Publications in journals and reports (n = 264)
200-400	5	
401-600	4	
601-800	3	
801-1000	2	
> 1000	1	

Trophic level	Rank	Remarks
2.0 – 2.4	6	MTL were estimated from diet studies, from developed trophic models and FishBase. The highest rank was given to species with low trophic level and a frequency table was generated. (n = 253)
2.5 – 2.9	5	
3.0 – 3.4	4	
3.5 – 3.9	3	
4.0 – 4.5	2	
> 4.5	1	

Maximum body depth/standard length ratio	Rank	Remarks
> 20	6	This ratio was estimated from the ratio of maximum body depth by standard length of finfishes. The highest rank was given to species with high ratio considering the superior probability of escapement of the species from fishing gears. Source: Vivekanandan (unpublished) (n = 142)
15 - 19	5	
10 - 14	4	
5 - 9	3	
3 - 5	2	
< 3	1	

(Lm/L_{∞}) ratio	Rank	Remarks
0.0 – 0.05	6	This ratio indicates the reproductive load of the species. A ratio of 0.5 (median) was ranked highest, and other ranks were based on the deviation from the median. Source: Analysis from publications in journals and reports (n = 92)
0.06 – 0.10	5	
0.11 – 0.15	4	
0.16 – 0.20	3	
0.21 – 0.25	2	
> 0.25	1	

Number of spawning months	Rank	Remarks
11 & 12	6	This rank was based on the number of months a fish spawns. A species spawning throughout the year (12 months) was ranked the highest. Source: Analysis from publications in journals and reports (n = 41)
9 & 10	5	
7 & 8	4	
5 & 6	3	
3 & 4	2	
1 & 2	1	

Measured fecundity	Rank	Remarks
> 150,000	6	Fecundity measurements are usually *in-situ* observations and do not indicate annual reproductive potentials. A species having high fecundity was ranked the highest. Source: Publications in journals and reports (n = 228)
100,000–150,000	5	
50,001–100,000	4	
25,001-50,000	3	
2001-25,000	2	
< 2001	1	

b) Exploitation

Susceptibility to fishing gear	Rank	Remarks
< 5	6	Most of the species are exploited by a number of gears. Proportional weightage was given to catch contribution by different gears to each species. Subsequently, a catch susceptibility score was assigned for each species to different gears following Bjordal (2002) and a product of these values was obtained which was scaled to 6. A species
5 – 7.5	5	
7.6 - 10	4	
10.1 – 12.5	3	
12.5 – 15.0	2	
> 15	1	

		with high rank is considered to be less susceptible to fishing gear. Source: Estimated from CMFRI database on gear-wise catch (n = 264)

Lr/L_∞ ratio	Rank	Remarks
> 0.6	6	Length at recruitment and L_∞ were derived from published records. Recruitment at larger sizes was given higher ranking. Source: Publications in journals and reports (n = 135)
0.5 – 0.59	5	
0.4 – 0.49	4	
0.3 – 0.39	3	
0.2 – 0.29	2	
< 0.2	1	

Exploitation rate	Rank	Remarks
< 0.4	6	E was calculated from F/Z. A species with low ratio was given higher ranking. Source: Publications in journals and reports (n = 264)
0.4 – 0.49	5	
0.5 – 0.59	4	
0.6 – 0.69	3	
0.7 – 0.79	2	
> 0.79	1	

Price index	Rank	Remarks
Very low	6	A species with low market price was given higher ranking, considering that it is not targeted by fishers. Source: CMFRI database (n = 264)
Low	5	
Medium 1	4	
Medium 2	3	
High	2	
Very high	1	

c) Distribution

Distribution (% of continental shelf area)	Rank	Remarks
> 80	6	Catch along each maritime state was taken as a surrogate of distribution of species. The number of states contributing to the catch was considered for arriving at area of distribution of species in km^2. The species distributed in larger areas was given higher rank. Source: Estimated from CMFRI database (n = 264)
66 - 80	5	
51 - 65	4	
36 - 50	3	
21 - 35	2	
< 21	1	

d) Habitat Productivity

Coastal Productivity Index (CPI)	Rank	Remarks
> 550	6	Estimated as a product of monthly Coastal Upwelling Index (CUI) and Chlorophyll a concentrations from 30 lat-long positions along the Indian coast for the period 1998-2008. The monthly values were averaged to arrive at annual values for each maritime state. This was linked to the species distribution index to arrive at the CPI. Species maximally distributed in highly productive waters are given higher score. Source: CUI: ERD of NOAA; Chlorophyll: SeaWiFS; Species distribution: CMFRI database (n = 264)
401 - 550	5	
251 - 400	4	
151 - 250	3	
101 - 150	2	
< 101	1	

Interim Results of the siFISH Analysis

The ranking was made for 98 species and 140 stocks from 264 records. Since more records are to be added to the siFISH database an interim results of the analysis is presented below. The first table shows the sustainability ranking by species and region along the coefficient of variation (CV). The sustainability index ranged from 2.17 (*Carcharhinus sorrah*) to 5.45 (*Oratosquills nepa*). Most fishes had values ranging between 3 and 4 indicating medium level of sustainability (see frequency histogram). In general, the elasmobranchs had very low sustainability index values. At the other end of the index were the shrimps, other crustaceans and mollusks. The CV is high for some species because of the variability between regions and periods of original study. Among the 3 regions for which sufficient data are available, the index for NW, SE and SW were 3.67, 3.59 and 3.71 respectively. The mean index value for all the regions was 3.65.

SpcID	Species	IND	LAK	NE	NW	SE	SW	siFISH	CV
0052	Carcharhinus sorrah					2.17		2.17	3.59
0146	Rhinobatos granulatus						2.27	2.27	0.00
0121	Sphyrna lewini						2.45	2.45	0.00
5011	Sepia aculeata				2.50			2.50	0.00
0101	Rhizoprionodon acutus				2.45		2.73	2.55	6.65
0636	Ablennes hians					2.63		2.63	0.00
0547	Tachysurus dussumieri						2.70	2.70	0.00
1286	Parastromateus niger						2.75	2.75	0.00
1521	Otolithoides biauritus				2.78			2.78	0.00
1202	Caranx ignobilis					2.81		2.81	3.27
1911	Lepturacanthus savala				2.90			2.90	0.00
1916	Trichiurus lepturus				3.00	2.88	2.96	2.94	10.93
0048	Carcharhinus limbatus						3.05	3.05	10.45
1261	Selaroides leptolepis					3.09		3.09	0.00
1966	Scomberomorus commerson	3.45				3.18	3.00	3.12	7.20
1517	Otolithes ruber						3.17	3.17	0.00
2246	Cynoglossus arel				3.20			3.20	0.00
1612	Upeneus taeniopterus					3.28		3.28	2.38
1977	Thunnus albacares		3.20		3.20	3.50		3.30	5.25

0361	Sardinella gibbosa						3.38	3.38	0.42
0106	Scoliodon laticaudus				3.57		3.22	3.39	8.31
1363	Pristipomoides filamentosus						3.40	3.40	0.00
1936	Euthynnus affinis	3.45			3.50	3.39	3.29	3.40	8.86
1953	Rastrelliger kanagurta					3.54	3.39	3.41	6.44
0316	Tenualosa ilisha			3.42				3.42	0.00
1171	Rachycentron canadum						3.42	3.42	0.00
1412	Leiognathus bindus					3.44	3.33	3.42	3.41
0431	Chirocentrus dorab						3.45	3.45	0.00
1244	Scomberoides tol						3.45	3.45	0.00
5021	Sepiella inermis				3.45			3.45	2.05
1516	Otolithes cuvieri				3.48			3.48	1.66
5026	Loligo duvaucelii				3.48		3.50	3.49	12.20
0410	Thryssa mystax						3.50	3.50	0.00
0815	Sphyraena jello						3.50	3.50	0.00
1231	Megalaspis cordyla						3.50	3.50	5.66
1489	Johnieops macrorhynus				3.50			3.50	0.00
1967	Scomberomorus guttatus						3.50	3.50	0.00
2306	Odonus niger						3.50	3.50	0.00
4204	Panulirus polyphagus				3.50			3.50	0.00
0376	Coilia dussumieri				3.53			3.53	9.24
0472	Saurida tumbil				3.73		3.37	3.54	10.85
2186	Pseudorhombus arsius						3.55	3.55	0.00
2011	Pampus argenteus						3.58	3.58	0.00
1186	Atropus atropos				3.60			3.60	0.00
1608	Upeneus vittatus					3.60		3.60	0.00
1946	Katsuwonus pelamis		3.41			4.00		3.61	9.61
0944	Ephinephelus diacanthus				3.67		3.60	3.62	5.63
0360	Sardinella fimbriata						3.64	3.64	0.00
0301	Escualosa thoracata						3.67	3.67	0.00
1431	Secutor insidiator					3.65	3.71	3.67	4.15
2027	Ariomma indica					3.67		3.67	0.00
4066	Penaeus monodon			3.73		3.65		3.67	3.03
1511	Nibea maculata					3.68		3.68	1.73
0389	Stolephorus devisi						3.70	3.70	4.19
1488	Johnieops vogleri				3.70			3.70	0.00
1927	Auxis thazard				3.64	3.67	3.79	3.72	6.51
4032	Metapenaeus brevicornis				3.72			3.72	2.09
0291	Dussumieria acuta						3.73	3.73	0.00
0387	Stolephorus punctifer						3.73	3.73	0.00
0386	Stolephorus waitei						3.74	3.74	4.40
1979	Thunnus tonggol				3.91		3.58	3.74	6.23
0362	Sardinella longiceps						3.75	3.75	5.46
1367	Nemipterus japonicus	3.83			3.76	3.78	3.72	3.76	5.24
0473	Saurida undosquamis					3.90	3.58	3.78	4.87
1606	Upeneus sulphureus			3.91		3.71		3.78	6.27
1181	Alepes djeddaba						3.82	3.82	0.00
1926	Auxis rochei						3.82	3.82	3.33
1487	Johnieops sina				3.90		3.82	3.86	1.47
1184	Alepes kalla						3.87	3.87	1.83
0501	Harpadon nehereus				3.91			3.91	5.54
1498	Johnius dussumieri				3.91			3.91	0.00

4316	Portunus pelagicus					3.85	4.08	3.94	3.61
0817	Sphyraena obtusata					4.00	3.91	3.95	1.61
1211	Decapterus russelli					4.09	3.83	4.00	4.37
1252	Selar crumenophthalmus						4.00	4.00	0.00
1419	Leiognathus jonesi					4.00		4.00	2.50
1007	Priacanthus hamrur			4.09	3.97		4.17	4.04	6.24
1166	Lactarius lactarius						4.08	4.08	2.94
1486	Johnieops aneus					4.10		4.10	0.00
2252	Cynoglossus macrostomus						4.13	4.13	2.35
1213	Decapterus macrosoma						4.14	4.14	4.62
4031	Metapenaeus affinis				4.15			4.15	1.70
1369	Nemipterus mesoprion				4.35		4.13	4.19	6.72
4042	Parapenaeopsis hardwickii				4.25			4.25	8.32
4317	Portunus sanguinolentus						4.26	4.26	6.94
4111	Exhippolysmata ensirostris				4.27			4.27	0.00
2126	Grammoplites suppositus						4.36	4.36	0.00
5013	Sepia pharaonis						4.36	4.36	0.00
4033	Metapenaeus dobsoni					4.40	4.35	4.38	1.14
4035	Metapenaeus monoceros	4.38			4.25	4.80	4.37	4.42	5.09
4101	Nematopalaemon tenuipes				4.60			4.60	0.00
5012	Sepia elliptica						4.60	4.60	0.00
4045	Parapenaeopsis stylifera				4.45		4.80	4.63	4.46
4082	Acetes indicus				4.81		4.33	4.64	6.29
4008	Solenocera choprai						5.00	5.00	0.00
4891	Paphia malabarica						5.00	5.00	4.37
4401	Oratosquilla nepa						5.45	5.45	0.00

The family-wise index values are shown below. The elasmobranch families had low sustainability index values and crustacean families had high values. Among teleosts, Belonidae, Ariidae and Trichuiridae had low sustainability index values.

Family	Average Sustainability Index	CV
RHINOBATIDAE	2.27	0
SPHYRNIDAE	2.45	0
BELONIDAE	2.63	0
ARIIDAE	2.70	0
TRICHUIRIDAE	2.93	10.33
CARCHARHINIDAE	2.96	18.36
LUTJANIDAE	3.40	0
RACHYCENTRIDAE	3.42	0
CHIROCENTRIDAE	3.45	0
SCOMBRIDAE	3.46	8.76
BALISTIDAE	3.50	0
Palinuridae	3.50	0
Loliginidae	3.50	12.2
BOTHIDAE	3.55	0
MULLIDAE	3.58	8.07
STROMATEIDAE	3.58	0
SCIAENIDAE	3.59	9.6
LEIOGNATHIDAE	3.60	6.61

CLUPEIDAE	3.61	5.39
CARANGIDAE	3.61	13.54
SYNODONTIDAE	3.62	9.72
SERRANIDAE	3.62	5.63
ENGRAULIDAE	3.67	5.58
ARIOMMIDAE	3.67	0
Sepiidae	3.67	22.83
SPHYRAENIDAE	3.80	7.01
NEMIPTERIDAE	3.89	7.78
HARPADONTIDAE	3.91	5.54
CYNOGLOSSIDAE	3.99	8.99
PRIACANTHIDAE	4.04	6.24
LACTARIIDAE	4.09	2.94
Portunidae	4.12	6.98
PENAEIDAE	4.26	8.57
Hippolytidae	4.27	0
PLATYCEPHALIDAE	4.36	0
Palaemonidae	4.60	0
SERGESTIDAE	4.65	6.29
SOLENOCERIDAE	5.00	0
Veneridae	5.02	4.37
Squillidae	5.45	0

When the values were compared based on ISCAAP codes, the index was lowest for sharks and rays and highest for miscellaneous crustaceans. Since several species groups were pooled for this estimation, the CV values were generally high.

ISSCAP CODE	**Sustainability Index**	**CV**
31 – flatfishes	3.93	9.32
33 – Misc coastal fishes	3.67	7.11
34 – Misc Demersal fishes	3.71	9.35
35 – Sardines, anchovies	3.64	5.42
36 – Tunas, sailfish	3.55	8.41
37 – Misc pelagic fishes	3.39	13.73
38 – Sharks, rays	2.88	18.98
42 – Crabs	4.12	6.98
43 – Lobsters	3.50	0
45 – Shrimps	4.34	8.67
47 – Misc crustaceans	5.45	0
56 – Clams	5.02	4.37
57 – Squid, cuttlefishes, octopus	3.60	18.19

Among the 264 records for which Sustainability Index has been generated in a scale of 1 to 6, a major part of records (68% of total) was between 3 and 4 in sustainability ranking. Thirty five records are below the Index 3, and these stocks may be considered to indicate vulnerability. It is found that 12 species have Index values below 3, which may be considered as vulnerable species. They are: the sharks *Carcharhinus sorrah, Sphyrna lewini* and *Rhizoprionodon acutus*, the guitarfish *Rhinobatos granulatus*, the needlefish *Ablennes hians*, the catfish *Tachysurus dussumieri*, the black pomfret *Parastromateus niger*, the sciaenid *Otolithoides biauritus*, the giant trevally *Caranx ignobilis*, the ribbonfish *Lepturacanthus savala* and *Trichiurus lepturus* and the cuttlefish *Sepia aculeate*.

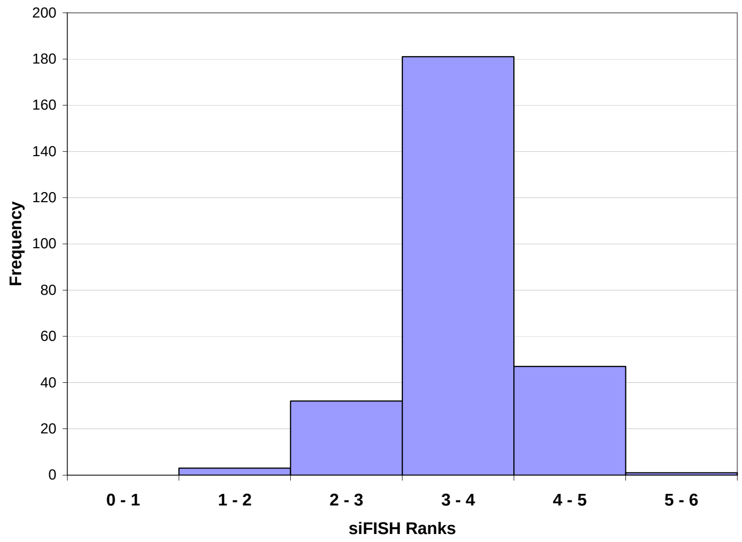
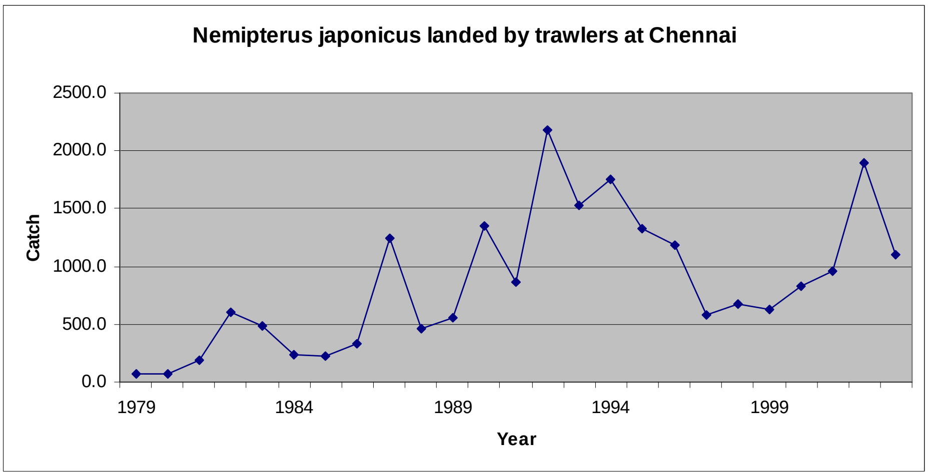


Figure showing frequency histogram of Sustainability Index of Indian marine fish stocks/ species (n = 264).

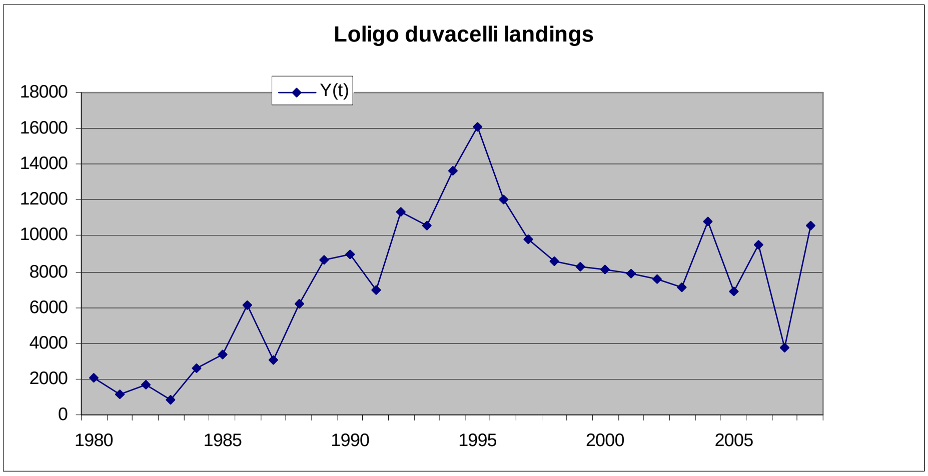
Validation of simple stock assessment method of NMFS proposed by FAO

We attempted an analysis based on the Depletion-Adjusted Average Catch method (MacCall, 2007), for two species namely the threadfin bream *Nemipterus japonicus* and the squid *Loligo duvauceli*, for which stock estimates by using conventional methods are available.

For *N. japonicus,* we used time series data on catch by trawlers for 1979-2003 period off Chennai (southeast coast of India) and natural mortality estimate, M = 2.53 estimated using Pauly's empirical formula. The time series data used did not show any clear decreasing catch trend. When we give alpha the suggested minimum value 0.4 then both beta and delta have to be as low as 0.15 and 0.1 to get positive estimates of biomass. Also, the yield estimate continues to increase and does not reduce at any stage and the maximum is for the year 2003. This does not allow estimation of MSY as there is no peak in the series of yields estimated.



The same problem was observed when we analyzed time series data on catch of *Loligo duvacelli* by trawlers for the period 1980-2008 off Kerala (southwest coast of India).



Data sets used for the two Indian species for validation are given below:

Nemipterus japonicus landed by trawlers at Chennai					
	M	2.5254	**WbY**	1.237	
	alpha	0.4	**rest**	0.323251	
	Beta	0.16	**MSY**	813.214	
	Delta	0.1	**K**	10062.93	
Year	**NJcatch**	**CumCatch**	**U(t)**	**Y(t)**	**B(t)**
1979	66.3	66.3	2.237	29.6	10062.9
1980	76.8	143.1	3.237	44.2	9996.6
1981	187.7	330.8	4.237	78.1	9941.1
1982	598.6	929.4	5.237	177.5	9792.3
1983	482.7	1412.1	6.237	226.4	9278.8
1984	231.4	1643.5	7.237	227.1	9029.8
1985	228.4	1871.9	8.237	227.2	9098.1
1986	327.3	2199.2	9.237	238.1	9151.7
1987	1238.3	3437.5	10.237	335.8	9092.3
1988	464.3	3901.9	11.237	347.2	8137.5
1989	558.4	4460.2	12.237	364.5	8176.5
1990	1352.4	5812.6	13.237	439.1	8113.6
1991	869.9	6682.5	14.237	469.4	7269.3
1992	2179.3	8861.7	15.237	581.6	7051.7
1993	1523.3	10385.1	16.237	639.6	5554.6
1994	1758.2	12143.3	17.237	704.5	4835.7
1995	1330.1	13473.4	18.237	738.8	3889.4
1996	1190.3	14663.7	19.237	762.2	3330.7
1997	577.8	15241.5	20.237	753.1	2860.6
1998	673.7	15915.2	21.237	749.4	2944.6
1999	626.0	16541.2	22.237	743.8	2944.3
2000	834.1	17375.3	23.237	747.7	2991.6
2001	964.2	18339.5	24.237	756.7	2837.0
2002	1890.2	20229.7	25.237	801.6	2531.3
2003	1106.9	21336.6	26.237	813.2	1253.5

Loligo duvauceli catch Kerala							
M	**2.14**	**beta**	**0.35**	**WbY**	**0.242748**	**K**	**89075.09**
Alpha	**0.22**	**delta**	**0.02**	**rest**	**0.32956**	**Fmsy**	**0.16478**
				MSY	7338.90	**Bmsy**	**44537.55**
Year	**LDcatch**	**CumCatch**	**U(t)**	**Y(t)**	**B(t)**		
1980	2037	2037	1.24	1639.21	89075		
1981	1140	3178	2.24	1416.83	87038		
1982	1697	4875	3.24	1503.32	86553		
1983	829	5704	4.24	1344.37	85664		
1984	2595	8299	5.24	1582.90	85916		
1985	3396	11695	6.24	1873.33	84325		
1986	6145	17839	7.24	2463.07	82411		
1987	3089	20929	8.24	2539.05	78298		
1988	6214	27142	9.24	2936.61	78331		
1989	8691	35833	10.24	3498.37	75231		
1990	8954	44787	11.24	3983.67	70394		
1991	6936	51723	12.24	4224.80	66305		
1992	11329	63052	13.24	4761.26	64955		
1993	10532	73584	14.24	5166.45	59422		
1994	13664	87248	15.24	5723.91	55409		
1995	16082	103330	16.24	6361.58	48647		
1996	12002	115332	17.24	6688.72	39842		
1997	9820	125152	18.24	6860.38	35097		
1998	8562	133715	19.24	6948.83	32286		
1999	8274	141988	20.24	7014.28	30507		
2000	8116	150104	21.24	7066.15	28844		
2001	7902	158006	22.24	7103.72	27156		
2002	7589	165595	23.24	7124.58	25475		
2003	7092	172687	24.24	7123.24	23881		
2004	10838	183525	25.24	7270.39	22549		
2005	6921	190446	26.24	7257.09	17261		
2006	9486	199932	27.24	7338.90	14926		
2007	3764	203696	28.24	7212.33	9535		
2008	10533	214229	29.24	7325.89	8577		

Negative biomass values were encountered probably because of high M values (which is common for tropical stocks) estimated empirically using Pauly's method. In the case of widow rockfish from USA (MacCall, 2007), the M value used was 0.15 only. On the other hand, the M value records (n = 264) available for Indian species ranges from 0.18 for the catfish *Tachysurus dussumieri* to 4.26 for the paste shrimp *Acetes indicus*.

References

Banerji, S.K. and D. Chakraborty. 1972. On estimation of yield from exploited marine stocks with reference to southeast Asia: In: Proceedings of Symposium on Living Resources of the Seas around India. CMFRI Spl. Publ., 176-183.

Beverton, R.J. and S. J. Holt 1957. On the dynamics of exploited fish populations. UK Min. Agri and Fish, Invest. 19: 533p.

Bjordal, A. 2002. The use of technical measures in responsible fisheries: regulation of fishing gear. In: K.L. Cochrane (ed.) A Fishery Managers Guidebook, management measures and their application. FAO Fish. Tech .Pap. 424: 21-47.

CMFRI, 2000. A code list of common marine living resources of the Indian seas. *CMFRI Spl. Publ.*, 12(revised): 115 pp.

CMFRI, 2006. Marine Fisheries Census 2005. Ministry of Agriculture, Government of India, New Delhi.

CMFRI, 2007. Annual Report 2006-07. Central Marine Fisheries Research Institute, Cochin, 133 pp.

MacCall, A. 2007. Report of the Lenfest working group on annual catch limits. NMFS/SWFSC/FED (draft 9/6/07). P 27-31.

Mohamed, K.S., P.U. Zacharia, C. Muthiah, K.P. Abdurahiman and T.H. Nayak (2008). Trophic model of the Arabian Sea ecosystem off Karnataka and simulation of fishery yields. *Bull. Cent. Mar. Fish. Res. Inst.* 51: 140p.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer. 39: 175-192.

Srinath, M., Somy Kuriakose and K.G. Mini. 2005. Methodology for estimation of marine fish landings in India. *CMFRI Spl. Publ.*, 86: 57pp.

Thompson, W.F. and H. Bell. 1934. Biological statistics of the Pacific halibut fishery. Rep. Int. Fish. Comm. 8: 48p.

Vivekanandan, E., M. Srinath, V.N. Pillai, S. Immanuel and K.N. Kurup. 2003. Trophic model of the coastal fisheries ecosystem of the southwest coast of India. In: Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries. *Worldfish Center Conference Proceedings*, 67: 281-298.