

## Benthic Production & Assessment of Demersal Fishery Resources of the Indian Seas

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Quantitative study on the benthos (macro and meio) and its possible relationship with the demersal living resources in the  $6.2 \times 10^6$  km<sup>2</sup> area of the Indian Seas (between lat. 24°30' to 5°N and long. 97° to 65°E) shows that biomass production varies from 0.01 to 601 gm<sup>-2</sup> with mean values of 17.6, 7.3, 5.5 and 0.7 gm<sup>-2</sup> in the Arabian Sea, the Andaman Sea, the Bay of Bengal and the Lakshadweep Sea, respectively. The shelf produces maximum biomass and the production decreases with the increasing depth. Richness of benthos in the Arabian Sea is related to the upwelling phenomenon while the high biomass values in the northern Bay of Bengal is due to riverine enrichment. Macrobenthos dominates the shelf whereas meiobenthos contributes more than 70% in the slope and the deep sea (above 1000 m), region. Overall, the macrofauna accounts for 27, 28, 30 and 44% of the total fauna in the Arabian Sea, Andaman Sea, Lakshadweep Sea and the Bay of Bengal, respectively. Annual benthic production is maximum ( $\bar{x} = 3.7$  gCm<sup>-2</sup>yr<sup>-1</sup>) along the southwest (between lat. 12 and 7°N) coast of India. Other areas of high production are the northwest part of Arabian Sea and the northern Bay of Bengal. Potential yield of demersal fish and crustaceans is assessed to vary from 28 kg/ha along the shelf of Lakshadweep to 909 kg/ha off the West Bengal shelf. An overall threefold increase in the exploitation of demersal resources is envisaged. The potential resources have been estimated as 1.8 million tonnes out of which the shelf alone can sustain an annual yield of 1.2 million tonnes. The relevance of benthic standing crop for the estimation of marine living resources is discussed.

In the last 2 decades, a number of reports on the benthos of the Indian Ocean have appeared. Most of the information pertains to regional studies on macrobenthos and quite a few<sup>1-4</sup> have attempted to correlate the benthic standing crop as an indication of the potential resources of demersal fish and the prawns.

Since 1973, the NIO has collected exhaustive data on various aspects of bottom organisms in different regions of the Indian Ocean and some of the results have already been documented<sup>5-11</sup>. However, no attempt, so far, has been made to project the role of benthos, both macro and meio, in the assessment of potential demersal fish and prawn resources of the Indian Seas.

The present communication is an attempt to highlight some of the relevant aspects of quantitative distribution, standing crop and annual production of benthos of the Indian Seas (Arabian Sea, Lakshadweep Sea, Andaman Sea and Bay of Bengal) and the efficacy of the data for assessing the potential demersal resources.

### Materials and Methods

Data presented here were obtained during the 5 OCEANOVAX cruises (1973-74) on board *INS Darshak* and from more than 56 cruises of *R V Gaveshani* (March 1976 to Nov. 1980). A total number of 1108 samples, both of macro and meiobenthos representing 982 stations (504 in the Arabian Sea, 398 in the Bay of Bengal, 75 in the Andaman Sea and only 5 in the Lakshadweep Sea) were considered. Sampling

was done by deploying different gears like Petersen's grab (0.2 m<sup>2</sup>), van Veen grab (0.04 m<sup>2</sup>) and La Fond Dietz snapper (0.016 m<sup>2</sup>), but the data on the fauna and production were uniformly represented on meter square basis. The procedure, for collection, processing and analysis of samples, was same as reported<sup>8</sup>. Organic carbon equivalent for respective macro and meiofaunal taxon was determined by the procedure of Lie<sup>12</sup> and productivity estimates were made as per the methodology of Sanders<sup>13</sup> and Crisp<sup>14</sup>.

*Scope and limitations of the study*—The present study covers roughly a total sea floor area of  $6.2 \times 10^6$  km<sup>2</sup> with regionwise break-up of  $2.8 \times 10^6$  km<sup>2</sup> in the Arabian Sea,  $0.3 \times 10^6$  km<sup>2</sup> in the Lakshadweep Sea,  $1.4 \times 10^6$  km<sup>2</sup> in the Andaman Sea and  $1.7 \times 10^6$  km<sup>2</sup> in the Bay of Bengal. The area lies within the geographical limits of lat. 24°30' to 5°N and long. 97° to 65°E and in the depth range of 10 to 2750 m.

As listed in Table 1, almost 83.6% of the

Table 1—Number of Observations (Depth-wise) for Benthic Studies in the Indian Seas

Depth zone (m)	Arabian Sea	Lakshadweep Sea	Andaman Sea	Bay of Bengal
Shelf (0-200)	462	1	25	333
Slope (200-1000)	13	1	29	61
Deep (> 1000)	29	3	21	4

observations are from the shelf region and except possibly for the Andaman Sea, sampling from the slope and deep (above 1000 m) is relatively less. Similarly, the overall coverage for the Lakshadweep Sea is rather scanty.

In the course of the present study, almost all the seasons generally encountered in the Indian Seas have been covered. However, the results do not necessarily pertain to the annual cycle at any or all the regions investigated. But the results depict a broad-based picture of seasonal changes in the fauna, standing crop and organic carbon production of macro and meiobenthos in the Indian Seas. Description of fauna is also broad-based and general terms like macrofauna and meiofauna have been used and the details of individual taxon are not included. Macrofauna includes those organisms which are retained by a mesh screen of 0.5 mm whereas meiofauna necessarily includes such forms which can pass through 0.5 mm mesh screen but are retained in 45  $\mu\text{m}$  sieve.

### Results and Discussion

**Biomass: Distribution and standing crop**—An overall distribution of biomass produced by macro and meiobenthos is shown in Figs 1a and b respectively. The nearshore areas of <30 m depth, mainly contribute for high biomass production and the standing crop decreases with the increasing depth. Another notable feature is that the macrofauna mainly contributes to biomass production in the shelf region whereas along the slope and in the deep regions (above 1000 m), the meiofauna is dominant.

The biomass for the Indian Seas as a whole, varies from 0.01 to 601  $\text{gm}^{-2}$  with varying sectional values (Table 2). Some of the values higher than 500  $\text{gm}^{-2}$  are from northwest and southwest coasts of India. The mean biomass was 17.61  $\text{gm}^{-2}$  in the Arabian Sea, 7.32  $\text{gm}^{-2}$  in the Andaman Sea, 5.32  $\text{gm}^{-2}$  in the Bay of Bengal and the lowest (0.74  $\text{gm}^{-2}$ ) in the Lakshadweep Sea. A scrutiny of Table 2 reveals that the continental shelf (up to 200 m depth) supports the highest standing crop which varies from 14.1  $\text{gm}^{-2}$  in the Arabian Sea to 1.8  $\text{gm}^{-2}$  in the Lakshadweep Sea. Except the Arabian Sea, in the other regions of the Indian Seas reported here, the standing crop along the continental slope decreases over 50% than in the shelf and the decline is greatly enhanced in deeper waters above 1000 m depth. The decrease varies from 8.5% in the Bay of Bengal to 80.5% in the Andaman Sea and the Lakshadweep Sea. Surprisingly enough, the slope region in the Arabian Sea (Table 2) supports 30% more standing crop than in the shelf. In the deep regions (depth above 1000 m) except in the Andaman Sea, where an increase of about 20% has been observed, in

all the other areas, the mean standing crop decreases from 16% in the Bay of Bengal to 50% in the Lakshadweep Sea, with an intermediate value of 25% in the Arabian Sea.

The latitudinal variations (Fig. 2) in the biomass production show a regional pattern. In the northernmost part of the Arabian Sea and the Bay of Bengal, very high mean values of 38.5 and 45  $\text{gm}^{-2}$  respectively have been observed. Such high biomass values are followed by (Fig. 2) great decrease up to 19°N lat. in the Arabian Sea and up to 15°N lat. in the Bay of Bengal. Thereafter, while in the Arabian Sea consistently high mean values ranging from 15 to 30  $\text{gm}^{-2}$  are observed to be prevailing in the southerly direction, in the Bay of Bengal, except substantial increase between 11 and 10°N lat., the benthic standing crop goes on decreasing from north to south. Similarly, in the Andaman Sea, high mean biomass values which are observed between 11 and 10°N lat. are followed by consistent decrease culminating in the lowest mean value of 0.34  $\text{gm}^{-2}$  in between 7 and 6°N lat. This is followed by an unusually high mean value of 21.5  $\text{gm}^{-2}$  in the most southerly latitudes of 6 and 5°N. In the Lakshadweep Sea, in spite of less number of observations, a gradual decrease along the north to south axis is observed (Fig. 2).

An appraisal of the available data indicates that the richness of benthic fauna in the northern part of the Arabian Sea can be explained by the earlier findings of Humphrey<sup>15</sup> who observed, "in the Red Sea and Persian Gulf, a characteristic feature is the southward increase in phytoplankton, zooplankton, benthos, fish and primary production". Similarly, the high biomass values encountered in the region south of 19°N lat. in the Arabian Sea, corroborates the earlier report of Elizarov<sup>16</sup> who has correlated the abundance of bottom life in the southern part of the Arabian Sea to an inflow of equatorial waters of low salinity causing a strongly expressed stratification of water masses. The prevalence of high standing crop in the northernmost part of the Bay of Bengal is traceable to the effect of riverine inflow enriching the environment<sup>17</sup>. The general impoverishment of bottom life in the southern Bay of Bengal as also in the northern Andaman Sea is attributable to peculiar meteorological and environmental regimes<sup>18</sup>. High benthic standing crop as observed in the southernmost part of the Andaman Sea indicates a continuity of the rich bottom life of the Malacca Strait<sup>19</sup>. The observations in the Lakshadweep Sea are too meagre to arrive at any generalization. The zoogeographic boundary of the Neymann<sup>20</sup> around 15°N demarcating the rich northern region and impoverished southern region has not distinctly been observed in the present study.

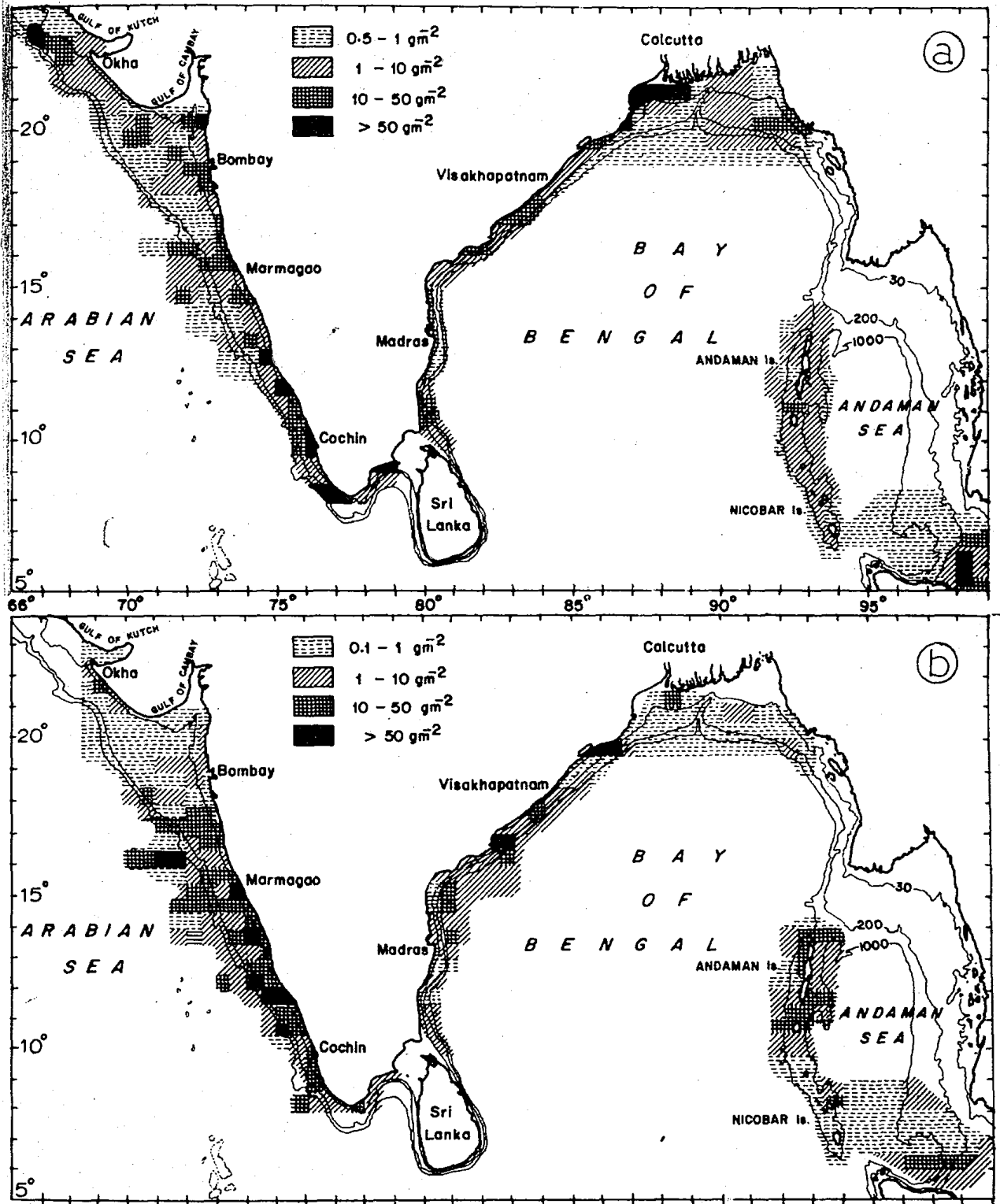


Fig. 1—Distribution of (a) macrobenthic and (b) meiobenthic biomass in the Indian Seas

**Benthic fauna**—The contribution of macro and meiofauna to the production of benthic biomass in the Indian Seas clearly indicates (Table 3) that there exists a distinct depthwise demarcation. Accordingly, in the shelf region of the Bay of Bengal and the Lakshadweep Sea, there is the dominance of macrofauna which contributes 82 and 60% respectively. Along the continental slope in all the 4 regions (Table 3), the meiofauna accounts for more than 73%, whereas at higher depths above 1000m, the meiofauna alone contributes for more than 78% in the Bay of Bengal to 90% in the Lakshadweep Sea. In an overall analysis, it may be said that in the Arabian Sea, the Andaman Sea and the Lakshadweep Sea, the macrofauna accounts for only 27, 28 and 30% respectively, in different depth zones as against 44% in the Bay of Bengal.

Geographical variations, latitude-wise, in the faunal composition (Fig. 3) depict an uniform pattern of distribution. Accordingly, macrofauna largely contributes for the standing crop and consequently for the biomass production in the region between 24 and 18°N lat. Thereafter, the dominance of macrofauna goes on reducing and is replaced by meiofauna up to 6°N lat. Between the lat. 6 and 5°N the macrofauna regains the dominance. Thus, in the area surveyed, the meiofauna, in an overall analysis, dominates the benthos and contributes above 70% to the standing crop in all the regions except the Bay of Bengal where its contribution is around 56%. As far as the depthwise distribution is concerned, the macrofauna contributes 56% along the shelf while on the slope and in the deep, it is the meiofaunal component which accounts for 78 and 83% respectively.

**Production**—Benthic production, in terms of the formation of carbon has been estimated with reference

to depth as also the geographical variations in the different sectors of the Indian Seas. The carbon production, as a function of trophic ecology and marine food chain, is uniformly high in all the nearshore regions below 30m depth and especially so in the Arabian Sea (Fig. 4). The productivity is moderate with isolated high production areas in the Bay of Bengal and in the Andaman Sea, whereas in the Lakshadweep Sea, the annual production is of a low magnitude.

An analysis of the results on the annual benthic production in terms of organic carbon generation by bottom fauna in the Indian Seas reveals (Table 4) that

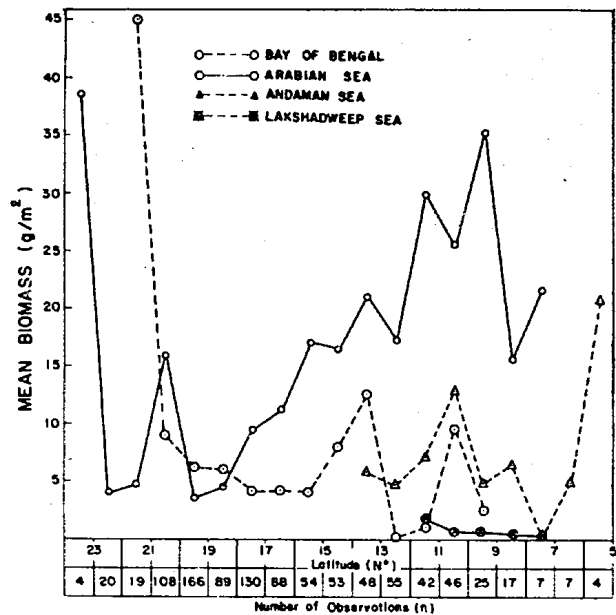


Fig. 2—Latitudinal variations in the benthic biomass in the Indian Seas

Table 2—Benthic (Macro + Meio) Biomass Production ( $gm^{-2}$ ) in the Indian Seas

[Values represent range with mean in parentheses]

Depth zone	Arabian Sea	Lakshadweep Sea	Andaman Sea	Bay of Bengal
0-20	0.01-147(17.87)	-	2.46-43.7(19.61)	0.01-37.06(5.7)
20-40	0.01-601(14.06)	-	4.5 -74.3(29.89)	1.09-176.7(12.08)
40-60	0.01-190-5(14.50)	1.80*	-	0.55-44.7(3.75)
60-80	0.02-67.9(5.13)	-	0.7 -80.9(3.85)	0.18-10.99(1.40)
80-100	0.05-52.6(9.13)	-	0.7 -19.4(4.42)	1.4 -12.86(2.40)
100-200	0.11-66.2(13.66)	-	2.41-14.68(8.54)	0.4 -98.79(4.20)
200-300	0.05-44(20.41)	-	-	0.4 -60.2(6.02)
300-400	-	0.45*	0.15-12.47(6.18)	0.72*
400-500	-	-	0.90-15.75(4.73)	0.05-8.46(3.10)
500-600	31.00*	-	0.50-10.41(3.82)	0.76-4.52(2.64)
600-700	-	-	0.40-28.25(14.32)	-
700-800	-	-	0.7 -23.9(9.62)	1.11-10.87(5.99)
800-900	1.92*	-	1.58-3.57(2.57)	-
900-1000	9.20-44.13(26.66)	-	1.72-3.11(2.41)	3.28*
1000-2000	0.01-119.6(20.02)	0.03-0.45(0.37)	1.47-19.52(2.32)	0.7 -5.2(2.32)
> 2000	0.8 -43.3(14.29)	0.71*	1.04- 6.80(3.92)	6.56*

\*Single observation

the shelf of the Arabian Sea, Bay of Bengal and the Andaman Sea, generates uniformly high organic carbon. Away from the coast and with increasing depth, the productivity decreases manifold. In the Arabian Sea, the decrease in benthic productivity from shelf to slope and further onto the deep is only 16% whereas in the Lakshadweep Sea, it varies from 40% between slope and the deep to more than 90% between shelf and the slope. Similarly, in the Bay of Bengal and in the Andaman Sea, the productivity decreases by 58 and 70% respectively from shelf to slope. However, the further decrease is of a low magnitude.

Geographically (Fig. 5), the southern region of the Arabian Sea, between 12 and 7°N lat., harbours high organic production with an average value of 3.7 g C m<sup>-2</sup> yr<sup>-1</sup>. This is followed by the northernmost latitudes of 20 to 24°N where in the values range between 0.7 and 5 with a mean production of 2.9 g C m<sup>-2</sup> yr<sup>-1</sup>. Similarly, in the northern part of the Bay of Bengal, especially in the vicinity of major river openings, high production values ranging from 1.4 to

11.8 g C m<sup>-2</sup> yr<sup>-1</sup> are observed (Fig. 5). The mid latitudes, both in the Arabian Sea and the Bay of Bengal, denote the area of low production. In the Andaman Sea and the Lakshadweep Sea, the annual production is of a low magnitude and varies from 0.7-7.8 g C m<sup>-2</sup> yr<sup>-1</sup> ( $\bar{x}$  = 1.313) to 0.02-0.7 g C m<sup>-2</sup> yr<sup>-1</sup> ( $\bar{x}$  = 0.176), respectively.

*Demersal fish and crustacean resources*—Direct relevance of benthic standing crop and production to the exploited demersal fish and crustacean resources is, by now, a well established fact<sup>1-4</sup>. The data on biomass and carbon production obtained during the course of the present study are analysed for quantifying the potential fishery (demersal and crustacean) resources of the seas around India. The potential yield is taken<sup>21</sup> as the 10% of the benthic standing crop.

As already indicated (vide Table 1), the present set of data mainly pertain to the Indian Continental Shelf, which at present, sustains more than 90% of the exploited living resources and hence, the estimates and the projections attempted here are principally relevant to the shelf only.

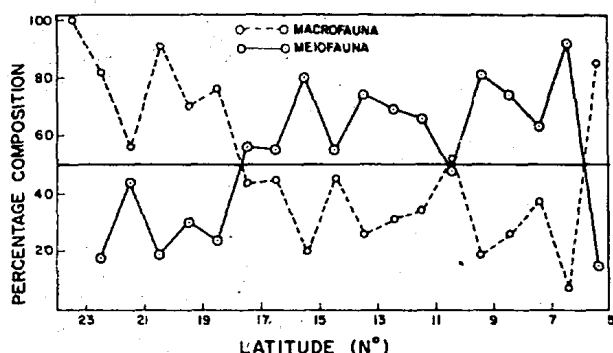


Fig. 3—Latitudinal variations in the percentage composition of macro and meiofauna in the Indian Seas.

Table 4—Benthic Productivity (g C m<sup>-2</sup> yr<sup>-1</sup>) in the Indian Seas

[Values represent range with mean in parentheses]

Province	Arabian Sea	Lakshadweep Sea	Andaman Sea	Bay of Bengal
Shelf (0-200 m)	1.0-2.3 (1.9)	- (0.7)	0.5-7.2 (1.9)	0.6-3.1 (1.18)
Slope (200-1000 m)	0.004-9.7 (1.6)	- (0.07)	0.1-1.2 (0.46)	0.1-2.4 (0.75)
Deep (> 1000 m)	0.6-2.0 (1.3)	0.02-0.05 (0.04)	0.2-0.5 (0.39)	0.4-1.0 (0.75)

Table 3—Composition (%) of Macro and Meiofauna in the Indian Seas

[n denotes number of observations]

Depth zone (m)	Arabian Sea			Lakshadweep Sea			Andaman Sea			Bay of Bengal		
	n	Macro	Meio	n	Macro	Meio	n	Macro	Meio	n	Macro	Meio
0-20	63	40	60	-	-	-	3	100	-	31	92	8
20-40	212	44	56	-	-	-	4	62	38	120	90	10
40-60	108	36	64	1	60	40	-	-	-	65	86	14
60-80	37	70	30	-	-	-	8	21	79	20	70	30
80-100	29	24	76	-	-	-	8	23	77	23	75	25
100-200	13	9	91	-	-	-	12	14	86	70	80	20
200-300	9	9	91	-	-	-	-	-	-	55	30	70
300-400	-	-	-	1	20	80	5	29	71	1	-	100
400-500	-	-	-	-	-	-	10	45	55	4	12	88
500-600	1	-	100	-	-	-	4	16	84	2	14	86
600-700	-	-	-	-	-	-	2	1	99	-	-	-
700-800	-	-	-	-	-	-	4	5	95	2	9	91
800-900	1	-	100	-	-	-	2	30	70	-	-	-
900-1000	2	82	18	-	-	-	2	64	36	1	100	-
1000-2000	19	12	88	2	12	88	19	15	85	3	45	55
> 2000	10	31	69	1	9	91	2	13	87	1	-	100

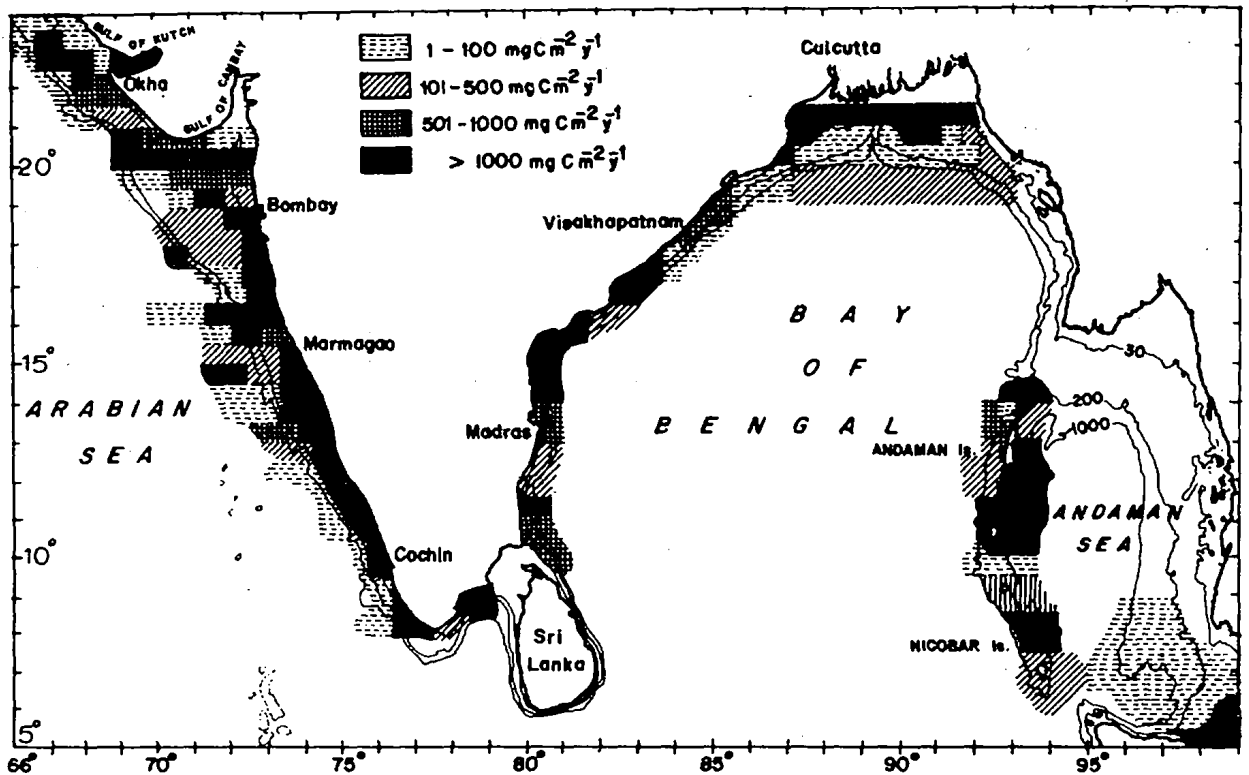


Fig. 4—Annual benthic production in the Indian Seas

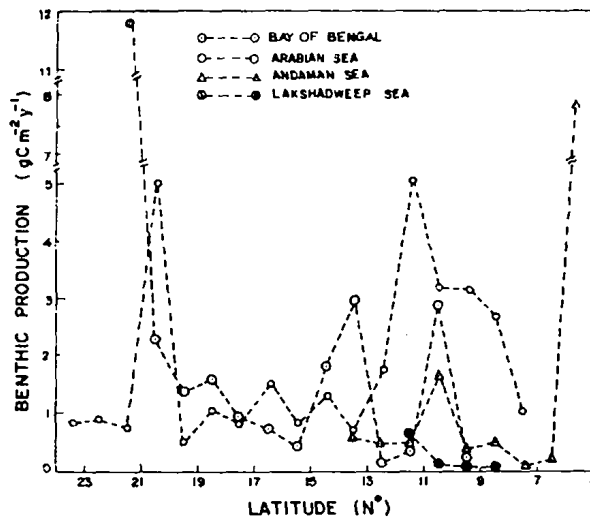


Fig. 5—Latitudinal variations in the annual benthic production ( $\text{g C m}^{-2} \text{yr}^{-1}$ ) in the Indian Seas

The 10 maritime states and 2 island groups (Table 5) together contribute for the demersal fish and crustacean catch which on an average [based on the last 10 yr (1969-78) fish landing figures] accounts for 39% of the total marine fish landing of India. As seen in Table 5, the mean biomass value varies from 0.93 in Lakshadweep to 45.49  $\text{gm}^{-2}$  in West Bengal and consequently the annual benthic production in terms of carbon and biomass production also exhibits wide

variations. Accordingly, depending on the rate of production and the shelf area, the potential yield is estimated to vary from 28 kg/hectare along the shelf of Lakshadweep to 909 kg/ha off the West Bengal shelf. The areas along the shelf of Gujarat, Goa, Karnatak, Orissa, West Bengal and Andaman-Nicobar can sustain 3 to 50 times more demersal catch. Similarly, the state of Maharashtra, Kerala and Tamil Nadu which at present have the high rate of exploitation, both in terms of effort and catch, can still sustain an increased exploitation of demersal fish and prawns by more than 39% in Maharashtra, 50% in Tamil Nadu and 66% in Kerala. The demersal resources of the Lakshadweep shelf can further be exploited by over 75%.

In the case of Andhra Pradesh, where mechanised fishing in a big way has started during the last few years, the exploited catch may not truly represent the magnitude of potential resources as in all probability the vessels operating from Kakinada and Visakhapatnam base must also be fishing along the shelf of the adjacent maritime states of Tamil Nadu, Orissa and West Bengal, which have high demersal fishery resources (Table 5).

The potential demersal fish and crustacean resources of the Indian continental shelf based on the present set of data, can be estimated to be 1.2 million tonnes as against the present level of exploitation of

Table 5—Benthic Biomass, Annual Production, Exploited Demersal Catch and Estimated Potential Yield from the Continental Shelf

Region	Mean biomass (gm <sup>-2</sup> )	Annual carbon produc., mean (gCm <sup>-2</sup> yr <sup>-1</sup> )	Shelf area (000 hectares)	Annual biomass produc. (tons/yr)	Potential yield (kg/ha)	Exploited* catch (kg/ha)
Gujarat	12.40	2.957	99,313	2.4 × 10 <sup>6</sup>	248	80.13
Maharashtra	9.35	0.921	1,04,758	1.9 × 10 <sup>6</sup>	187	134.30
Goa	16.61	1.340	9,984	0.3 × 10 <sup>6</sup>	332	77.12
Karnatak	19.06	1.329	25,473	0.9 × 10 <sup>6</sup>	381	84.01
Kerala	26.75	3.764	35,941	1.9 × 10 <sup>6</sup>	535	329.78
Tamil Nadu	11.91	2.139	37,722	0.8 × 10 <sup>6</sup>	238	159.23
Pondichery	1.13	0.352	3,680	8.3 × 10 <sup>3</sup>	22	58.01
Andhra Pradesh	3.42	1.066	31,044	0.2 × 10 <sup>6</sup>	68	152.43
Orissa	7.34	1.760	23,624	0.3 × 10 <sup>6</sup>	147	51.65
West Bengal	45.49	11.853	23,862	2 × 10 <sup>6</sup>	909	35.00
Andaman & Nicobar	7.62	1.273	16,056	0.2 × 10 <sup>6</sup>	158	3.00
Lakshadweep	0.93	0.720	1,674	4 × 10 <sup>3</sup>	28	16.30

\*Source: Marine Fisheries Information Service, Bulletin No. 9, May-June 1979.

0.45 million tonnes/yr. Out of this 62.5% or 0.75 million tonnes will be from the Arabian Sea, about 27.5% or 0.33 million tonnes from the Bay of Bengal and the rest from the island groups. Besides the continental shelf, the areas along the slope and the deep sea can support (Table 3), a potential yield of 0.4 million tonnes in the Arabian Sea, 0.13 million tonnes in the Bay of Bengal and 0.07 million tonnes in the island groups. Thus, the total potential demersal fish and prawn yield is estimated to be 1.8 million tonnes which indicates that the exploitation can be stepped up by 2.5 times in the shelf and by more than 6 times in the slope and deep regions.

A number of estimates about the potential demersal resources from the Indian Ocean are available. Prasad *et al.*<sup>22</sup> have assessed the potential yield to be 0.99 million tonnes for the Indian Seas, whereas Jones and Banerji<sup>23</sup> have reported 0.72 million tonnes. Gulland<sup>24</sup> predicted  $4.65 \times 10^6$  and  $3.01 \times 10^6$  tonnes for the Western and the Eastern Indian Ocean respectively. Qasim<sup>25</sup> has given the estimated fish yield for the Indian Ocean (between lat. 26°N to 4°S and long. 30°E to 125°E) to be 15-17 million tonnes with India's share to be around 46% or 7.36 million tonnes. He has estimated 14% or 1.03 million tonnes out of the total 7.36 million tonnes to come from the demersal resources.

The estimates by the above authors differ by 40 to 100% from the inferences drawn from the present study. The probable reason for such differences lies in the fact that all the earlier workers have based their estimates either on primary productivity or secondary productivity or on the exploratory fish survey data and calculated the tertiary production either as 0.1% of primary production or 10% of secondary productivity. In all these estimates based on secondary productivity,

only the zooplankton biomass has been considered and the contribution by benthos has been overlooked probably due to non-availability of data. As far as the demersal resources are concerned, the benthic biomass, as rightly pointed out by Moiseev<sup>26</sup>, is a more valid parameter for projecting the potential demersal fish (including the crustacean and molluscs) resources and this explains the differences between the present estimate and the earlier ones. However, based on the present study, it is reasonable to conclude that exploitation of demersal fisheries can be increased at least by an order of magnitude without adversely affecting these resources.

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