J. mar. biol. Ass. India, 1973, **15** (2) : 496–537

A SURVEY OF THE FISHERY RESOURCES IN THE NORTHEASTERN PART OF THE ARABIAN SEA*

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ABSTRACT

In this paper the authors present a rough stock assessment for demersal fish and shrimps off the coast of West Pakistan. They note that local fishing appears very intense and that the local stocks are probably fully exploited. This applies only to depths upto about 30 m and perhaps to the area close to Karachi. Landings of demersal fish at Karachi, presumably come mostly from the heavily fished area, is equivalent to a yield of a little under 30 kg/ha. Assuming that this could be increased somewhat by better management, the potential might be as much as 40 kg/ha.

In the offshore waters, between 30 - 100 m the demersal species may form the bulk of the potential fish resources. Beyond 100 m catches tend to decrease.

Study of shrimp populations by the analysis of commercial catches indicates that over its range of exploitation, the shrimp exhibits a pronounced decreasing gradient of abundance. Maximum stock density, during 1966-69, occurs off the mouth of the Indus River, near the Indian border. Continuous decline in catch of large specimens may be connected with an apparent higher fishing mortality rate of adult individuals.

In studying the problem of yield in relation to lunar phases, there is reason to believe that shrimp fishing increases in brighter phase of the moon. The difference between the two series is not suggestively, and statistically significant (P = 0.10-0.05). The catch related to the time of day indicates that the catches per unit effort (kg/hr) were higher during the day time.

This study is the first attempt to assess the potential catches for commercial bottom trawling and to obtain the basic biological information necessary to establish more effective and efficient fishing methods to harvest the existing fisheries resources off West Pakistan. Investigations of the environmental factors, such as physical and chemical characteristics of the water masses and their seasonal changes have also been discussed.

INTRODUCTION

THE scientific investigations of the northeastern part of the Arabian Sea carried out so far, are fragmentary and limited mainly to shallow waters. There is no systematic research regarding the distribution of the commercially important species of fishes and edible crustaceans. There exists only some informative data on ecological elements which could influence the abundance and distribution of the organisms under study.

The first attempts of exploratory fishing with mechanised vessels in West Pakistan were made in 1948. Trawling surveys in the Arabian Sea have been continued till middle of March, 1970. The major objectives were to study the

*Presented at the 'Symposium on Indian Ocean and Adjacent Seas — Their Origin, Science and Resources' held by the Marine Biological Association of India at Cochin from January 12 to 18, 1971.

distribution, relative abundance and taxonomy of benthic fauna inhabiting the continental shelf off West Pakistan.

In this analysis the results obtained during the trawling surveys are presented (Fig. 1 a).

The authors wish to thank the Captains and their crews of the research vessel, M. F. V. "MACHHERA", and the commercial boat M. V. "MACHRANGA" for their co-operation in collecting the data. Further the authors are indebted to Mr. S. Alam, the owner of M. V. "MACHRANGA" for providing the data which made this report possible, and the Director, Marine Fisheries Department, for his kind help, assistance and advice.

FISHERY RESOURCES AND PRODUCTION

Some authors (Panikkar, 1967; Schaefer and Alverson, 1968; Messeck, 1969; etc.) are of the opinion that very high productivity in the Arabian Sea indicates the presence of large potential resources. Schaefer and Alverson (1968) admitted that it might "confidently be expected that this region will support commercial fisheries not dissimilar in magnitude to those off the coast of Peru where the annual fish harvest is about 10 million tons". The pelagic fish resources (first of all clupeids) are almost untouched. There seems to be prospects foi progressive increase in its fishery in the Arabian Sea. A continuous research programme, may undoubtedly, uncover many new possibilities of exploitation.

Wooster *et al.* (1967), based on the data obtained during the International Indian Ocean Expedition, indicated that both in terms of potential productivity and trophic level area adjoining the territories of West Pakistan, though fairly corresponding to the levels of productivity recorded from the Somali-Arabian region, is about 3-4 times more productive than the rest of the Arabian Sea. A comparison with the results of similar studies recorded from the Bay of Bengal by Panikkar (1967) and from the North Atlantic (Sargasso Sea) by Ryther and Menzel (1965) show productivity of the area under investigation to be many times more.

PELAGIC FISH POTENTIALS

Studies on the commercial catches on the Mekran coast have shown that *Sardinella longiceps* is dominating on this coast (Ahsanullah, 1966) while other species (*S. fimbriata*) is less common. *Sardinella longiceps* is found in abundance throughout the year in the northeastern part of the Arabian Sea and attains a maximum size of 22 cm in the month of June (Moinuddin *et al.*, 1962). Quereshi (1954, 1955) has also described the occurrence of sardine in shallow waters and reported the abundance of the fish from November to December on the Mekran coast. The average catch per day is quite encouraging, indicating the rich population of sardine schools in inshore shallow waters and its catch can be increased substantially using better crafts and gears. This indicated also the research on the distribution of pelagic fish carried out by Azcher NIRO Expedition during 1969 on the areas of the shelf outside the 12th mile and in deep waters of the northern part of the Arabian Sea.

No information is available on the quantity of the stocks of pelagic fish in deep waters off West Pakistan. One of the salient features which emerges from the present studies is the high nutrient potential productivity reflected in the high

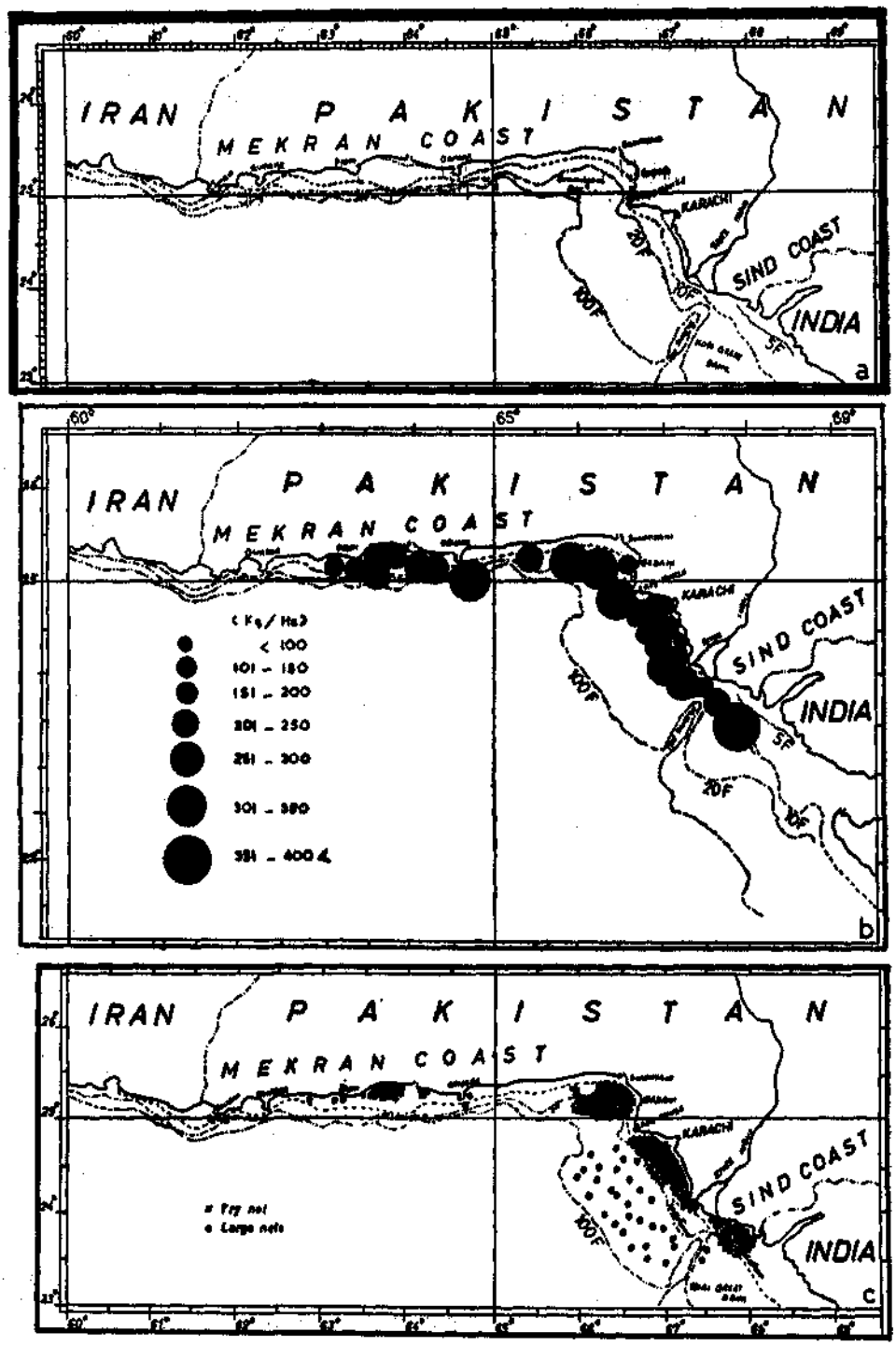

Fig. 1 a. Area of the N. E. part of the Arabian Sea discussed by authors; b. Average catch per unit effort of demersal fish by M. V. "MACHRANGA" arranged by subsubareas; and c. Trawl sampling of shrimp by M. V. "MACHRANGA" and M.F.V. "MACHHERA".

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nutrient and correspondingly high trophic level (zooplankton biomass), as compared to those from other parts of the World Ocean (Kabanova, 1961, 1964; Zernova and Ivanov, 1964, and on the basis of that it is assumed that enormous quantities of pelagic fish exist in this area (Travin, 1968). The location of areas of high concentrations of zooplankton and tunas in the West part of Pakistani shelf substantiate this. Haq (1968) found towards the end of March, 1967 a maximum biomass of zooplankton (77 cc) for the depth range 0–200 metres at station 8 (24° 46′N; 63° 37′E) indicative of rich production in these areas. It must be mentioned that this area had good potentialities for commercial tuna fishing and in catches small pelagic fish were taken. Schools of sardinella, mackerel, carangids and some other pelagic fish are known to occur in these water and an effort should be made to apprise their stocks in view of the scope for their further exploitation.

DEMERSAL FISH POTENTIALS

The inshore trawl fishery off West Pakistan began just a decade ago. Since that time, the total trawl fishing has increased in production and has become one of the major fisheries of the region. In a ten year period landings by trawl fleets of West Pakistan, increased manyfold. This rapid growth of the fishing was, particularly, the result of increased mechanisation, technological improvements and a greater demand for sea products.

The trawl fishing off the Coast of West Pakistan has been limited to the depth shallower than 30 m. The area where the commercial trawlers are working becomes very congested with trawlers, especially outside Karachi, and there are many symptoms of depletion of the fisheries resources.

Surveys and stock assessment in the inshore waters:

A total of 1200 hauls were made along the coast of West Pakistan by research vessel M. F. V. "MACHHERA" from September 1960, till the middle of May, 1967. The maximum catch per trawling hour was 284.4 Kg. in November 1964, and the lowest was 3.2 kg in December, 1960 (Hussain *et al.*, 1968).

Catch-rates and composition of groups by depth:

For convenience in analysing the distribution and relative abundance of fish, the survey area was divided into the following areas:

AREA A (Karachi & Sind Coast)

AREA B (Sonmiyani Bay & Mekran Coast)

To facilitate geographical distribution of trawling effort and hence classification of stock density, the hauls were grouped into depth-classes over a range of 9 m (5fm). The fish caught by M. F. V. "MACHHERA" was classified into seven major depth groups, the ranges of which are: 0–18; 19–27; 28–37; 38–46; 47–55; 56–65 and 66–73.

Area A (Karachi & Sind Coast):

The highest catch rates in this area was obtained in the 28–37 m depth range, followed by those in the 66–73 m; 38–46m; 0–18m; 47–55m; and 56–65 m depth ranges respectively.

Grunters (*Pomadasyidae*) were abundant in waters 38-55 m deep where the catch per hour approached the 14·4 kg; Flatfish (*Soleidae* and *Cynoglossidae*) were most abundant at 0–27 m; eel (*Congridae* and *Muraenosocidae*) were abundant at 0 to 46 m. The best depth for catfish (*Ariidae*) was 46–73 m where the average catch per hour trawling was 38·0 kg. Jewfish (*Sciaenidae*) were found at all depths investigated, but they were most abundant at 18 to 66 m. Red Snappers (*Lutianidae*) were abundant at 28 to 47 m. Shrimps (*Penaeidae*) were abundant in the shallow zone of 0–18 m.

AREA B (Sonmiyani Bay & Mekran Coast):

The relative abundance of fish was in shallow waters. The highest catch was obtained in depths of 18 to 27m, followed by those of 28 to 37 m; 47–55m; 38–46m; and 0–18m depth ranges respectively.

Grunters (*Pomadasyidae*) were found at all depths investigated, but they were most abundant at 18–55 m. Soles (*Soleidae* and *Cynoglossidae*) were abundant in shallower waters, *i.e.* from 0–27m; eel (*Congridae* and *Maraenosocidae*) at 28 to 35 m. Rays and sharks were found at all depths. Jewfish (*Sciaenidae*) were equally abundant at all depths also. Catfish (*Ariidae*) were abundant at 0 to 46 m. Red Snappers (*Lutianidae*) in deeper waters, *i.e.* between 38 and 55m, while shrimps (*Penaeidae*) were most abundant in the shallower waters at 0–18 mm.

Study of Fish Population by an Analysis of Commercial Catches:

From January 1966 till the end of 1969 the commercial boat "MACHRANGA" (a 67 ft double rigged shrimp trawler) made 3939 effective fishing hauls. The average catch of demersal fish per trawling hour was 215.5 Kg (including "trash" fish). Exploitation fishing operation has been carried out in a depth zone from 5 to 75 m along the coast of West Pakistan. The highest catch was 2,000 Kg not including Elasmobranchs.

Fig. 1 b shows the average catch per unit effort of one hour's duration from 1966 to 1969, arranged by subsubarea. It can be seen that the highest catch is obtained in underexploited area, and the lowest in fully exploited area close to Karachi. The better catch period off Cape Monze and Sonmiyani Bay coincided with spawning period (March-April) of nearly all species (*Pseudosciaena coibor, Pomadasys hasta, Lutianus argentimaculatus, Chorinemus lysan, Netuma thalassinus, Nemipterus japonicus, Trichiurus savala, Pampus argenteus, Lactarius lactarius, Pomadasys maculatus, Platycephalus spp., Rhabdosargus sarba,* etc.).

The following areas with comparatively dense fish concentrations were located: 1. The Sonmiyani Bay; 2. Mekran Coast; 3. The area near the Indian border (Kori Great Bank) and 4. Area off the mouth of the Indus river.

Standing Stock Estimation:

The technique employed to determine the standing stock has been described by Alverson (1967, 1968) and Alverson and Pereyra (1968). The method is founded on the basic assumption that catch per unit effort is a function of the average stock density in the area being surveyed (Ricker, 1940; Gulland, 1964). The changes in catch per unit effort, are directly proportional to changes in density. In this scope the whole area must be divided up to a number of small subarea in each of of which the catch and effort are known. The standing stock for the i^{th} subarea

then can be expressed as the product of area x density, and thence the sum of the abundance in each subarea (Gulland, 1956; 1966).

In assessing the standing stock, each haul may be considered as giving a sample of the density of the fish at the position of the haul and thus estimate total populations of fish in a defined area where $P_w - k_c\ C_w\ A/a$*. The authors assumed that for all fish the co-efficient of the catchability (q) of the trawl was 1.0, that is, all forms which were within the acutual path of the net were captured, though there are difficulties in the estimation, since no trawl will catch all the fish in its path (Gulland, 1968).

In computing the standing stocks of demersal fishes in the inshore waters off West Pakistan, we have calculated densities based on catch rates given by Burney and Mohiuddin (1966, 1969). The potential is divided up into two areas, *i.e.* Karachi and Sind Coast (A) and Sonmiyani Bay & Mekran Coast (B). Estimated standing stock for the demersal fishes by area is shown in Table 1.

TABLE 1. *Survey data of catches of research vessel M. F. V. "MACHHERA" during 1960—1967*

Area	A (5–55 m)	B (5–55 m) ..	A+B (5–55 m)
Number of hauls (n)	241	104	345
Total catch (C_w)	29,291.67 Kg	16,197.60 Kg	45,289.27 Kg
Hours fished (f)	389.00 hrs	189.00 hrs	578.00 hrs
Average catch per hour (cpue)	75. 3 Kg	85. 9 Kg	78. 7 Kg
Area sampled per hour (a)	0.015 sq. mi	0.015 sq.mi	0.015 sq.mi
Total area (A)	4,500 sq. mi	3800 sq.mi	8300 sq.mi
Estimated standing stock (P_w)	23 x 10^6 Kg	22 x 10^6 Kg	44 x10^6 Kg

The figures of 8300 sq. mi (naut.) or 28,400 sq. km and potential of 44 x 10^6 Kg in Table 1 gives an estimate of 1549 kg/sq. km or 15.5 Kg/ha, which agrees roughly with the average total hectare production of the North Sea.

TABLE 2. *Catches by commercial vessel M/V "MACHRANGA" during 1966—1969*

Area	A (5–40 m)	B (5–75 m)	A+B (5–75 m)
Number of hauls (n)	2435	1504	3939
Total catch (C_w)	670,039.00 Kg	559,848.00 Kg	1,220,787.00 Kg
Hours fished (f)	3,607.20 hrs	2,109.45 hrs	5,717.05 hrs
Average catch per hour (cpue)	186. 0 Kg	265.4 Kg	215.5 Kg
Area sampled per hour (a)	).042 sq. mi	0.042 sq.mi	0.042 sq.mi
Total area (A)	4,500 sq. mi	3,800 sq.mi	8,300 sq.mi
Estimated standing stock (P_w)	20 x 1· 6	24 x 10^6	43 x 10^6

Analysis of catches by commercial vessel "MACHRANGA" during 1966-1969 in the inshore waters of the coast of West Pakistan is shown in Table 2.

The results obtained by the analysis of fisheries resources in the inshore waters off West Pakistan show that the survey data of catches of research vessel provides good estimates of standing stocks.

*P_w – weight of exploitable stock (based on sampling gear)
k_c – coefficient of catchability for fish in path of trawl
C_w – average catch in weight per hour trawling
A – total area involved
a – fraction of total area covered by one hour of fishing effort.

Surveys and stock assessment in deeper waters:

A few preliminary observations were made in deeper waters off West Pakistan (Pruter, 1964; Hida and Pereyra, 1966). Commercial trawl fisheries for fish and shrimps are restricted, to relatively shallow waters of a maximum of about 55 m and generally less than 30 m.

In these surveys the results of preliminary attempts to trawl in deeper water with M. F. V. "MACHHERA" are presented.

Analysis of demersal catches taken by the Exploratory fishing:

Trawling surveys in the Arabian Sea by M. F. V. "MACHHERA" were suspended during 1968. They have been started again from January, 1969. Therefore, it seems interesting to present the data, which was gathered during the trawl operations with M. F. V. "MACHHERA" from 9th January to March 4, 1969. During the trips in January, 14 hauls were made and total catch was 2106.7 Kg. The biggest catch per hour of trawling was taken in the Swatch ground (347.2 Kg). In February, 5 hauls were made and total catch was 293.5 Kg. In March, 3 hauls were made, and total catch was 424.6 Kg. The lowest catches were registered in February when perhaps migration towards deep waters takes place.

The fishing area is shown in Fig. 2. In January, the depths trawled ranged between 46 and 99 m; in February between 79 and 115 m, and in March between 96 and 125 m. The nature of bottom was mostly muddy. Several times the bottom was very hard (*Lamellibranchiata* and *Gastropoda*) and rocky. The bottom of the central part of the area is rather rough.

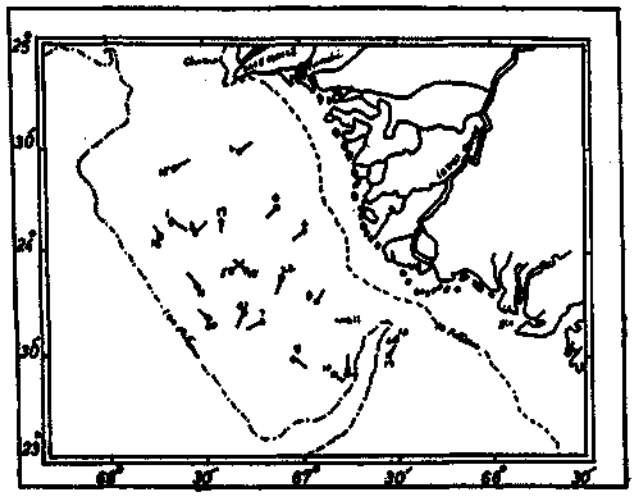

Fig. 2. Position of bottom trawling stations.

The biological analysis of fish of different species were carried during the trips. A total of 19,961 specimens of fish, 1052 specimens of crustacea, and 1043

specimens of cephalopoda were collected and analysed. The length of 45 specimens of fish was recorded to the 1 cm below, and the size of each species of shrimps to 1 mm below.

Catch-rates and percentage composition of species by depth:

The data from M. F. V. "MACHHERA" and M. F. V. "NEW HOPE" (Burney and Mohiuddin, 1966, 1969) show that in deeper waters of the continental shelf, latent reserves of the economically important species of fish may be found. The old age-class was mainly represented in the catches made, which also show that the ground fished was under-exploited.

The relative abundance of fish progressively increased with depth. The average catch per trawl hour in waters ranging 0-17 m was 22.6 Kg; 18-35 m was 51.1 Kg and in waters ranging from 36-55 m it was 76.9 Kg.

The trawling results of the R/V ANTON BRUUN of the coast of West Pakistan (Hida and Pereyra, 1966) show that highest catch rates were obtained in the 15 to 37 m depth range followed by those in the 111-183 m; 74-110 m; 38-73 m and 184-366 m depth ranges respectively. Stingrays provided the highest catch from 15-37 m and 111-183 m depth ranges. Threadfin breams, which followed the stingrays in importance, were mainly taken in the 74-110 m depth range.

Pruter (1964) found from the same trawling surveys that the demersal fish off West Pakistan "appeared as abundant in the 50 to 99 fathom interval as in the shallower 8 to 49 fathom interval." Catch rates in the 15 to 90 m depth interval was 62.2 Kg/fish/hour; in the 91 to 182 m interval was 111.7 kg/fish per hour trawled.

The average catch-rates in Kg/hour, and percentage compositions of the species caught in the trawl hauls with M. F. V. "MACHHERA" during Jan-March 1969 are shown in Table 3.

TABLE 3. *Average catch in Kg/hr and percentage composition of various species at different depth-classes.*

Species	Depth Class							
	46—51(m)		62—71(m)		80—100(m)		101—125(m)	
	Kg/hr	%	Kg/hr	%	Kg/hr	%	Kg/hr	%
CARCHARINIDAE								
Scoliodon sorrakowah (Cuvier)	14.25	1.38	10.50	3.78	1.48	0.73	—	—
Eulamia melanoptera (Quoy & Gaimard)	8.50	0.41	—	—	—	—	—	—
Hyporion macloti (Muller & Henle)	44.00	4.28	—	—	0.73	0.36	—	—
Murmillo manazo (Bleeker)	12.00	0.58	—	—	—	—	—	—
RHINOBATIDAE								
Rhynchobatus djeddensis (Forsskal)	19.50	1.89	—	—	0.50	0.24	—	—
TRYGONIDAE								
Gymnura poecilura (Shaw)	10.00	0.97	—	—	—	—	—	—
Gymnura micrura (Bloch & Schneider)	5.50	0.53	4.25	1.53	0.27	0.23	—	—

TABLE 3 (CONTD.)

Species	Depth Class 46—51 (m) Kg/hr	%	62—71(m) Kg/hr	%	80—100 (m) Kg/hr	%	101—125 (m) Kg/hr	%
Pastinachus sephen (Forsskal)	44.00	4.30	—	—	—	—	—	—
Himanture bleekeri (Blyth)	192.00	20.95	60.25	21.68	7.45	3.69	—	—
RHINOPTERIDAE								
Rhinoptera javanica (Müller & Henle)	—	—	1.00	0.36	—	—	—	—
CLUPEIDAE								
Illisha filigera (Valenciennes)	—	—	0.06	0.02	—	—	—	—
DUSSUMIERIDAE								
Dussumieria acuta Valenciennes	—	—	0.06	0.02	—	—	—	—
CHIROCENTRIDAE								
Chirocentrus dorab (Forsskal)	—	—	0.25	0.09	—	—	—	—
SYNODONTIDAE								
Saurida undosquamis (Richardson)	—	—	—	—	—	—	—	—
Saurida tumbil (Bloch)	5.50	0.85	8.25	2.98	9.68	4.79	10.56	5.37
ARIIDAE								
Netuma thalassinus (Ruppell)	90.60	13.22	14.75	5.30	0.73	0.36	—	—
MURAENESOCIDAE								
Muraenosox cinereus (Forsskal)	—	—	—	—	3.40	1.68	6.50	3.30
CONGRIDAE								
Conger conger (Linnaeus)	—	—	—	—	0.14	0.07	—	—
Ariosoma sp.	—	—	—	—	0.02	—	—	—
FISTULARIIDAE								
Fistularia villosa Klunzinger	2.00	—	1.00	—	0.23	0.11	0.19	0.10
SYNGNATHIDAE								
Trachyrhampus longirostris Kaup	—	—	—	—	—	—	—	—
Syngnathus sp.	—	—	—	—	—	—	—	—
SPHYRAENIDAE								
Sphyraena obtusata Cuvier	—	—	0.06	0.02	0.09	0.04	—	—
Sphyraena acutipinnis Day	68.80	6.68	—	—	1.07	0.53	3.69	1.87
POLYNEMIDAE								
Eleutheronema terradactylum (Shaw)	—	—	—	—	—	—	—	—
Polynemus sextarius Bloch	0.25	0.01	2.06	0.74	8.48	4.20	1.19	0.60
SERRANIDAE								
Epinephelus diacanthus Valenciennes	—	—	0.12	0.05	6.52	3.23	12.19	6.19
PRIACANTHIDAE								
Priacanthus hamrur (Forsskal)	—	—	—	—	0.14	0.07	10.50	5.34
APOGONIDAE								
Apogon quadrifasciatus Cuvier	0.50	0.02	0.05	0.02	—	—	—	—
Apogon septemstriatus Gunther	—	—	—	—	0.09	0.04	—	—

TABLE 3 (CONTD.)

Species	Depth Class							
	46—51 (m)		62—71(m)		80—100 (m)		101—125 (m)	
	Kg/hr	%	Kg/hr	%	Kg/hr	%	Kg/hr	%
LACTARIDAE								
Lactarius lactarius (Schneider)	—	—	1.19	0.43	1.40	0.69	1.87	0.95
CARANGIDAE								
Decapterus kiliche (C & V)	—	—	2.00	0.72	1.93	0.95	0.25	0.13
Alectis indica (Rüppell)	—	—	—	—	—	—	—	—
Atropus atropus Bloch	1.00	0.05	—	—	—	—	—	—
Carangoides chrysophrys (Cuvier)	—	—	—	—	—	—	—	—
Carangoides malabaricus (Bloch)	63.00	9.19	—	—	—	—	—	—
Carangoides armatus (Forsskål)	—	—	—	—	—	—	—	—
Caranx melampygus Cuvier	2.60	0.25	—	—	0.02	—	—	—
Selar mate (Cuvier)	—	—	—	—	—	—	—	—
Caranx ignobilis (Forsskål)	3.00	0.14	—	—	—	—	—	—
LUTIANIDAE								
Lutianus argentimaculatus (Forsskål)	9.00	0.44	21.00	7.56	—	—	—	—
NEMIPTERIDAE								
Nemipterus japonicus Bloch	10.16	1.48	32.50	11.69	113.27	56.13	107.50	54.65
Nemipterus peronii (C&V)	—	—	—	—	0.02	—	1.50	0.76
LEIOGNATHIDAE								
Secutor insidiator(Bloch)	0.50	0.05	—	—	—	—	—	—
Leiognathus equala (Forsskål)	24.00	1.17	—	—	—	—	—	—
Gaza minuta (Bloch)	—	—	1.37	0.49	0.18	0.09	2.12	1.08
POMADASYIDAE								
Pomadasys hasta Bloch	—	—	10.12	3.64	2.40	1.19	—	—
Pomadasys maculatus (Bloch)	53.00	7.78	55.62	20.01	0.99	0.49	—	—
Pomadasys argyreaus (Valenciennes)	9.50	0.92	—	—	—	—	—	—
SCIAENIDAE								
Sciaena dussumieri (Valenciennes)	—	—	—	—	0.52	0.25	0.50	0.25
Johnius diacanthus (Lacépède)	11.25	2.19	—	—	—	—	—	—
Johnius sina (Cuvier)	38.00	5.55	6.00	2.16	4.25	2.16	3.00	1.53
Johnius coitor (Hamilton-Buchanan)	—	—	0.25	0.09	0.30	0.14	—	—
Johnius maculatus Schneider	0.50	0.02	—	—	—	—	—	—
Johnius belengerii (Cuvier)	—	—	4.87	1.75	1.82	0.90	—	—
Otolithus argenteus (Cuvier)	3.50	0.34	4.00	1.44	2.02	1.00	8.75	4.45
LETHRINIDAE								
Lethrinus nebulosus (Forsskål)	1.50	0.07	—	—	—	—	—	—
PENTAPODIDAE								
Monotaxix grandoculis (Forsskål)	—	—	—	—	0.18	0.9	—	—
SPARIDAE								
Argyrops spinifer (Forsskål)	39.20	5.90	5.31	1.91	1.41	0.69	1.37	0.69
Acanthopagrus berda (Forsskål)	4.25	0.82	—	—	—	—	—	—

TABLE 3 (CONTD.)

Species	Depth Class 46—51 (m) Kg/hr	%	62—71 (m) Kg/hr	%	80—100 (m) Kg/hr	%	101—125 (m) Kg/hr	%
MULLIDAE								
Upeneus sulphureus (Cuvier)	—	—	—	—	0.43	0.21	—	—
Upeneus vittatus (Forsskål)	2.75	0.27	1.37	0.49	0.84	0.41	1.25	0.63
PLATACIDAE								
Platax pinnatus (Linnaeus)	—	—	—	—	—	—	—	—
DREPANIDAE								
Drepane punctata (Linnaeus)	38.20	5.56	1.87	0.67	0.25	0.12	—	—
URANOSCOPIDAE								
Uranoscopus architonema Regan	—	—	—	—	0.50	0.24	—	—
GEPOLIDAE								
Acanthocepola limbata (Cuvier)	—	—	—	—	—	—	—	—
TRICHIURIDAE								
Trichiurus savala Cuvier	—	—	3.12	1.12	0.45	0.22	0.25	0.13
SCOMBEROMORIDAE								
Cybium commersoni (Lacépède)	—	—	1.87	0.67	—	—	—	—
Indocybium guttatum (Bloch & Schneider)	—	—	5.25	1.90	—	—	—	—
STROMATEIDAE								
Parastromateus niger (Bloch)	—	—	0.56	0.20	1.90	0.94	—	—
Pampus argenteus (Euphrasen)	1.50	0.07	—	—	0.18	0.09	—	—
SCORPAENIDAE								
Scorpaenopsis roseus (Day)	—	—	—	—	—	—	—	—
Parascorpaena erostris (Alcock)	—	—	—	—	—	—	—	—
Scorpaenopsis sp.	—	—	—	—	—	—	—	—
PLATYCEPHALIDAE								
Rogadius asper (Cuvier)	—	—	—	—	0.27	0.13	—	—
Suggrundus tuberculatus (Cuvier)	1.25	0.12	4.12	1.47	12.64	6.26	7.75	3.94
Thysanophrys crocodilus (Tilesius)	—	—	2.37	0.85	—	—	—	—
TRIGLIDAE								
Lepidotrigla punctata?	—	—	0.25	0.09	2.64	1.30	0.42	0.21
PSETTODIDAE								
Psettodes erumei (Schneider)	1.50	0.14	0.50	0.18	—	—	—	—
BOTHIDAE								
Pseudorhombus arsius (Hamilton-Buchanan)	—	—	—	—	—	—	—	—
Pseudorhombus javanicus (Bleeker)	—	—	—	—	—	—	—	—
Arnoglossus sp.	—	—	—	—	—	—	—	
Grossorhombus azureus (Alcock)	0.37	0.04	—	—	—	—	0.12	0.06
SOLEIDAE								
Solea elongata Day	—	—	—	—	—	—	—	—
Brachirus orientalis (Bloch)	—	—	—	—	—	—	—	—
ALUTERIDAE								
Alutera monoceros (Linnaeus)	1.00	0.07	—	—	—	—	—	—

Table 3 (Contd.)

Species	Depth Class 46—51 (m) Kg/hr	%	62—71 (m) Kg/hr	%	80—100 (m) Kg/hr	%	(m) 101—125 Kg/hr	%
LAGOCEPHALIDAE								
Gastrophysus lunaris (Bloch)	0.50	0.02	0.50	0.18	0.27	0.13	03.7	0.19
CRUSTACEA								
Penaeus monodon Fabricius	0.50	0.02	0.06	0.02	—	—	—	—
Metapenaeus monoceros (Fabricius)	—	—	0.25	0.09	2.89	1.43	0.69	0.35
Solenocera sp.	—	—	—	—	0.09	0.04	0.12	0.06
CEPHALOPODA								
Sepia sp.	0.42	0.06	0.25	0.09	1.36	0.67	1.31	0.69
Loligo sp.	27.00	1.31	4.00	1.44	1.23	0.61	12.62	6.41
Octopus sp.	—	—	—	—	0.33	0.16	0.12	0.06
Average total catch per haul	233.90 Kg		125.92 Kg		91.38 Kg		89.10 Kg	
Minimum catch of all species	84.60 Kg		90.95 Kg		26.20 Kg		19.05 Kg	
Maximum catch of all species	347.23 Kg		193.80 Kg		168.74 Kg		170.78 Kg	
Total number of hauls	3		4		11		4	

The most abundant group belong to the family *Nemipteridae*; particularly at 80-100 m. The group became less prominent at 46-71 m. The Nemipterids were found at all depths and the bulk of the weight was due to the commonest species, *Nemipterus japonicus*. At depths where they were dominant, Nemipterids usually represented 50-60% of the total catch by weight.

Other species was *Nemipterus peronii*. The latter was only occasionally caught.

Threadfin breams recorded by Echo-sounder are shown in Plate I A.

The *Ariidae* were represented by *Netuma thalassinus*. These fish were found in shallower waters. They were most abundant in 46-51 m where in a standard haul the species, as a whole, formed about 13.2% of the total catch by weight. The average catch per hour at 46-51 m was 30.8 Kg. In deeper waters the ariids seldom appeared in the catch.

The *Sciaenidae* were abundant in water of 46-51 m where the catch per hour approached the 18.9 Kg level. These fish were found at all depths. In deeper water the group became less common. *Johnius sina* and *Otolithus argenteus* were the commonest. *Sciaena dussumieri* was only occasionally caught. *Otolithus argenteus* was caught in larger number in deeper waters (101-125 m).

The *Pomadasyidae* were identified as *Pomadasys hasta*, *P. maculatus* and *P. argyreus*. *Pomadasys maculatus* formed the bulk of the catch. The average catch per hour was 25.2 Kg or 442 specimens respectively. This species, as a whole, formed about 20.01% of the total catch by weight at 62-71 m depth.

The *Synodontidae* were found at all depths investigated but they were most abundant at 101-125 m. The average catch per hour at 101-125 m was 4.9 Kg respectively. The commonest species was *Saurida tumbil* found at all depths.

The *Mullidae* were found at all depths. The commonest species was *Upenaeus vittatus*. *Upenaeus sulphureus* was less common in the catch.

The *Lactaridae* were represented by *Lactarius lactarius* obtained from deeper water. The average catch per hour was 1.2 and 1.9 Kg respectively.

Among the *Carangidae* the commonest was *Carangoides malabaricus* and it was the only species that appeared regularly in most of the hauls. The average catch per hour at 46-51 m was 21.4 Kg. The species became less prominent at 62-71 m but in deeper waters *Carangoides malabaricus* seldom appeared in the catch. Other species that occasionally appeared with *C. malabaricus* were *Decapterus kiliche, C. melampygus, Atropus atropus, C. ignobilis, Alectis indica, C. chrysophrys, C. armatus* and *Selar mate*. Carangids catch as a whole was low (about 3.0%) of total catch.

The *Polynemidae* were found at all depths investigated but they were most abundant at 80-100 m. The dominant species was *Polynemus sextarius*. The average catch per hour at 80-100 m was 3.8 Kg. The catch in shallow waters was lower.

Among the *Sphyraenidae* the commonest was *Sphyraena acutipinnis*. The species appeared at all depths. They were abundant at 46-51 m. The average catch per hour was 15.8 Kg at 46-51 m depths. The Sphyraenids were less common in deeper waters.

The *Sparidae* were found at all depths. The commonest species was *Argyrops spinifer*. The species formed the bulk of the catch at 46-51 m where the average catch per hour was 13.3 Kg. The Sparids seemed to be rare in deeper waters.

The *Drepanidae* were most abundant at 46-51 m where 5.56% of the total catch was due to this species. The average catch per hour was 13.0 Kg. The Drepanids were represented by *Drepane punctata*. In deeper waters the Drepanids seldom appeared in the catch.

The *Lutianidae* were abundant in waters at 62-71 m deep were the catch per hour approached the 9.5 Kg. The dominant species was *Lutianus argentimaculatus* and here the weight of *Lutianids* caught was almost entirely due to this single species.

Among the *Serranidae*, the commonest was *Ephinephelus diacanthus* and it was the only species that appeared regularly at all depths and in most hauls. The best depth was 101-125 m where the catch per hour was 5.5 Kg.

Though they were found at all depths, Flatfishes were seldom caught in large numbers. *Psettodes erumei* was much less common although specimens were much bigger and heavier than other flatfishes.

The *Muraenesocidae* and *Congridae, Scomberomoridae, Stromateidae, Leiognathidae*, though commercially important were seldom caught in large numbers.

Plate I A. Threading beams recorded by echo-sounder off the coast of Karachi and Sind (depth 120 m); B. The proportion of shrimps to "trash" fish (1 : 25) in the Sonmiyani Bay, April, 1969; depth 58 m; and C. The proportion of shrimps to "trash" fish (1 : 20) in the Sonmiyani Bay, April, 1969; depth 55 m.

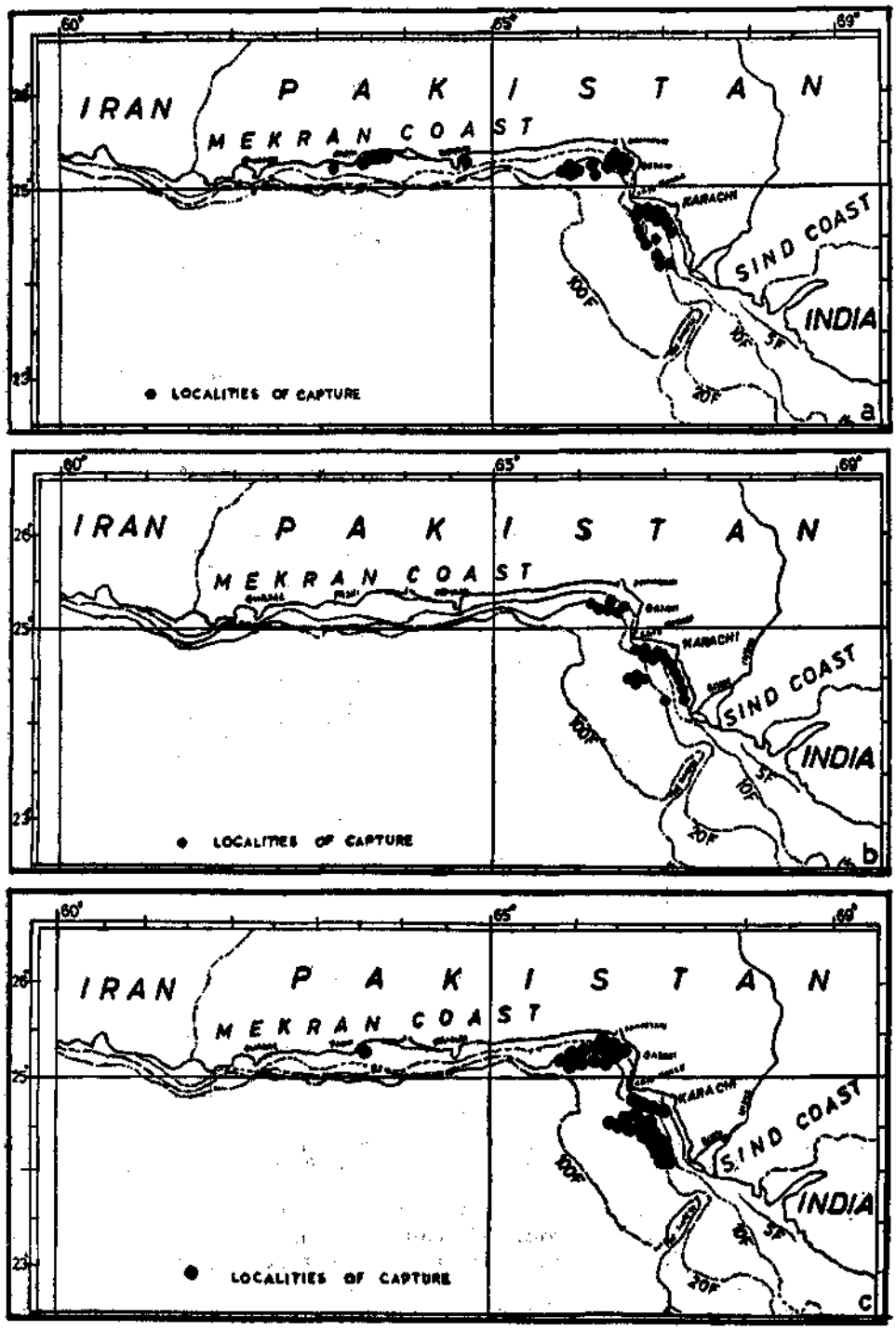

Fig. 3 a. Distribution of adult forms of *Penaeus merguiensis* during winter and spring seasons; b. Distribution of adult forms of *Penaeus penicillatus* during winter and spring seasons; and c. Distribution of adult forms of *Penaeus semisulcatus* during winter and spring seasons.

Groups of fish found in large numbers at all depths were: the *Platycephalidae, Triglidae* and the *Lagocephalidae.* The Platycephalids were most abundant. They were represented by *Rogadius asper, Suggrundus tuberculatus* and *Thysanophrys crocodilus.*

Among the Elasmobranchs, the commonest and most abundant were two species of Trygonids (Stingrays). They were: *Himantura bleekeri* and *Gymnuar micrura.* These species were present in all the hauls from 46 to 100 m depth. Less common Trygonids were *Gymnura poecilura* and *Pastinacus sephen. Rhynchobatus djeddensis* and *Rhinoptera javanica* were sometimes present in the catch. The average catch per hour of rays was 66.8 Kg at 46-51 m.

The sharks were common in shallower waters. The dominant species was *Scoliodon sorrakowah.* Other sharks which were less abundant were: *Eulamia melanoptera, Hypoprion macloti* and *Myrmillo manazo.* The average catch per hour of sharks was 15.5 Kg. at 46-51 m depth.

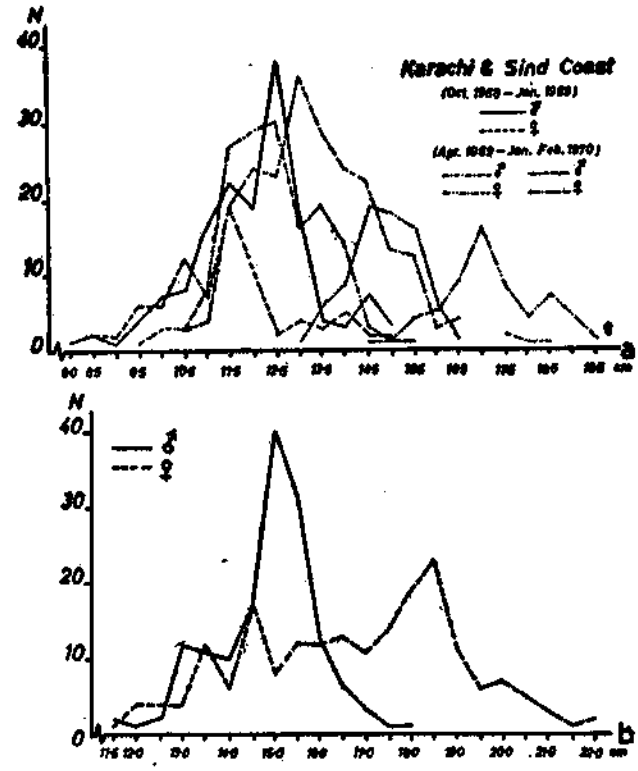

Fig. 4 a. Length frequency distribution of *Penaeus penicillatus* off the coast of Karachi and Sind; and b. Size frequency of female and male *Penaeus semisulcatus.*

Among the crustaceans, the commonest were the Penaeids. The dominant species was *Metapenaeus monoceros.* The latter were found at all depths and formed the bulk of the catch at 80-100 m. The average catch per hour at 80-100 m was 1.3 Kg (67 specimens). The catch at 101-125 m was slightly lower. Other groups that occasionally appeared with Penaeids were *Solenocera* spp., and non-commercial species of small size.

Loligo and *Sepia* were found in all depths investigated, constituting 1.5 - 7% of the whole catch. They were present in almost all the hauls. *Octopus* was very rare and seldom caught.

Our investigations showed that most of the fish caught could be classified into three major groups, based on their depth of distribution. The ranges were 45-80 m; 81-100 m and 101-125 m.

The greatest number of species were represented in the shallow zone of 45-80 m. The fish which were caught here in commercially good numbers were: *Johnius sina, Argyrops spinifer, Pomadasys maculatus, Sphyraena acutipinnis, Saurida tumbil, Upenaeus vittatus, Drepane punctata, Scoliodon sorrakowah, Hypoprion macloti, Netuma thalassinus* and *Carangoides malabaricus.*

At 81-100 m, most of the fish caught were of little commercial value. *Nemipterus japonicus,* which was insignificant below 80 m now appeared in exceptionally large numbers, forming the bulk of the catch in the hauls (56%). Other species which were not as abundant but were characteristically represented in these depths were: *Saurida tumbil, Polynemus sextarius: Epinephelus diacanthus, Lactarius lactarius, Pomadasys hasta, Suggrundus tuberculatus* and *Lepidotrigla* spp. Among the crustaceans, the commonest was *Metapenaeus monoceros.*

TABLE 4. *Mean size and size range for dominant species taken off Karachi and Sind Coast*

Species	No. of specimens	Mean size (cm)	Size range (cm)
Nemipterus japonicus	594	16.13	4–31
Saurida tumbil	265	26.88	9–49
Carangoides malabaricus	189	19.63	13–41
Argyrops spinifer	174	21.23	13–46
Pomadasys maculatus	153	17.69	12–31
Upeneus vittatus	133	15.53	12–23
Decapterus kiliche	114	20.30	16–28
Otolithus argenteus	110	24.93	17–36
Epinephelus diacanthus	97	23.38	13–39
Polynemus sextarius	84	19.25	15–24
Johnius sina	84	19.40	13–29
Lactarius lactarius	74	21.42	16–27
Sphyraena acutipinnis	74	25.10	12–81
Johnius belengerii	73	18.74	14–26
Drepane punctata	69	20.19	9–42
Gazza minuta	37	23.27	9–32
Pomadasys argyreus	24	43.66	18–52
Parastromateus niger	16	20.94	15–25
Leiognathus equula	16	19.00	15–26
Acanthopagrus berda	16	28.25	19–38
Johnius coibor	7	88.71	83–99
Lutianus argentimaculatus	6	68.33	65–72
Johnius diacanthus	4	80.25	76–86

The third group (101-125 m) consists of species which could be also found in shallower waters. They were: *Nemipterus japonicus, Saurida tumbil, Muraenosox cinereus, Epinephelus diacanthus, Priacanthus hamrur, Otolithus argenteus* and *Suggrundus tuberculatus.*

Among Cephalopods, the commonest was *Loligo* sp.

Table 4 gives the mean size and size range for dominant species.

The average catch-rates and also the maximum and minimum catches obtained at the different depth-classes are shown at the end of Table 3. The best depth for trawling during these surveys was found to be around 46-51 m yielding an average catch per hour of trawling 233.9 Kg the average catch per hour trawling at 62-71 m was 125.9 Kg. The deeper part of the area surveyed, yielding an average catch-rate only 91.4 Kg/hr and 89.1 Kg/hr, showed a sharp drop in the production of the bottom fish.

Further exploratory fishing in the offshore waters of West Pakistan (outside 12 mi down to 1000 m) was carried out in the early part of 1969 by USSR vessels, in collaboration with Pakistan. Beyond 100 m catches tended to decrease, becoming small at 300 m, and the limited number of hauls between 800 and 1000 m caught virtually nothing. At these depths only single specimens of bathypelagic fish were observed.

The most concentrations of commercially important species were observed at depths of 30-80 m. In deeper waters of continental shelf *Nemipterus japonicus* predominated in catch.

Standing Stock Estimation:

In computing the standing stocks of demersal fishes in deeper waters off the coast of Karachi and Sind, the authors have calculated densities based on the average catch per trawling hour with M. F. V. "MACHHERA".

The fishing method which was used in this trawl survey was the same as that practised during 1960-1967.

Karachi and Sind Coast
(45-125 m Interval)

1. Number of hauls: 22
2. Total catch: 2901.83 Kg.
3. Hours fished: 23.00
4. Average catch per hour: 126.2 Kg.
5. Area samples per hour: 0.015 sq. mi (naut.)
6. Total area: 5000 sq. mi (naut.)
7. Estimating standing stock (P_w) : 42 x 10^6 Kg.

Using above figure of 5000 sq. mi (naut.) or 17000 sq. km and potential of 42 x 10^6 Kg gives an estimate of 2470 Kg/sq. km or 24.7 Kg/hr.

Potential catches off West Pakistan:

Several methods are now being used to estimate the potential catches from biomass or standing stock figures of latent resources. Gulland (1968) suggested that the Potential (P) yield is, in an unexploited stock, roughly:

$$P = 0.4\ MP_0, \text{ where } F = M$$

The ratio of standing stock: potential catches probables varies in the range 1: 0.5 or higher for heavily exploited stocks.

Summary of the potential catches of demersal fishes in the region is shown in Table 5. In calculating the potential catches it is presumed that the shallow water (under 50 m) stocks are heavily exploited, and all deeper water (over 50 m) stocks are still lightly exploited.

TABLE 5. *Estimating total demersal potential in the region off West Pakistan*

Area	Area (000 sq km) (5–50 m)	(50–200 m)	Catch (Kg/hr) (5–200 m)	Density (Kg/hr) (5–50m)	(50–200 m)	Standing stock (000 tons) 5–50	(50–200 m)
A	15.4	17.0	175.0	15.0	25.0	23	42
B	13.0	19.6	248.0	17.0	25.0	22	50
Total:	28.4	36.6	202.4	—	—	45	92

The data of Table 5 gives an estimate of total demersal potential in the region off West Pakistan of 0.5 x 45 + 0.2 x 92 = 40.9 say 41,000 tons. This estimate is too low. In fact, the stocks in some parts of the region have been heavily reduced by fishing. This applies only to depths out to about 30 m and to the area close to Karachi, *i. e.*, to a strip about 20-25 n. mi wide, and perhaps 80-100 n. mi long, with an area of ca 7,000 km². Landings of demersal fish at Karachi average around 20,000 tons in 1966-1969, presumably, mostly from the heavily fished area, and is equivalent to a yield of a little under 30 Kg/hr. Assuming that this could be increased somewhat by better management the potential might be as much as 40 Kg/ha.

Tiews (1966) calculated that the Thai and Philippines sea fisheries produce by trawl fisheries about 36 Kg of bottom fish per hectare. Using Tiews figures, Gulland (1968) estimated in the Gulf of Thailand a demersal potential of 60 Kg/hectare.

SHRIMP POTENTIALS

Shrimp fisheries occupy the most important position in the coastal fisheries along the coast of West Pakistan. The extent of these resources has not yet been assessed, and it is necessary to gain further knowledge about them.

Thirteen species of shrimps (not including the doubtful *Penaeus orientalis*) have been identified. Three genera - *Penaeus, Metapenaeus* and *Parapenaeopsis* (sub-family *Penaeinae*) - are represented. Species of *Penaeus* grow to a large size and make up the main bulk of landing.

The shrimp fishery:

The exploitation of marine shrimp resources is mainly limited to coastal and shallow waters. Fishing is done exclusively in the territorial water to the maximum of 30 m depths. The catch in West Pakistan, therefore, is a catch in the narrow sector of inshore waters. The shrimp fishing off West Pakistan is continuous throughout the year. The main season is from September to May. During the monsoon season (June to August) only bigger trawlers operate off Karachi in near shore water.

Total Landings:

The local fishermen have divided the shrimps into three categories, according to size, colour and texture. These are: "Jaira", "Kalri" and "Kiddi".

"Jaira" is commercially the most important shrimp (*Penaeus merguiensis, P. penicillatus* and *P. indicus*). They are usually whitish and pinkish in colour.

"Kalri" is the second important shrimp (*Metapenaeus monoceros, M. affinis, M. brevicornis, M. stebbingi,* and sometimes small quantities of *Penaeus monodon, P. semisulcatus* and *P. japonicus*). They are usually grey and brown in colour.

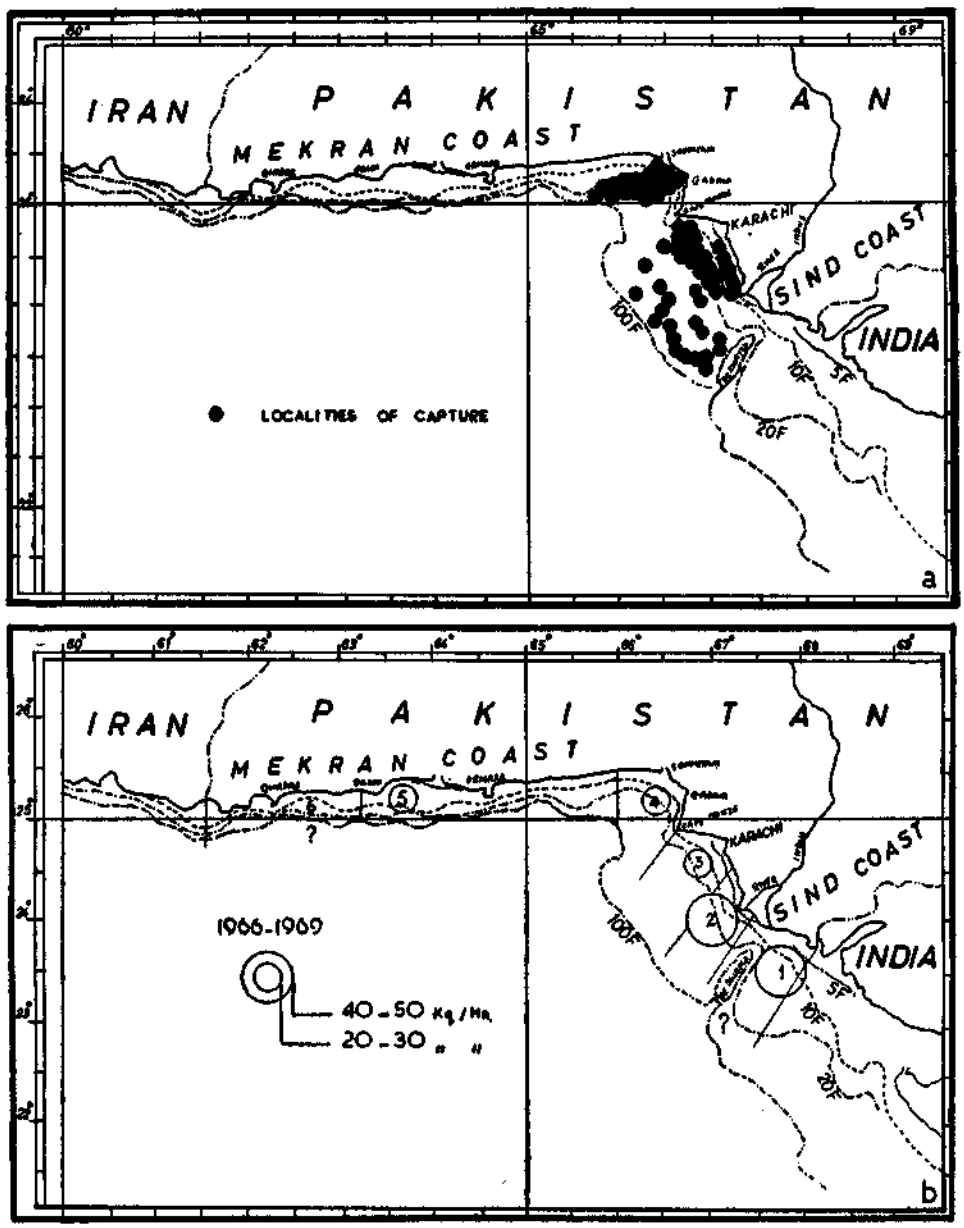

Fig. 5 a. Distribution of adult forms of *Metapenaeus monoceros* during winter and spring seasons; and b. Average catch per unit effort of shrimp by M. V. "MACHRANGA" arranged by subareas.

"Kiddi" comprises smallest shrimps (*Parapenaeopsis stylifera, P. sculptilis* and *P. hardwickii*) including juveniles of "Jaira" and "Kalri".

The following species are predominent in catches: *P. merguiensis* and *P. penicillatus* for "*Jaira*"; *Metapenaeus monoceros* and *M. affinis* for "Kalri" and *Parapenaeopsis stylifera* for "Kiddi".

Table 6 shows the landing of shrimp at Karachi Fish Harbour in relation to total estimated catch during 1959-1969 (Landing in tons).

TABLE 6. *The landing of different groups of shrimp at Karachi Fish Harbour in relation to total estimated catch during 1959–1969*

Year	"Jaira" (tons)	"Kalri" (tons)	"Kiddi" (tons)	Total landing (tons)	Total estimated catch (tons)
1959	125	120	163	408	2853
1960	714	686	933	2333	4513
1961	1166	954	1413	3533	6600
1962	1651	1039	1193	3883	4576
1963	1400	2102	2335	5837	9171
1964	2246	2434	5317	9997	16059
1965	2698	3297	1900	7895	18025
1966	1816	2721	3633	8170	18196
1967	1605	3210	3725	8540	17232
1968	2051	4113	4192	10356	15535
1969	3843	1660	8254	13757	20973

Source: Marketing Section, Marine Fisheries Department, Karachi.

The data of Table 6 demonstrates the considerable rise in the shrimp landings in the period 1963-1969.

The analysis of the shrimp population structure carried out during the current decade has revealed that the catch of adult specimens ("Jaira" and "Kalri") are on the decrease in catches, while the occurrence of undersized and economically non important species ("Kiddi") is on the increase. Continuous decline in catch of large specimens may be connected with an apparent higher fishing mortality rate of adult individuals. The decline in these catches of the last two-three years, is likely to reflect a real decrease in the shrimps population either due to the fishery itself, or to natural causes.

Study of shrimp populations by the Analysis of commercial catches:

The exploratory trawling surveys of shrimp resources by M. F. V. "MACHHERA" and by commercial boat "MAÇHRANGA" in the coastal and offshore waters of West Pakistan extended from October 1968 to October 1970 (Fig. 1c). The biological analysis of different species of shrimps were carried out during these trips. The following species of shrimps have been identified from the catch: *Penaeus merguiensis, P. penicillatus, P. indicus, P. semisulcatus, P. monodon, P. japonicus, Metapenaeus monoceros, M. affinis, M. brevicornis, M. stebbingi, Parapenaeopsis stylifera, P. sculptilis,* and *P. hardwickii.*

Little work on the taxonomy and biology of the Penaeid shrimps has been done in West Pakistan. Presence of different species on the "Mekran Coast" was described by Moinuddin *et al.* (1962 a and b). More information is available from Tirmizi (1969).

The present paper deals with biological and commercial aspects of the shrimps off the coast of West Pakistan. Observation on the distribution, size composition, sex ratio and state of maturity has also been included in this analysis.

BIOLOGICAL DATA

Penaeus merguiensis de Man

This species is commercially very important. She outnumbers all the others in catches in the coastal waters of West Pakistan.

DISTRIBUTION

This species prefers muddy or sand/muddy bottom and shallow waters of the sea within 3 to 20 m. The adult form was found at 55 metres depth (in winter season). Fig. 3a, gives an idea of distribution of adult forms off West Pakistan during our winter and spring season surveys. Its occurrence in fishery is subjected to seasonal fluctuation.

SIZE COMPOSITION

The maximum length of male and female was found to be 190 and 202 mm and minimum was recorded to be 85 mm respectively. The dominant size group of male and female to be ranging from 146 to 155 mm and 166-180 mm respectively.

Penaeus merguiensis is caught in large quantities on the Mekran Coast and this species attains a considerable size. It is interesting to note that smaller size range of specimens was found on the Karachi and Sind Coast.

SEX RATIO

1613 specimens were collected from October, '68 to March, '70 and analysed. The number of males was found to be 768 and that of females 845. The ratio of male to that of female comes to be 1 : 1.1. The sex ratio of this species showed 47.61% for male and 52.39% for females. In the large size (almost) only female specimens were recorded.

SPAWNIG SEASON

The breeding season of *Penaeus merguiensis* have been found out by the gonadial study and it has been observed that the spawning season starts in the month of December and lasts for three to four months (April). The offshore movement of this species in deeper waters probably commences from January onwards.

Penaeus penicillatus Alcock

This species is also very common in the commercial catches in the coastal waters of West Pakistan.

DISTRIBUTION

The adults are associated with shallow coastal waters and sand or sand/ muddy sea bottom. The distribution of this species is subjected to the physical conditions of the coastline. The adult form was found at 70 metres depth. Fig. 3b shows the distribution of this species during winter and spring seasons.

SIZE COMPOSITION

The maximum length of male and female was found to be 163 and 195 mm and minimum was recorded to be 102 mm per male and 95 mm per female. Fig. 4a gives the size comosition of male and female during winter and spring seasons. It is evident that the modal length shifting from 111–130 mm in October-Jan. to 116–145 mm in April, and again to 140–155 mm in Jan.- February 1970 for males and from 101–120 mm to 111–140 mm for female in April 1969 and again from 160 to 175 mm in January-Feburary, 1970.

SEX RATIO

762 specimens were collected during October, 1968 to February, 1970 and analysed. The number of males was found to be 385 and that of females 377. The ratio of male to that of female was 1: 1.02.

SPAWNING SEASON

Based on the occurrence of mature specimens in catches during October - April, 1968/70 survey trips, the spawning of *Penaeus penicillatus* extending from October to May off the coast of West Pakistan.

Penaeus semisulcatus De Haan

This species is common in deeper waters of West Pakistan during cold season, though it is not represented as an important economic species. It is not abundant in catches.

DISTRIBUTION

This species prefers muddy bottom. The adult form was found at depths of 70 metres. Fig. 3c gives the distribution of this species off West Pakistan during our survey trips.

SIZE COMPOSITION

The maximum lengths of males was found to be 176 mm and that of females 220 mm. The minimum length of male and female was found to be 92 mm and 114 mm respectively. It is interesting to note that bigger size of specimens was found in the area of Sonmiyani Bay in deeper waters.

SEX RATIO

A total of 342 specimens were collected during the months of October '68 to March '70 and analysed. The number of males was found to be 151 and that of females 191. The ratio of males to that of females comes to be 1: 1.3. Fig. 4b shows the sex ratio of *P. semisulcatus* off West Pakistan.

SPAWNING SEASON

It is observed that the breeding season of *P. semisulcatus* starts in the month of January and lasts for three to four months (May).

Metapenaeus monoceros (Fabricius)

This species is widely distributed on the West Pakistan Coast and is caught in sufficient quantities in almost all the fishing stations. In deeper waters of West Pakistan, *Metapenaeus monoceros* made up great proportions of the catch - 80.0%; *Penaeus* sp. (*P. japonicus, P. indicus, P. semisulcatus*) represented - 10.0% ; *Solenocera pectinulata* - 4.0% non commercial shrimps of small size (20-33mm) - 6.0%

DISTRIBUTION

The best catches during winter and spring seasons were recorded at depths of 22-57 m. Small concentrations of *Metapenaeus monoceros* were observed at depths of 80-125 metres off Karachi and Sind Coast. With the depth increasing to 170 metres in catches *M. monoceros* almost disappeared.

Small, but nearly constant occurrence of *M. monoceros* in trawl catches in deeper waters of the continental shelf might explain, evidently, by the fact that in the explored season shrimps dispersed along the area. Fig. 5a gives an idea of distribution of *M. monoceros* along the coast of West Pakistan during winter and spring seasons.

SIZE COMPOSITION

The maximum length of male and female in deeper waters off Karachi and Sind Coast during winter season was found to be 150 mm and 192 mm and minimum size was recorded to be 90 mm and 85 mm respectively. On combined basis, the dominant size group of male and female was to be ranging from 110-135 and 125-160 respectively.

Metapenaeus monoceros is caught in large quantities in the area of Sonmiyani Bay at depths of 22-57 m and it attains a considerable size. (Length of 90-180 mm, and weight of 6-45 g) Fig. 6a shows the length composition of *Metapenaeus monoceros* off the coast of West Pakistan.

SEX RATIO

Regarding its sex ratio out of a total of 2402 specimens measured 1143 were males and 1259 females. Their percentage being 47. 59% and 52. 41% respectively. The ratio of male and female size ranges was 1 : 1. 1.

SPAWNING SEASON

George *et al.* (1968) stated that the offshore movement of this species commenced from November. The specimens of larger sizes only were encountered in deeper waters of Cochin. Investigations carried out by the Central Marine Fisheries Research Institute show that *M. monoceros* breeds in 50-60 m region (Mohamed, 1967).

Our investigations during winter season in deeper waters off Karachi and the area of Sonmiyani Bay lend additional support to this view. The better catches of this species were in deeper waters.

Based on the occurrence of mature specimens in catches, the breeding season of *M. monoceros* in deeper waters was during winter and spring seasons (Feb. - May).

Parapenaeopsis stylifera (H. Milne-Edwards)

This species is very common in the inshore waters off West Pakistan. Though represented in the commercial catches, the specimens of this species are mostly removed. In the future, however, this species will be commercially much more important, especially if total catch of larger size continues to decline in catches.

DISTRIBUTION

Almost all the Peaneid shrimps breed in the sea and their young ones enter the estuaries and backwaters when they are in post-larval stages. The only known exception to this is *Parapenaeopsis stylifera* which however, completes its life cycle in the sea itself without entering the estuarine environment during any stage of its life cycle (Mohamed, 1967). Hence, some difference in the pattern of behaviour and movements in and out of the fishing grounds can naturally, be expected in the case of this species (George *et. al.*, 1968). Inhabits shallow, coastal waters, more abundant in summer.

SIZE COMPOSITION

About 735 specimens were measured. The maximum lengths of males were found to be 100 mm and that of females 128 mm. The minimum length of male and female was found to be 30 mm and 50 mm respectively. On a combined basis of male and female sexes together, the dominant size group ranging from 66-75mm and that of males in the group ranging from 61-70 mm and that of females in the group ranging from 66-75 mm. It is interesting to note that bigger size range of specimens was found on Mekran Coast.

SEX RATIO

A total of 735 specimens were analysed during the months of October '68 to March '70. The number of males was found to be 173 and that of females was 562. The ratio of males to that of females comes 1 : 3. 3. Fig. 6b shows the sex ratio of *Parapenaeopsis stylifera* off the coast of West Pakistan.

SPAWNING SEASON

No information is available on its spawning season in the waters of West Pakistan. The authors found this species breeding in February to March.

Menon (1963) has observed the breeding of the species on the Malabar Coast during October to December, while Shaikhmahmud and Tembe (1960) recorded the species breeding throughout the year in Bombay waters with an intensive period in March to May. Rao (1968) found that the species breeds throughout the year in the Cochin area, with peaks during December and June to August.

OTHER SPECIES

Other species *(Penaeus monodon, P. indicus, P. japonicus, Metapenaeus brevicornis* and *Parapenaeopsis hardwickii)* are rather rare, some of it extremely

rare, in West Pakistan waters. *Metapenaeus stebbingi, M. affinis* and *Parapenaeopsis sculptilis* are fairly well represented in shallow waters off West Pakistan. *Metapenaeus affinis* and *M. stebbingi* are very common in the inshore area during cold season and sometimes predominated in trawling catches.

CATCH PER UNIT EFFORT AS AN INDEX OF ABUNDANCE

The "MACHRANGA" Records:

This analysis is based on two sets of records: 1) the log kept by the ship's Captain and 2) the record kept at the wharf, of the catches discharged from the vessel.

The Captain kept the usual trawler log as follows:- No. of hauls, date, moon, tide, wind, nature of bottom, locality, depth, time, towing (hr/min), catch ("Jaira", "Kalri", "Kiddi", fish, trash fish, and try net.

The record of the catch in the logs is the captain's tally of number of baskets each of 100 lbs capacity.

The record of landed catch was separated on the wharf into three categories and the weight of two ("Jaira" and "Kalri") was recorded.

The discrepancies between Captain's Tally and Record of landing are given in Table 7 (for "Jaira" and "Kalri" only).

TABLE 7. *The discrepencies between Captain's Tally Record in landing (in Kg)*[1]

Month	Year										
	1966		1967		1968		1969		Total		Difference
	a	b	a	b	a	b	a	b	a	b	a − b
I	2210	2325	4869	3749	3298	3001	3886	3109	14263	12184	+2079
II	2458	2717	1952	2156	2825	3130	3271	2903	10506	10906	− 400
III	5816	5761	2140	2034	2248	2480	4306	4225	14510	14500	+ 10
IV	2685	2555	5354	3118	4903	1736	3544	3414	16486	10823	+5663
V	4033	3123	5639	5634	5595	5611	2101	2096	17368	16464	+ 904
VI	2209	1828	2372	2449	3485	4203	3653	3413	11719	11893	− 174
VII	3688	2910	660	626	4735	4079	2086	1999	11169	9614	+1555
VIII	3478	1755	2873	2691	4171	4052	4477	4420	14999	12918	+2081
IX	2682	3239	8203	9833	2722	4314	1131	837	14738	19223	− 4485
X	4145	3969	10066	7803	6005	7208	2184	2236	22400	21216	+1184
XI	5835	6502	7904	7315	4722	4618	4858	4073	23319	22508	+ 811
XII	5266	5035	7387	7342	5510	4241	1323	2223	19486	18841	+ 645
Total:	44505	41719	59419	54750	50219	48673	36820	34948	190963	180090	+10873
%		−6.26		−7.85		−3.08		−5.09			−5.69

[1] Record of landing (a)
Captain's tally of catch (in baskets each of 100 lbs.) converted to Kgs weight (b).

The total of the estimates by the captain, of the catches from 1966 to 1969 fell below the total recorded at the wharf by nearly 10,873 Kg (5.69% of the recorded catch). The estimates for 1966 in relation to the wharf record was: 2786 Kg (6.26%); 1967 - 4669 Kg (7.85%) ; 1968 - 1546 Kg (3.08%); 1969 - 1872 Kg (5.09%).

In fig. 7a is presented the relation between total tally kept by captain on "MACHRANGA" and landings from the vessel during 1966-1969.

This figure shows that although the captain's tally of "Jaira" and "Kalri" catch along the coast of West Pakistan lies within confidential limit, it seems that the captain's tally of two main groups was subject to various sources of error which operated at random, and in the long run of 3948 effective hauls, cancelled out to result in total very close to the true value.

We have to assume that these sources of error operated randomly throughout the operations and that their effect has introduced no bias to our estimates of catch rates.

CATCH RATES

On the 975 effective fishing days from which detailed records have been kept, the "MACHRANGA" landed 182,133 Kg as the result of just over 5815 hour's trawling. These values give an average catch rate of 31.32 Kg per hour of trawling, or about 186.80 Kg per day on the fishing grounds.

Table 8 shows the catch rates by "MACHRANGA" during 1966-1969 (in Kg).

TABLE 8. *Catch rates by "MACHRANGA" during 1966–1969 calculated from Captain's tally.*

Year	Fishing days	No. of hauls	Hours trawling (hrs)	Total catch (Kg)	Av. per fish/day (Kg)	Av. per haul (Kg)	Av. per trawling hour (Kg)
1966	274	880	1419.30	41,718.04	152.25	47.49	29.39
1967	233	1137	1392.45	56,801.61	243.79	49.95	40.47
1968	223	947	1448.00	48,670.37	218.25	51.49	32.01
1969	245	984	1555.00	34,943.53	142.62	35.51	22.48
Total:	975	3948	5815.15	182,133.55	186.80	46.13	31.32

The main premise on which arguments from catch rates to stock density are based, is that the catch taken in a single operation of a gear, such as a trawl net, is direct index of the abundance of shrimps over the gear that has been hauled. In assessing the density, this formula is used for computation of the density index of the West Pakistan coastal shrimp fishery:

$$D = \frac{1}{2} \frac{\sum a_i d_i}{A}$$

where D = density in whole area
2 = constant
a_i = area of i^{th} subarea
d_i = catch per unit effort in i^{th} subarea
A = total area involved

If we suppose that the region is divided up into a number of small subareas, then the density index is the weighed mean of the catch per unit effort in each subarea, the weighing factors being the size of the subarea.

FISHABLE BIOMASS INDEX

Table 9 gives made commercial effort and shrimp ("Jaira" and "Kalri") catch figures (1966-1969) for each of 5 unequal subareas comprising the West Pakistan Coast offshore trawling grounds (not including subarea 6, *i. e.*, Gwadar and Jiwani).

TABLE 9. *Commercial catch by "MACHRANGA" from the offshore shrimp fishery in the West Pakistan Coast area during 1966-1969*

Year	Statistical area	Sub-area	Area/sq. mi.naut.	Area weighing factor	Total effort (24 hrs) unit	Total catch (000's Kg)	Total catch / Total effort
	A	i	a_i	w_i	g_i	Y_i	d_i
1966	Karachi & Sind	1	860	0.47	1.2	3.0	2.50
1967	,,	,,	,,	,,	5.7	7.3	1.38
1968	,,	,,	,,	,,	5.3	4.7	0.89
1969	,,	,,	,,	,,	6.2	4.6	0.74
Total	,,	,,	,,	,,	18.4	19.6	1.07
1966	,,	2	250	0.14	3.3	2.2	0.67
1967	,,	,,	,,	,,	6.0	9.9	1.65
1968	,,	,,	,,	,,	8.2	9.3	1.13
1969	,,	,,	,,	,,	7.5	4.8	0.64
Total	,,	,,	,,	,,	25.0	26.2	1.05
1966	,,	3	230	0.12	34.1	19.4	0.57
1967	,,	,,	,,	,,	28.7	23.7	0.83
1968	,,	,,	,,	,,	27.0	20.2	0.75
1969	,,	,,	,,	,,	17.5	7.8	0.45
Total	,,	,,	,,	,,	107.3	71.1	0.66
1966	Sonmiyani Bay	4	395	0.21	15.0	10.9	0.72
1967	,,	,,	,,	,,	1.9	1.2	0.63
1968	,,	,,	,,	,,	13.9	10.6	0.76
1969	,,	,,	,,	,,	29.0	15.5	0.53
Total	,,	,,	,,	,,	59.8	38.2	0.64
1966	Mekran Coast	5	110	0.06	12.3	5.5	0.45
1967	,,	,,	,,	,,	16.1	12.6	0.78
1968	,,	,,	,,	,,	4.9	3.4	0.69
1969	,,	,,	,,	,,	4.2	2.4	0.57
Total	,,	,,	,,	,,	37.5	23.5	0.64
Areas Total			1845	1.00	248.0	179.0	0.72

Table 9 shows that over its range of exploitation, the shrimp exhibits a pronounced gradient of abundance. Maximum stock density during 1966 - 1969, occurs in statistical subarea 1 and 2 (Kori Great Bank near Indian border and off the mouth of the Indus River). Minimun stock density occurs in statistical subareas 3, 4 and 5 (off Karachi, Sonmiyani Bay and around Pasni on the Mekran Coast.)

We can divide the entire West Pakistan Coast into six shrimp grounds. Three along the Sind and Karachi Coasts and three along the Sonmiyani Bay and Mekran Coast (Fig. 5b).

Area : Sind and Karachi Coast

Subarea 1. (No. of subsubarea 4)

It is situated 100 miles South east of Karachi near the Indian border, and upto a distance of 60 miles offshore (Kori Great Bank), and is quite underexploited being beyond the reach of small trawlers. Only bigger trawlers go far for shrimp fishing there. The catch statistics show that the catch per hour of trawling varies from 40 to 50 Kg.

Subarea 2. (No. of subsubarea 6)

It is situated beyond 70 miles to the South east of Karachi adjacent to Subarea 1. In this subarea there is moderate fishing intensity and the catch rate per hour of trawling is about 35 to 50 Kg.

Subarea 3 (No. of subsubarea 8)

It is entered between Paitiani and Cape Monze, about 60 miles North-westward. Here the fishing intensity is very heavy and the catch rate varies from 15 to 30Kg per hour. The intensity of fishing in this subarea is due to the "good" shrimp ground and its being easily accessible by small trawlers, so most of the trawlers go for, one or two day fishing trips. But when the catch rate diminishes, they spread over to the adjacent subareas. In this subarea, in our opinion, much more attention need be given for reducing fishing effort or limiting catches on the basis of scientific findings.

Area: Sonmiyani Bay and Mekran Coast

Subarea 4. (No. of subsubarea 3)

It is situated around Sonmiyani Bay (40 miles North westward of Karachi). This area is moderately exploited for shrimp fishing, because most of the trawlers remain engaged in shrimp fishing near Karachi area. The catch rate per hour of trawling in this area is about 20 to 30 Kg.

Subarea 5. (No. of subsubarea 9)

This subarea includes Ormara, Kalmat and Pasni on Mekran Coast, a distance of nearly 180 miles. This subarea has good shrimp population but is less exploited, because the number of trawlers, which operate in this subarea is less. Moreover, there is no ice plant and fresh water facilities, Small trawlers from Karachi area are unable to go far a long trip. Shrimp fishing is usually done by cast net and small boats. The production of shrimps in this subarea is about 400 tons per year. The catch rate per hour of trawling in this subarea is the same as in subarea 4, *i.e.*, 20 to 30 Kg per hour of trawling.

Subarea 6.

This subarea is entered between Ras Shamal Bandar to the frontier of Persian Mekran about 110 miles, and has good shrimp fishing grounds. It is also underexploited and fishing is usually done by cast net. The production is about 500 tons per year.

The value obtained 0.72 for total areas may be referred to as the "catch per unit fishing effort" and employed as a *population index* (Kutkuhn, 1962).

If it is assumed that these statistics are reasonably accurate and that the biomass as manifested by the ratio of catch to effort (d_i) was constant within each the of i subsubareas throughout the period indicated, then the best index of population biomass is the weighed mean catch-effort ratio for each subsubarea. Hence:-

$$\sum_i w_i d_i = 0.91 \text{ (Fishable Biomass Index)}$$

where w_i, the area weighing factor, is the proportion of the total occupied area represented by i^{th} subsubarea. The value obtained 0.91 may also be referred to as the "catch per unit effective fishing intensity."

POTENTIAL OF THE STOCKS

The trawl used by the "MACHRANGA" (a 67-ft double rigged shrimp trawler) was 60-ft semi-balloon trawl, which has a swept area per hour of cca 0.0212 sq. mi (naut.), when towed at a speed of 3 knots. For two trawls towed simultaneously off port and starboard booms, the swept area is approximatly 0.0424 sq. mi (naut.). Using a value of 31.00 Kg per hour trawling as an index of density for the continental shelf area, and assuming a catch efficiency of the trawls of 1.0, we arrive at a standing stock for "Jaira" and "Kalri".

West Pakistan Coast

(5-75 m Interval)

1. Number of hauls: 3948
2. Total catch: 182.133.00 Kg
3. Hours fished: 5815.00
4. Average catch per hour: 31.00 Kg
5. Area sampled per hour: 0.042 sq. mi (naut.)
6. Total area: 10.000 sq. mi (Naut.)
7. Estimating standing stock (P_w): 7.4 x 10^6 Kg

In calculating the standing stock natural mortality of shrimps of the coast of West Pakistan was considered to be in the range 0.5 - 1.0 (implying that the average life-span would be only 1-2 years). Hence, the maximum average sustainable yields would be between 0.5 and 1.0 times 0.4 the virgin stock size.

Using above figure of 10.000 sq. mi (naut.) or 34,000 sq. km and potential of 7.4 x 10^6 Kg gives an estimate of 218 Kg/sq. km or 2.18 Kg/ hectare.

This as described earlier is for the most part based on the assumption that most species will ultimately yield unfished standing stock catches in the order of 20-40 per cent per annum of the original standing stock. The total expectation of the sustainable shrimp yield ("Jaira" and "Kalri") off West Pakistan is from 1,500 to 3,000 metric tons.

INTERACTION BETWEEN SHRIMP AND FISH STOCKS EXPLOITATION

Some areas of operations by commercial boat "MACHRANGA" were very congested with trawlers (about 225 trawlers have been working on an area of about 25 square miles on 24th April, 1969 outside Phitti and more than 150 trawleis on an area less than 20 sq. miles on 26th January 1970 off Cape Monze). Therefore,

there are many symptoms of destruction of fish and shrimp stocks, especially outside Karachi. The reason for decline in the quantity of landed fish at Karachi Fish Harbour, in our opinion, is probably connected with interaction between fisheries on different stock in the same area. This statement is also tested by landings of demersal fish and shrimps inhabiting the coastal waters off West Pakistan. This very important problem for Pakistan's fisheries is presented in Table 10.

TABLE 10. *Interaction between shrimps, fish and "trash" fish catches by "MACHRANGA" during 1966-1969*

Year	Fishing days	No. haults	Fishing hours	Shrimp (Kg)	Catch Fish (Kg)	Trash fish (Kg)
			Area			
			Karachi and Sind Coast			
1966	166	546	927.45	24630	20638	69118
1967	158	713	970.15	40939	5763	151705
1968	157	657	972.40	34267	9163	268214
1969	145	519	759.45	15653	5421	124400
Total	626	2435	3650.25	115489	40985	613437
			Area			
			Sonmiyani Bay and Mekran Coast			
1966	108	352	657.23	16378	34098	115804
1967	75	414	445.02	14172	3198	91151
1968	66	282	460.30	13834	7938	102196
1969	101	456	780.30	17841	17940	213847
Total	350	1504	2343.25	62225	63174	522998
			Karachi & Sind + Sonmiyani Bay & Mekran Coast			
1966	274	898	1585.08	41008	54736	184922
1967	233	1127	1415.17	55111	8961	242856
1968	223	939	1433.10	48101	17101	370410
1969	245	975	1540.15	33494	23361	338247
Total	975	3939	5973.50	177714	104159	1136435

Examination of Table 10 illustrates that a sizeable quantity of "trash" fish is caught with shrimp which are thrown overboard again. The proportion of shrimps to "trash" sometimes is approximately 1 : 25 (Plate I B and C).

We can use catch ratio given by "MACHRANGA" to calculate the total catch of "trash" fish along the coast of West Pakistan. In calculating the total catch of "trash" fish it is assumed that the ratio of catch of the single trawler was about 40% of "MACHRANGA" catches. Table 11 provides an estimate of the total during catch of "trash" fish in relation with the total landings at the Karachi Fish Harbour 1966-1969.

TABLE 11. *Estimating catch-ratio between "trash" fish and total landings at Karachi Fish Harbour during 1966-69 (In tons)*

Year	No. of trawlers	Catch of trash fish	Total landings of fish at Fish Harbour	Catch-ratio
1966	296	23680	89725	1 : 3.8
1967	320	31072	62622	1 : 2.0
1968	363	53712	54572	1 : 1.0
1969	403	54641	66294	1 : 1.2

Table 11 shows that large quantities of fish discarded at present can be employed usefully for production of fish meal and in the form of products like fish protein concentrates. (F.P.C.).

FLUCTUATION AND VARIATION IN ABUNDANCE OF COMMERCIALLY IMPORTANT SPECIES OF SHRIMPS

Factors effecting catches

Diurnal and seasonal migrations of shrimps can affect the catch considerably. Therefore, an important subject, in our opinion for study of shrimp stock is the problem of the causes of and the factors regulating the diurnal and seasonal fluctuation in abundance. Understanding of these might assist in prognosis of the seasonal migration, and be of value for the location of concentration of shrimp species.

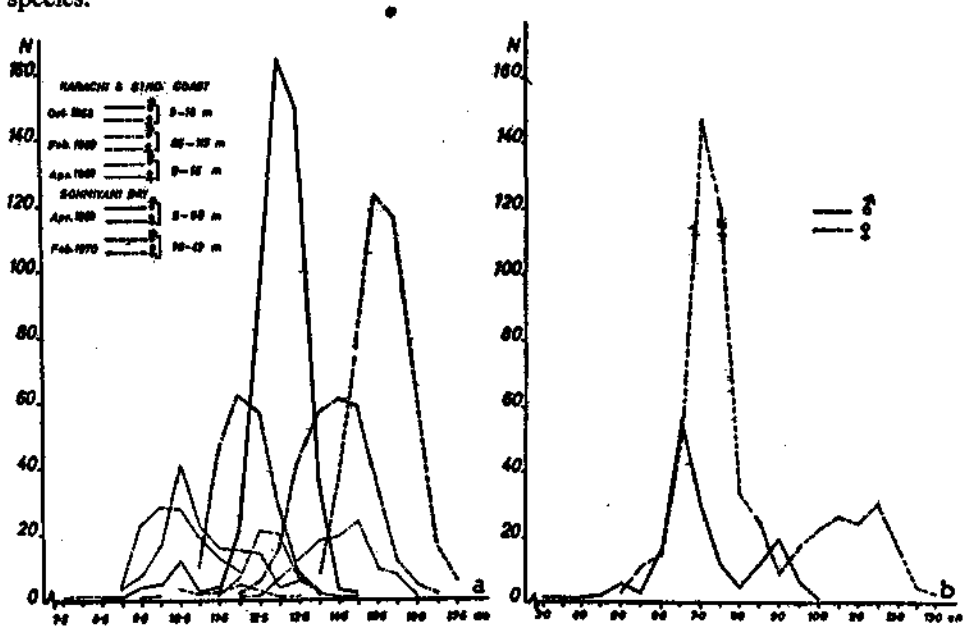

Fig. 6 a. Length frequency distribution of *Metapenaeus monoceros* off the coast of West Pakistan; and b. Size frequency of female and male *Parapenaeopsis stylifera.*

Dirunal Fluctuation

Diurnal fluctuation in catch of shrimps by M. V. "MACHRANGA" is presented in Fig. 7 b.

The results of our analysis show that the higher catches per unit effort (Kg/hr) were obtained during the daytime. The present observations also suggested that the daily fluctuation in catches might be influenced by intensity of light or by the tidal rhythm (manuscript in preparation).

Seasonal Fluctuation

Seasonal fluctuation in landing of shrimps at Karachi Fish Harbour during 1965-1970 by M. V. "MACHRANGA" is presented in Fig. 8.

This figure shows that October is the peak season for "Jaira" and "Kalri". In July the landing is the lowest and increases during the subsequent month but again falls from January onwards. This, perhaps, shows that shrimp population

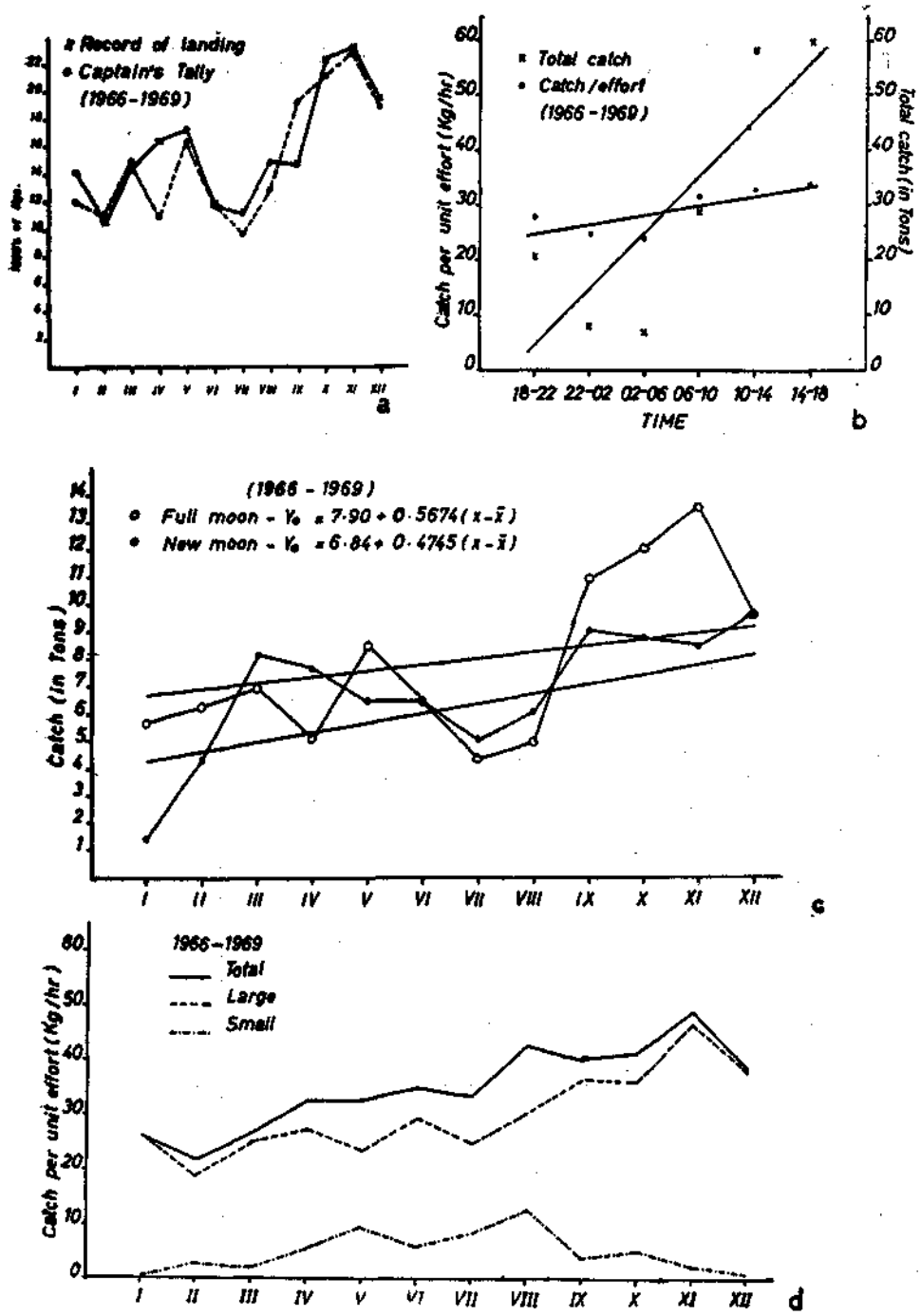

Fig. 7 a. Discrepancies between Captain's Tally and record of landing; b. The catch of shrimp related to time of day, during 1966-1969; c. The catch of shrimp in relation to lunar phases; and d. Average catch per unit effort of shrimp by M. V. "MACHIRANGA" arranged by size.

migrate from deep water to shallow water in the month of August-September (after monsoon season), but they again migrate in January in reverse, *i. e.*, from shallow to deeper waters.

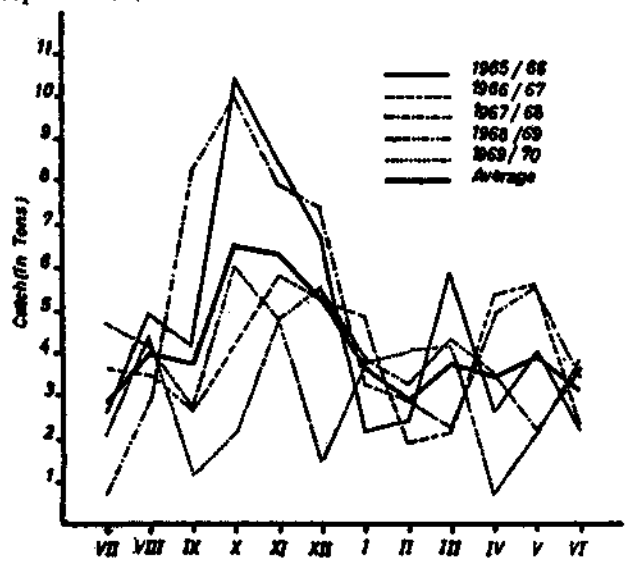

Fig. 8. Monthly catch rates by M. V. "MACHRANGA" during 1965-1970.

Offshore Move.nent

The offshore movement of shrimps from January, particularly of the larger species, *Metapenaeus monoceros* and *Penaeus semisulcatus*, indicates prospects of better yield if trawling is carried out in deeper waters. The better catches of shrimps obtained by commercial boat "MACHRANGA" from the deeper waters off sonmiyani Bay, operating during winter and spring seasons (Jan. - Apr.) of 1966-1969 lend additional support to this hypothesis (Table 12).

TABLE 12. *Distribution of shrimps at different depths during January-April, 1966-69*

Year	Month	Sonmiyani Bay Av. depth (m)	Fishing hours	No. of hauls	Total catch (Kg)	Catch rate (Kg/hrs)
1966	I	14.8	54.15	40	1182	21.74
,,	II	14.1	26.15	17	376	14.40
,,	III	20.1	75.45	44	2885	37.84
,,	IV	21.4	35.15	21	470	13.38
Total	I-IV	17.9	191.30	122	4884	25.53
1967	III	21.2	38.00	26	1106	29.10
,,	IV	23.8	8.15	6	90	11.07
Total	III-IV	21.8	46.15	32	1197	25.92
1968	I	24.5	81.15	41	3001	36.97
,,	II	26.2	43.00	18	1878	43.67
,,	III	21.9	53.40	36	759	14.22
,,	IV	24.9	8.00	5	161	20.13
Total	I-IV	24.0	185.55	100	5799	31.25
1969	I	30.0	68.30	43	2073	30.35
,,	II	43.7	168.30	83	2726	16.20
,,	III	54.4	189.45	97	3876	20.45
,,	IV	50.0	129.30	71	2777	21.51
Total	I-IV	47.2	556.15	294	11452	20.59

It is evident from Table 12 that the offshore movement of shrimps commenced from January onwards. The distribution and movement of the adult shrimps are, probably connected with the most dense concentration of feeding benthos, spawning migration and with the influence of the environmental factors, such as physical and chemical characteristics of the water masses and their seasonal changes.

According to investigations of the Azcher NIRO Expedition (Jan - March, 1969) in area of Sonmiyani Bay, the average benthos biomass was very high. The most dense concentration of bottom animals was located at depths of 20–50 m, and 51–80 m (personal communication). Thus, the feeding conditions for shrimps were favourable at the study time.

The relationships between the temperature of sea water near bottom, the average benthos biomass (g/m^2) and catch of shrimps at different depths, are shown in Table 13.

TABLE 13. *The relationships between bottom temperature, the average benthos biomass (g/m^2 and catch of shrimps by commercial boat "MACHRANGA"*

1969 Month	Sonmiyani Bay Average depth (m)	Bottom T°C	Average benthos biomas (g/m^2)	Total catch (Kg)	Catch rate (Kg/hrs)
January	30.0	21.29	6.9	2073	30.35
February	45.0	22.68	27.4	2726	16.20
March	55.0	22.76	35.0	3876	20.45

The data of Table 13 show that in period from January to February the benthos biomass in the area of Sonmiyani Bay increased four times. In March also the benthos biomass in this area was much higher than in January. The bottom temperature also increased off the coast. Thus, in period from January to March increasing bottom temperature and the standing crop of the benthos biomass, off the coastal zone, probably influenced the offshore movements and distributon of shrimp stocks (the spwaning and feeding movements in this case might be mutually related).

Apart from these movements which form a link in the life cycle, many shrimps perform, sometimes, mass movements which frequently bear a protective character. Examples of such movements are the movements away from the coastal zone or toward the surface when the bottom waters are cooled by "upwelling".

Effect of Moon on the Catch of Shrimp

Some authors considered that the phases of moon may exert considerable influence in catches. Menon and Raman (1961) found higher catches at new and full moon and a couple of days following each. Subramanyan (1965) observed relatively better catches of shrimps during the darker fortnights in the stake net fishery of the Godavari estuarine system on the east coast of India. George *et al.*, (1968) recorded a comparatively better yield of shrimps during the brighter phase of the moon.

Lunar effect on the shrimp catch has also been observed by authors on the coast of West Pakistan during 1966–1969 (Fig. 7 c).

In studying the problem of yield in relation to lunar phases (new and full moon) the authors concluded that there is reason to believe that shrimps fishing increased in brighter phase of the moon. The difference between the two series is not suggestively and stastically significant (P = 0, 10-0, 05).

BIOLOGICAL EFFECT OF WATER MASSES

Monsoon and Upwelling

The circulation of the surface water in the Arabian Sea and adjacent sea is influenced by the monsoons. The strong south-west wind during May to early September often deflect large masses of water from the surface and the replenishment of these by the deeper waters takes place by the process of upwelling (Panikkar, 1967). The cool water is present from July onward below 50 m, sometimes even at shallower depths. Off Karachi this situation may persist from April-May (Lee, 1963) to November (Doe, 1965). The cool water has a low oxygen content.

The main reasons of formation of such a minimum of dissolved oxygen lie in the climate and hydrological peculiarities of the regions of formaton of deep water and also in a high intensification of biological and chemical processes in the Arabian Sea (Neyman, 1961).

The upwelling appears to be seasonal; there is no evidence that upwelling occurs during the northeast monsoon (Banse, 1968). The northeast monsoon (November-March) however, brings about considerable changes in the circulatory patterns, especially in the northern areas. Horizontal temperature gradients with warmer water offshore prevail near the coast of Saurashtra and West Pakistan from December to about April (Warners, 1952). They are strongest from November to February, and may be taken as an indication of upwelling to the surface. Some authors (Jayraman and Gogate, 1957; Caruthers *et al.*, 1959; Neyman, 1961; Galagher, 1966; Haq, 1968) have tentatively suggested upwelling in the northern Arabian Sea during the northeastern monsoon.

Hydrography of the Sea Shelf

Doe (1965) observed physico-chemical conditions of neritic region along the south coast of West Pakistan during the post-monsoon calm. According to him, in November and early December thermal stratification starts building up as calm period returns after a long vigorous mixing in the area under the influence of SW monsoon. The stable layer as thick as 10-20 m near the coast and 50-70 m towards the edge of the shelf is noticed which coincide with thermocline formation in the region. Oxygen distribution also changed to gradient formation with marked decline in concentration from within the euphotic zone downward to a level below 1 ml/L. The phosphate concentration at most of the stations was below. The deficiency in the nutrient in the surface water during post-monsoon may partly be due to thermocline formation and to phytoplankton bloom which generally occurs in the area in October and early November.

Haq (1968) made observation on the physical, chemical and biological conditions prevalent in the waters off the eastern coast of West Pakistan during the premonsoon period (March, 1967). In contrast to Doe's observations, the studies made during early spring show considerable change in the physico-chemical

features of the sea particularly with regard to temperature, oxygen and phosphate distribution. The top mixed layer in the area is extended to about 70–100 metres depth towards the edge of the continental shelf and that no distinct thermal stratification is noticed at the inshore stations. The oxygen profile showed decline content from within the euphotic zone, approaching anoxic conditions at 250 metre depths in the offshore stations. The phosphate concentration is markedly high as compared to that of post-monsoon calm period suggestive of very high fertility and mineralisation to have taken place during this period.

The variation in the physico-chemical parameters noted in the two areas, referred to above, may largely be attributed to seasonal differences.

Oxygen and Catch of demarsal fishes and shrimps

a. Fish

Earlier work in the Arabian Sea shows that the movement of oxygen deficient zone towards the surface takes place, particularly, in the area of "upwelling" near the coastal region under the influence of monsoon (Banse, 1959, 1968), causing fish mortality due to oxygen depletion (Neyman, 1961; Panikkar,1967; Banse, 1968; Elizarov, 1968). Hida and Pereyra (1966) found a poor, although a significant correlation of catch to the oxygen, and an inverse correlation of the phosphate content of the bottom water off Karachi. The authors are of the opinion that the tongue of mixed waters, as indicated by low phosphate concentrations, intruded over the continental shelf just north and east of Karachi, caused in general, the large trawl catches in the areas of well mixed water. Banse (1968) has suggested that the distribution of the bottom fauna, demersal fishes and prawns between Bombay and Karachi would, sometimes, be affected by the oxygen content above the sea bed. The fishes very likely disappear before the oxygen has completely vanished.

Examination of the data obtained in respect of vertical distribution of oxygen, in the northern part of the Arabian Sea in April, 1960 (Chimitza, 1968) indicates its association with three layers, *i. e.*,

1) a top 100 m layer with very rich concentrations of oxygen;
2) the layer with minimum concentrations of oxygen (100-1000 m); and
3) below 1000-1500 metres depth down to the bottom, the oxygen concentrations show slight increase again.

TABLE 14. *Relation between temperature of bottom water, oxygen and catch per unit effort (Kg/hrs) in Jan - Feb., 1969 on the continental shelf area in the northeastern part of the Arabian Sea*

Depth (m)	Bottom T°C	O_2 ml/L	Catch (Kg/hrs)
20	20.22	4.98	100
25	21.83	4.92	100
30	21.54	4.93	500
40	22.64	5.04	1000
50	23.38	4.16	1500
90	23.17	4.08	800
100	23.67	4.03	500
250	17.16	0.16	20

Between the surface and 100 metres there is Arabian Sea water of high oxygen content. Next to that, we find Persian Gulf water with very poor concentrations of oxygen and this water is found at 200 m depths, which represents an oxygen minimum. Further down at 400 metres depth we find traces of Red Sea water, also of poor oxygen. The deoxygenation of the near-bottom water results in the regular disappearance of demersal fishes and in unprofitable trawling in a belt between the aerated water nearshore and the relatively new bottom water on the outer of shelf. Table 14 shows the catch-rates of fishes per unit effort of one hour's trawling according to depth, temperature and oxygen content

It is evident from Table 14 that there is obvious relation between bottom temperature, oxygen and catch per unit effort in the shallow and deeper waters.

In some years (during the cold season) the species of family *Sciaenidae* are caught in large numbers by the fishermen quite near to the coast. These fishes by habit, remain near the sea bed and are caught in fairly large numbers by the trawl-net but when in schools they are found near the surface. Qureshi (1955) had the opportunity of seeing a portion of a shoal in November, 1948 which consisted of about 6,000 fishes. The catch consisted of *Sciaena sina, S. diacanthus* with a few *S. glaucus* also. The largest catch during the winter season recorded in 1959 near Karachi comprised 30,000 fishes, the weight varied between 16 to 30 lbs.

Large population of fish at the surface are very often associated with regions of upwelling. Along the Saurashtra coast of India, cool subsurface water creeps up over the continental shelf as the monsoon and the surface current change. It is then that the great Indian salmon *(Polynemus indicus), Polydactylus indicus* or '*Dara*' swarms into the stake nets. Similar phenomena occur annually on the north-eastern shore of the Arabian Sea. The "upwelling" may reduce the bottom temperature, and at such time in some years the fish may leave the bottom and may be caught only at the surface and towards the beach. This phenomenon is also observed by Longhurst (1964) for *Sciaenidae* off Ghana, where the upwelling is strongest.

b. Crustaceans

Crustacea are in the same situation as are demersal fishes when the cool water is upwelling during the southwest monsoon. George *et al.* (1968) found that the physical and chemical properties of the sea (upwelling) could possibly have influence in the size distribution and movement of the commercial prawns of the southwest coast of India.

There are scattered notes that this might be true for the postmonsoon period off the coast of West Pakistan. During June and July, due to upwelling caused by the strong monsoonic winds, water from the bottom which has low oxygen content and high nutrient salts, was observed rising to the surface. By the month of August the bottom layer of poor oxygen was observed to have risen up to a depth of about 150-100 metres in the open sea and to 50-30 metres in the shelf zone.

Similar conditions persisted in the months of September and October. Sometimes in these months drift currents activated by the previous monsoonic winds caused such intensive upwelling of poorly oxygenated deep waters from the bottom

to the surface that the oxygen content in depths beyond 30 metres reached critical value of 0.25-0.50 ml/L causing fish and shrimp to migrate to the oxygen rich layers within 30 metres depth zone.

The increased mean catch per unit effort (stock abundance) during the summer and autumn seasons in shallow water, and decrease of shrimps catch from January onwards (Fig. 7d) could be interpreted as caused by shrimp movement "from adjoining deeper zones" and vice versa. Sometimes, the adult shrimps come in with cool, upwelling water at the surface during the cold season, and may be caught in tons then.

If the "upwelling" or "breeding" migration, and consequently abundance or scarcity of shrimps in shallow water appeared to be related, the catch in deeper waters should be of special importance. The aeration of the bottom water on the shelf during the winter season could make the fish and shrimp population reach much further seaward than is known today (Banse, 1968; Hussain *et al.* 1968).

This hypothesis has been substantiated by the catches of fish and shrimps taken by R. V. "ANTON BRUUN" in the deeper waters of West Pakistan coast during November and December, 1963, as well as from our analysis of catches per unit effort during the winter season.

CONCLUSIONS

The results obtained by the analysis of fishery resources off West Pakistan are as follows:

1. The catch per unit effort of one hour's duration in area close to Karachi, shows an apparent decrease. Any increase in numbers of trawlers in this area will be probably followed by a corresponding decrease in the average catch per boat.

2. If intensity of fishing in the coastal waters continues to grow opportunities per increased production will be limited to two alternatives: a. obtaining a greater yield from existing underexploited fishing grounds (potential catches in the subareas 1, 2, 5 and 6) and b. extending existing fishing grounds to greater depths (around Swatch ground, Kori Great Bank and off the mouth of Indus river on the Sind and Karachi Coast and off all Mekran Coast).

3. In the offshore waters, between 30-100 m the demersal species may form the bulk of the potential fish resources, during winter and spring seasons.

4. It is estimated that the potential catches of demersal fish off West Pakistan could be, by better management, as much as 40 Kg/ha.

5. An effort should be made to apprise the stocks of sardine, tuna, mackerel, carangids and some other pelagic fish in view of their further exploitation.

6. The total expectation of the sustainable shrimps yield is too low. Continuous decline in catch of large specimens and the increase of undersized and commercially non-important species, may be connected with an apparent higher fishing mortality of adult individuals.

7. The catch related to the time of day indicates that the catch per unit effort (Kg/hr) was higher during daytime.

8. A 'selective' shrimp-trawl must be designed (based on shrimp behaviour) for interaction between shrimp and fish exploitation on the same area.

9. The distribution and offshore movements of the adult shrimps and fish during the cold season might be connected with influence of the environmental factors, such as physical and chemical characteristics of the water masses and their seasonal changes.

10. A particular emphasis ought to be put on studying the relation between oxygen content on shelf and fish and shrimp catch.

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DISCUSSION

S. OLSEN : Was the gear used the same all the time, if not how was comparisons made and the subsequent computations of standing stock?

S. ZUPANOVIC : The gear are of the same size. The Research vessel "MACHHERO" and the commercial vessel "MACHRANGA" are 67' length.

A. NOBLE : The title of your paper, Dr. Zupanovic, is "A survey of the fishery resources in the northeastern part of the Arabian Sea". Throughout in the presentation you were dealing only with trawling and demersal fishes. Does it mean that there are no pelagic fisheries in the area?

S. ZUPANOVIC : My paper includes also the pelagic resources.

JOHN P. GEORGE: Is your observation on prawn landings confined to a single observation or to a series of observations?

S. ZUPANOVIC : A series of observations have confirmed the findings as regards to prawn abundance.

JOHN P. GEORGE : Any difference between new moon and full moon nights?

S. ZUPANOVIC: During day time and brighter phases the catches are better.

JOHN P. GEORGE At certain regions it has been noticed that the catches start increasing from 6.00 P. M till midnight and then they appear to decline; again increase from sun rise till 8.00 A. M and then taper off. Are there such features in your data?

S. ZUPANOVIC : Similar behaviour of Prawns, we found along the coast of West Pakistan.

T. PIYAKARNCHANA : Do you find any differences between day and night catches of the prawn?

S. ZUPANOVIC : Yes, we found the differences between day and night catches of prawns. The better catches were during the day time.