Bulletin 20

MARINE FISHERY RESOURCES POTENTIAL IN THE INDIAN EXCLUSIVE ECONOMIC ZONE-AN UPDATE

Govt. of India
FISHERY SURVEY OF INDIA
Bombay

MARINE FISHERY RESOURCES POTENTIAL IN THE INDIAN EXCLUSIVE ECONOMIC ZONE - AN UPDATE

D. SUDARSAN, M.E. JOHN AND V.S. SOMVANSHI

December 1990

Govt. of India
FISHERY SURVEY OF INDIA
(Ministry of Food Processing Industries)
Botawala Chambers, Sir P.M. Road
Bombay 400 001

Cable : Meena
Telex : 011-85778
Phone : 2617144
2617145
2621259

Bulletins are issued by Fishery Survey of India with the objective of presenting results of comprehensive studies on marine fisheries resources

Abbreviation: *Bull. Fish. Surv. India*

Published by: D. Sudarsan, Director General, Fishery Survey of India
Botawala Chambers, Sir P.M. Road, Bombay 400 001
Technical Assistance: S.M.Patil, A.K.Bhargava and V.V.Naik
Secretarial Assistance: Meena A.Chawla and Radha P. Balchandani
Cover Design: R. Selvaraj

FOREWARD

Estimation of natural resources is a prerequisite for their optimum exploitation. The tools and methods of estimation of natural resources vary according to the nature of the resource itself. Whereas in the case of natural nonliving resources a one-time estimate may be adequate, in the case of natural living resources it has to be a continuous process involving approximation, assessment by different scientific methods, monitoring, reassessment by refined techniques, revalidation and so on. The potential of marine fisheries resources in the Indian Exclusive Economic Zone was first estimated in 1977 by Prof. P.C. George and his associates, who placed the exploitable potential at 4.5 million tonnes. Subsequent estimates tended to hover around that figure. Since then a large amount of data has become available to the scientific community affording them an opportunity for refining the estimates. The present study is one such effort leading to a figure of 3.92 million tonnes. This estimate was arrived at by a synthesis of results obtained by using different techniques. Though the present study is a commendable refinement over the earlier ones, it still cannot be taken as the last one. Future investigations, more extensive and scientifically refined data collection and a better insight into the production dynamics and access to new resources and the components thereof could lead to more refined estimates. Annual and long term fluctuations in living natural resources such as fish could and would alter the picture. While the studies on primary production indicate a wide range for the potential yield of fisheries production ranging from 3.12 to 4.8 million tonnes, the estimate now made by FSI indicates a potential of 3.92 million tonnes which falls within that range. With our present knowledge of resources, techniques of exploration and methodologies for computation of potential, the assessment now made could be taken as more acceptable. The Ministry of Agriculture, Govt. of India has recently appointed a Working Group to **inter alia** go into this issue. The assessment by this Group is also likely to be close to the figure arrived at in this exercise. However, fisheries scientists should keep an open mind and continue their studies in this area of endeavour.

The present study, it is hoped, would lead to greater clarity than before and would help the scientists, planners, administrators and the industry.

Bombay

31st December 1990

D. SUDARSAN
DIRECTOR GENERAL

CONTENTS

1. INTRODUCTION

Appraisal of marine fishery resources of the Indian Exclusive Economic Zone was made earlier by various authors using diverse techniques (Jones and Banerjee, 1973; George **et al.**, 1977; Joseph, 1980, 1985, 1987; Sudarsan **et al.**, 1988, 1989; Nair and Gopinathan, 1981; Alagaraja, 1989; Desai **et al.**, 1990; Mathew **et al.**, 1990). Based on the exploratory survey data collected recently by Fishery Survey of India, Sudarsan **et al.** (op.cit.) estimated the marine fishery potential of demersal stocks in the outer continental shelf and slope beyond the 50m contour as 0.55 million tonnes and the deepswimming oceanic tunas and allied species in the EEZ as 0.048 million tonnes. This has helped those who were looking for diversification in fishing to obviate pressure on coastal shrimp stocks and opt for fishing for the recently located and assessed deepsea resources in our EEZ. More specific as well as comprehensive resource potential estimates based on additional data would be useful. As such studies on fishery potential is a continuing exercise.

Recent developments in tuna fishing by longlining under charter scheme in India (Sudarsan **et al.**, 1990) and tuna fishing by purse seining in the Western Indian Ocean have also increased enthusiasm among the Indian fishing industry circles and entrepreneurs. This publication attempts to provide requisite refined estimates of fishery resources potential in the Indian EEZ enabling the planners, fishing industry, entrepreneurs and the financing agencies to develop deepsea fishing and manage the deepsea fish stocks on a rational basis.

1. Continental shelf, continental slope and Exclusive Economic Zone

The continental shelf and slope essentially support the demersal resources and small pelagics, and the oceanic waters within 200 nautical miles and beyond support larger pelagics comprising of tunas, bill fishes and sharks. The extent of the continental shelf and slope are presented on a region-wise basis in Table 1.

It will be seen from the Table that the continental shelf area reckoned at 200m depth is about 4.145 lakh sq.km. and the continental slope between 200-300m is about 0.241 lakh sq.km. The latter figure includes area between 300-500m also in the case of south west coast off Quilon (Lat. 8°-10°N) where a distinct Bank known for its deepsea prawn and deepsea lobster resources exists.

Table 1. Extent of area in the continental shelf and slope along Indian EEZ, region-wise and depth-wise.

Area in '000 sq.km)

Region/Latitude	Depth range (m)				
	0-50	50-100	100-200	200-300	Total
North west coast (Lat.15°00'- 23°40'N)	99.2	97.7	16.5	6.1	219.5
South west coast(Lat.8°00'-15°00'N)	28.3	30.3	10.2	10.1*	78.9
Wadge Bank & Gulf of Mannar	11.7	5.1	5.8	2.9	25.5
Lower east coast(Lat.10°00'-15°00'N)	27.1	6.7	4.8	2.2	40.8
Upper east coast(Lat.15°00'-21°40'N)	39.3	17.3	14.5	2.8	73.9
TOTAL	205.6	157.1	51.8	24.1	438.6**

* Upto 500m depth in Lat. 8°-10°N

** The continental shelf area around the Union Territories of Lakshadweep and Andaman & Nicobar islands is not included.

- In some of the earlier publications of FSI the regions have been designated as inclusive of the area upto the next latitude whereas in this report the latitudes indicated form the northern and southern boundaries of the respective regions.

The area covered by the continental shelf and EEZ of India is presented below:

Region	Area in '000 sq km	
	Continental shelf (0-200m)	EEZ upto 200 nautical miles
West coast	282.2	860.0*
East coast	132.3	561.4
Andaman & Nicobar Islands	35.0	596.5
TOTAL	449.5	2017.9

* Including Lakshadweep Sea.

It will be seen from the above that the EEZ off the west coast forms about 42.6%, off the east coast 27.8% and around Andaman and Nicobar islands about 29.6% of the Indian EEZ.

2. Present status of marine fisheries

It is widely accepted that the present fishing fleet comprising the traditional (non-motorised and motorised boats) as well as mechanised boats and offshore shrimp trawlers are fishing mainly within 50m depth, particularly for demersal species even though some go beyond while fishing for other species. Barring a very few tuna vessels, there are practically no deepsea fishing vessels engaged in fishing upto our legal regime of 200 nautical miles from the coastline.

The marine fish production in the country has gradually grown from 1.44 million tonnes to 2.27 million tonnes during the 80's with an annual average of 1.72 million tonnes in the decade and 1.87 million tonnes during the last five years. Fish landing from 1981 to 1989-90 are furnished in Table 2.

3. Estimates of fishery potential in Indian EEZ

Several estimates have been made of the fishery resource potential or annual maximum sustainable yield from the Indian EEZ based on primary productivity studies, exploratory surveys and other parameters (Jones and Banerjee, 1973; Mitra, 1973; George **et al.**, 1977; Nair and Gopinathan, 1981; Joseph, 1985, 1987; Sudarsan **et al.**, 1988; Alagaraja, 1989; Desai **et al.**, 1990; Mathew **et al.**, 1990). The methodology followed and estimates of potential yield with respect to the recent estimates are indicated in Annexure I to VII and a summary of the estimates in Table 3. These estimates range from 3 to 5.5 million tonnes for the EEZ upto 200 nautical

Table 2. Marine fish production (tonnes) in India and share of demersal and pelagic components

Year	Demersal		Pelagic		Total
	Catch	%	Catch	%	
1981	649240	44.94	745539	51.60	1444779
1982	755841	52.95	671646	47.05	1427487
1983	758940	49.95	760371	50.05	1519311
1984	916065	51.48	863294	48.52	1779359
1985	907340	52.32	826817	47.68	1734157
1986	905946	52.77	810998	47.23	1716944
1987	90696	54.22	769789	45.78	1681485
1988	1017738	55.25	824178	44.75	1841916
1988-89					1817400*
1989-90					2270000*

Source: Ministry of Agriculture

* Breakup details not available

Table 3. Marine fishery resources potential in Indian EEZ - some estimates

('000 tonnes)

Author	George et al. (1977)	Nair & Gopinathan (1981)	Joseph (1987)	Sudarsan et al. (1988)	Alagaraja (1989)	Sudarsan et al. (1989)	Desai et al. (1990)	Mathew et al. (1990)
Depth zone (m) / Region	0-200m and oceanic*	EEZ	0-500m and oceanic*	50-300/ 500m (Demersal only)	0-200m	Oceanic**	EEZ	EEZ
North west coast	883	5500	1620	460	1050	9	3660	2390
South west coast	1422		853		900	25		
Lower east coast	674		425	94	750	3		660
Upper east coast	735		531		300	6		
U.T. of Lakshadweep	90		90					
U.T. of Andaman & Nicobar	160		160			5		690
*Oceanic	500		500					
TOTAL	4464	5500	4179	554	3000	48	3660	3740

** Only deep swimming tunas, bill fishes and sharks

miles from the coast. The most direct among the estimates are those based on exploratory surveys in case of demersal resources and acoustic surveys coupled with test fishing in the case of small pelagics. Joseph (1980, 1987) made estimates of demersal resources upto 40 fathoms (73 m) depth based on exploratory surveys and demersal and pelagic resources combined for the areas between 0-200m and 200-500m depth. Sudarsan **et al.** (1988) assessed the demersal resources along the Indian coast in 50-300m depth on the basis of exploratory surveys. The details of assessments based on the survey data generated by FSI are furnished in Table 4.

Though the expression "MSY" indicates the maximum yield a stock can sustain year after year the term "potential yield" has a marginally different connotation in so far as it indicates how much could be taken from a stock annually year after year. Apart from biological factors the latter concept takes cognisance of economic considerations and social factors. In this study, the expression potential yield is used as a synonym of MSY.

II. DEMERSAL FISHERY RESOURCES

1. Earlier assessments

Assessment of demersal fishery resources based on the exploratory surveys are mainly those of Joseph (1974, 1980, 1985, 1987), Joseph **et al.** (1976 a,b, 1987), Sudarsan (1978), Sudarsan **et al.** (1987, 1988) and Sivaprakasam (1986). Among these, the studies pertaining to demersal resources within 70m depth along mainland India (Joseph, op.cit.), around Andaman islands (Sudarsan op.cit) and the deeper water resources from 50-300m depth zone (Sudarsan **et al.**, 1988) provide estimates of demersal resources potential based on exploratory survey data of over a long period. These assessments indicate the annual potential of demersal stocks from areas within 70m depth along mainland as 1.7 million tonnes, around Andamans as 22.5 thousand tonnes and from 50-300m depth zone around the mainland as about 0.55 lakh tonnes. Some of the recent estimates of potential yield of demersal resources are presented below:

('000 tonnes)

Author	Jones & Banerjee (1973)	George **et al.** (1977)	Joseph (1987)		Sudarsan **et al.** (1988)		
Depth zone (m) / Region	0-200	0-200	0-200	200-500	50-100	100-200	200-300
West coast	577.0	1127.5	1378.0	50.0	315.2	102.6	22.0
East coast	143.0	867.5	434.0	33.0	55.9	28.9	3.4
Wadge Bank	-	-	-	-	6.8	12.1	0.7
Gulf of Mannar	-	-	-	-	1.7	4.4	0.2
U.T. of Andaman & Nicobar	4.0	20.0	21.0	-	-	-	-
U.T.of Lakshadweep	1.1	-	27.0	-	-	-	-
TOTAL	725.1	2015.0	1860.0	83.0	379.6	148.0	26.3

Table 4: Estimates of marine fishery potential in Indian EEZ based on FSI data base

Author	Resource	Potential yield estimate ('000 tonnes)							
		North west coast	South west coast	Wadge Bank	Gulf of Man-nar	Lower east coast	Upper east coast	Andaman Sea	Total
Joseph, 1974	Demersal (0-40fm)	231							
Joseph et al., 1976a	Demersal (0-40fm)		124						
Joseph et al., 1976b	Demersal (0-40fm)					75	131		
Joseph, 1980	Demersal (0-75m)	699	377			231	372		1679
Joseph, 1985	Demersal (0-200m)	928	438			243	416		2025
Joseph, 1987	Demersal (0-500m)	1124	331*			228	239	21	1943
Joseph et al., 1987	Demersal (10-100fm)			19					
Sivaprakasam, 1986	Demersal (20-200m)			27	17				
Sudarsan, 1978	Demersal (in shelf area)							45**	
Sudarsan et al., 1987	Demersal (0-500m)		240						
Sudarsan et al., 1988	Demersal (50-500m)	440		20	6	88			554
Sudarsan et al., 1989	Oceanic tuna and allied species (EEZ)	9	25			3	6	5	48

* Including 27000 tonnes from Lakshadweep

**Standing stock

2. Methodology and approach

2.1 Demersal fishery resources in the seas around India upto 500m depth as surveyed by FSI are considered here.

2.2 The potential of demersal stocks within 50m depth along mainland is apportioned from the estimate of demersal resources upto 70m depth along the Indian coast made by Joseph (1980). The standing stock estimated by Sudarsan (1978) is adopted for assessing the potential of demersal stock around Andaman assuming 50% of the standing stock as MSY.

2.3 Data collected by seven of the survey vessels of FSI since 1979, during different periods till March 1987 are analysed for this study.

2.4 The survey area, period of survey and fishing gear used in respect of each of the vessels are given in Table 5.

2.5 The Indian coast and shelf is divided, for the purpose of this study, into six regions namely, north-west coast (Lat. 15°N to 23°40'N), south west coast (Lat. 8°N to 15°N), upper east coast (Lat. 15°N to 21°40'N), lower east coast (Lat. 10°N to 15°N), Wadge Bank and Gulf of Mannar.

2.6 The "swept area" method is followed taking 40% of the head rope length as effective horizontal trawl opening and the catchability coefficient as 0.4 for 34m fish trawl and 0.5 for other trawls taking into consideration the difference in mesh size.

2.7 New approach by introducing natural mortality coefficient in estimating MSY of different species/groups constituting the demersal catches is adopted in this study. Studies made by various authors on natural mortality in respect of demersal species from Indian waters are considered and for some of the species values from other areas in the tropics published elsewhere are taken into account (Annexure VIII).

2.8 As exploitation of demersal stocks beyond 50m depth is very nominal, the MSY is computed using Gulland's (1971) formula,

$$MSY = 0.5\ M\ Bv$$

Where M is the natural mortality coefficient and Bv the virgin standing stock.

2.9 In case of deepsea crustaceans sampling effort by FSI vessels using resource specific gear was not adequate. However, the standing stock figures obtained in relatively intensive surveys by the Integrated Fisheries Project (IFP) in the 70's (Oommen, 1980, 1985) are adopted for south west coast and Gulf of Mannar.

Table 5. Area, vessels, fishing gear and period of survey

Region/Area	Name of vessel	Depth zone (m)/gear used		Period of survey
		50-200	200-300/500	
West coast				
Lat. 20°-22°	Matsya Nireekshani	34m fish trawl	-	1979-81
Lat. 18°-20°	Matsya Varshini	45.5m Expo model trawl	-	1982-83
Lat. 14°-18°	Matsya Shakti,M.Vishwa	27m fish trawl	47m shrimp trawl	1983-87
Lat. 11°-14°	Matsya Shakti, M.Vishwa	27m fish trawl	47m shrimp trawl	1983-87
Lat. 8°-11°	Matsya Nireekshani	34m fish trawl	45m shrimp trawl	1983, 1985-87
Wadge Bank	Matsya Nireekshani	34m fish trawl	34m fish trawl	1981-83
Gulf of Mannar	Matsya Nireekshani	34m fish trawl	34m fish trawl	1983-85
East coast				
Lat. 10°-15°	Matsya Jeevan	27m fish trawl	47m shrimp trawl	1982-87
Lat. 15°-20°	Matsya Shikari	34m fish trawl	34m fish trawl	1979-87
Lat. 20°-21°	Matsya Darshini	44m Star Model trawl	44m Star model trawl	1980-87

2.10 The demersal resources in the 300-500m depth zone have been surveyed only along the Quilon segment in Lat. 8°-10°N. It is assumed that the potential from 300-500m depth zone of the remaining regions would be roughly the same as the potential in 200-300m depth zone. The region-wise and species-wise breakup is, however, not attempted.

3. Assessment

The results obtained by following the above mentioned methodology and approach are furnished in Table 6 and 7. It may be seen that the MSY of demersals from the continental shelf and slope upto 500m depth is about 1.93 million tonnes. Of this, 1.28 million tonnes is expected from within 50m depth contour and 0.65 million tonnes from deeper waters (50-500m depth zone). Coast-wise, the potential along west coast including Lakshadweep is assessed as 1.25 million tonnes, east coast 0.66 million tonnes and Andaman Sea 0.02 million tonnes.

The principal demersal resources, their standing stock and potential estimates in 50-300/500m depth zone are presented in Tables 8 and 9. . The principal stocks identified are the threadfin breams, cat fishes, horse mackerel, elasmobranchs, Bull's eye (**Priacanthus** spp.), perches, mackerels, ribbon fishes, scads (**Decapterus** spp.), sciaenids, lizard fish, carangids, pomfrets, black ruff (**Centrolophus niger**), Indian drift fish (**Ariomma indica**), clupeids, barracuda and silver bellies among the finfishes. The crustaceans are represented by deepsea prawns and lobster whereas cephalopods are mainly constituted by squids and cuttle fish.

Of the total potential yield of 649.4 thousand tonnes, threadfin breams (110.6 thousand tonnes), horse mackerel (66 thousand tonnes), cat fishes (63.4 thousand tonnes), mackerels (62.2 thousand tonnes) and Bull's eye (54.8 thousand tonnes) form the first five main constituents of the finfish stock. The other significant resources are scads, ribbon fishes, lizard fish, squids and cuttle fish, sciaenids, **Caranx** spp. and perches.

III. COASTAL PELAGIC RESOURCES

1. Present status

The pelagic resources contributed on an average 47.3% to the total marine fish landing in the country between 1981 and '90 (March). As in the case of demersal resources the current exploitation of pelagic stocks is mostly confined to the coastal belt.

2. Earlier estimates

The pelagic resources potential in Indian waters have been assessed by various authors. The estimates are in the range of 0.6 to 2.46 million

Table 6. Potential yield of demersal resources within 50m depth along the Indian coast based on trawl surveys

Region	Area in sq.km (upto 40 fm)	Pot. yield ('000 t)	Area in 0-50 m depth (km^2)	Potential yield in 0-50m depth ('000 t)
North west coast	129400	698.8	99200	535.7
South west coast	54800	376.8	32505	223.5
Lower east coast	38100	231.3	31020	188.3
Upper east coast	51500	372.1	42860	309.7
TOTAL	273800	1679.0	205585	1257.2

Reconstructed from Joseph, 1980

Table 7. Potential yield of demersal resources in the continental shelf and slope along Indian coast based on trawl surveys

('000 tonnes)

Region	Depth zone (m)				Total
	0-50	50-100	100-200	200-300/500	
North west coast	535.7	274.3	104.3	0.4	914.7
South west coast	223.5	63.2	29.1	20.0	335.8
Lower east coast	188.3	13.4	23.4	3.1	228.2
Upper east coast	309.7	72.9	44.5	0.8	427.9
Andaman sea	22.5				22.5
Sub total	1279.7	423.8	201.3	24.3*	1929.1
300-500m depth zone **				4.0	4.0
TOTAL	1279.7	423.8	201.3	28.3	1933.1

* Includes resources upto 500m depth in lat. 8°-10°N along west coast and upto 300m in other regions.

** Except lat. 8°-10°N along west coast.

Table 8. Biomass of demersal resources in 50-300/500m depth along Indian coast as estimated from trawl surveys

(in '000 tonnes)

Species/group \ Region	North west coast	South * west coast	Wadge Bank	Gulf of Mannar	Lower east coast	Upper east coast	Total
Threadfin breams (Nemipterus spp.)	130.4	45.5	18.4	0.5	0.8	5.7	201.3
Cat fishes	70.8	18.4	1.2	-	0.3	15.0	105.7
Sharks, skates and rays	70.0	5.5	3.0	1.2	0.5	5.9	86.1
Bulls eye (Priacanthus spp.)	29.1	20.8	0.6	0.3	3.9	8.0	62.7
Perches	39.5	4.6	5.0	1.8	1.2	5.7	57.8
Mackerels	8.2	2.3	-	-	0.8	45.2	56.5
Ribbon fishes	43.9	5.1	-	0.3	-	2.4	51.7
Squids & cuttle fishes	24.6	7.9	0.9	0.3	0.2	0.5	34.4
Horse mackerel	82.7	-	-	-	1.1	4.2	88.0
Scads (Decapterus spp.)	2.5	11.4	1.3	0.2	1.9	12.4	29.7
Trevally (Caranx spp.)	11.1	4.4	2.1	0.3	0.9	4.0	22.8
Ghol (Protonebea diacanthus)	10.1	-	-	-	-	1.8	11.9
Other sciaenids	24.3	0.1	-	-	0.2	5.2	29.8
Lizard fish	15.5	9.6	2.2	-	0.2	0.2	27.7
Pomfrets	13.3	-	-	-	-	2.7	16.0
Black ruff (Centrolophus niger)	-	15.3	-	-	1.6	1.5	18.4
Crabs	-	8.0	1.6	3.4	0.2	0.5	13.7
Indian drift fish (Ariomma indica)	-	3.1	1.1	0.3	1.4	8.0	13.9
Clupeids	6.2	-	-	-	0.6	7.5	14.3
Barracuda	1.5	-	-	2.4	-	2.4	6.3
Silver bellies	-	-	-	0.2	0.8	3.6	4.6
Deepsea prawns	-	5.2 **	-	-	0.2	0.1	5.5
Deepsea lobster	-	12.9 **	0.1	1.9 **	-	-	14.9
Other fishes	110.8	11.3	1.9	1.2	2.0	15.1	142.3
TOTAL	694.5	191.4	39.4	14.3	18.8	157.6	1116.0

* Upto 500m depth in lat. 8°-10°N along south west coast only

** Adopted from Oommen (1980, 1985)

Table 9. Potential yield of demersal resources in 50-300/500m depth along the different regions of Indian coast as estimated from trawl surveys

(in '000 tonnes)

Species/group \ Region	North west coast	South * west coast	Wadge Bank	Gulf of Mannar	Lower east coast	Upper east coast	Total
Threadfin breams (Nemipterus spp.)	71.7	25.0	10.1	0.3	0.4	3.1	110.6
Cat fishes	42.5	11.0	0.7	-	0.2	9.0	63.4
Sharks, skates and rays	10.5	0.8	0.5	0.2	0.1	0.9	13.0
Bulls eye (Priacanthus spp.)	25.5	18.2	0.5	0.2	3.4	7.0	54.8
Perches	9.9	1.2	1.3	0.5	0.3	1.4	14.6
Mackerels	9.0	2.5	-	-	0.9	49.8	62.2
Ribbon fishes	19.8	2.3	-	0.1	-	1.1	23.3
Squids & cuttle fishes	14.8	4.7	0.5	0.2	0.1	0.3	20.6
Horse mackerel	62.0	-	-	-	0.8	3.2	66.0
Scads (Decapterus spp.)	2.9	8.6	1.0	0.2	1.4	9.3	23.4
Trevally (Caranx spp.)	8.3	3.3	1.6	0.2	0.7	3.0	17.1
Ghol (Protonebea diacanthus)	3.5	-	-	-	-	0.6	4.1
Others sciaenids	14.6	0.1	-	-	0.1	3.1	17.9
Lizard fish	11.6	7.2	1.7	-	0.2	0.2	20.9
Pomfrets	10.0	-	-	-	-	2.0	12.0
Black ruff (Centrolophus niger)	-	7.7	-	-	0.8	0.8	9.3
Crabs	-	4.8	1.0	2.8	0.1	0.3	8.2
Indian drift fish (Ariomma indica)	-	1.6	0.6	0.2	0.7	4.0	7.1
Clupeids	6.2	-	-	-	0.6	7.5	14.3
Barracuda	0.8	-	-	1.2	-	1.2	3.2
Silver bellies	-	-	-	0.2	0.6	2.7	3.5
Deepsea prawns	-	3.1	-	-	0.1	0.1	3.3
Deepsea lobster	-	4.5	0.1	0.7	-	-	5.3
Others	55.4	5.7	1.0	0.6	1.0	7.6	71.3
TOTAL	379.0	112.3	20.6	6.8	12.5	118.2	649.4

* Upto 500m depth in lat. 8°-10°N along south west coast only

tonnes. Some of the estimates are furnished below.

('000 tonnes)

Region	George et al. (1977)	Joseph (1987)	Desai et al. (1990)
North west coast	395	496	
South west coast	840	549	
Lower east coast	310	197	
Upper east coast	240	292	2460
Andaman & Nicobar	140	139	
Lakshadweep	55	63	

George et al. (1977) estimated the potential of pelagic resources at about 2.0 million tonnes of which the potential from 50-200m depth around the mainland was placed at 0.7 million tonnes. Joseph (1987) assessed the total potential of pelagic resources at 1.7 million tonnes from 0-200m depth zone of which 1.5 million tonnes is anticipated from the seas around the mainland.

3. Methodology and approach

3.1 The assessment of pelagic resources within 50m depth is essentially based on current production from the different coastal segments. It is assumed that the current production represents about 80% of the potential within the 50m contour, except in south-west coast where in view of the high level of fishing effort directed at pelagic stocks the current production is considered to represent the potential yield.

3.2 In the 50-200m depth zone, it is assumed that the potential of pelagic resources per unit area will be about 50% of the potential from within 50m depth line.

3.3 The average annual landing of pelagic species during 1986-88 is taken as the current production.

3.4 It is assumed, supported by the survey data, that the principal components of pelagic resources in 50-200m depth would be coastal tunas, carangids, ribbon fish and pelagic sharks. Contribution of each of these group is computed based on the relative proportion followed by Joseph (1987). It is also assumed that 90% of carangids in 50-200m depth zone would be horse mackerel and 10% scads.

3.5 The potential yield estimates by Joseph (op.cit.) for the Union Territories of Lakshadweep and Andaman and Nicobar Seas are adopted without revision in the absence of any significant addition to the data base enabling refinement of these estimates.

4. Assessment

The results obtained by following the above methodology and approach are given in Tables 10 and 11. The total potential yield of pelagic resources over the continental shelf is estimated to be 1.74 million tonnes. About 63% of the estimated stock is on the west coast, 25% on the east coast, 4% in the Lakshadweep Sea and 8% in the Andaman and Nicobar waters. By depth, about 57% of the stock is supported by the column over 0-50m depth zone.

The components of the pelagic resources as per the above assessment are indicated in Table 11. Apart from the resources of oil sardine, mackerel, anchovies and Bombay duck the major resources contributing to the pelagic fishery potential are coastal tunas, ribbon fishes and carangids. Distribution of these resources in significant concentrations is observed beyond the present fishing zone. The resource in the offshore region beyond 50m depth is mainly formed of coastal tunas (242 thousand tonnes), ribbon fishes (193 thousand tonnes), horse mackerel (177 thousand tonnes) and pelagic sharks (58 thousand tonnes).

IV. OCEANIC RESOURCES

Tuna fisheries in the Indian Ocean account for about 10-12% of the world production of tunas. But it is one of the least exploited resources in Indian seas.

1. Earlier estimates

There have been several estimates of potential yield of larger tunas in the Indian Ocean as given below.

Source	Potential yield estimate ('000 tonnes)
Gulland (1971)	100-150
IPFC/IOFC (1973)	115-137
Suda (1974)	123-131
IOFC (1977)	125
Silas and Pillai (1982)	175*

* 510-785 thousand tonnes inclusive of skipjack, bill fishes and small tunas.

But with the commencement of large scale surface fishery in Western Indian Ocean in the early 80's the production reached a very high level indicating that the earlier assessments were underestimates. The current average annual production of larger tunas in the Indian Ocean is in the order of 218 thousand tonnes (1985-88).

Table 10. Potential yield of pelagic resources over the continental shelf (0-200m) along Indian coast

('000 tonnes)

Depth zone	0-50m	50-100m	100-200m	Total
North west coast	331	161	27	519
South west coast	342	183	62	587
Lower east coast	213	32	29	274
Upper east coast	114	25	21	160
Lakshadweep				63
Andaman & Nicobar				139
TOTAL	1000	401	139	1742

Table 11. Estimated potential yield of different pelagic stocks over the continental shelf (0-200m) along Indian coast

(in '000 tonnes)

Region / Species/group	North west coast			South west coast			Lower east coast			Upper east coast			Laksh-adweep*	Andaman & Nicobar*	Total
	0-50	50-200	Total	0-50	50-200	Total	0-50	50-200	Total	0-50	50-200	Total	0-200	0-200	
Mackerels	12	-	12	36	-	36	17	-	17	7	-	7	-	-	77
Oil sardine	11	-	11	160	-	160	6	-	6	4	-	4	-	-	181
Lesser sardines	10	-	10	24	-	24	49	-	49	8	-	8	-	10	101 ✓
Anchovies	33	-	33	21	-	21	18	-	18	7	-	7	-	1	80
Other clupeids	36	-	36	18	-	18	13	-	13	35	-	35	5	10	117
Bombay duck	115	-	115	-	-	-	-	-	-	17	-	17	-	-	132
Coastal tunas	3	11	14	11	67	78	6	10	16	1	4	5	50	100	263 ✓
Carangids	4	67	71	9	73	82	15	36	51	5	21	26	-	1	231 ✓
Seer fish	15	-	15	5	-	5	31	-	31	10	-	10	-	5	66
Ribbon fish	49	94	143	6	74	80	9	10	19	9	15	24	-	-	266 ✓
Pelagic sharks	1	15	16	2	29	31	1	4	5	1	5	6	-	5	63 ✓
Others	42	1	43	50	2	52	48	1	49	10	1	11	8	2	165
TOTAL	331	188	519	342	245	587	213	61	274	114	46	160	63	139	1742

* Adopted from Joseph, 1987

In view of the continuous and wide-spread distribution as well as the long range migratory habit of the larger tunas, assessment of likely stock size within EEZ has serious limitations. Dwivedi and Devaraj (1983) projected an assessment of standing stock of larger tunas in Indian EEZ as 6000 tonnes and MSY as 3000 tonnes. This was based on the proportion of the standing stock of tuna in the Indian Ocean that is likely to be available within Indian EEZ based on the extent of area. But in view of the habitat preference of the major tuna species in favour of warmer waters the proportion is likely to be much higher in Indian Seas. Silas and Pillai (1985) have recently indicated prospects for production of 210-225 thousand tonnes tunas including skipjack from Indian EEZ.

2. Survey estimates by FSI

FSI conducted extensive surveys for deep-swimming tunas along south west coast and lower east coast by longlining. Also limited survey coverage was made in other regions of EEZ. The results of surveys have been discussed by various authors (Sulochanan **et al.**, 1986; Sivaprakasam and Patil 1987; Sivaprakasam and Sudarsan, 1988; Sudarsan **et al.**, 1988). Based on the results of survey during 1983-1987 by the vessels **Matsya Sugundhi** and **Matsya Harini** (total fishing effort 8.9 lakh hooks) Sudarsan **et al.**, (1989) estimated the potential of deep-swimming tunas as 27,400 tonnes, bill fishes - 3800 tonnes, pelagic sharks - 15,800 tonnes and other species - 1,200 tonnes.

3. Methodology and assumptions

3.1 The assessment of larger pelagics is based on the estimate of 27400 tonnes deep-swimming tunas in Indian EEZ of which 27000 tonnes is yellowfin tuna.

3.2 The component of yellowfin tuna in Indian Ocean longline fishery (1984-87) is 24.8% of the total production of the species. The rest (75.2%) is contributed by surface fishing methods. It is assumed that this percentage is valid for Indian EEZ and the relative component of the surface swimming segment is assessed

3.3. The most effective surface fishing method for tunas is purse seining which is well developed in the western Indian Ocean. Data for the period 1984-87 reveals that the percentages of yellowfin and skipjack is about 45% and 55% respectively. Assuming this percentages to be valid for Indian EEZ the potential yield of skipjack is estimated.

3.4 As the distribution range of sharks extends from subsurface to surface layers it is assumed that the yield from surface fishery would be about the same from subsurface fishery.

In the absence of refined methods suitable for application in our fishery with the existing data base, these estimates could be accepted as approximations on the size of the stocks. It could also be considered more

realistic than the other assessments as the estimation is based on survey data, though limited.

4. Potential yield estimates

The estimates of potential yield of larger pelagic stocks from the surface fishery for the Indian EEZ assessed as above alongwith estimates from subsurface fishery (Sudarsan **et al.**, 1989) are given below.

(Potential yield in '000 tonnes)

Species/group	Subsurface* fishery	Surface** fishery	Total
Yellowfin tuna	27.0	81.9	108.9
Big eye tuna	0.3	-	0.3
Skipjack	0.1	100.1	100.2
Bill fishes	3.8	-	3.8
Pelagic sharks	15.8	15.8	31.6
Other fishes	1.2	-	1.2
TOTAL	48.2	197.8	246.0

* Estimate by Sudarsan **et al.** (1989)

** Estimate in the present study

With the phased development of oceanic fishery, the tuna resources available outside EEZ would also become accessible to the class of vessels likely to enter the Indian fleet. Assuming this component at the level of 20% of the oceanic resources estimated in the Indian EEZ it would amount to 49.2 thousand tonnes.

5. Other oceanic resources

The oceanic resources not covered in this assessment are the myctophid species and oceanic squids. Larval studies in the International Indian Ocean Expedition have revealed that Myctophidae formed about 25.3% of the total larvae collected from Arabian Sea and Bay of Bengal (Peter, 1985). The common genera represented in the area are **Diaphus, Lampanyctus, Diogenichthys, Symbolophorus, Hygophum, Notolychnus** and **Myctophum.** Though pelagic trawling by **FORV Sagar Sampada** has indicated availability of myctophid fishes the CPUE was observed to be very low. Exploratory fishing by R.V. Varuna (Silas, 1969) in oceanic waters off the south west coast has also shown availability of myctophid species. Data is however inadequate to arrive at even a prefatory assessment. It may however be stated that though this group of tiny fishes constitutes one of the primary forage foods forming a vital link in the oceanic food web, it is not considered to be of much economic importance at present.

Among the oceanic squids, Symplectoteuthis oualaniensis and Thysanoteuthis rhombus are reported to be potential resources in Indian seas. (Sreenivasan and Sarvesan, 1990). Silas (1986) has projected the potential harvest of oceanic squids from the Indian EEZ by 2000 AD to be in the order of 25-50 thousand tonnes. In the absence of suitable data, no attempt is made in this study to assess the potential of this resource.

V. POTENTIAL YIELD ESTIMATE BASED ON ORGANIC PRODUCTION

The fishery resources potential in the entire Indian Ocean, based on organic productivity, has been assessed to be in the range of 7.8 to 16 million tonnes (Prasad **et al.**, 1970; Moiseev, 1971; Prasad and Nair, 1973; Cushing, 1975; Qasim, 1977). More recently the potential yield from Indian EEZ alone was estimated as 5.5 million tonnes by Nair and Gopinathan (1981), 3.66 million tonnes by Desai **et al.**, (1990) and 3.74 million tonnes by Mathew **et al.**, (1990). The methodology adopted and details of estimates for the Indian EEZ are given in Annexures II, VI and VII.

The tertiary production has been computed by different authors using different conversion coefficients. Cushing (1975) estimated 1% of primary production as tertiary production. Qasim (1977) and Desai **et al.**, (1990) used a factor of 0.1% whereas Nair and Gopinathan (1981) applied 0.2%. The choice of conversion coefficient thus appears highly arbitarary. A perusal of world literature reveals that the factor normally varies from 0.1% for underexploited region to 0.4% for highly exploited regions. It is also known that the ecological efficiency or the transfer coefficient varies depending on the level of primary productivity. Qasim (1977), based on 90 values of transfer coefficient from primary to secondary productivity, found that the efficiency of conversion ranges from 0.3% in cases of high productivity areas to 56.2% where productivity is very low. However, most of the values fall in the range of 1 to 5% for which relative ranges of primary productivity could be identified. Assuming tertiary production to be 10% of the secondary production the transfer coefficients from primary to tertiary production are likely to be in the range of 0.1 to 0.5% as below.

Primary productivity ($mg/C/m^2/day$)	<100	100-200	200-400	400-600	>600
Transfer coefficient from primary to tertiary productivity	0.5%	0.4%	0.3%	0.2%	0.1%

By using the primary productivity data as read from the isoline map by Desai **et al.** (1990) it is calculated that the total primary production in 0-50m depth and from 50m to the EEZ boundary is 38.6×10^6 and 210.4×10^6 tonnes carbon/year respectively. On applying the different transfer coefficients as mentioned above the tertiary production is computed. The carbon in tertiary production is converted to live weight (fish standing stock) by multiplying by a factor of 10. Potential yield is taken as 50% of the standing stock within 50m

Table 12. Estimates of potential yield of fishery resources beyond 50m depth in the Indian EEZ based on primary productivity studies

('000 tonnes)

Region			West coast	East coast	Andaman & Nicobar	Total
Primary production (carbon/year)			81503	66821	62051	210375
Transfer coefficient*	0.1%	Fish standing stock	815	668	621	2104
		Potential yield	326	267	248	841
	0.2%	Fish standing stock	1630	1336	1241	4207
		Potential yield	650	535	496	1683
	0.3%	Fish standing stock	2445	2005	1861	6311
		Potential yield	978	802	744	2524
	** 0.1% to 0.5%	Fish standing stock	2088	1483	1735	5306
		Potential yield	835	593	694	2122

* Transfer coefficient from primary to tertiary productivity.

** Varying transfer coefficients (from primary to tertiary productivity applied depending on the level of primary productivity as below

Primary productivity (mg C/m^2/day)	100	100-200	200-400	400-600	600
Transfer coefficient	0.5%	0.4%	0.3%	0.2%	0.1%

depth and 40% beyond 50m depth considering the relatively low natural mortality coefficient of the oceanic species.

The estimates of potential yield obtained with respect to the resources within 50m depth are in the range of 0.2 to 0.6 million tonnes, far below the level of current production as well as the estimates by direct methods and hence not realistic. A close scrutiny of the primary productivity data reveals that the under-estimation is probably due to the inadequate sampling in the coastal areas.

The estimates of potential yield obtained for the area beyond 50m depth are in the range of 0.84 million tonnes to 2.52 million tonnes (Table 12). On combining this estimate of resource potential beyond 50m depth with the potential yield estimate of 2.28 million tonnes from within 50m depth as estimated based on surveys, the total fishery potential in the Indian EEZ falls in the range of 3.12 to 4.80 million tonnes.

VI. SUMMARY OF POTENTIAL YIELD ESTIMATED

The potential yield of demersal, coastal pelagic and oceanic fish resources based on the resources surveys and current production is 3.92 million tonnes from the Indian EEZ as given below.

(million tonnes)

Region / Resource	West coast	East coast	Laksha-dweep	Andaman & Nicobar	Total
Demersal	1.251	0.656	-	0.022	1.929 0.004*
Pelagic	1.106	0.434	0.063	0.139	1.742
Oceanic					0.246
TOTAL	2.357	1.090	0.063	0.161	3.921

* Demersal resources from 300-500m depth zone (except from Lat.8°-10°N along west coast)

The depth-wise distribution indicates the fishery potential in the inshore sector within 50m depth as 2.28 million tonnes and from 50m contour

to the EEZ limit as 1.64 million tonnes. Break up details are given below.

(million tonnes)

Depth zone (m) / Resource	0-50	50-200	200-500	Oceanic	Total
Demersal	1.280	0.625	0.028	-	1.933
Pelagic	1.000	0.742	-	-	1.742
Oceanic	-	-	-	0.246	0.246
TOTAL	2.280	1.367	0.028	0.246	3.921

Of the total resource potential, demersal stocks constitute 49.3%, coastal pelagic stocks 44.4% and oceanic species 6.3%.

VII. ADDITIONAL HARVESTABLE YIELD

The average marine fish production in the country is in the order of 1.87 million tonnes per annum (1986-90) which forms about 48% of the estimated fishery potential of 3.92 million tonnes from the Indian EEZ suggesting possibility of an additional yield of about 2 million tonnes. But in the inshore sector within the 50m depth the production is about 82% of the estimated potential leaving very little scope for further development. The additional yield is to be harvested largely from the offshore sector and the oceanic realm which are hardly exploited now, but estimated to sustain a potential of 1.64 million tonnes. The assessments given in the foregoing sections indicate the regions and resources offering scope for increased exploitation.

VIII. REFERENCES

Alagaraja, K., 1989. A brief appraisal of marine fisheries in India: National symposium on Research and Development in Marine Fisheries, Mandapam Camp, **Bull. Cent. Mar. Fish. Res. Inst.**, 44 (I): 36-41.

Cushing, D.H., 1975. **Marine ecology and fisheries.** Cambridge Univ. Press. 278 pp.

Desai, B.N., R.M.S. Bhargava and J.S. Sarupria, 1990. Biological productivity and estimates of fishery potential of the EEZ of India. **Current trends in coastal marine sciences** (Ed. Ramachandran, S. and S. Rajagopal).

Dwivedi, S.N. and M.Devaraj, 1983. Tuna fisheries of the Indian Ocean and development prospects in Indian EEZ. **Tuna Update:** 6-11.

George, P.C., B.T. Antony Raja and K.C. George, 1977. Fishery resources of the Indian Economic Zone, **Souv. Integrated Fisheries Project Silver Jubilee Celebration:** 79-116.

Gulland, J.A., 1971. **The fish resources of the Ocean.** Fishing News (Books) Ltd., England: 255 pp.

IOFC, 1977. The tuna stocks of the Indian Ocean and their fisheries. IOFC, Vth Session, Cochin, Oct. 1977. **IOFC/77/Inf.** 11 July 1977, 14 pp.

IPFC/IOFC., 1973. Adhoc working party of Scientists on Stock Assessment of Tuna, 7-9 June 1972. Report of the Ist session of the IPFC/IOFC. **FAO Fish. Rep.**, 137: 17 pp.

Jones, S. and S.K. Banerji, 1973. A review of the living resources of the Central Indian Ocean. **Proc. Symp. living Res. of Seas around India, Sp. Pub. CMFRI:** 1-17.

Joseph K.M., 1974. Demersal fishery resources off the north west coast of India. **Bull. Expl. Fish. Proj.**1: 45 pp.

Joseph, K.M., 1980. Comparative study of the demersal fishery resources of the Indian waters as assessed by 17.5m trawlers. **Bull. Expl. Fish. Proj.** 10: 40 pp.

Joseph, K.M. 1985. Marine Fishery Resources of India. In: **A system framework of marine food industry in India** (Ed. E.R. Kulkarni and U.K. Srivastava): 90-149.

Joseph, K.M. 1987. The fish resources of the Indian Exclusive Economic Zone. **National Seminar on planning export strategy for Indian marine fisheries**, New Delhi, March 11, 1987.

Joseph, K.M., N. Radhakrishnan and K.P. Philip, 1976 a. Demersal Fishery Resources off South West Coast of India. **Bull. Expl. Fish. Proj;** 3: 56 pp.

Joseph, K.M., N. Radhakrishnan, Antony Joseph and K.P. Philip, 1976 b. Results of demersal fisheries resources survey along the east coast of India. **Bull. Expl. Fish. Proj.** 5: 53 pp.

Joseph, K.M., P. Sulochanan, M.E. John, K.N.V. Nair, V.S. Somvanshi and Antony Joseph, 1967. Demersal fishery resources of Wadge Bank. **Bull. Expl. Fish. Proj.** 12: 50 pp.

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

Mitra G.N., 1973. Method of estimation of fish abundance in the Indian seas and steps to be taken for management of the commercial fisheries. **Proc. Symp. living Res. of Seas around India, Sp. Pub. CMFRI:** 145-154.

Moiseev, P.A., 1971. The living resources of the World Ocean. Isreal Program for Scientific Translation, Jerusalem. 0: 1-334.

Nair, P.V.R. and C.P. Gopinathan, 1981. Productivity of the Exclusive Economic Zone of India. **J. Mar. Biol. Ass. India;** 23(1&2): 48-53.

Pauly. D., 1980. On the inter-relationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. **J. Cons. Ins. Explor. Mer.,** 39 (3): 179-192.

Peter, K.J., 1985. Myctophid resources of the Arabian Sea and Bay of Bengal. In: **Harvest and Post-harvest Technology of Fish.** Society of Fisheries Technologists (India), Cochin: 83-84.

Prasad, R.R. and P.V.R. Nair, 1973. India and the Indian Ocean Fisheries. **J. Mar. Biol. Ass. India.** 15(1): 1-19.

Qasim, S.Z. 1977. Biological productivity of the Indian Ocean. **Indian J. of Marine Sci.,** 6(2): 122-137.

Silas, E.G., 1969. Exploratory fishing by R.V. Varuna, **Bull. Cent. Mar. Fish. Res. Inst.** 12, 86 pp.

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

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

Silas, E.G. and P.P. Pillai, 1985. Indian Tuna Fishery development perspectives and a management plan. In: (E.G. Silas Ed.), Tuna Fisheries of the Exclusive Economic Zone of India: Biology and stock assessment. **Bull. Cent. Mar. Fish. Res. Inst.,** 36: 193-198.

Sivaprakasam, T.E., 1986. A study of the demersal resources of the Wadge Bank and Gulf of Mannar. **Bull. Fish. Surv. India;** 15: 35 pp.

Sivaprakasam, T.E. and S.M. Patil, 1986. Results of exploratory tuna longline survey conducted in the Arabian Sea, off south west coast of India during 1985-86. **Occ. Pap. Fish. Surv. India** No.3: 10 pp.

Sivaprakasam, T.E. and D. Sudarsan, 1988. Tuna resources off the south west coast of India as surveyed during 1986-87. **Bull. Fish. Surv. India**; 17: 1-20 p.

Sreenivasan, P.V. and R. Sarvenan, 1990. On the cephalopods collected during the exploratory survey by **FORV Sagar Sampada** in the Andaman-Nicobar Seas. **Proc. First Workshop Scient. Resul.** FORV Sagar Sampada, 5-7 June, 1989: 409-413 (1990).

Suda, A. 1974. Recent status of resources of tuna exploited by longline fishery in Indian Ocean. **Bull. Far. Seas. Fish. Res. Lab.** 10: 29-64.

Sudarsan, D., 1978. Results of exploratory survey around the Andaman Islands. **Bull Expl. Fish. Proj**; 7: 43 pp.

Sudarsan, D., M.E. John and Antony Joseph, 1987. An assessment of demersal stocks in the south west coast of India with particular reference to the exploitable resources in outer continental shelf and slope. **National symposium on research and development in marine fisheries, Mandapam Camp. Bull. Cent. Mar. Fish. Res. Inst.**, 44(I): 266-274.

Sudarsan, D., M.E. John and V.S. Somvanshi, 1988. Observations on abundance, distribution and seasonality of yellowfin tuna in Indian Seas as revealed by exploratory surveys during 1983-88. **IPTP Coll. Vol. Work. Doc.** 3: 251-261.

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

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

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

Sulochanan, P., M.E. John and K.N.V. Nair, 1986. Preliminary observations on tuna resources of the Arabian Sea with particular reference to distribution pattern of yellowfin tuna, **Thunnus albacares** (Bonnaterre). **Bull. Fish. Surv. India**; 14: 21-32.

Varghese, P. Oommen, 1980. Results of the exploratory fishing in Quilon Bank and Gulf of Mannar. **Bull. No. 4 IFP.**

Varghese, P. Oommen, 1985. Deepsea resources of the south west coast of India, **Bull. No.11, IFP.**

GOERGE et al. (1977)

METHODOLOGY FOLLOWED AND ESTIMATE OF FISHERY POTENTIAL IN INDIAN EEZ

A: **Methods**

(i) Average annual rate of increase in marine fish production (1952-76)

(ii) Organic production

(iii) Average rate of fish production per unit area (1972-76)

By giving due allowance to the organic production and the present status of fishery (1976-77) the following rates of fish production were arrived at by the authors for the seven regions.

(tonnes/sq.km)

Region	0-50m	50-200m
North west coast	6	3
South west coast	30	15
Lower east coast	12	6
Upper east coast	20	10
Andaman & Nicobar		10
Lakshadweep		20
Residual areas of Economic Zone		0.3

B: **Estimate of fishery potential**

Region	Potential yield ('000 tonnes)		
	0-50	50-100	0-200m/EEZ
North west coast	542	341	883
South west coast	701	721	1422
Lower east coast	478	196	674
Upper east coast	540	195	735
Andaman & Nicobar			160
Lakshadweep			090
Residual areas of Economic Zone			500
TOTAL	2261	1453	4464

NAIR AND GOPINATHAN (1981)

METHODOLOGY FOLLOWED AND ESTIMATE OF FISHERY POTENTIAL IN INDIAN EEZ

A: **Data base:** Published literature on primary productivity. Annual carbon production from EEZ 283 x 10^6 tonnes

B: **Method:** On assuming 0.1% of net primary production as potential yield, an estimate of 2.8 million tonnes was worked out which is considered as an underestimate

In view of the potential for tunas and tuna like fishes of the high seas, but excluding myctophids, 0.2% of primary production is assumed as exploitable yield.

C: **Estimate of fishery potential:**

Exploitable yield: 5.5 million tonnes

JOSEPH (1987)

METHODOLOGY FOLLOWED AND ESTIMATE OF FISHERY POTENTIAL IN INDIAN EEZ.

A: **Data base :** (i) Demersal: Exploratory trawl survey data from 1979

(ii) Pelagic: Exploratory survey data of limited period and data on fish production

B: **Method:** (i) Demersal: Swept area method

(ii) Pelagic: Based on survey and annual fish production, a certain percentage of the production is taken as the harvestable yield.

C: **Estimate of potential yield**

Region	Potential yield ('000 tonnes)		
	0-200m	200-500m	Total
North west coast	1598	22	1620
South west coast	825	28	853
Lower east coast	411	14	425
Upper east coast	512	19	531
Andaman & Nicobar	160	-	160
Lakshadweep	90	-	90
Oceanic	-	-	500
TOTAL	3596	83	4179

Annexure-IV

ALAGARAJA (1989)

METHODOLOGY FOLLOWED AND ESTIMATE OF FISHERY POTENTIAL IN INDIAN EEZ

A: **Methods:** 0-50m depth (i) Relative response model

(ii) Maximum contribution approach

50-200m depth Primary production

B: Estimate of potential yield

Region	Potential yield ('000 tonnes)		
	0-50m	50-200m	0-200m
North west coast (Goa, Maharashtra, Gujarat)	700	350	1050
South west coast (Kerala, Karnataka)	600	300	900
Lower east coast (Tamil Nadu, Pondicherry Andhra Pradesh)	500	250	750
Upper east coast (West Bengal, Orissa)	200	100	300
TOTAL	2000	1000	3000

SUDARSAN et al. (1988)

METHODOLOGY FOLLOWED AND ESTIMATE OF FISHERY POTENTIAL IN INDIAN EEZ.

A: **Data base**

(i) Demersal: Exploratory survey data (1979 to 1987)

(ii) Oceanic: Tuna longline survey data (1983-87)

B: **Method:**

(i) Demersal: Swept area, with 40% trawl opening and a catchability coefficient of 0.4 for 34m trawls and 0.5 for other trawls

(ii) Oceanic: Based on hooking rate obtained in surveys and integrating with current production on tunas in other parts of Indian Ocean

C: **Estimate of potential yield**

(i) Demersal:

Region	Potential yield ('000 tonnes)			
	50-100m	100-200m	200-300m	Total
West coast	315.2	102.7	22.0	439.9
East coast	55.9	28.9	3.4	88.2
Wadge Bank	6.8	12.1	0.7	19.6
Gulf of Mannar	1.7	4.3	0.2	6.2
TOTAL	379.6	148.0	26.3	553.9

(ii) Deepswimming oceanic : (i) 25,100 tonnes (only for south west coast)
(ii) 48,200 tonnes (EEZ)*

* Sudarsan et al., 1989

MATHEW **et al.** 1990)

METHODOLOGY FOLLOWED AND ESTIMATE OF FISHERY POTENTIAL IN INDIAN EEZ

A: **Data base** : Secondary productivity data collected on board **FORV Sagar Sampada** in 1113 stations from the Indian EEZ and contiguous seas during 1985-88.

B: **Method** : 10% of secondary production is assumed as tertiary production. 50% level of the total stock is assumed as the potential yield.

C: **Estimate of potential yield (million tonnes) in EEZ.**

West coast	:	2.39
East coast	:	0.66
Andaman & Nicobar Seas	:	0.69
Total		3.74

DESAI et al. (1990)

METHODOLOGY FOLLOWED AND ESTIMATE OF FISHERY POTENTIAL IN INDIAN EEZ.

A: **Data base** : Data on primary production and zooplankton collected in the National Oceanographic Programmes by the vessel **R.V.Gaveshani** (1976-85) and in the International Indian Ocean Expedition (1962-66) by several vessels. Altogether 419 stations in the EEZ are taken for the study.

B: **Method** : 0.1% of primary production is assumed as tertiary production. It is then multipled by a factor of 10 to convert into live weight.

10% of secondary production is assumed as tertiary production. It is then multiplied by a factor of 10 to convert into live weight. 25% of the live weight is taken as the potential.

Average of the values obtained as above from primary production and secondary production is taken as the potential yield of pelagic resources. To this is added the estimate of demersal resources potential worked out by an earlier author.

C: **Estimate of potential yield (million tonnes) in EEZ**

1.	Based on primary production	- 2.66
2.	Based on secondary production	- 2.25
3.	Average of (1+2) above	- 2.46
4.	Demersal resources	- 1.2*
5.	Total (3+4)	- 3.66

*Adopted from Parulekar, A.H., S.N. Harkantra and Z.A. Ansari (1982). Indian J. Mar. Sci., 11:107-114.

Annexure-VIII

NATURAL MORTALITY COEFFICIENT (M) OF IMPORTANT DEMERSAL SPECIES

Fam/group	Species	M. Value	Area	Reference	M.value adopted in this study
Nemipterids	Nemipterus japonicus	0.504	Andhra-Orissa	Krishnamoorthi (1978)*1	1.1
		1.142	Kakinada	Murty (1988)*2	
		2.525	Madras	Vivekanandan & James (1986)*3	
		1.3186	North west coast	Devaraj & Gulati (1988)*4	
		1.0	Kerala coast	John (1989)*5	
		1.10	Kakinada	Murty (1989)*6	
	Nemipterus mesoprion	1.7	Kakinada	Murty (1982)*7	
Cat fishes	Arius thalassinus	1.30	Java Sea	Dwiponggo et al. (1986)*8	1.2
	Arius maculatus	1.11	Java Sea	-do-	
	Arius tenuispinis	0.5124	Visakhapatnam	Dan (1981)*9	
Elasmobranchs	Rhizoprionodon acutus	0.2-0.3	Kenya	Anon (1982)*10	0.5
		0.2982	Madras	Krishnamoorthi & Jagdis(1986)*11	
Priacanthids	Priacanthus tayenus	2.09	Samar Sea	Dwiponggo et al. (1986)*8	1.75
	P. macracanthus	2.13,2.28	Java Sea	-do-	
	Priacanthus spp.	1.75	Indian seas	John & Sudarsan (1988)*12	
Perches		0.2-0.3	Kenya	Anon (1982)*10	0.9
	Lutjanus malabaricus	0.545	Vanautu,S. Pacific	Brouard & Grandperrin (1984)*13	
	Lutjanus sebae	0.48	Seychelles	Lablache & Carrara (1988)*14	
	Lutjanus johni	0.61	Indonesia	Lai-Shing (1968)*15	
Mackerels	Rastrelliger kanagurta	0.65	West coast	Banerji (1973)*16	2.2
		0.9	West coast	Sekharan (1976)*17	
		1.5	Mangalore	Yohannan (1983)*18	
		2,4, 2.61	Indian seas	Cited from Devaraj (1983)*19	
Ribbon fishes	Trichiurus lepturus	0.9	Kakinada	Narasimham (1983)*20	0.9
		0.8	North west coast	Somvanshi & Antony (1989)*21	
		0.86 (♂)	Manila Bay(60-61)	Ingles & Pauly (1984)*22	
		0.80 (♀)	Manila Bay(60-61)	-do-	
		1.08	Manila Bay(78-79)	-do-	

*1 Krishnamoorthi, B., 1978. Indian J. Fish., 23 (1976): 252-256.

*2 Murty, V.S., 1988. Indian J. Fish., 30(2): 225-260.

*3 Vivekanandan, E. and D.B. James, 1986. Indian J. Fish., 30(2): 145-153.

*4 Devaraj, M. and D. Gulati, 1988. The first Indian Fisheries Forum, Proceedings. 159-164.

*5 John, M.E., 1989. Contributions to tropical fish stock assessment in India: FI: GCP/INT/394/DEN/1: 45-62.

*6 Murty, V.S., 1989. Ibid. 69-86.

*7 Murty, V.S., 1982. Indian J.Fish., 28 (1981): 199-207.

*8 Dwiponggo, A.T., T. Hariati, S. Banon, M.L. Palomares and D. Pauly, 1986. ICLARM Tech. Report 17: 91p.

*9 Dan, S.S., 1981. Indian J. Fish., 28: 41-46.

*10 Anon, 1982. Work report No. 8 UNDP/FAO Project-KEN/74/023: 57p.

*11 Krishnamoorthi, B. and I. Jagdis, 1986. Indian J. Fish. 33(4): 371-383.

*12 John, M.E. and D. Sudarsan, 1988. Symp. Tropical Marine Living Resources, Mar. Biol. Assoc. India., Cochin, 12-16 Jan. 1988.

*13 Brouard, F., and R. Grandperrin, 1984. ORSTOM Notes Doc. Oceanogr. ORSTOM Port - Villa II. (Not referred in original).

*14 Lablache, G. and G. Carrara, 1988. FAO Fish. Rep., (389): 171-192.

*15 Lai-Shing, A., 1968. Proc. IPFC, 13 (3): 270-297.

*16 Banerji, S.K., 1973. Proc. Symp. Living Res. of seas around India. Spl. Pubn. CMFRI: 137-142.

*17 Sekharan, K.V., 1974. Indian J. Fish., 21 (1): 177-182.

*18 Yohannan T.M., 1982. Indian J. Fish., 29 (1&2): 50-62.

*19 Devaraj, M., 1983. Bull Central Institute of Fish Education No.3 (10): 98pp.

*20 Narasimham, K.A., 1983. Indian J. Fish., 30(1): 99-109.

*21 Somvanshi, V.S. and Antony Joseph, 1989. FSI Special Publication No.2: 1-30.

*22 Ingles, J. and D. Pauly, 1984. ICLARM Tech. Report, 13: 127pp.

contd.

Fam/group	Species	M.value	Area	Reference	M.value adopted in this study
Squids & cuttle fishes	Sepia pharaonis	1.1	Wadge Bank	Philip and Ali (1989)*23	1.2
	Sepia aculeata	1.4	Bombay	Menon (1988)*24	
	Loligo duvauceli	1.1	Bombay	Kuber & Deshmukh (1988)*25	
		2.2	Cochin	Meiyappan & Srinath (1989)*26	
		0.9	Gulf of Thailand	Supongpan (1988)*27	
Decapterids	Decapterus russelli	1.9	Kakinada	Murty (1988)*28	1.5
		1.8	Java sea	Dwiponggo et al. (1986)*8	
		2.0	Jakarta Bay	-do-	
		1.19,1.59	Manila Bay	-do-	
		1.44,1.51, 1.03	Palawan	-do-	
		1.46	Mozambique	Souza MI (1989)*29	
		1.8	Java sea	Widodo (1988)*30	
	Decapterus macrosoma	1.33,1.41	Manila Bay	Dwiponggo et al. (1986)*8	
		1.61	Palawan	-do-	
Horse mackerel					1.5
Smaller sciaenids	Otolithes cuveiri	1.45	Bombay	Chakraborthy (1987)*31	1.2
	Johnius carutta	1.0	Kakinada	Murty (1984)*32	
Lizard fishes	Saurida tumbil	1.71	Manila Bay	Ingles and Pauly (1984)*22	1.5
		1.30	Visayan sea	-do-	
	Saurida undosquamis	1.54	Visayan sea	-do-	
		1.69	Java sea	Dwiponggo et al.(1986)*8	
Carangids	Selar leptolepis	1.56	Manila Bay	Ingles & Pauly (1984)*22	1.5
		2.21	Java sea	Dwiponggo et al. (1986)*8	
	S.crumenophthalmus	1.57	Manila Bay	-do-	
		2.19	Java sea	-do-	
Pomfrets	Pampus argenteus	0.526	Gujarat	Khan (1988)*33	1.5
		1.72	Java sea	Dwiponggo et al. (1986)*8	
	Formio niger	1.40	Java sea	-do-	
Black ruff	Centrolophus niger				1.0
Ghol	Protonebea diacanthus	0.83,0.641	North west coast	Rao (1968)*34	0.7
Crabs		1.2	Kenya	Anon (1982)*10	1.2
Indian drift fish	Ariomma indica				1.0

*23 Philip, K.P. and D.M. Ali, 1989. FSI Special Publication No.2: 66-74.

*24 Menon, N.R., 1988. Jour. Indian Fish. Assoc. 18: 475-481.

*25 Kuber Vidyasagar and V.D. Deshmukh, 1988. Symp. Tropical Marine Living Resources, Mar. Biol. Asson. India, 12-16 January, 1988.

*26 Meiyappan, M.M. and M.Srinath, 1989. Contributions to tropical fish stock assessment in India. FI: GCP/INT/392/DEN/1: 1-14.

*27 Supongpan, M., 1988. FAO Fish. Rep. (389): 25-41.

*28 Murty, V.S., 1988. Symp. Tropical Marine Living Resources, Mar. Biol. Asson. India, 12-16 January 1988.

*29 Souza, MI, 1988. FAO. Fish. Rep., (389): 288-307.

*30 Widodo, Johannes, 1988. FAO. Fish. Rep., (389): 308-322.

*31 Chakraborty K. Sushant, 1989. CMFRI Bulletin No.44 (Part I): 238-244.

*32 Murty, V.S., 1984. J. Mar. Biol. Assoc. India, 21 (1979): 77-85.

*33 Khan, Mohammad Zafar, 1988. Stock assessment of Pampus argerteus (Euphrasen) off Gujarat waters. Symp. Tropical Marine Living Resources., Mar. Bio. Assoc., India, 12-16 January 1988.

*34 Rao, K. Venkata Subba, 1968. Indian J. Fish., 15(1&2): 88-98.

contd.

Fam/group	Species	M.value	Area	Reference	M.value adopted in this study
Clupeoids	Sardinella albella	3.1	Indian seas	Cited from Devaraj (1983)*19	2.0
	Sardinella fimbriata	2.16	-do-	-do-	
	Sardinella gibbosa	3.2	-do-	-do-	
	Sardinella sirm	1.16	-do-	-do	
	Sardinella dayi	0.7961	Karwar	Annigiri (1982)*35	
Barracuda	Sphyraena obtusata	1.0	Gulf of Mannar	Somvanshi (1989)*36	1.0
Leiognathids	Leiognathus bindus	1.5	Kakinada	Murty (1986)*37	1.5
	Leiognathus jonesi	2.1	Palk Bay	Venkataraman et al. (1981)*38	
	Leiognathus splendens	1.76	Manila Bay	Ingles & Pauly (1984)*22	
Deepsea prawns		1.2	Kenya	Anon (1982)*10	1.5
Deepsea lobster	Puerulus sewelli	0.7	South Yemen	Sanders (1981)*39	0.7
Other fishes					1.0

*35 Annigeri, G.C., 1982. J. Mar. Biol. Assoc. India, 24 (1&2): 133-140.

*36 Somvanshi,V.S., 1989. Contributions to tropical fish stock assessment in India. FI: GCP/INT/392/DEN/1: 87-101.

*37 Murty, V.S., 1986. Indian J. Fish., 33(3): 277-283.

*38 Venkataraman, G., M. Badrudeen and R.Thiagarajan, 1981. Indian J.Fish., 28(1&2): 65-86.

*39 Sanders, M.J., 1981. UNDP/FAO/RAB/77/008/18: 48pp.