

ARABIAN SEA OCEANOGRAPHY AND FISHERIES

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ABSTRACT

The physical and chemical forcing which drive the Arabian production is now fairly well understood. The main attributes which contribute to the productivity are (1) the boundary processes which manifest as upwelling during summer monsoon and (2) winter cooling in the northern Arabian Sea. Phytoplankton blooms and high mesozooplankton biomass are common and we examine how these might contribute to the fisheries along the west coast of India. From an oceanographic point this region can be divided into two areas: south of 15°N and north of this latitude. Although the catches from these two areas are fairly equal, there is considerable differences in the composition. In the former, planktonivorous fishes dominate whereas in the north carnivores seem to be more abundant. Based on the lower food-web, we do not seem to be able to explain these differences.

Introduction

Recent estimates of potential fishery resources from the Exclusive Economic Zone of India is about 3.5 to 4.7 million tonnes (Sudarsan *et.al.*, 1990; Bhargava, 1996; Goswami, 1996). The recent annual marine fish landings from the Indian coast fluctuate between 2.2 and 2.8 million tonnes. Of this, about 73% of the catches originate from the west coast of India. But a cursory look at the catch statistics (CMFRI, 1995) shows that the composition of marine fish landings significantly changes not only between the east and west coasts, but within the west coast as well.

The paper deals with (1) the seasonal and spatial variability of the physics and chemistry of the west coast of India (2) how these influence the fish composition and (3) speculate on the relation of Arabian Sea productivity to potential fisheries.

Data Set

The major data set on Arabian Sea oceanography (physics, chemistry, primary production, and abundance of bacteria, micro and meso zooplankton) are based on a series of observations made between 1994 and 1997 on board **FORV Sagar Kanya**. These observations were made along the western and central Arabian Sea (Fig.1) during inter-monsoon (March-May), summer monsoon (June-September) and winter monsoon (November-February). The protocols of the measurements (done under the Joint Global Ocean Flux Study, JGOFS-India programme) are detailed in Bhattathiri *et.al.* (1996); deSousa *et.al.* (1996); Gauns *et.al.* (1996); Kumar and Prasad (1996); Madhupratap *et.al.* (1996a, b) and Ramaiah *et.al.* (1996). The data set on marine landings and catch composition are taken from the statistics given by CMFRI (1995) for the period 1985-1993.

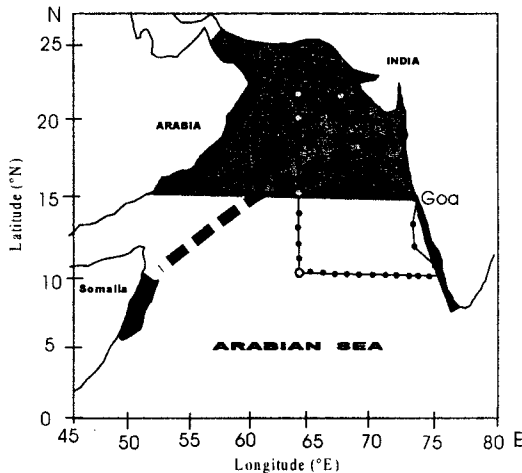


Fig.1 Cruise track in central and eastern Arabian Sea.

Hatched areas show regions of coastal upwelling along Somalia, Arabia and south west coast of India, while the stippled area comes under winter cooling effects. The arrow show the axis of the Findlater jet, active during summer monsoon, north of which open ocean upwelling takes place.

Results and discussion

Based on the physics, the seasonality in the Arabian Sea could be clearly defined and divided in to three seasons as given earlier. This is also reflected in

the spatio-temporal variations in productivity. During the inter-monsoon period (March-May), the entire Arabian Sea has very low primary production (163 to $310 \text{ mg C m}^{-2} \text{ d}^{-1}$). Almost the same scenario prevails during the transition period between the summer to winter monsoons (September-October). These periods are associated with high sea surface temperature (SST, about 28°C), shallow mixed layer depths (MLDs, around $20\text{-}30\text{m}$) and stratification. Nutrients (especially nitrate; Fig.2b) are at undetectable levels in the surface waters during this period.

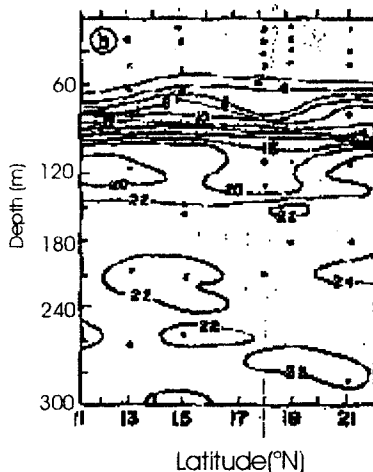


Fig.2b Nitrate in the surface water during September-October

With the onset of the summer monsoon the situation changes considerably. Under the influence of the southwesterly winds, along the west coast the surface waters move away from the cost and are replaced by cold, nutrients rich and often oxygen depleted waters from the subsurface (Ekman Pumping). This leads to phytoplankton blooms (often diatoms and dinoflagellates) and increased productivity. For example, in 1995, the 24°C isotherm surfaced, nitrate was about $2 \mu\text{M}$ (Fig.2c, d) and primary production exceeded $1700 \text{ mg m}^{-2} \text{ d}^{-1}$ off

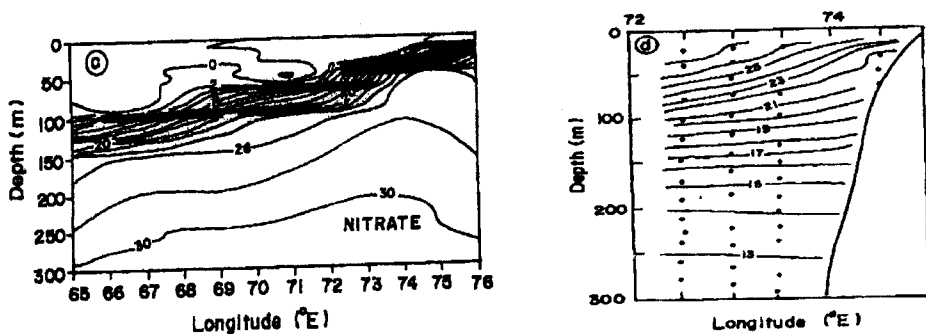


Fig.2c & d Isotherm surface in 1995

Mangalore. The upwelling seems to start at the southern tip of the west coast by end May/early June and propagate northwards with time. Some recent observations (McCreary *et.al.*, 1993) show that apart from winds, remote forcing may be a major cause to this. Surprisingly, the upwelling does not penetrate north of Lat.16°N. This condition prevails until end of August/early September and then subsides. Notwithstanding the fact that upwelling does not occur, the coastal waters of the north also have fairly high abundance of phytoplankton and zooplankton in this season (Bhattathiri *et.al.*, 1996; Madhupratap *et.al.*, 1992) probably as a result of river run-off. A major finding from the JGOFS results is that open ocean upwelling occurs in this season in the northern region as a result of positive wind stress curl north of the Findlater Jet, (Fig.1) leading to shallow MLDs and high productivity (800 to 1700 $\text{mg C m}^{-2} \text{d}^{-1}$).

A third, and hitherto unknown feature which has emerged is the winter cooling effects in the northern Arabian Sea (Madhupratap *et.al.*, 1996a). During winter (November-February), the cold, dry continental air blowing into the northern Arabian Sea causes densification of surface waters and sinking. This in turn, leads to deep MLDs (exceeding 100m, SST ca. 24°C) and a convective mixing, pumping nutrients up into the surface layers (Fig.2a) generating high production (800 to 1000 $\text{mg C m}^{-2} \text{d}^{-1}$).

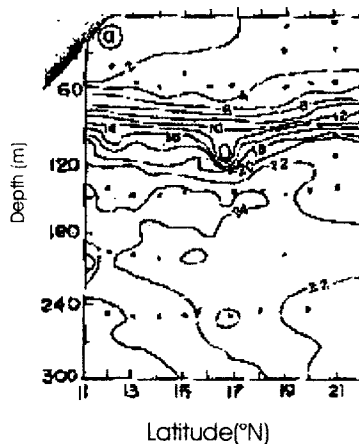


Fig.2a High production surface layers during November-February

Bacterial and microzooplankton production, by contrast, is highest during the inter-monsoon season when productivity is low (Gauns *et.al.*, 1996; Ramaiah *et.al.*, 1996). This is believed to happen through the Dissolved Organic Carbon (DOC) that builds up as winter blooms senescence. The paradox of the

Arabian Sea is that the mesozooplankton biomass remains invariably high irrespective of the seasons (Madhupratap *et.al.*, 1992, 1996a, b). In productive seasons this happens through a phytoplankton-zooplankton relationship whereas during inter-monsoon the microbial loop (bacteria-micro-mesozooplankton) becomes active.

In short, the productivity in the Arabian Sea is mainly through upwelling during summer and cooling during winter. The former occurs up to about Lat. 15°N whereas the latter is restricted to north of Lat. 15°N. During inter-monsoon, when the productivity is low, the microbial loop may be important and anyhow mesozooplankton abundances are high in all seasons. With this background, the fisheries along the west coast of India are analysed.

The source of analysis of capture-fisheries is the marine fish landings in the west coast for the years 1985-93 (CMFRI, 1995). All values presented are averages for these years as tonnage or percentage. Based on oceanographic features presented above, we have the landings from south in respect of Kerala, Karnataka and Goa are (south of Lat. 15°N) clubbed together and from north Maharashtra and Gujarat are combined. The main consideration for this cut off is that coastal upwelling occurs only south of Goa and winter cooling is a predominant feature north of it. The split-up is also logical since the length of the coast line of each state is different and each half represents approximately 8° (7-15°N; 15-23°N).

Obviously, the total quantity or percentage of landings from these two areas are more or less equal (52 and 48% in south and north respectively, Table-1). A few groups dominate the total composition along the entire coast : clupeids – 21%, carangids – 7%, Bombay duck – 7%, mackerels – 5%, ribbon fishes – 4% and seer fishes – 2.1% are the major pelagic components whereas crustaceans – 20%, croakers – 6%, perches – 5%, cephalopods – 4%, cat fishes – 2% and pomfrets – 2% are the common demersal groups. The crustaceans (mostly consisting of shrimps) and the carnivorous cephalopods are excluded in further analysis although it is important to notice that their catches are slightly more from the north compared to south. However, more important as well as interesting is to have a look at the composition of landings from each half and further analyse them on a seasonal basis. It is apparent that the fisheries in the two regions differ very much. For example, among some of the groups mentioned above, 99% of Bombay duck, 81% of croakers, 75% of ribbon fishes are caught from the northern half (Table 1). On the other hand, 77% of clupeids,

Table 1 : Percentage catch of major groups of fish from north of Goa and south of Goa (1985-1993)

Species/Groups	North of 15° West Coast	South of 15°
Elasmobranchs	78.5	21.5
Eels	99.3	0.7
Catfishes	71.2	28.8
Clupeids	22.3	77.7
Bombayduck	99.99	0.01
Lizard fishes	25.7	74.3
Half beaks and Full beaks	11.2	88.8
Flying fishes	10.3	89.7
Perches	28.4	71.6
Goat fishes	25.4	74.5
Threadfins	96.3	3.7
Croakers	81.1	18.9
Ribbon fishes	75.1	24.9
Carangids	15.6	84.4
Silver bellies	16.0	84.0
Big-Jawed Jumper	67.8	32.2
Pomfrets	83.4	16.6
Mackerels	15.2	84.8
Seer fishes	58.2	41.8
Tunnies	23.3	76.7
Bill fishes	64.0	36.0
Barracudas	22.7	77.3
Mulletts	91.9	8.1
Unicron cod	99.7	0.3
Flat fishes	31.7	68.3
Crustaceans	58.8	41.2
Cephalopods	51.7	48.3
Others	57.3	42.7
Total average tonnage	5963951	6458635
	±32013	±1730817
Total Average catch (%)	48	52

71% of perches, 84% of carangids and 84% of mackerels are landed from the southern area. Within some of these groups, species like *Sardinella longiceps* (oil sardine), *Rastrelliger kanagurta* (Indian mackerel), and *Stolephorus* hardly occur in the north. Further, majority of the catches of some lesser groups like

elasmobranchs, eels, cat fishes, threadfins, pomfrets etc. are from the north while lizard fishes, flying fishes, silver bellies, tunnies, barracudas and flat fishes are from the south. Why these differences ? Can these be answered based on the general oceanography or biology of the fish itself ? Understanding the biology would require looking into the feeding, breeding, and behavioural habits and relate them to other parameters. Are we equipped to do this ? Apparently we are not.

The data available on the food web at a lower level show that diatoms dominate the phytoplankton composition all along the coast in all seasons except during blooms of the dinoflagellate *Noctiluca*; blue green alga *Trichodesmium* and the premnesiophyte *Phaeocystis* (Sawant and Madhupratap, 1996; Nair *et.al.*, 1992; Sawant *et.al.*, in press). The zooplankton community is virtually unchanged over seasons in the upper 200 m, or so, composed of both herbivorous calanoids and carnivorous poeciliostomatids and cyclopoids – more or less small forms, below 2 mm class size (e.g. Paracalanidae, Calanidae and Clausocalanidae – herbivores; Oncaidae and Oithonidae-carnivores). A major difference may be that ostracods (again a small crustacean) and salps (larger forms including *Pagea*) often are more common in north compared to south during the periods of peak blooms.

Nonetheless, it is interesting to note that some of the major pelagic fisheries in the north are based on carnivores like Bombay duck, horse mackerel and ribbon fishes. But the dominant forms in south like sardines, mackerels and anchovies are planktonivorous (both phytoplankton and smaller zooplankton). Apart from this, carnivorous groups of fishes which forms a small percentage of catch, elasmobranchs, eels and cat fishes are mainly caught in north. Thus a general tendency of carnivorous fishes dominating along northern coast and planktonivorous forms in south is discernible. It might be interesting to analyze the landings seasonally (Table 2) albeit the fact that the quarterly landings presented often overlap the seasons described earlier from the oceanographic view point.

Table 2 : Average quarterly percentage of catches from West coast of India

Quarter	I QR	II QR	III QR	IV QR
Percentage	23	17	18	42

The averages show that the total catch along the west coast peaks in the last quarter (42%, October-December) followed by first quarter (24%, January-

March) and is fairly lower (about 17% each) in mid year. The trend is same in the major fisheries also (Table 3). The poor catch in the second quarter (April-

Table 3 : Quarterly percentage catch of major fish of West coast for each group

Species	Quarter			
	I	II	III	IV
Oil Sardine	28	12	24	36
<i>Stolephorus</i>	14	21	27	38
Bombay duck	17	13	12	58
Perches	26	17	38	19
Croakers	27	19	12	42
Carangids	12	12	34	42
Mackerel	8	10	34	48

June) may be related to low primary production during the season. The highest catches in the north in first and last quarters (Bombay duck, croakers) may also be due to the indirect effects of winter cooling. But the fairly high catches of some fishes during summer monsoon along the southern coast (oil sardine, *Stolephorus*, perches, carangids and mackerel) show that they indeed abound in this area during this season. They take advantage of the upwelling during this season (Madhupratap *et.al.*, 1994) and it should be noted that landings may not be truly representative since fishing is either prohibited or comparatively less during peak monsoon.

Thus, it could be pointed out that the better landings in first and last quarters is mainly due to fair weather plus the oceanographic conditions. But the fact still remains to be known as to how the carnivore vs planktonivore food chains have developed between north and south. Is the wide shelf area of north compared to south a reason for this? The mesopelagic myctophid (estimated turn over of an amazing 100 million tonnes per year, Gjosaeter, 1984) feeds on zooplankton and to a certain extent the paradox mentioned earlier gives an answer to this. It is obvious that there is need to pay more attention to the feeding and breeding habits of the fishes to understand their response to oceanographic conditions. Finally, a brief comparison between Arabian Sea and Bay of Bengal shows that the oceanographic conditions between these two seas differ considerably. In the northern Bay heavy discharge of fresh water reduce the surface salinity. But in the Bay also fishes like Bombay duck and croakers are predominantly caught from the northern areas. It could be that they some how take advantage of the winter cooling effects in the northern Bay. Lesser sardines are more important in the southern Bay. However, there is an increasing

trend in catches of Indian mackerel and oil sardine from the south east coast over the years.

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