The Bombay Duck, *Harpodon Nehereus* (Ham.)

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THE BOMBAY DUCK, *HARPODON NEHEREUS* (HAM.)

By
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September, 1970

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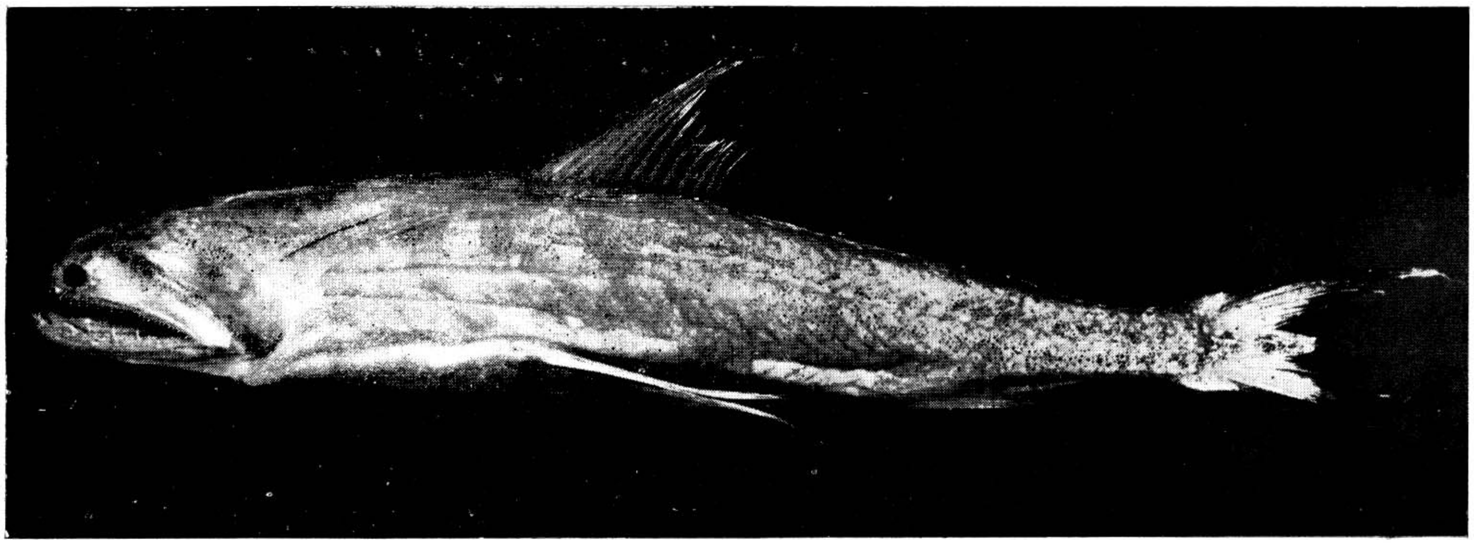


The Bombay duck, ***Harpodon nehereus*** (Ham.)

CONTENTS

FOREWORD

The Bombay duck fishery supported by a single species, *Harpodon nehereus*, contributes to about 10% of the estimated average annual marine fish landings of India. With a peculiar disjunct distribution of the species, the fishery is of utmost importance in two maritime states of Gujarat and Maharashtra, where over 98 percent of the all-India Bombay duck catches are landed. In fact, from the bulk of the landings and the economic returns, the Bombay duck fishery in Gujarat and Maharashtra is what the oil sardine and mackerel fisheries are in the Mysore and Kerala States. From the fishery statistics collected by this Institute it is seen that there are both annual and long term fluctuations in its fishery as in the other single species fisheries. Its landings are however comparatively steadier, for they have never touched such alarmingly low levels as witnessed often in the case of the oil sardine and the mackerel fisheries.

A good amount of fishery biological work on *H. nehereus* by Dr. S. V. Bapat has been carried out at this Institute and I express my very high appreciation of the investigations carried out and offer my sincere thanks to him for having ably compiled the results of his own work and the work of others in this field and presented the material for this Bulletin, which is expected to furnish a fairly comprehensive account to those interested in the subject. I also express my sincere thanks to all concerned for rendering the necessary help in various ways in bringing out this publication.

Dr. R. V. Nair
Director,
Central Marine Fisheries
Research Institute.

Mandapam Camp,
Sept. 22, 1970.

I INTRODUCTION

The principal aim of any comprehensive fisheries research programme is primarily to obtain a maximum sustained yield and avoid depletion of stocks. Researches on the biology of the species contributing to a fishery form an essential prerequisite in regulating the exploitation of stocks to the maximum advantage. The study of distribution of the species and the stocks from which the fishery is supported forms valuable information in assessing the fishery potential. Considerable amount of information on these lines in respect of the commercially important fish species has been gathered by the Central Marine Fisheries Research Institute in the past two decades.

The Bombay duck fishery supported by a single species, *Harpodon nehereus* (Ham) has received much attention from various workers. Setna (1939, 1949) and Gokhale (1957) have contributed valuable information on the crafts and tackle and the methods employed in fishing this species off the Bombay and Saurashtra coasts. Hora (1934) has attributed this discontinuous distribution of *H. nehereus* on the east and west coasts of India to varying salinities. He has also suggested that the availability of their favourite food in the particular areas may probably be responsible for their abundance. Chopra (1939) observes that the food of the Bombay duck mainly consists of shrimps and its migrations are traceable by the movement of shrimp shoals. Raj (1954) has made an attempt to correlate this peculiar distribution to the 80^0F July isotherm.

Pillay (1951, 1953) has studied the food and feeding habits of this species in the Matlah estuary near Calcutta and Bapat, Banerji and Bal (1951) have contributed valuable information on the recruitment to the stocks, the rate of growth, food and feeding habits, minimum size at maturity and the breeding season of this species off Bombay. Palekar and Karandikar (1952) have studied the ovaries and determined the minimum size at maturity and the spawning season at Bombay. Patakoot, Pradhan and Murti (1950) determined the fat content of the muscle of this species and found it to be too low.

Due to the advent of mechanisation of fishing craft, the fishing activity off the Maharashtra coast has considerably increased in recent years. Consequently the area of exploitation of the fishery has increased and the Bombay duck fishery today has attained the status of one of the major fisheries of India. Commensurate with the increased fishing effort, the landings of Bombay duck have phenomenally gone up from 2% of the All India sea fish landings in 1949 to nearly 17% in 1958. More than 90% of the total Bombay duck landings of India are from the Bombay-Saurashtra coast alone. Hence the success or failure of this fishery determines to large extent the well-being of the fishing community in the Maharshtra State. In addition, an export market for dried Bombay duck is building up with demands from the United Kingdom and the United States of America, and thus has become a commodity of valuable foreign exchange earning.

The present work which deals with a comprehensive account of our knowledge of the fishery and biology of *Harpodon nehereus* is expected to help in formulating expansion programmes of further research and exploitation of one of the major marine fishery resources of the country.

The author acknowledges with pleasure and gratitude, the encouragement and valuable advice given by Dr. R. V. Nair, Director of the Central Marine Fisheries Research Institute in the preparation of this bulletin. Part of the present work was submitted in the form of a thesis to the University of Bombay for the Ph. D. degree under the guidance of Dr. D. V. Bal, Director and Professor of Zoology, Institute of Science, Bombay to whom he expresses his sincere thanks. He is grateful to Shri S. K. Banerji, Head of Division (Survey and Statistics) of the Central Marine Fisheries Research Institute who took special interest in this investigation from the beginning and gave valuable help in the statistical analysis and interpretation of data. His sincere thanks are due to Shri K. Virabhadra Rao, Fishery Scientist for help rendered in editing the material in the present form.

II TAXONOMY AND DISTRIBUTION

IDENTITY

Phylum: Vertebrata
Sub-phylum: Craniata
Superclass: Gnathostomata
Series: Pisces
Class: Teleostomi
Subclass: Actinopterygii
Order: Physostomi
Family: Scopelidae
Genus: *Harpodon* Le Sueur 1825
Species: *H. nehereus* (Hamilton) 1822.

Description

Genus *Harpodon* Le Sueur 1825: Journal of the Academy of Natural Sciences, Philadelphia Vol. V, P. 48 (Type: *Osmerus nehereus* Ham. Buch. 1822).

The genus derives its name from the enlarged teeth in the lower jaw, each ending in a sharp barb. Unequal and partly curved, subulate, depressible teeth in a band on the jaws, especially in the lower jaw the inner ones are enlarged and conspicuously hastate. Similar teeth present on the vomer, palatines, pterygoids, tongue and branchial arches. Body elongate, compressed. Head thick, very short with very short rounded snout. Cleft of mouth very wide, slender intermaxillary, the maxillary being absent. Lower jaw prominent. Dorsal in the middle of the length, narrow adipose fin opposite to the middle of the anal. Caudal three lobed, the lateral line being continuous with the central lobe. Ventrals exceedingly long. Gill openings extremely wide. Branchiostegal membranes free and extending beyond the opercles. Branchiostegal rays 17-25.

Distribution

The Indo-Pacific region, along the coasts and estuaries.

Nomenclature

Gunther (1864) included the genus *Harpodon* under the family Scopelidae. Jordan (1923) created the family Harpodontidae.

The earliest record of the fish was from the mouth of Ganges by Hamilton (1822) who called it *nehereus* and referred it doubtfully to the genus *Osmerus*. Le Sueur (1825) proposed the generic name *Harpodon* for his *Salmo microps* which is synonymous with *Osmerus nehereus*. Gunther (1864) assigned the species *nehereus* to the genus *Harpodon*.

Three more species, *H. microchir* Gunther, *H. squamosus* Alcock and *H. mortensoni* Hardenburg, have been described under this genus of which only *H. squamosus* Alcock is from Indian waters.

Harpodon nehereus (Hamilton)

Br. 23-26; D. 12-14; A. 14-15; P. 11-12; V. 9, L. l. *ca* 40.

Height 5-8, head about height. Body soft, translucent, lateral line tubules phosphorescent commencing behind the head, eye very small covered by adipose membrane; pectorals reach below middle of dorsal and as long as ventrals. Brownish to grayish white, fins darker.

Synonyms

Osmerus nehereus Hamilton Buchanan 1822
Salmo (Harpodon) microps Le Sueur 1825
Saurus ophiodon Cuvier & Valenciennes 1849
Saurus nehereus Cantor 1850
Harpodon nehereus Gunther 1864

Local names

Harpodon nehereus (Ham.)

Bombay duck	…	English
Bombil	…	Marathi
Bumaloh	…	Bengali
Cucah sawahri Coco mottah	…	Telugu

DISTRIBUTION

From Zanzibar to China, Seas and estuaries of India, most common at Bombay reducing in numbers along the Kerala coast. Is seen in small numbers along the Coromandal coast and is abundant in the estuaries of Bengal, East Pakistan, Burma and Straits of Malacca.

III. BIONOMICS AND LIFE HISTORY

REPRODUCTION

Sexuality: The sexes are separate and no hermaphrodite individuals have so far been recorded. The sexes cannot be differentiated from external morphological features.

Maturation: The ovary can be distinctly differentiated for the first time in fish measuring between 120-140 mm against testis in the male at 170 mm. Therefore fishes below 120 mm can be termed as indeterminates. In immature fish the ova are more or less round with a large central nucleus and vary between 0.045-0.14 mm. In the ova of the maturing fish yolk deposition along the periphery takes place but the nucleus is still visible but not distinctly; the ova reach a size of 0.26-0.37 mm in diameter. In mature fish, the ova are spherical, the entire space is occupied by vacuolated yolk and the nucleus is not discernible. In advanced stages of maturation, the yolk becomes transparent at the periphery and in still advanced stages, accumulation of yolk at one or two places may develop into an oil globule. The ova now measure between 0.37-0.60 mm in diameter and are more or less spherical. In the ripe ovary the ova are loosely strewn. The vacuolated yolk is completely diffused, and is translucent with a distinct oil globule. The ova have a size range of 0.60-0.75 mm.

Minimum size of maturity in the female: In order to determine the minimum size of maturity a total of 323 specimens were examined. They were grouped into 10 mm size groups and analysed into immature, maturing, mature, ripe and spent fish based on their gonadic condition (Table 1). It can be seen from the table that fish below 190 mm length did not spawn at all as majority of them possessed immature gonads. In the 190-200 mm size group 4.34% of fish were observed to have ripe gonads. The remaining in this class were either immature or maturing. In the next size class i. e. 200-210 mm, 5.40% of the fish were ripe and another 5.40% were mature. The remaining fish were either immature or maturing.

Table 1

Size distribution of immature, maturing, mature, ripe and spent individuals in commercial landings

Size group in mm	Number examined	Immature (Stage I)		Maturing (Stage II & III)		Mature (Stage IV & V)		Ripe (Stage VI)		Spent (Stage VII)	
		No.	%	No.	%	No.	%	No.	%	No.	%
131-140	5	5	(100.00)								
141-150	5	5	(100.00)								
151-160	6	6	(100.00)								
161-170	9	9	(100.00)								
171-180	15	15	(100.00)								
181-190	11	9	(81.81)	2	(18.19)						
191-200	23	18	(78.26)	4	(17.39)			1	(4.34)		
201-210	37	23	(62.16)	10	(27.03)	2	(5.40)	2	(5.40)		
211-220	49	29	(59.18)	11	(22.44)	3	(6.12)	5	(10.20)	1	(2.04)
221-230	34	18	(52.94)	10	(29.41)	1	(2.94)	5	(14.70)		
231-240	30	11	(36.66)	12	(40.00)	2	(6.66)	5	(16.66)		
241-250	22	6	(27.27)	9	(40.91)			4	(18.18)	3	(13.63)
251-260	33	5	(15.15)	10	(30.30)	6	(18.18)	9	(27.27)	3	(9.09)
261-270	9			3	(33.33)	3	(33.33)	1	(11.11)	2	(22.22)
271-280	7			4	(57.12)	1	(14.28)	1	(14.28)	1	(14.28)
281-290	10			3	(30.00)	4	(40.00)	1	(10.00)	2	(20.00)
291-300	7	1	(14.28)	1	(14.28)	2	(28.56)	3	(42.84)		
301-310	5	1	(20.00)	2	(40.00)	2	(40.00)				
311-320	5			1	(20.00)	4	(80.00)				
321-330	1					1	(100.00)				
Total number examined	323										

From this size class onwards the percentage of mature and ripe fish gradually increase till the recorded maximum size i. e. 330 mm.

It may be noticed that there is a sudden increase in the pooled percentage of mature, ripe and spent fish from the 250-260 mm size group onwards. This high percentage is probably due to the increase in the second and subsequent spawners in the population.

Palekar and Karandikar (1952) have determined the minimum size of maturity of *H. nehereus* as 240 mm. Bapat, Banerji and Bal (1951) in a preliminary study of the biology of Bombay duck have fixed the minimum size of maturity at 200 mm. The present observations show that *H. nehereus* attains maturity for the first time in its life between 200-210 mm in total length.

It may be pointed out that large quantities of fish below 200 mm in total length do not get an opportunity to spawn as they are being landed regularly at Bombay in the commercial catches. If this type of fishing continues, it is feared that the stocks of Bombay duck are likely to be affected resulting possibly in diminishing returns from the fishery.

Fecundity: It has been observed by previous workers that the number of eggs produced by a fish varies from species to species and within the same species according to its length. The larger females maturing on the second or subsequent occasion are known to produce more eggs (Palekar and Karandikar, 1952, 1953; Palekar, 1957).

For the determination of fecundity in *H. nehereus*, ovaries of seventeen specimens ranging from 229-318 mm in total length were examined. Ovaries in the V and VI stages of development were selected for this study. Care was taken to exclude spent or insufficiently mature fish. The usual procedure of determining the number of mature eggs was followed. The ovaries were preserved in 5% formaldehyde for over a week. After removing the ovaries from the formaldehyde, the surface moisture was drained and dried in the folds of a blotting paper. Then the entire ovary was weighed to the nearest milligram. A small piece of the ovary from the middle region was taken out and weighed accurately. This piece was teased on a microslide to separate the ova from each other. The number of mature eggs which could be distinctly seen by the naked eye were counted. From this number, the total number of eggs in the ovary based on the weight of the sample and the weight of the ovary was computed. The estimated number of ova along with the data on the length and weight of the fish and the length and weight of the ovary are given in the table below.

Table 2

Estimated number of mature ova with relevant data on length and weight of the fish and its ovaries

Length of fish (mm)	Weight of fish (gm)	Length of ovary (mm)	Weight of ovary (gm)	Estimated number of mature ova
229.0	61.0	94.0	3.60	26,578
240.0	67.0	101.0	4.78	52,501
247.0	87.0	96.0	1.185	17,859
250.0	93.0	99.0	3.70	23,632
265.0	107.0	110.0	2.607	20,517
273.0	95.0	114.0	7.439	68,256
283.0	134.0	106.0	7.017	53,295
285.0	137.0	118.0	22.837	1,26,717
291.0	167.0	135.0	28.007	1,46,416
292.0	103.0	121.0	5.577	14,606
294.0	139.0	122.0	11.379	74,596
295.0	159.0	112.0	4.487	29,650
299.0	127.0	115.0	4.477	27,561
308.0	207.0	125.0	4.082	29,501
308.0	169.0	132.0	3.657	15,885
314.0	180.0	122.0	9.077	66,240
318.0	179.0	132.0	11.467	81,205

It can be seen from the table that the number of ova produced by individual specimens of *H. nehereus* ranging between 229-318 mm in total length vary between 14,600-1,46,400. It can also be seen from the table that the length and weight of the fish do not apparently bear any relation to the total number of eggs produced. There is, however, a relation between the weight of the ovary and the number of mature ova.

The spawning season: In order to determine the spawning season of *H. nehereus* 323 female specimens were examined during a period of eleven months from July 1958 to May 1959. The specimens were dissected in the laboratory and the appropriate stage of development of the ovary was recorded. The data for determining the spawning season were analysed and the results of the same are given in Fig. 1.

It can be seen from the figure that the maximum percentage of specimens in the VI stage were in the month of July. But the total number of female specimens examined in July were only six, a comparatively smaller number than in other months. Therefore this high percentage of VI stage specimens in July cannot be given much importance although the presence of spawners in the month is conceded. In August and September 8.33% and 5.14% of spawners were recorded. It was only in the month of October, out of the eleven months, that fish of the V and VI stage were conspicuously absent. From November to February the percentage of spawners gradually increased, the highest percentage being in February. The percentage of spawners in March was also high. During April and May comparatively small percentages of VI stage specimens were recorded.

The VII stage i. e. the spent fish were first recorded in December and from there onwards were seen in all the months till May when they reached the maximum percentage of 10.

It has been stated earlier that *H. nehereus* attains maturity for the first time in its life between 200-210 mm. in total length. In view of this it was considered undesirable to include specimens less than 210 mm in total length for determining the spawning season, as by chance if a large number of specimens below 210 mm were taken in a month, it may vitiate the percentage of fish in the advanced stages of development and lead to erroneous conclusions. Therefore, the data on 216 specimens varying between 210-330 mm were reanalysed for the stage of maturity and the results of the same are given in Table 3.

It can be seen from the table that the occurrence of specimens in the VI stage is more or less of the same pattern as seen in Fig. 1. As for stage VII fish, the highest percentage was reached in the month of May with a similar peak in April. In view of the fact that this

Table 3

Showing the number and percentage of specimens in different stages of maturity during 1958-59 (specimens above 210 mm i. e. the minimum size at maturity are taken into consideration)

Month	Number examined	Stage I	Stage II	Stage III	Stage IV	Stage V	Stage VI	Stage VII
July 1958	4	1 (25.00)	-	-	-	-	3 (75.00)	-
August	6	2 (33.33)	3 (50.00)	-	-	-	1 (16.16)	-
September	24	6 (25.00)	16 (66.66)	-	-	-	2 (8.33)	-
October	27	12 (44.44)	7 (25.92)	6 (22.22)	2 (7.41)	-	-	-
November	25	12 (48.00)	5 (20.00)	1 (4.00)	-	5 (20.00)	2 (8.00)	-
December	28	15 (53.57)	3 (10.71)	-	1 (3.57)	3 (10.71)	5 (17.85)	1 (3.57)
January 1959	27	4 (14.81)	3 (10.71)	5 (18.52)	3 (11.11)	3 (11.11)	7 (25.92)	2 (7.41)
February	33	5 (15.55)	9 (27.27)	3 (9.00)	-	3 (9.09)	10 (30.30)	3 (9.09)
March	15	3 (20.00)	3 (20.00)	1 (6.66)	1 (6.66)	2 (13.33)	4 (26.66)	1 (6.66)
April	11	1 (9.09)	1 (9.09)	1 (9.09)	-	5 (45.45)	1 (9.09)	2 (18.18)
May	16	5 (31.25)	5 (31.25)	-	-	1 (6.25)	2 (12.50)	3 (18.75)
Total	216							

Figures in brackets indicate percentages.

table gives a more accurate picture of the distribution of VI and VII stage specimens amongst fish which have attained maturity, it is reasonable to draw conclusions based on these data.

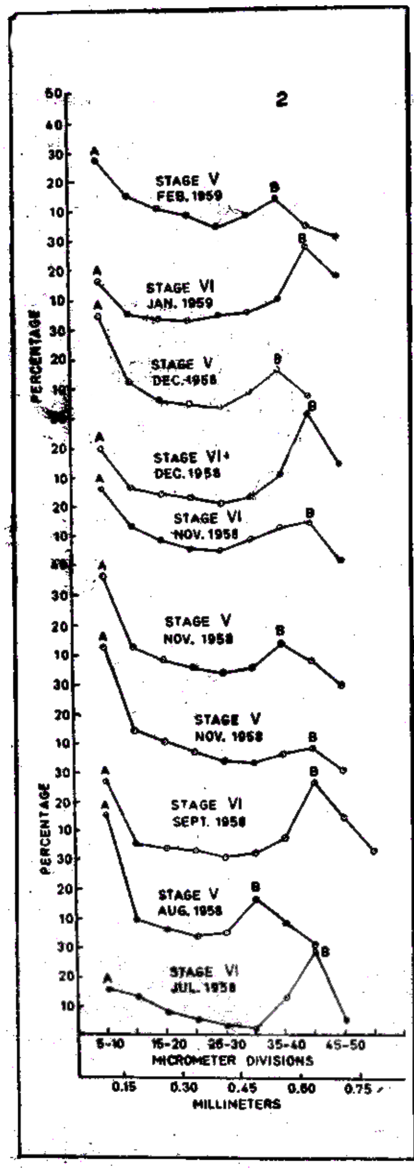
Except for October, VI stage specimens were recorded in all the months in fairly good percentages. From these observations, it appears that the species spawns throughout the year. In view of the limited number of female specimens examined in July, it is considered not proper to attribute much importance to the high percentage of VI stage specimens in the month. Similarly the absence of ripe fish in October may be ignored as an error of sampling, since earlier workers have recorded their presence. It can be seen from Fig. 1 that the highest percentage of ripe individuals was in February with a large number of them occurring during December to March. Based on these observations, the intensive spawning season for the species appears to be from December to end of March. This is further supported by the presence of spent individuals during December-March and the gradual increase in their percentage till the maximum is reached in May.

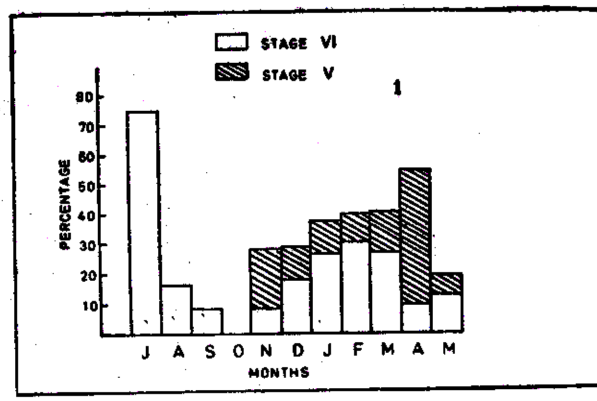
Palekar and Karandikar (1952) have suggested that *H. nehereus* breeds throughout the year, the spawning activity being intensive from October to April and slack from May to September. Bapat *et al*. (1951) in a study of the biology of this fish concluded that the species is a continuous breeder in view of the occurrence of mature specimens throughout the year. They also suggested the probability of two peak breeding seasons, the first falling between April-July and the second during November-December.

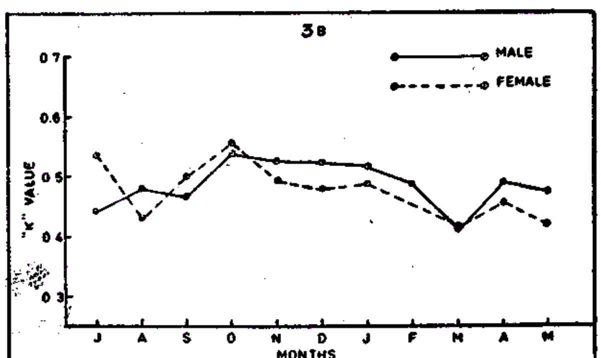
Spawning periodicity: In recent years the technique of ova-diameter measurements is frequently adopted to determine the spawning periodicity of fishes. Prabhu (1956) studied the spawning periodicity of nine species of fishes from Mandapam and the same method adopted by him is followed in the present study. The ova diameter measurements from the anterior, middle and posterior regions of the ovary were examined with a size interval of 5 micrometer divisions to study differences if any, in the distribution of ova of different sizes in various regions of the same ovary. It was found that the pattern of distribution of ova in all the three regions was more or less the same indicating that the ova of different diameters are uniformly distributed. Therefore the ova diameter measurements from the different regions of the ovary were pooled together and the results in respect of ten ovaries are graphically presented in Fig. 2.

It is seen from the figure that in July 1958 two modes are present. The first mode 'A' representing the immature crop is at 5-10 micrometer divisions and the second mode 'B' representing the mature crop at 40-45 m. d. In August also two modes 'A' and 'B' representing the immature and mature ova are visible. The only difference is that the mode 'B' is seen at 30-35 m. d. This variation can be explained by the fact that the specimen under study was in the V stage of maturity, whereas the former was in a more advanced stage, viz., the VI stage. Similarly, the remaining eight curves also prominently show two modes 'A' and 'B' representing the immature and mature crops well separated from each other. The only difference is the deviation of the mode 'B' which is due to the stage of development of the ovary under study. The mode 'A' represents throughout the immature stock of ova varying between 0.1 to 0.2 mm. in diameter. They are minute with a prominent nucleus and without any yolk deposition. The mode 'B' in all the graphs represents the mature ova with the size varying between 0.50-0.64 mm in diameter. Depending on the stage of the ovary they are seen to be either full of yolk where transparency or translucency has set in or more than half of the ova have already become translucent or even all the ova have become completely translucent ready for shedding. The ova in between the two modes represent the maturing ova and are comparatively very few in number.

Walford (1932) states that fishes which spawn only once in a season contain only two types of ova, the immature or the mature. Hickling and Rutenburg (1936) have concluded "In the ovary of the adult fish there is a general egg stock of small eggs. From this egg stock a quota is withdrawn each year to be matured and finally spawned and to this egg stock a fresh batch is added every year by the development of oocytes, the minimum period of development being two seasons. It has occurred to us that measurement of the diameter of eggs in ovaries well advanced towards spawning may give evidence of the duration of spawning in fish of which the spawning habits are unknown."







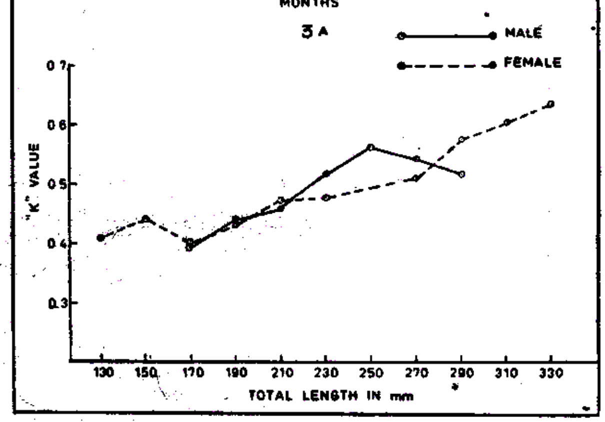


Fig. 1. Fluctuations in the percentage of stage V and stage VI specimens

Fig. 2. Frequency distribution of ova

Fig. 3A. Fluctuations in 'K' values in total length

Fig. 3B. Fluctuations in 'K' values in different months

Based on studies on *Therapon jarbua*, *Macrones vittatus* and *Chirocentrus dorab* Prabhu* (1956) has concluded "In the ovaries of fishes which spawn only once a year and in which the duration of spawning is restricted to a definite and short period, the mature stock of ova will be found to have differentiated from the general egg stock and in the whole ovary there will be only on batch of mature eggs to be shed during the succeeding spawning season."

Keeping in view the suggestions of these and many other workers, it is concluded from the present data on the ova diameter measurements of *H. nehereus* that the individual in the species spawns only once in a year. As specimens in the V and VI stages of maturity are recorded almost throughout the year, it has to be further concluded that the species as a whole has a prolonged breeding season.

In this context it will be appropriate to discuss the work of Palekar and Karandikar (1952) based on similar studies on *H. nehereus*. Majority of the curves in their figures relating to the frequency distribution of the ova diameters shown two distinct modes inspite of the fact that ova upto 0.21 mm have not been taken into consideration. The graphs for July, August 1946, May and June 1947 do not show the modes to be distinctly separate though the general trend of two modes continues to exist. The authors also agree to the presence of two modes, the first representing the immature crop and regarding the second they state as follows: "The second modal point is located in most cases at 0.64 mm. It represents collectively the group of maturing and mature ova, whose limits extend from 0.38-0.92 mm. No separation can be made between the maturing and mature groups as in the case of the immature group. The only assumption that can be made is that the ova lying on the left side of the modal point (i. e. from 0.31 to 0.64 mm) beyond the immature group, belong to the maturing stage, while those lying along the right side of that modal point represent the pure mature group."

In such studies, the entire mode which is nothing but a normal curve, represents on independent group and the modal point represents the mean value. It is not understood why the authors suggest to split the curve at the modal point, each part representing a different group. Under the circumstances, the very principle of drawing the size frequency distribution pattern where the modes represent the mean value of a group

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* Not listed in references

is lost. A critical examination shows that out of the twelve graphs, only in three cases the value of the second mode is between 0.38-0.64 mm, otherwise in most of the remaining months it fluctuates between 0.55-0.72 mm. In these graphs the maturing crop is represented by a mode. Moreover the number of maturing ova may be small and as is the case in the present study and hence not represented by a mode. Based on the assumption of splitting of the second mode, the authors have interpreted that there is a succession of ova from immature to maturing and to mature stages and have concluded that the fish breeds continuously throughout the year. If this interpretation were to be accepted, all the ovaries of fish above the minimum size of maturity, i. e. 240 mm, according to them, should be maturing, if not mature, as only the ripe ova are shed. In the present study, a number of fish 240 mm and above in total length with ovaries in the I and II stage of maturity have been recorded. Further a reference to table 4 and Fig. 5 of Palekar and Karandikar (1952) also shows the presence of fish which are not mature in the size range 240-304 mm.

In further support of their view they state that spent specimens in large number should be available if the species spawn only once as suggested by Walford (1932). This is perhaps true if the location of the breeding grounds of the species is very close to the finishing grounds. In case of *H. nehereus* just as spent fishes are few in the commercial catches, the actual spawners with fully ripe ova are also few suggesting thereby that the breeding grounds are away from the fishing grounds. Moreover, the percentage of spent specimens recorded by the authors in table No. 3 and also observed in the present investigation cannot be ignored. In view of the present observations, it can be inferred that the species as a whole breeds throughout the year but the individual of the species breeds only once in a year and not continuously.

Sex ratio: From an examination of 582 specimens of Bombay duck it is observed that sexes can be distinguished in fishes over 140-160 mm in total length. Though there are no external sex-differentiating features, the abdomen of females generally looks a little bulky particularly in fishes in an advanced stage of maturity. In specimens approximately below 160 mm in total length a microscopic examination of the gonad is necessary to determine the sex.

The distribution of males, females and fishes where sex could not be determined along with the sex ratio is given in the following table for a period of eleven months from July 1958 to May 1959.

Table 4

Sex composition in *H. nehereus* during different months

Month	Number exa- mined	Indeter- minate juveniles	Males	Females	Sex ratio
July 1958	26	-	20	6	77:23
August	39	1	26	12	68:32
September	59	6	16	37	30:70
October	39	1	10	28	26:74
November	51	11	13	27	32:68
December	83	12	25	46	35:65
January 1959	79	5	27	47	36:64
February	68	10	16	42	28:72
March	45	10	13	22	37:63
April	46	7	13	26	33:67
May	47	7	10	30	25:75
Total	582	70	189	323	100:171

It can be seen from this table that the ratio of the two sexes is not constant throughout the period and is fluctuating considerably. During the monsoon months of July and August the males were predominant in the catches. From September to May the females dominated the catches with negligible fluctuations in the sex ratio, varying between 25:75 and 37:63, When the data for all the eleven months are pooled, it is seen that the females predominate in the commercial catches, the ratio being 100 males for every 171 females.

The presence of large number of males during July-August suggests that the females have moved away from the inshore waters where fishing is normally carried out during these months. But it is rather difficult to explain this sudden movement of the females. The only explanation that could be put forward is that, after the main spawning season in

November-March, the spent females move out of the fishing grounds. Movements of this type, prior to or after the close of the spawning season, are not uncommon in fishes.

Ponderal index or the condition factor: The ponderal index is a measure to study the condition of the fish during different stages of growth and during different seasons. It reflect the general metabolic activities of the fish, viz. feeding, maturation, spawning, etc. and hence is appropriately termed the condition factor, generally denoted by 'K'. Hickling (1930) and Hart (1946) have correlated fluctuations in the ponderal index with the attainment of maturity and spawning. In the present study the 'K' values for 512 specimens of Bombay duck were determined individually by adopting the usual formula $K=\frac{W}{L3}$ where 'W' is the weight of the fish and 'L' the total length. In order to study the fluctuations in the 'K' values as the fish grows in size, the data were split up for both the sexes separately into 20mm length frequency groups and the average 'K' values for the size groups were determined and plotted in Fig. 3A. Similarly it was considered desirable to study the variations in 'K' in the two sexes for different months. Therefore the 'k' for all the sizes of one sex in a month were pooled together and the average values thus determined for the month were plotted in Fig. 3B. An attempt is made to study the fluctuations in 'K' in relation to the biological aspects, particularly the minimum size of maturity and the spawning season, observed during the course of this study.

It can be seen from Fig. 3A that ht values for 'K' in the case of the male go on increasing gradually upto 250 mm and thereafter there is a gradual fall. But in case of the female there is a sharp increase in the 'K' value at 150 mm followed by a decrease in the value at 170mm. From 170 mm onwards there is a gradual increase upto 210 mm. From 210 to 270 mm the increase in 'K' value is almost insignificant i.e. from 0.4714 to 0.5088 over a growth of 60 mm. From 270 mm onwards the value is consistently increasing. Another interesting point to be noted is the 'K' values for both the sexes are more or less the same till they reach 210 mm in length. After 210 mm the 'K' values for the female indicate a downward trend as against the upward trend in the male.

Hart (1946), in the report on the trawling on the trawling survey on the Patagonian continental shelf, has stated that the 'K' values may give a very good idea of the broad outline of the seasonal cycle of the species. He observes "….apart form the seasonal variation in the condition, there is a secondary variation related to the length of the fish. With the increase in age, there is a lower level of condition throughout the seasonal cycle consequent upon the increased metabolic strain of spawning. The point of inflection on the curve showing this diminution of 'K' with increasing length is thus a good indication of the length at which sexual maturity is attained.

In the present study, the first point of inflexion in the female is at 150 mm. The biological studies show that the gonads of *H. nerereus* are in a very early stage of development not beyond the second stage at this size. Therefore, this inflexion does not seem to be related to the maturation cycle of the fish, but to some other metabolic activity, probably the feeding habits. At 210 mm the female appears to suffer some amount of metabolic strain than the male as the values for the female are comparatively lower hereafter than for the male, if the more or less stationary values from 210 mm onwards are to be taken to be the next point of inflexion, them as shown here and as pointed out by Hart (1946) , it is due to the attainment of first maturity. The steep rise in the value between 270-and 290 mm may be due to the fish getting ready for the second or successive spawning.

Fig. 3B shows the values of 'K' for the two sexes plotted against different months. In the female fish there is a fall in the 'K' value in August. During September and October there is a sharp increase in the 'K' value but in November there is sharp inflexion and the low value reached is more or less maintained till the end of March. There is a small increase in April followed by a fall in May. Though the values for the male and the female run more or less parallel, the female appears to undergo considerable metabolic strain during November-March, the values being always lower. During the same period the values for the male are also gradually on the decline.

The biological studies have clearly shown that the main spawning season is during December to March. Therefore, the low 'K' value during this period can be attributed to the increased metabolic strain due to the intensive spawning activity of the fish.

FOOD AND FEEDING HABITS

The food feeding habits of *H. nehereus* were first described by Hora (1934) after examining two samples from Bombay. He found that *Bregmaceros mcclellandi* Thomson and *Acetes indicus* Milne Edwards formed it principal food. Based on these observations and the peculiar nature of distribution of Bombay duck he suggested that the wandering of this fish might be related to the availability of the food species and recommended a closer investigation of the problem. Chopra (1939) has remarked that the food of the Bombay duck mainly comprises of shrimps and its migrations can be traced by the movements of shrimp shoals. Mookerji *et al.* (1946) state that the food of this species consists of crustaceans, fish, protozoa, worms and univellular alage in the order of abundance. Pillay (1951 and 1953) has studied the food habits of Bombay duck from the Matlah river and found that the fish is carnivorous, prawns and shrimps forming the important item of its food. He has also noticed that it is cannibalistic, eating its own young ones. The other fishes taken are *Coilia*, *Anchoviella,* and *Mugil* . Bapat *et al.* (1951) have found that prawns form the main food of Bombay duck, the other important items being juveniles of *Harpodon nehereus*, *Bregamaceros mcclellandi*, *Coilia dussumieri Polynemus heptadcatylus.*

The material for the present study was collected from Sassoon Docks and Versova, the two major fish landing centres a Bombay. A total number of 582 specimens spread over a period of eleven months form July 1958 to May 1959 were examined for the purpose.

The specimens were fixed in 5% formaldehyde after bringing them to the laboratory. They were measured for total length, weighed and then cut open. The condition of feed was recorded taking into consideration the distention of the stomach (Job, 1940; Pillay, 1952) and points were allotted as follows: gorged stomach – 100 points, full stomach – 80 to 100 points, ¾ full stomach – 60 to 80 points, ½ full stomach – 30 to 60 points and ¼ or less full stomach – 0 to 30 points. After allotting the points the stomach contents were removed and the entire volume of the contents were determined. The volume of the major groups which could be indentified were similarly determined. Based in the total number of points allotted to a stomach, the total volume of the stomach contents and the volume of the different organisms in the stomach, points were allotted to the different constituents. Based on these points the quantitative analysis of the gut contents in different months in terms of percentages was carried out.

The prevalence of each food item during different months was calculated by the occurrence method (Hynes, 1950). From individual records the quantitative percentage composition of the food item and the percentage prevalence of the different food constituents were calculated for each month. As no appreciable variation in the food of young fish was noticed, except for the size of the food constituents, the data are not analysed separately.

It may not be out of place to describe in brief the salient features of its digestive system. The gape of mouth is wide and this helps in swallowing a prey almost equal to its own size. Both the jaws are provided with fine, innumerable long recurved teeth, turning inwards. These help the fish in catching hold of the prey and preventing it from escaping. Most of the food items in the stomach are found in-tact or in one piece, in a semidgested condition. Another peculiar feature is the high distensibility of the stomach. The empty stomach is a small tube-like organ with a thick musculature. In a fully distended stomach gorged with food, the stomach wall becomes almost transparent showing out the food items even to the naked eye examination. This capacity of distention suggests that the fish can take large quantities of food at one time. The intestine is short suggesting that the fish is carnivorous.

The state of feed: The state of feed of 582 specimens examined during a period of eleven months is given in Table 5.

More than 40% of the stomachs were empty during July and November December and between 30 and 40% during September and October 1958 and May 1959. In the remaining months, the percentage of empty stomachs varied between 17 and 28. Specimens in the gorged or full state of feeding were seen, though in lesser numbers in all the months except November. During the same month the percentage of specimens with empty and ¼ full stomachs was very high accounting for 86 percent of fish. A reference to table I of Bapat *et al.* (1951) shows that the percentage of empty stomachs, during November 1948 and 1949 was high, 40% and 35.5% respectively. It has been shown earlier that the active breeding season commences in

December. Therefore it is probable that the feeding activity is at a low level at about the commencement of the physiologically active period.

Table 5

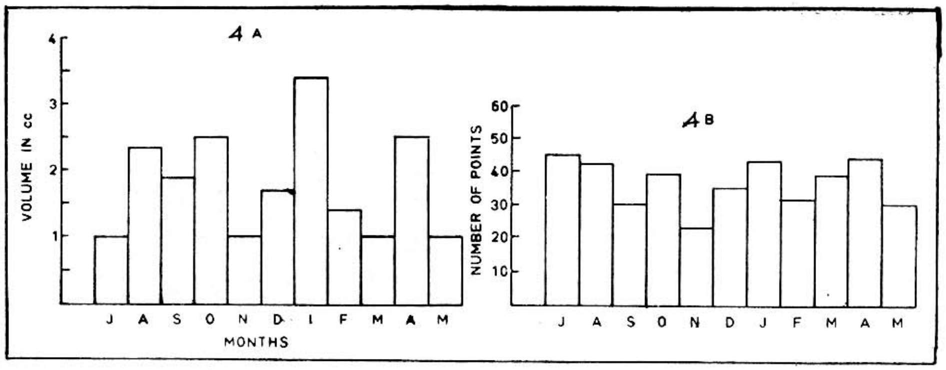
The state of feed of *H. nehereus*

Month	No. exa-mined	Empty	¼ Full	½ Full	¾ Full	Full	Gorged
July 1958	26	53.84	15.38	15.38	11.53	3.84	-
August	39	23.07	30.76	15.38	20.51	5.12	5.12
September	59	32.20	40.67	15.25	8.47	3.39	-
October	39	38.46	35.89	10.25	7.69	7.69	-
November	51	49.02	37.25	11.76	1.96	-	-
December	83	42.17	24.09	15.66	12.04	3.61	2.41
January 1959	79	26.58	25.32	25.32	10.13	8.86	3.79
February	68	23.53	42.64	14.70	10.29	7.35	1.47
March	45	17.77	35.55	20.00	13.33	11.11	2.22
April	46	28.26	26.08	19.56	13.04	6.52	6.52
May	47	36.17	38.29	10.64	12.76	2.13	-

Figs. 4A and 4B show the fluctuations in the average stomach contents of *H. nehereus* derived by the volumetric and the points method. The points method appears to give a more reliable picture of the feeding activity than the volumetric method, as the allotment of points is based on the fullness of the stomach, irrespective of the size of the fish. It is due to such anomalies that the low feeding activity is seen in July 1958 and March 1959 by the volumetric method in fig. 4A as against the points method in Fig. 4B.

Assuming that the points method gives a more realistic picture of the feeding activity, it will be seen that it was at a high level during July, August, October, December 1958 and January, march and April 1959 varying between 35 and 45 points. The feeding activity was at its lowest level in November.

Food components and their fluctuations: The fluctuations in the different food constituents during different months was worked out. The main food of the species consists of prawns, shrimps and fishes. Fig. 5 shows the



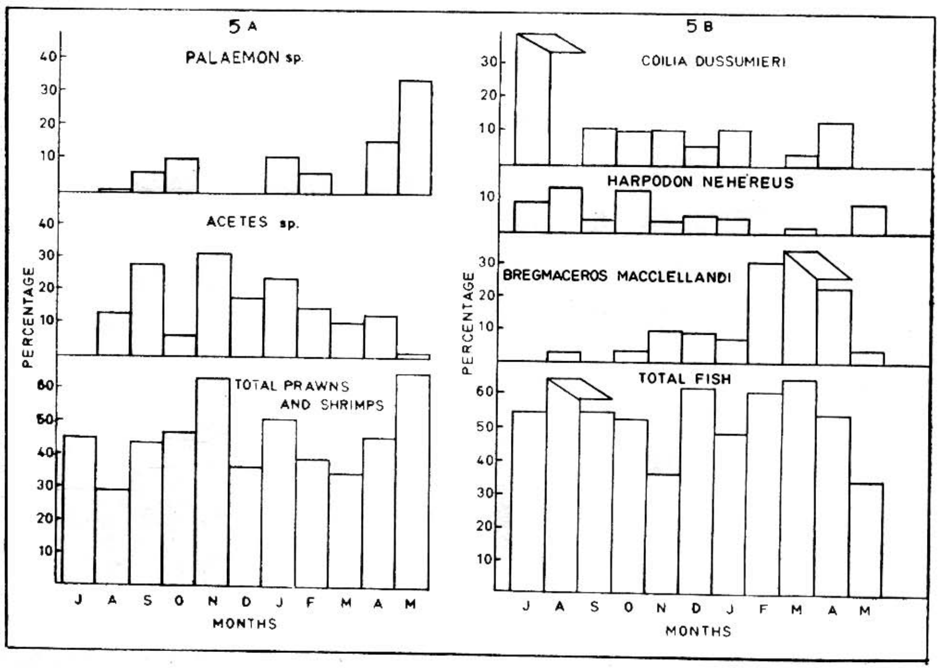


Fig. 4 A. ***Harpodon nehereus*** : Stomach contents by volumetric method.
Fig. 4 B. Stomach contents by points method.
Fig. 5 A. and 5 B. ***Harpodon nehereus*** : Fluctuations in some important food items during different months.

fluctuations in the prawn and shrimp and shrimp diet, two genera of prawns in particular and the fish diet with three important fish species. The fluctuations in the different food items are discussed below.

Prawns and shrimps:- Prawns and shrimp formed the major item of food of *H. nehereus* during November 1958, January and May 1959 when they formed more than 50% of the stomach contents. During December, February and March their percentages varied between 30 and 40 and in the remaining months between 40 and 50, excepting August when it was 29.05. The prawn and shrimp diet mainly comprised of *Acetes, Palaemon, Parapenaeopsis, Merapenaeus, Penaeus, Hippolysmata and Solenocera* in order of abundance. The occurrence of these genera in the stomachs of H. *nehereus* is discussed below.

Acetes sp.:- This genus was found in the stomach contents in varying percentages from August to May, the lowest being in May. They were taken in appreciable quantities varying between 24 and 32% during September, November and January. It has been observed that *Acetes* was common in fish landings during August, September, March, April and May. In view of its occurrence in the stomachs almost throughout the year it appears that *H.nehereus* has a preference to this food item. *Acetes indicus was* the most common species that could be indentified from the stomach contents.

Palaemonids :- Shrimps belonging to this group were taken during August. September, October, January, February, April and May, their highest percentage being 35.03 in May and the lowest 0.39 in August. The most common species recorded from the stomachs was *Palaemon tenuipes*; *P. styliferus* was seen in only two stomachs.

Parapenaeopsis sp:- Prawns belonging to this genus were seen in the stomach contents in August, and October- January. They accounted for 6.3% of the stomach contents in August and their percentage varied between 0.80 and 3.76 during the other months. Although *P. stylifera* and *P. sculptilis* are landed at Bombay almost throughout the year in appreciable quantities, *P. stylifera* alone has been recorded from the stomach contents.

Metapenaeus sp. :- The highest percentage, Viz. 12.03, of prawns of this genus was taken in October. They were taken in small quantities in September, January, February and April. *M. brevicornis* was the only species that could be identified.

Penaeus sp. :- Prawns of this genus were only occasionally seen in the gut contents in small percentages though they occurred in appreciable quantities in the landings almost throughout the year.

Hippolysmata sp. :- This was seen in small quantities during September, October and January.

Solenocera sp. :- These were found in the stomachs in percentages varying between 0.50 and 4.51 during September, October, January, April and May, the highest percentage recorded being in October.

The fish diet :- The intake of fish diet by *H. nehereus* was comparatively higher than prawns and shrimps. It can be seen from Fig. 5 that in nearly eight months the intake of fish diet was more than 50% of the total food consumed. It was only in two months, November, and May, that the fish diet was low ranging between 30 and 40%. It consisted of ten species, namely, *Bregmaceros mcclellandi, Harpodon nehereus, Coilia dussumieri, Anchoviella* sp., *Polynemus heptadactylus, Otolithus* sp., *Trypauchen vagina, Sciaena* sp., *Trichiurus* sp., and *Caranx* sp. Of these, the first six were common in the stomachs, and the details of their occurrence is given below.

Bregmaceros mcclellandi :- They were observed in the stomachs during nine months from October to May ; the maximum intake was in March when they constituted 43.51% of the stomach contents. During February and April their percentage varied between 20 and 30. The lowest percentage of 3.17 was noticed in August.

Harpodon nehereus :- The highest percentage of their intake was in the month of August when they formed 13.54 of the stomach contents. They were taken in fairly good percentages during July, October and May. In the remaining five months they were taken in small quantities.

Coilia dussumieri **:-** It will be seen from Fig.5 that this species formed an important constituent of food and was taken throughout. It formed 45.37% of the stomach contents in the month July. During the remaining period except December, February and march the intake varied between 9 and 13%.

Anchoviella spp. :- They formed an important item of food during August and January, their intake being 27 and 10% respectively. They were taken in small quantities during September, October, December, and February.

Polynemus heptadactylus **:-** It formed an important item of the food in December and February, and accounted for 12-17% of the stomach contents. In the remaining months, its percentage fluctuated between 0.78 and 6.78.

Otolithus sp. **:-** This genus was represented in the diet during September, December and February-April. It formed and important item of the food in September accounting for 25.75% of the stomach contents.

The remaining four groups cited earlier were more as stray specimens than as items of regular food. *Trypauchen vagina* was the only species which was found in good percentages in the month of October. The other items of food were Squilla and squids and their percentage was more or less negligible. Detritius was also observed in neigligible percentages during September and February.

In addition to the variations in the stomach contents, the percentage prevalence of the various food constituents was also studied. It will be seen that the highest percentage of the prawn diet was recorded in May and the fish diet in March. The prawn diet was prevalent in over 50% of the stomachs in seven months during the course of this study.

During the month of July the prawn diet was preferred to the fish diet. Amongst the fish-food *C. dussumieri* occurred more frequently than *H. nehereus* itself. In August, Bombay duck seems to have favoured the fish diet to prawns, the most prevalent fish being *Anchoviella* Sp. along with *H. nehereus* and *C. dussumieri* in equal percentages. As for the shrimp-food, *Acetes* sp. stood first. In September the prevalence of the crustacean diet was comparatively much more than in the previous month and the condition of prevalence appears to have almost reversed. The main constituents were *Acetes* sp. along with *palaemon* spp. The fish-food consisted of *Otolithus* sp. which was common and next in preference came *H. nehereus* and *C. dussumieri*. In October, the prevalence of the crustacean diet showed a decrease in *Acetes* sp. but *Palaemon* spp. continued to be the main constituent. The fish diet showed some increase in the stomachs, the common species being *H. hehereus* and *C. dussumeiri* in order of abundance.

During November, the prevalence of prawns showed some increase in the stomach contents and mainly comprised of *Acetes* sp. The fish-food consisted of *H. nehereus*. *B. mcclellandi* and *P. heptadactylus* in equal proportions. The increase in the prevalence of the prawn diet in November was followed by a marked decrease in December although *Acetes* sp. continued to be in preference. As for the fish-food, *P. heptadactylus, B. mcclellandi* and *H. nehereus* were seen in order of prevalence. The prevalence of crustaceans showed some increase again in January and this was accounted for by *Acetes* sp. and *Palaemon* spp. n order of abundance. The fish-diet comprised of *Anchoviella* sp., *C. dussumieri* and *B. mcclellandi*. In February the fish-diet was more common and consisted mainly of *B. mcclellandi* and *P. heptadactylus* in varying percentages of prevalence. *Acetes* sp. and *Leander* sp. continued to appear but in lesser percentages. In March the crustacean constituent of food reached its minimum and comprised of *Acetes* sp. and *Penaeus* sp. As against this, the fish-food prevalence reached its maximum, the most common species being *B. mcclellandi* supplemented by *C. dussumieri* and *P. heptadactylus* in equal percentage. During April and May the prawn diet showed a regular increase with corresponding decrease in the fish-food prevalence. *Palaemon* spp. Were predominant followed by *Acetes* sp. in both the months. The fish diet was mainly represented by *B. mcclellandi* in April supplemented by equal percentages of *C. dussumieri* and *Otolithus* sp. and in May by *P. heptadactylus.*

In general it can be stated that *H. nehereus* is voracious, carnivorous and, to some extent, cannibalistic in its feeding habits. Its food mainly consists of small prawns and fishes. Marked changes take place between the fish-diet and the prawn-diet in some months without any regularity. However, *Acetes* sp. and *Palaemon* spp. among the crusateceans diet and *B. mcclellandi, C. dussumieri, H. nehereus, P. heptadactylus* and *Anchoviella* sp. from the fish-diet were the common food items in order of prevalence among the two major food constituents. In view of the irregular fluctuations in its diet, it appears that it does not have any special preference among the two major food constituents.

AGE AND GROWTH

Length frequency studies

It is well known that when the length measurements of a large number of fish selected at random are arranged in suitable size groups, the resultant frequency graphs show modes which are interpreted as average sizes of the different year classes. These graphs also indicate the size composition of the commercial catches, in different months and show the periods when recruitment to the stock takes place, thus indirectly suggesting the probable spawning season of the species under investigation. The length frequency studies also help in determining the monthly and annual rates of growth in the respective year classes.

With a view to collect information on these aspects a total number of 7705 specimens of Bombay duck were measured during a period of 14 months from January to May 1958 and September 1958 to May 1959. All the measurements were taken at Versova, near Bombay. The fish landing place was visited at least three times a month and on each occasion measurements of total length of 100-200 specimens of *H. nehereus* were taken depending on the day's catch. Thus, on an average, measurements of at least 500 specimens were taken in a month except in January 1958 and March 1958 when the landings were poor.

The range of size of specimens measured varied between 35 and 328 mm. The data were analysed for the entire period keeping 15 mm as the size interval so that the number of size groups were around 20. The size frequency distribution of *H. nehereus* for these 14 months in terms of percentage are shown in Figs. 7, 8 and 9.

It was considered desirable to split the period of observation into the premonsoon months, i.e. from January to May, and postmonsoon months of September to December. The data collected during these periods were pooled and analysed and the resulting size frequency distribution pattern is graphically shown in Fig.6 a, b and c. Similarly the data collected during the entire period of study were analysed together and shown graphically in Fig. 6 d.

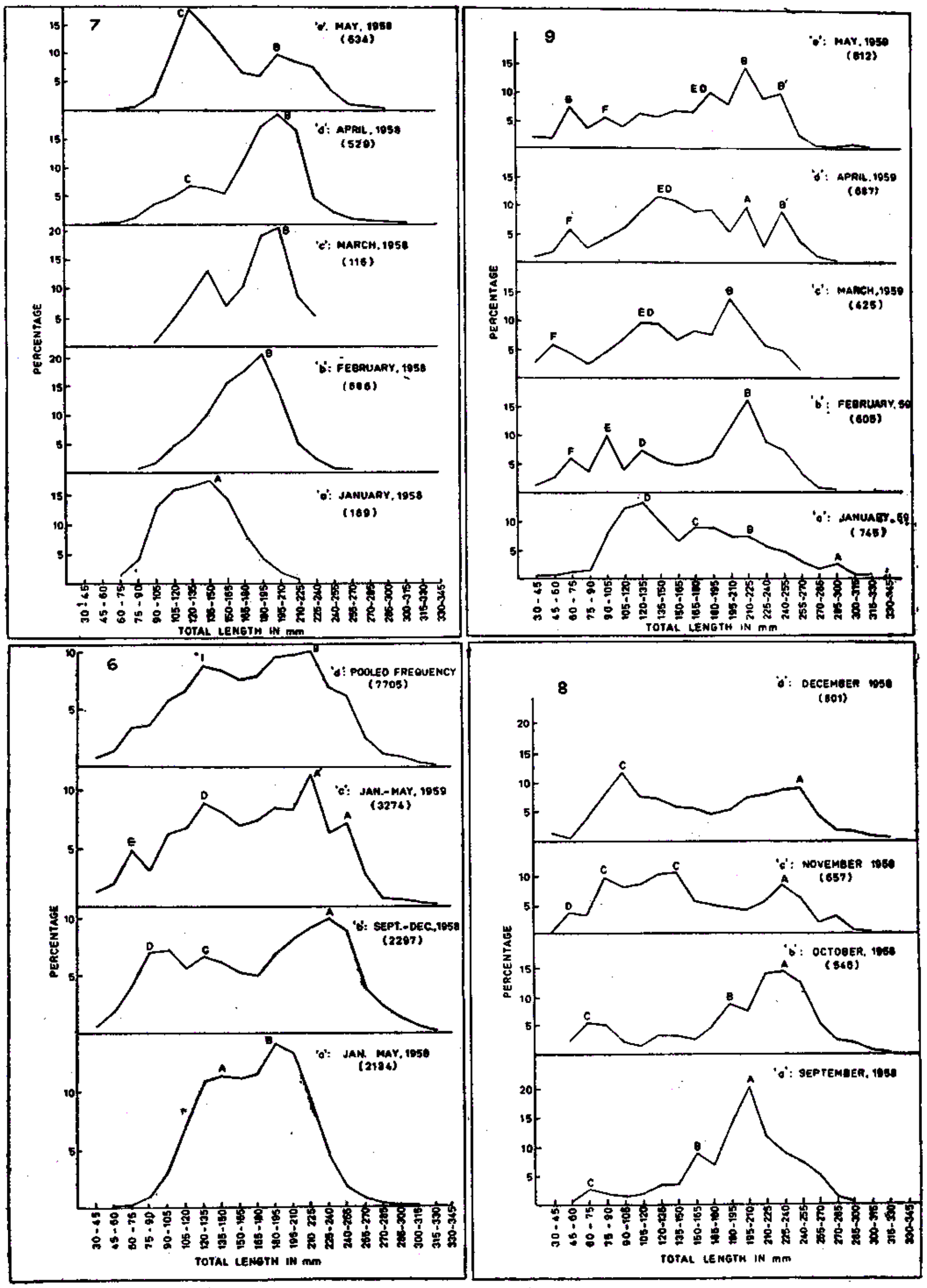
In Fig. 6d only two modes I and II are seen, at 120-135 mm and 210-225 mm in total length. These, in all probability, represent the one-year and two-year old fishes. Based on this assumption, it can be inferred that during the second year it grows 90 mm more in length.

The graph also indicates that the commercial catches during the entire period of study mainly consisted of fish varying from 60 to 270 mm, the mainstay of the fishery being the one and two-year old fishes, as 65% of the specimens were in the 60-210 mm size range. It has been determined earlier that the minimum size of maturity of *H. nehereus* is 210 mm. In view of this it can be inferred that the Bombay duck fishery at Versova depends entirely on fish which have yet to attain complete sexual maturity.

During the pre-monsoon period, January-May 1958, only two modes ‘A’ and ‘B’ at 135-150 and 180-195 mm can be made out. The two modes are not distinctly separated from each other. The modes ‘A and ‘B’ probably represent fishes more than one year old and slightly less than two years old respectively. They appear to be the result of intensive spawning during January-March 1957 and February-April 1956 respectively. Fishes varying 90-225 mm mainly supported the fishery during this period.

During the post-monsoon season, i.e. September to December 1958, three modes, ‘D’ at 75-90 mm, ‘C’ at 120-135 mm and ‘A’ at 225-240 are seen. The mode ‘A’ is very broad and appears to be the result of merging of the two modes A and B seen during January-May 1958. Majority of fishes in this mode appear to belong to the January-March 1956 brood and are more than two years old. The mode ‘C’ consists of fish about one year old and it is likely that they represent the continued spawning activity from May to December of 1957. The mode ‘D’ again stands out prominently at 75-90 mm and the intense spawning of January to March 1958 appears to be responsible for this. During this period the commercial catches comprised mainly of fish between 60-240 mm.

In the pre-monsoon period, i.e. January to May 1959, four distinct modes can be made out. The mode ‘E’ at 60 to 75 mm corresponds to about 5% of the catch representing the continued breeding activity from July-November prior to the main spawning season. This mode appears to be representing fishes less than 6 months old. The mode ‘CD’ at 120-135 appears to be the result of the merger of the modes ‘C and ‘D’ seen in the post-monsoon period. This mode also represents the one year old fish and is the result of the January-March 1957 brood. The mode ‘A’ is at 210-225 mm and the mode ‘A’ is at 240-255 mm, the former representing



Figs. 6—9. ***Harpodon nehereus*** : Length frequency measurements.

two year and the latter more than two year old fish. These modes appear to be the result of splitting of the broad mode ‘A’ seen in September-December 1958.This mode ‘A’ probably corresponds to the mode ‘A’ of January-May 1958. Fish measuring between 60 and 240 mm in length appear to have mainly supported the fishery during this period.

Considering these graphs together it appears that the major recruitment to the stocks takes place during the post-monsoon period of September-December which is the result of intensive spawning activity during January-April. Recruitment during other months also exists and is indicated by mode ‘E’ in January-May 1959. The presence of young ones throughout the year supports the view that *H. nehereus* breeds all round the year.

Due to the continuous spawning activity, the monthly size-frequency graphs do not show a correct picture of the growth of modes in different months. As the recruitment to the stocks is continuous one can generally expect too many modes in a month representing the same year class or just one or two broad modes where the smaller modes have merged together and remain stationary at one group without indicating any growth. This is very clearly depicted by the monthly size-frequency graphs.

Fig. 7 shows the size frequency distribution of *H. nehereus* during January to May 1958. During January and February only one broad mode at 135-150 and 180-195 mm respectively is seen. The broad mode in January 1958 represents the one year and 0 year size groups. The mode in February represents fish more than one year old. The mode at 193-210 mm continues to appear at the same size-range during March, April and May 1958. But the mode at 135-150 mm disappears in April and May 1958. But the mode at 135-150 mm disappears in April and May, probably due to merging and a new mode at 120-135 mm corresponding to one-year old fish appears during April and is more pronounced in May 1958.

During September 1958 (Fig. 8) a prominent mode at 195-210 mm is seen and it is rather difficult to trace its origin. In addition, two more modes at 60-75 mm and 150-165 mm can be made out. The mode at 60-75 mm seen in September can be traced to the mode at 90-105mm in December with reasonable accuracy. The mode persists at the same level in October and shows a growth of 30 mm during November and December. The mode at 150-165 mm seen in September may correspond to the mode at 120-135 mm seen in May 1958. In October two more modes at 180-195 and 225-240 mm in addition to the one at 60-75 mm are seen. The mode at 225-240 mm remain stationary during November and is seen in December at 240-255 mm. This mode represents fishes slightly more than two years old. In November one mode is seen at 135-150 mm and is rather difficult to trace its origin. It represents fishes slightly more than one year.

During January-May 1959 (Fig.9) many modes are seen in most of the months. During January four modes at 120-135, 165-180, 210-225 and 285-300 mm are seen, the first three representing the one year old, one and a half years old and two years old fishes respectively. The mode at 285-300 mm probably represents fish which have completed three years. The origin of the mode at 210-225 mm which persists till May 1959 except in March is difficult to explain. In February two modes representing the zero year class at 60-75 and 80-105 mm are seen. These modes may be the result of the prolonged breeding activity during May-November 1958. The prominent mode in March 1959 at 195-210 mm probably merges with the 210-225 mm group in April to May. It is difficult to trace the origin of the mode at 240-255 mm in April which persists in May also.

In view of the continuous breeding habits, the recruitment to the stocks is also continuous and is not restricted to definite periods. As a result of this, the size-frequency graphs sometimes show too many sharp modes or only one or two broad modes which remain stationary at one point. Therefore it is very difficult to trace the origin and growth of the modes month by month. Hence, it appears that in fishes with prolonged breeding season, the method of length-frequency does not appear to be very useful in determining the rate of growth. However, the following few points can be easily made out.

1. The fish appears to attain an average length of 127 mm at the end of the first year and 210 mm at the end of the second year. Therefore the average growth during the second year appears to be 90 mm. from this it may be inferred that the average monthly growth during I and II year appears to be about 11 mm and 8 mm respectively.
2. Keeping in view that the minimum size of maturity is at 210 mm it appears that the fish attains maturity is at 210 mm it appears that the fish attains sexual maturity when it completes two years of its life.
3. The frequent appearance of the zero-year class shows that the

recruitment is continuous and is more pronoumced during the post-monsoon period i.e. September-December.

4. The Bombay duck fishery at Versova appears to be mainly supported by one and two-year old fishes. As large quantities of fish of this category are landed, it is necessary to maintain accurate fish landing statistics to study the effects of fishing on the fishery.

Length-weight relationship

In the course of this investigation, the length and weight of 479 specimens of *H. nehereus* were measured individually with a view to determine the correlation between these two physical characters. Of these, 173 were males ranging from 160 to 280 mm and 306 females from 140 to 320 mm in total length.

In almost all fishes, the weight has been found to vary as the cube of the length. Therefore, a general equation $W = AL^B$ was considered where W and L represent the weight and length of the fish respectively; A and B are the constants to be determined, the value of B generally varying between 2.5 and 4.0. Since the length –weight ratio is a power relationship, logarithms were used so that the exponential relationship can be expressed by the linear equation: $\log W = \log A + B \log L$.

The data on length and weight in respect of the male and female fish were processed separately and the values of constants 'A' and 'B' were determined as indicated in the equations below.

Male ... $W = 0.0000009795\ L^{3.7169}$

Female … $W = 0.0000002268\ L^{3.4444}$

The formulae derived above were tested and the calculated values were plotted against the observed values as shown in Fig.10. A close agreement between the two sets of observations and the corresponding curves is seen.

It may also be noticed that the length-weight relationship curves for male and female cut each other at 210 mm which incidentally happens to be the minimum size of maturity.

IV. MORPHOMETRIC AND MERISTIC STUDIES OF THE STOCKS

LOCALITIES AND MEASUREMENTS

As a fishery Bombay duck is caught in large numbers along the west coast of India from Ratnagiri in the south to Jaffrabad in the north in the Gulf of Cambay. A small fishery also exists in the Gulf of Kutch and it is reported that it is taken in fairly good numbers at Bedi and Kandla. On the east coast, the fish are caught in small quantities north of Madras and along the Andhra coast; a good Bombay duck fishery also exists in the estuaries of the rivers in Orissa and Bengal.

In view of the peculiar distribution it is essential to determine whether the Bombay duck occurring on the east and west coasts of India belong to the same stock or they originate from more than one stock. If it is established that the entire fishery on the east and west coasts of India is supported by a single stock, then, intensive exploitation even at one place may have disastrous effects resulting in the depletion of catches all over. In such circumstances the fish-landing statistics have to be carefully watched for signs of over exploitation or depletion setting in when regulation of the fishing gear and the fishing effort have to be resorted to. But, if the fishery of over-exploitation even at one locality may not affect the fishery on the entire coast line and the chances of its revival will be bright. The present investigation was primarily aimed at studying this important aspect of the homogeneity or other wise of the fish populations from selected centers.

Material for the study was collected from four localities, three on the west coast, viz. Jaffrabad, Versova, Janjira-Murud, and one on the east coast at Masulipatnam. A total number of 706 specimens were examined, 169 from Jaffrabad, 235 from Versova, 98 from Janjira-Murud, and 204 from Masulipatnam. All the speciemens were preserved in 5% formalin for over two weeks prior to measuring, to avoid errors due to shrinkage. The morphometric measurements taken are detailed below and shown in Fig. 11.

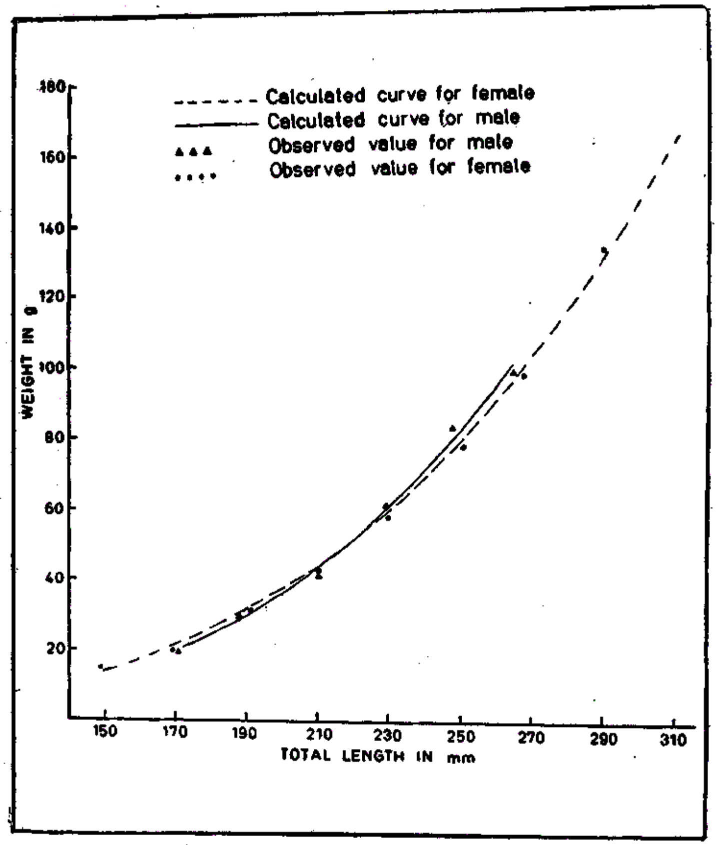


Fig. 10. ***Harpodon nehereus*** **:** Length-weight relationship.

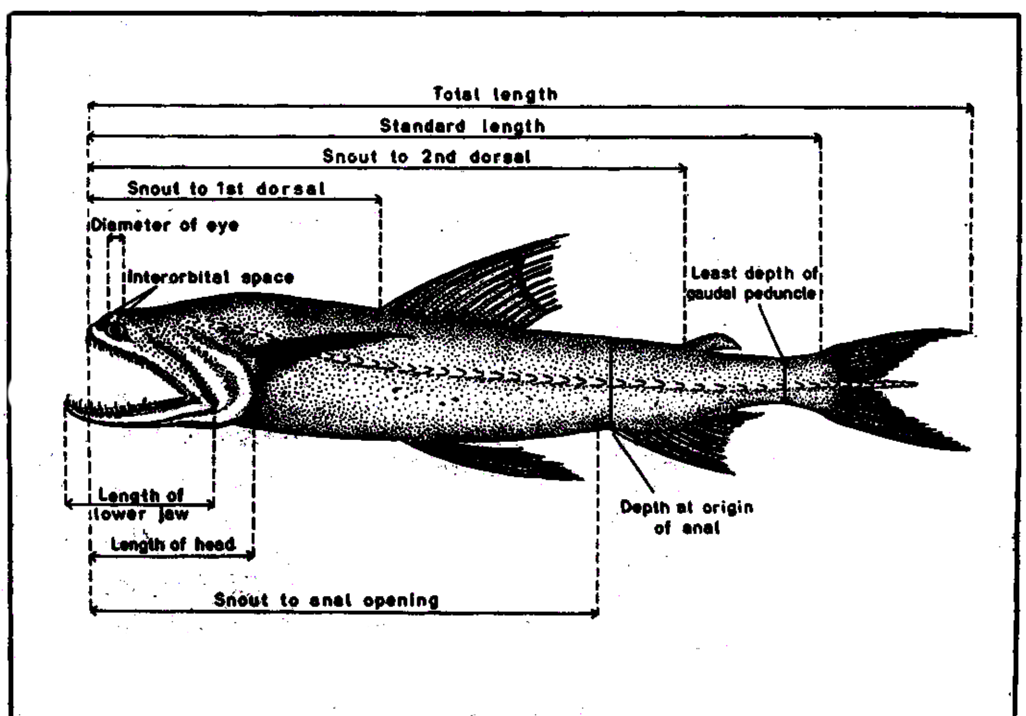


Fig. 11. ***Harpodon nehereus*** **:** Morphometric measurements.

1. **Total length-** from the tip of the snout to the tip of the longest caudal ray of the lower lobe.
2. **Standard length-** from the tip of the snout to the end of the hypural plate.
3. **Snout to anal opening-** distance from the snout to the anterior end of the anal opening.
4. **Snout to first dorsal -** from the tip of the snout to the point of insertion of the first dorsal fin.
5. **Snout to second dorsal -** from the tip of the snout to the point of insertion of second dorsal fin.
6. **Diameter of eye –** greatest diameter of the left eye (and, if that was damaged, he right eye was measured).
7. **Interorbital space -** the shortest distance between irises of the left and right eye.
8. **Least depth of caudal peduncle –** the minimum depth between the end of the anal fin and the origin of the caudal fin.
9. **Depth at origin of anal fin –** height of the fish taken at the base of the anal spine
10. **Length of lower jaw -** distance from the symphysis of the lower jaw to the point of articulation of the lower and upper jaws.
11. **Length of head –** distance between the tip of the snout to the cuter edge of the opercular membrane .

STATISTICAL ANALYSIS

It is seen in many cases that if there are more than one independent stock of a particular species, slight changes in the morphometric counts generally occur. The reasons for such changes are either genetic or phenotypic. These small changes in some particular character cannot be judged easily and statistical methods are employed to test the significance of such differences, if any. The first attempt to compare the samples was by comparing the mean ratios of one character in respect to another standard character, mostly the standard length. But as most of the morphometric characters are size-specific, the comparison of mean ratios will no lead to conclusive results unless all the samples consisted of fish of the same size. To overcome this, the method of comparing the regressions by the method of analysis of

Table 6

Equations for the regressions of variable characters (Y) on standard length (X) for different localities

Locality	Total length (Y) on standard length (X)	Snout to anal opening (Y) on standard length (X)	Snout to I dorsal (Y) on standard length (X)	Snout to II dorsal (Y) on standard length (X)	Diameter of eye on standard length (X)
Jaffrabad	Y= 8.52+1.175X	Y= 2.36+0.7495X	Y=–4.43+0.4579X	Y=13.11+0.7750X	Y= 0.33+0.0172X
Versova	Y=3.47+1.2028X	Y= 0.48+0.7334X	Y= 3.16+0.4150X	Y= 3.61+0.8172X	Y= 1.11+0.0125X
Janjira	Y=3.65+1.1971X	Y=–0.14+0.7384X	Y=–5.72+0.4666X	Y=–1.02+0.8455X	Y= 0.09+0.0177X
Masulipatnam	Y=1.48+1.2018X	Y= 7.40+0.6911X	Y= 2.76+0.4256X	Y=32.97+0.6601X	Y=–2.39+0.0062X

Locality	Interorbital space (Y) on standard length (X)	Depth at caudal peduncle (Y) on standard length (X)	Depth in origin of anal (Y) on standard length (X)	Length of lower jaw (Y) on standard length (X)	Head length (Y) on standard length (X)
Jaffrabad	Y= 1.72+0.0642X	Y= 1.04+0.0455X	Y= 2.60+0.0966X	Y=2.14+0.1597X	Y=–11.51+0.2759X
Versova	Y=–1.15+0.0578X	Y= 1.54+0.0632X	Y=–1.95+0.1226X	Y=1.93+0.1544X	Y=–0.96+0.2174X
Janjira	Y=–1.88+0.0609X	Y=–0.25+0.0608X	Y=–0.18+0.1206X	Y=3.94+0.1432X	Y=–0.60+0.2077X
Masulipatnam	Y=–1.62+0.0578X	Y=–2.69+0.0675X	Y=–5.33+0.1409X	Y=5.49+0.1279X	Y=–0.81+0.1987X

covariance was employed. In most cases, the regression of a character with respect to the standard length of the fish is found to be linear. In case of Bombay duck the regressions of all the ten characters on standard length were found to be linear. Hence comparisons of the slope of the regression will not the vitated even if the specimens from the different localitites are not of the same size. In case of characters which are not size-specific, such as meristic characters, the means of the samples are compared statistically by the method of analysis of variance.

The method of regression on one body-part on the other and the technique of analysis of covariance have been frequently adopted in recent studies. Godsil (1948) studies the stocks of the yellowfin tuna and the albaocore. Roedel (1952) investigated the populations of the Pacific mackerel, *Pneumatophorus diego* by adopting this techniques. Pillay (1957) adopted the regression method for studying the populations of Hilsa, *Hilsa ilisha* (Hamilton) from the river Hooghly and the Chilka Lake. Berdeque (1958) studied the American Anchoveta, *Cetengraulis mysticetus* (Gunther) with a view to delimit the populations on the American coast.

In the present study the range of size of specimens from different localities varied between 186-260 mm in total length. In spite of the small range of size the regression method was adopted in this study. Linear regressions with the formula $Y = a + bX$, where Y is the variable character, 'a' is the constant value to be determined, 'b' is regression coefficient and 'X' the standard length, have been adopted throughout in the study of morphometric measurements. The equations describing these regressions are given in Table 6 for all the variables.

Body measurements of specimens from Versova indicated the possibility of seasonal differences in some of the morphometric measurements. Therefore it was considered desirable to test whether the various samples from Versova are homogenous or not. Hence the data collected from Versova over a period of nine months were first analysed month wise and tested for their homogeneity.

MORPHOMETRIC CHARACTERS

A summary of the results of the analysis of covariance of ten body measurements of standard length observed over a period of nine months from September 1958 to May 1959 is given in the following table.

	Body measurement	Significant/not significant
1.	Total length	Not significant
2.	Snout to anal opening	Not significant
3.	Snout to origin of I dorsal	Not significant
4.	Snout to origin of II dorsal	Significant at 5% level but not at 1% level
5.	Diameter of eye	Not significant
6.	Inter-orbital space	Not significant
7.	Least depth of caudal peduncle	Significant at 5% level but not at 1% level
8.	Depth through origin of anal	Significant at 5% level but not at 1% level
9.	Length of lower jaw	Significant at 5% level but not at 1% level
10.	Length of head.	Significant at 1% level

It is seen from the above statement that out of the ten morphometric characters studied, five show significant differences, four at 5% level but not at 1% level and one at 1% level. Out of the ten measurements six are linear and two are vertical. Out of the six linear characters two are significally different at 5% level and one highly significant even at the 1% level. Both the vertical measurements are significantly different at the 5% level but not at the 1% level.

From the above evidence it appears that the samples of Bombay duck collected at Versova in different months are coming from a homogenous stock. But the possibility of heterogeneity in the Versova catches during different months is not completely ruled out in view of the fact that the regression of one important character, the length of head, is highly significant and four other regressions are significant at the 5% level.

Variations between different localities: On the assumption that the samples from Versova were more or less homogeneous it was decided to compare these samples with others from different localities. To study this aspect, the data collected from Versova were pooled together and treated as one sample. Thus the morphometric measurements of 706 specimens from four different localities were analysed by adopting the same technique of analysis of covariance.

In the first instance the data from all the four localities were analysed together and the results are given below.

	Body measurement	Significant/Not significant
1.	Total length	Not significant
2.	Snout to anal opening	Not significant
3.	Snout to origin of I dorsal	Significant at 1% level
4.	Snout to origin of II dorsal	Significant at 1% level
5.	Diameter of eye	Significant at 1% level
6.	Inter-orbital space	Not significant
7.	Least depth of caudal peduncle	Significant at 1% level
8.	Depth through origin of anal	Significant at 1% level
9.	Length of lower jaw	Significant at 1% level
10.	Length of head.	Significant at 1% level

It will thus be seen from the above that the regressions of seven of the characters namely, snout to I dorsal, diameter of eye, depth at caudal peduncle, depth at origin of anal, length of lower jaw and length of head on standard length show highly significant differences indicating that the pooled data are heterogeneous. The regression lines in fig.12 also indicate the existence of these differences by varying slopes.

In order to determine the samples that are responsible for this significant variaion, the data for samples from the west coast of India i.e. from Jaffrabad, Versova and Janjira –Murud were tested together. The results of the analysis of covariance in respect of the west coast samples are given below.

	Body measurement	Significant/Not significant
1.	Total length	Not significant
2.	Snout to anal opening	Not significant
3.	Snout to origin of I dorsal	Significant at 1% level
4.	Snout to origin of II dorsal	Not significant
5.	Diameter of eye	Significant at 1% level

6.	Inter-orbital space	Not significant
7.	Least depth of caudal peduncle	Significant at 1% level
8.	Depth through origin of anal	Significant at 5% level but not at 1% level
9.	Length of lower jaw	Not significant
10.	Length of head.	Significant at 1% level

It will be seen from the above that regressions of five characters on standard length vary significantly. Of these, four are highly significant and one significant at 5% level but not at 1% level. It therefore appears that the samples from the different localities on the west coast, though closer to one another than was the case when the east coast sample was also taken into consideration, do not appear to have their origin in one stock but appear to be heterogeneous in character.

To determine which sample or samples is responsible for this variation, the samples from Janjira-Murud and Versova were tested first, as the ecological and environmental conditions prevailing at these places are more or less similar. The results of the analysis of covariance between the samples of these two localities for the ten regressions on standard length are given below.

	Body measurement	Significant/Not significant
1.	Total length	Not significant
2.	Snout to anal opening	Not significant
3.	Snout to origin of I dorsal	Significant at 1% level
4.	Snout to origin of II dorsal	Not significant
5.	Diameter of eye	Significant at 1% level
6.	Inter-orbital space	Not significant
7.	Least depth of caudal peduncle	Not significant
8.	Depth through origin of anal	Not significant
9.	Length of lower jaw	Not significant
10.	Length of head.	Not significant

The above results indicate that both the samples appear to come from closely related stocks as only the regressions of two characters, namely, snout to first dorsal and diameter of eye on standard length are significantly different. The remaining eight regressions are not significantly different. In view of this and the results of the analysis between all the samples from the west coast, it appears that samples from Jaffrabad originate from a stock quite independent of the one from Versova and Janjira-Murud. Thus it is evident from these results that there are at least two stocks of *H. nehereus* occurring on the west coast of India, one from Jaffrabad and the other from Versova and Janjira-Murud.

After comparing the regressions on standard length between the west coast samples it was decided to compare them with those of the Masulipatnam samples. The following table gives the results of the analysis of covariance where the samples from Janjira-Murud and Masulipatnam are compared.

	Body measurement	Significant/Not significant
1.	Total length	Not significant
2.	Snout to anal opening	Significant at 1% level
3.	Snout to origin of I dorsal	Significant at 5% level but not at 1% level
4.	Snout to origin of II dorsal	Significant at 1% level
5.	Diameter of eye	Significant at 1% level
6.	Inter-orbital space	Not significant
7.	Least depth of caudal peduncle	Significant at 5% level but not at 1% level
8.	Depth through origin of anal	Significant at 5% level but not at 1% level
9.	Length of lower jaw	Not significant
10.	Length of head.	Not significant

The results of the above analysis show that three regressions on standard length are significantly different at 1% level and three more at 5% level but not at 1% level indicating thereby that the differences between the two samples are greater than that found between Janjira-Murud and Versova samples. This suggests that the two stocks are not so closely related to each other as in the case of those from Versova and Janjira-Murud.

In view of this significant variation it was desirable to know whether the Masulipatnam samples agree with those of Jaffrabad or they are independent of each other. The following table gives the summary of the results of the analysis of covariance between Jaffrabad and Masulipatnam samples.

	Body measurement	Significant/Not significant
1.	Total length	Not significant
2.	Snout to anal opening	Significant at 1% level
3.	Snout to origin of I dorsal	Not significant
4.	Snout to origin of II dorsal	Significant at 5% level but not at 1% level
5.	Diameter of eye	Significant at 1% level
6.	Inter-orbital space	Not significant
7.	Least depth of caudal peduncle	Significant at 1% level
8.	Depth through origin of anal	Significant at 1% level
9.	Length of lower jaw	Significant at 1% level
10.	Length of head.	Significant at 1% level

It will be seen from the above analysis that the differences among six of the regressions namely, snout to anal opening, eye diameter, depth at caudal peduncle, depth at origin of anal, length of lower jaw and length of head on standard length are highly significant and one more i. e. snout to II dorsal at 5% level but not at 1% level. The highly significant differences indicate that the two samples come from widely different stocks and are not homogeneous in character.

MERISTIC COUNTS

In addition to the above morphometric measurements the following three meristic counts were also studied. They are: 1. number of fin rays in the first dorsal fin, 2. number of fin rays in the anal fin, and 3. total number of vertebrae.

In *Harpodon nehereus* as in many other fishes, the last dorsal and anal fin rays branch very close to the base of the fin. In the present study, following the criteria of Hubbs and Langler* (1949), they have been counted as one. Both the dorsal and anal fins commence with a spine and

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* Not listed in references

these spines have not been taken into account. For taking the vertebral count the specimens were kept in hot water between 85 and 90^0 C for about half an hour, the flesh was removed, and the vertebral column was cleaned and dried. The total number of vert brae including the atlas and the urostyle were counted and noted. The fin counts of a total number of 612 specimens, 141 from Versova, 98 from Janjira, 169 from Jaffrabad and 204 from Masulipatnam have been recorded in this study. Skeletons of 348 specimens, 55 from Versova, 90 from Janjira, 100 from Jaffrabad and 103 from Masulipatnam were prepared. The number of fin rays in each fin from different localities were first compared in terms of percentages. But to determine whether the variations apparently seen are significant or otherwise, the method of analysis of variance was employed.

First dorsal fin: The variation in the number of dorsal fin rays in 612 specimens from different localities in terms of percentages is given below.

Locality		Number of rays		
		10	11	12
Jaffrabad	..	0.59	65.58	33.72
Versova	..	1.41	72.34	26.24
Janjira	..	7.14	69.38	23.46
Masulipatnam	..	11.76	77.45	10.78

The percentage of specimens having 11 rays varied between 65 and 77 in these four localities. The percentage of specimens having 10 rays was negligible at Jaffrabad and the highest number of that category came from Masulipatnam on the east coast of India. The range of fluctuations with 12 rays was between 10 and 33 percent. In order to see whether there was significant difference between specimens of these localities in respect of the first dorsal fin, the technique of analysis of variance was adopted. The results of the same are given below.

Source of variation	d. f.	Sum of squares	Mean square	F
Between places	3	11.84	3.946	16.79*
Within places	608	143.15	0.235	
Total	611	154.99		

* Significant at 1% level

From the above table it is seen that there is significant difference in the variations in the dorsal fin counts between places. In order to determine which of the localities that are contributing to this significant difference, the analysis of variance between two localities at a time was made. A summary of the results are present below.

Source of variation (Locality)	Significant/Not significant
Between Janjira-Murud and Versova	Not significant
Between Versova and Jaffrabad	Not significant
Between Janjira-Murud and Masulipatnam	Significant at 1% level
Between Masulipatnam and all other places	Significant at 1% level

It is thus seen the variations in the dorsal fin counts of specimens from Janjira and Versova and Versova and Jaffrabad are not significant. The results also show that the variations between Masulipatnam and all the other three places together are highly significant. It may therefore be concluded that in respect of the first dorsal fin rays the samples from Jaffrabad, Versova and Janjira on the west coast of India belong to the same stock, whereas the Masulipatnam samples differ from the above localities indicating thereby that they have their origin in a different stock.

Anal fin: The variations in the number of anal fin rays of 612 specimens from different localities is given in the following table in terms of percentages.

Locality		Numbr of anal fin rays				
		11	12	13	14	15
Jaffrabad	..	-	3.55	49.70	45.56	1.18
Versova	..	0.70	4.96	52.48	40.42	1.41
Janjira	..	-	3.06	56.12	38.77	2.04
Masulipatnam	..	-	7.84	55.37	35.78	0.98

It can be seen from the above table that the range of variation of anal fin rays in terms of percentages is comparatively smaller than the dorsal fin rays. The analysis of variance between all localities together and between two localities at a time indicated that there were no significant difference.

Vrtebrae: The vertebral counts of a total number of 348 specimens, 55 from Versova, 90 from Janjira-Murud, 100 from Jaffrabad and 103 from Masulipatnam were taken. The fluctuations in the total number of vertebrae in terms of percentages from different localities are given below.

Locality		Total numbr of vertebrae					
		39	40	41	42	43	44
Jaffrabad	..	-	-	9.00	47.00	42.00	2.00
Versova	..	1.81	5.45	34.54	47.27	10.90	-
Janjira	..	-	2.22	25.55	47.77	23.33	1.11
Masulipatnam	..	-	4.85	29.12	45.63	20.38	-

It may be seen from the above table that larger percentage of specimens from all the localities have 42 vertebrae. But specimens with 40, 41, 43 and 44 vertebrae vary from place to place. In order to see whether these variations are significantly different, the technique of analysis of variance was adopted with all places together in the first instance. The results of the same given below show that there is significant difference between samples.

Source of variation	d. f.	Sums of squares	Mean square	F	
Between places	3	25.96	8.65	14.46	**
Within places	344	205.86	0.598		

In order to determine which of the samples contribute to these variations, two samples at a time were tested and a summary of the results is given below.

** Significant at 1% level

Source of variation (Locality)	Significant/Not significant
Between Janjira-Murud and Versova	Significant at 5% level but not at 1% level
Between Versova and Jaffrabad	Significant at 1% level
Between Janjira-Murud and Masulipatnam	Not significant

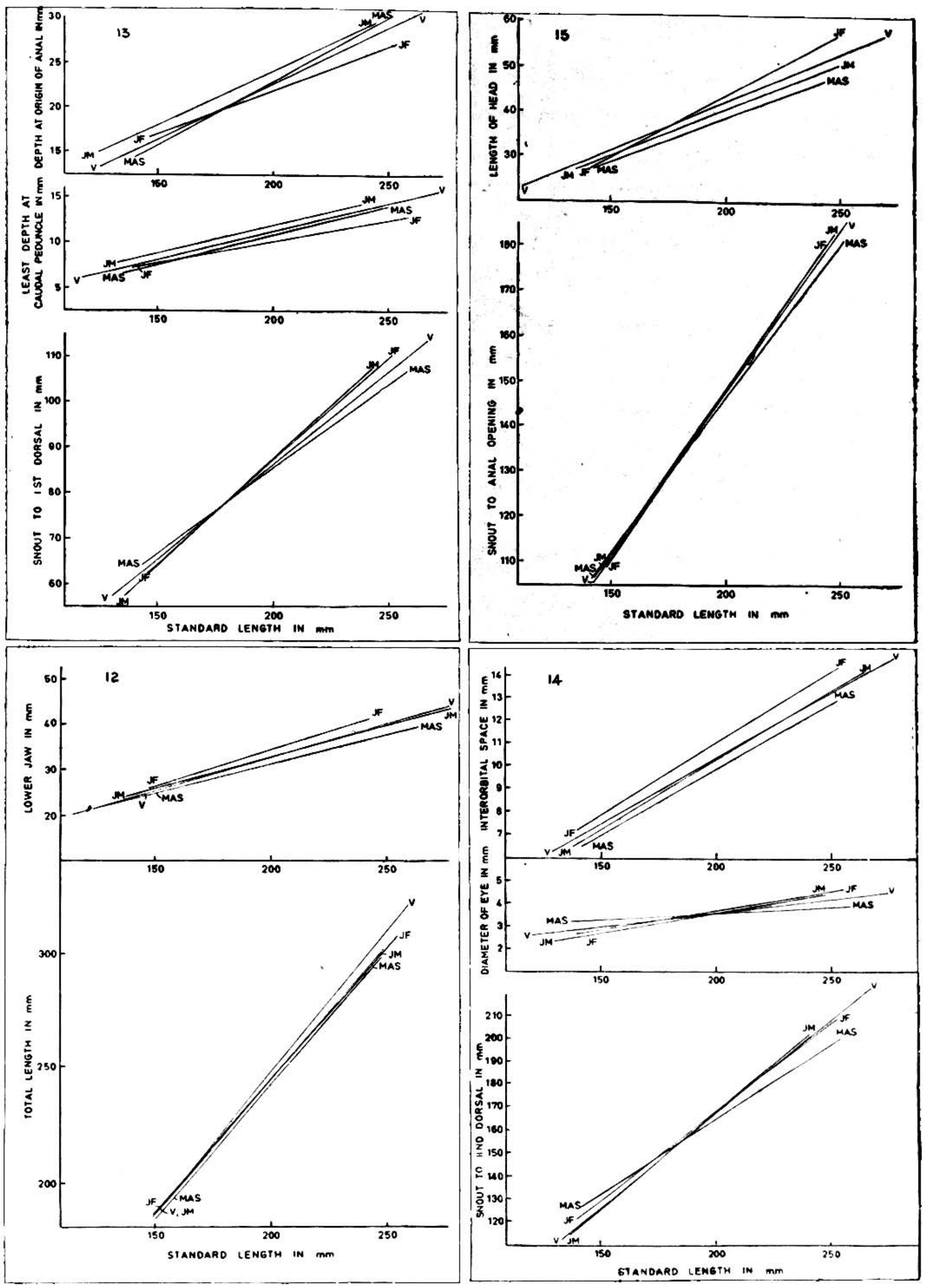
The analysis of variance shows that the samples from Versova and Janjira-Murud are significantly different at 5% level but not at 1% level and that the differences between Jaffrabad and Versova are highly significant. It is interesting to note that the analysis between Janjira-Murud and Masulipatnam samples show no significant differences.

RESULTS OF ANALYSIS

The following two tables (7 & 8) give a summary of the results of the analysis of covariance in respect of regressions of morphometric measurements on standard length and analysis of variance in respect of meristic counts.

It will be seen from the results of the analysis of convariance that the regressions of total length and inter-orbital space on standard length are non-significant throughout. Thus it appears that these characters do not vary with changes in the ecological and environmental conditions and are hence not likely to be useful in the delimitation of stocks. It may also be seen that the regressions of eye diameter on standard length vary significantly in all the comparisons indicating that this character is easily affected by even slight changes in the ecological conditions and hence may not be very suitable in studies of delimiting of stocks. Similarly in the meristic counts, the analysis of variance in respect of the anal fin-rays shows non-significant results in samples from all places. Therefore this character also does not help to delimit stocks. Therefore, in arriving at conclusions the results of the analysis of these characters are to be ignored and have not been taken into consideration.

In Figs. 12 to 15 regression lines are shown in respect of different variable characters for all localities on standard length. The



Figs. 12–15. *Harpodon nehereus* : Regression of standard length on body parts

Table 7

Summary of the results of the analysis of covariance in respect of regressions of morphometric measurements between places.

Between different localities	Total length	Snout to anal opening	Snout to I Dorsal	Snout to II Dorsal	Diameter of eye	Inter orbital space	Caudal peduncle	Depth at origin of anal	Lower jaw	Length of head
All places	N. S.	N. S.	**	**	**	N. S.	**	**	**	**
Jaffrabad Versova & Janjira	N. S.	N. S.	**	N. S.	**	N. S.	**	**	N. S.	**
Versova & Janjira	N. S.	N. S.	**	N. S.	**	N. S.	N. S.	N. S.	N. S.	N. S.
Janjira & Masulipatnam	N. S.	**	*	**	**	N. S.	*	*	N. S.	N. S.
Jaffrabad & Masulipatnam	N. S.	**	N. S.	*	**	N. S.	**	**	**	**

* Significant at 5% but not at 1% level
** Significant at 1% level
N. S. Not significant

Table 8

Summary of the analysis of variance in respect of meristic counts between places.

Between different localities	Dorsal fin	Anal fin	Vertebrae
All places	**	N. S.	**
Versova and Janjira	N. S.	N. S.	*
Jaffrabad and Versova	N. S.	N. S.	**
Janjira and Masulipatnam	**	N. S.	N. S.

* Significant at 5% but not at 1% level
** Significant at 1% level
N. S. Not significant

significant differences indicated by the analysis of covariance are clearly seen in these figures by the varying slopes of the regression lines.

The results of the analysis of covariance in respect of all the localities show that of the seven regressions on standard length, difference among six of them are highly significant. Similarly the analysis of variance of both the meristic counts show highly significant difference. Therefore it appears that the catches of *Harpodon nehereus* at these places do not belong to a single stock but to more than one stock. Further analysis of covariance is respect of the three west coast samples, namely Jaffrabad, Versova and janjira-Murud shows highly significant differences in regard to three regressions and with regard to one more regresion at 5% level but not at 1% level. Therefore there is reason to believe that these samples, may not belong to a single stock. The analysis between Janjira-Murud and Versova samples shows highly significant difference in respect of only one regression thereby suggesting that they are likely to be coming from a single stock or from a closely related stock. The fact that the entire west coast Bombay duck fishery is not supported by a common stock and that the samples from Versova and janjira-Murud are probably derived from one stock suggests that the catches at Jaffrabad come from a stock independent of that of Versova and Janjira-Murud. This conclusion is further supported by the analysis of variance of meristic counts between Versova and Janjira-Murud and between Versova and Jaffrabad.

Further analysis of the east and west coast samples shows significant differences between Janjira-Murud and Masulipatnam. In this case, out of seven regressions on standard length, the difference among three are highly significant and three more are sigficantly different at 5% level but not at 1% level. In the analysis of variance of the meristic counts, highly significant differences are noticed in case of dorsalfin rays. This suggests that the stocks of Janjira-Murud and Masulipatnam are independent of each other. The results of the analysis of covariance between Jaffrabad and Masulipatnam show highly significant differences in five regressions on standard length and in one case the regression is significantly different at 5% level but not at 1% level. This clearly indicates that the Bombay duck fishery at these two places is supported by stocks independent of each other.

Therefore, based on the results of the analysis of covariance of seven regression on standard length and analysis of variance of two meristic characters there is ample evidence to believe that there are at least three stocks of Bombay duck independent of each othet on the Indian coasts, each supporting the fisheries off Jaffrabad, Versova and Janjira-Murud and Masulipatnam.

The reasons for these differences may not be genetic. Possibly they are due to the ecological and environmental factors available in these areas. This is supported by the fact that greater the distance between two places, there are significant differences among more number of characters.

V. FACTORS DETERMINING DISCONTINUOUS DISTRIBUTION

The discontinuous distribution of Bombay duck along the coasts of India has baffled many research workers. Hora (1934) suggested three factors as responsible for this peculiar distribution viz. 1. the distribution and movements of the favourite food organisms of Bombay duck, 2. the variations in salinity along the coasts of India, and 3. the fluctuations in the surface temperature of sea water. He also suggested that the distribution may be due to the monsoon conditions prevailing in the areas of its occurrence and recommended closer investigation of the problem. Chopra (1939) also observed that the wanderings of the Bombay duck may be traced with the movements of its food items along the Indian coasts. Raj (1954) while attributing the peculiar distribution of Bombay duck to 80^{o}F Summer isotherm of July, disputed the possibility of salinity being one of the factors responsible. He emphasised that the monsoon conditions have something to do with its peculiar occurrence. Subsequent to the suggestions put forward by these authors considerable Data on the biology of Bombay duck and the physical and chemical conditions of sea water along the coasts of India are available. Therefore, it was considered worthwhile to examine these data in the light of the above suggestions and see whether any conclusions could be arrived at.

A systematic study of the food and feeding habits of this species occurring in Bombay was first carried out by Bapat *et al*. (1951) during 1948 – '50. They concluded that prawns and shrimps formed the main food of the species, supplemented by *H. nehereus, B. moclellandi, C. dussuimeri* and *P. hetadactylus* in order of abundance. Pilly's (1951) examination of the stomach contents of this fish from the Matlah estuary in West Bengal has shown that prawns and shrimps form the principal food of the species and accounting for 63.03% of the stomach contents, the second in importance being *H. nehereus* and other fishes as *Anchoviella* and *Mugil*. The present observations based on an examination of 582 specimens of *H. nehereus* from Bombay indicate that it is primarily a carnivorous fish, mainly subsisting on fish and prawns. Thus the two studies conducted at Bombay with an interval of about ten years show that the species does not show any special preference either to fish or the prawn diet.

In view of the results of these three investigations which are based on adequate samples, it appears that the wanderings of the Bombay duck cannot be attributed to the movements of its food organisms. If prawns and shrimps are to be considered as its main food and the occurrence of the Bombay duck is to be associated with the occurrence of these food items, then they should have occurred in large quantities along the Kerala coast which has rich prawn grounds. *Acetes* sp. the common food item of Bombay duck is well represented in the Kerala fish landings The absence of Bombay duck along the kerala coast lends further support to the view that they do not migrate in shoals in search of any particular food item.

The next common explanation put forward relates to surface salinity. It has been suggested by Hora (1934) that the areas between Ratnagiri and the Gulf of Cambay on the west coast are low salinity areas. On the west coast, the low salinity is caused by the influx of waters of the Narbada and Tapti and also the heavy south-west monsoon rains. The low salinity on the east coast between Madras and Calcutta is caused by waters from the major rivers of India, namely, the Brahmaputra, the Ganges, the Mahanadi and the Godavari which pour into the bay of Bengal.

Valuable data relating to surface salinity and surface temperature have been collected by La Fond (1958), Ramamurthy (1953)*, George (1953) and Jayaraman and Gogate (1957) from different localities on the coasts of India. Table No. 10 gives the values of average surface salinity from the published records of the above authors and data supplied by individual workers at eight stations, namely, Saugor Island, Waltair, Madras, Mandapam, Calicut, Karwar, Bombay and off Jaffrabad, on the east and west coasts of India.

It will be seen from the table that the values for surface salinity were generally on the lowest side at all the four stations on the east coast

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* personal communication.

Table 9 Fluctuations of average surface salinity of sea water at different localities along the coasts of India

Month	Saugor Island Sept. 50- Dec. 51	Waltair October 51 - April 53	Madras Harbour July51- March 54	Madras Harbour Feb. 51- April 52	Mandapam January 50 - Dec. 53	Calicut May 48- April 51	Karwar April 56 to March 57	Bombay Jan. 55 Feb. 57	Bombay 1958	Jaffrabad June 55 May 56
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
January	31.11	29.20	24.14	30.06	28.87	34.03	27.91	35.87	35.64	34.65
February	32.36	31.45	25.90	30.68	30.16	34.35	33.71	35.67	35.53	35.60
March	34.72	33.72	27.72	34.10	31.89	34.73	34.37	-	35.62	35.28
April	37.03	34.20	27.70	34.39	33.26	35.26	34.48	-	36.42	35.35
May	37.54	34.08	27.83	34.68	35.10	36.01	33.74	-	36.29	36.00
June	36.92	33.41	28.01	34.32	35.56	33.81	16.61	35.95	34.48	36.60
July	34.04	33.20	27.59	34.44	35.55	30.06	6.34	35.50	16.81	36.45
August	27.65	32.68	27.92	34.12	36.09	29.00	7.16	-	23.11	36.76
September	19.40	31.62	26.80	33.53	36.22	31.54	18.97	33.55	26.68	-
October	17.47	25.10	24.04	32.39	36.13	32.76	26.88	34.81	34.64	35.30
November	22.79	24.40	19.25	26.24	33.02	33.91	31.58	35.41	35.76	33.55
December	29.04	26.14	22.25	28.80	28.83	34.59	33.32	36.15	35.79	35.11

1, 2, 3, 4, 5. LaFond, E. C., Andhra Univ. Mem. Ocea. **2**. Ser. 62, 12-21, 1958.
6. George, P. C., *J. Zool. Soc. India.* **5**: 76-107, 1953
7. Ramamurthy, S., Personal communication
8. and 10. Jayaraman, R and S. S. Gogate, *Proc. Indian Acad. Sci.* **45**: 151-164, 1957.
9. Data available at the C. M. F. R. Sub-station, Bombay.

than those on the west coast. Of the four stations on the west coast, the values for Karwar and Calicut are generally lower than those of Bombay and Jaffrabad. During the monsoon months, the values for Bombay are lower than those for Calicut and this may be due to the fact that the samples were taken in the vicinity of the harbour, where the effect of the influx of rainwater are likely to be more pronounced.

Another important factor that will have to be taken into consideration is the extreme adaptability of the species to variations in salinity. This is suggested by the fact that Bombay duck is available in the esturies of big rivers on the east coast where the variations in salinity are naturally high. On the Andhra coast, it occurrs primarily as a marine fish. At Bombay it occurs in failry good quantities from September to May when the surface salinity is high and also during the monsoon months within the harbour limits when the surface salinity is considerably low. At Jaffrabad it is taken in large quantities during November-January or February, even though the values for surface salinity are failry high. Thus, the evidence at hand indicates that the Bombay duck is relatively euryhaline and hence salinity

are fairly high. Thus, the evidence at hand indicates that the Bombay duck is relatively euryhaline and hence salinity does not appear to be the decisive factor, restricting the distribution of the species along the coasts of India.

In this connection, it may be of some interest to study the morphological feature of the Bombay duck. It is an elongate, slender fish with comparatively large head and soft body, gelatinous in appearance. The lower jar is prominent and the cleft of the mouth is wide. A band of unequal, recurved, depressible teeth is present in the jaws and especially in the lower jaw where they are enlarged and hastate. The eyes are small and are covered by an adipose membrance. It is reported to be brilliantly phosphorescent in fresh condition. These characteristics give it the resembalnce to deep sea species which live in environs where water temperatures are low. It is probable that temperature of the sea water may have a bearing on the distribution of the Bombay duck. Bapat *et al.* (1951) have observed that the intensive fishing for Bombay duck off Bombay coincides with the low surface temperature period.

Sunder Raj (1954) correlated the occurrence of Bombay duck with the 80^{o}F isotherm for july and the monsoon condition prevailing in the areas of its distribution. It is not clearly understood, how the atmospheric temperature influence the occurrence of fish in the sea. Jayaraman and Gogate (1957) have shown that the variations in the surface temperature and salinity are primarily influenced by currents and drifts in the sea and that surface heating is of negligible consequence along the Bombay and Saurashtra coasts in the Arabian sea. The values for surface temperature for eight stations available from published records and personal communications are presented in Table 10.

Bombay duck have been recorded from the east coast north of Madras from July onwards till December. From a study of Table No.10 it can be seen that the average values for surface temperature both at Waltair and Saugor Island during July-December were 27.8^{o}C and 27.9^{o}C respectively. During the same period the values at madras and Mandapam were 28.6^{o}C and 27.5^{o}C respectively. In general it appears that the waters north of Madras are less warm than those in the south. On the west coast of India, particularly on the Konkan coast, the major Bombay duck fishery commences in September and lasts till February although then fish are landed in some quantities in other months also. The average values for surface temperature at Bombay and off Jaffrabad during the period September to March were 26.9^{o}C and 25.1^{o}C respectively. During the same period the values at Karwar and Calicut were 27.9^{o}C respectively. Thus it can be seen that the surface temperature values were lower in the areas of distribution of the Bombay duck during the fishing season on both the east and west coasts, the regional differences being more marked on the west coast where the magnitude of the Bombay duck fishery is greater. Therefore it would appear that, more than the salinity of the water and the availability of food, it is the surface temperature that seems to be the principal factor influencing the peculiar distribution of Bombay duck along the coasts of India.

Table 10 Fluctuations of average surface temperature of sea water at different localities along the coasts of India

Month	Saugor Island Sept. 50-Dec. 51	Waltair October 51 - April 53	Madras Harbour July51-March 54	Madras Harbour Feb. 51-April 52	Mandapam January 50 Dec. 53	Calicut May 48-April 51	Karwar April 56-March 57	Bombay Jan. 55 Feb. 57	Bombay 1958	Jaffrabad June 55-May 56
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
January	23.20	25.06	26.39	27.20	25.17	27.65	27.00	25.90	25.60	22.50
February	23.18	25.72	27.50	27.60	25.98	28.39	26.85	25.20	25.60	23.50
March	23.33	26.28	28.17	28.50	27.82	29.25	28.90	-	27.50	25.50
April	23.78	26.56	29.17	29.60	29.66	29.82	30.27	-	29.80	27.03
May	23.78	27.00	28.56	29.20	29.09	29.75	29.88	—	31.30	28.00
June	24.22	28.72	28.78	28.00	27.62	26.97	27.96	28.30	29.70	27.90
July	27.39	28.22	28.44	28.30	27.58	25.30	25.96	28.30	27.20	28.80
August	28.94	27.61	28.11	28.00	28.13	25.24	25.80	-	28.20	28.30
September	29.33	28.44	29.28	29.40	27.83	25.86	26.40	27.00	27.60	-
October	29.11	28.94	29.39	30.10	28.06	26.56	27.60	28.50	28.20	26.30
November	27.22	27.67	28.39	28.50	27.42	28.26	28.20	28.30	27.30	28.50
December	24.72	26.32	26.22	27.40	25.67	27.72	27.20	27.70	26.50	24.30

1, 2, 3, 4 & 5. LaFond, E. C., Andhra Univ. Mem. Ocea. **2**. Ser. 62, 12-21, 1958.
6. George, P. C., *J. Zool. Soc. India*. **5**: 76-107, 1953
7. Ramamurthy, S., Personal communication
8. and 10. Jayaraman, R and S. S. Gogate, *Proc. Indian Acad. Sci.* **45**: 151-164, 1957.
9. Data available at the C. M. F. R. Sub-station, Bombay.

VI. **EXPLOITATION**

FISHING METHODS AND ZONES

The fishing methods for Bombay duck vary from place to place along the coasts of India. The principal method of capture is by the fixed bag net known as “Dol”. It is also taken by gill-netting, boat-seining and occasionally by trawling. The coastal region could be divided into the following five important zone in respect of the Bombay duck fishery.

Zone 1- The south and south east coast of Saurashtra: The adventurous fishermen of Gujarat from Kolak, Umersadi, Doong Bulsar and Billimoria go to Saurashtra for Bombay duck fishing during the months of October to December- January and land their catches at Madhwad, Navabander, Rajpara and Jaffrabad. There is also fishery of some importance at Madhwad during March-April.

About 400-500 boats operate in the area during the fishing season, each boat carrying a crew of 7-9 men. The nets are operated 6-12 miles from the coast in waters of 10-15 fathoms deep. The majority of fishermen operate two bag nets at a time from each boat, but some units operate three nets.

The net used in this zone is essentially a bag type of net, fixed during the operation to stakes. It is locally known as ‘Dol’ and is made of cotton or hemp or both. The details about the operation of the ‘Dol’ net off Saurashtra are given by Gokhale (1957).

The nets is lowered and hauled depending upon the turn of the tides. The fishermen shoot the nets when they are certain that there will be a strong tidal current. The mouth of the net is always in the direction of the tide and the bag net works as a strainer which retains the fish. Because of the effect of strong tidal current, the fish are unable to retreat from the bag net.

Usually fishermen collect catches of two tides before returning to port. When the weather is favourable, they are tempted to fish for the third tide resulting in the spoilage of the fish taken in the first haul. This deterioration could be reduced to the minimum by mechanisation of boats and ice-on-board facilities.

Zone 2 –The Gujarat coast, particularly a stretch of 10 miles from Kosamba to Kolak: The fishermen of Kosamba, Survada, Doongri, Umersadi, Udvada and Kolak fish for Bombay duck by gill nets along a stretch of 10 miles of coastline in the inshore waters during the months of June to September.

About 2,000 pieces of gill nets, known as ‘Khanderi’, are operated in this zone. These gill nets are 30 feet long and 3 feet high with a mesh of 1 inch from knot to knot. They are made from cotton yarn and are operated from the shore during the monsoon period when Bombay duck approaches inshore waters. The net being selective in operation, only the adults are caught.

ZONE 3 – The Konkan coast from Kalai to Waroda, north of Ratnagiri: The fisherman of the Konkan coast, from Kalai (south of Daman) to Waroda along a stretch of about 200 miles, operate ‘Dol’ nets of varying sizes from September-October to May-June in waters ranging in depth from 6 to 18 fathoms. During the monsoon there is generally no fishing by the local fishermen. However, at the mouths of rivers and creeks a few small ‘Dol’ nets are occasionally operated.

The northern half of this zone from Kalai to Rewdanda is the richest and most of the fishermen have taken to mechanisation of their boats with diesel engines of the range of 15 H.P. to mostly 30/35 H.P. At present there are over two thousand fishing boats which have been mechanised.

Some of the most important fish landing centres of this zone are Versova, Satpati, Bassein, Arnala, Uttan, Murbai, Dahanu, etc. Mention may be made here of Sassoon Docks at Bombay, which has become a very important fish landing centre.

There would be about 20,000 pieces of ‘Dol’ nets of varying sizes owned by the fishermen of the Konkan coast. The boats mostly fish for two tides, but with the introduction of mechanisation many boats have taken to fishing for three tides. Some boats around Bombay have evolved the system of companion-cum-carrier boats and operate in pairs, a sail boat and mechanised boat. In this combination the sail boat remains permanently on the fishing ground and thus fishes for all the four tides of the day, whereas the mechanised boat fishes for two or three tides and brings back the catch of both the boats. When the catch is poor, it has become customary for the powered boats to lift the good quality catch of other boats and transport the same to the fish landing centres.

The size of the boats in this zone is much smaller than that of the Saurashtra coast. When the boat is of large size, usually two to three nets are operated from each boat. The number of men required for operating a sail boat is 3 to 4, and for as mechanised boat 5 to 7.

Essentially the ‘Dol’ net of the Konkan coat is same as that of the Saursthra coast and the nets and their operation along the Konkan coast has been described in detail by Senta (1949). However, there are difference in the operation of the same, particularly in respect of the fixation of permanent anchors of the net. While in the Saurashtra ‘dol’ the permanent anchor for the net consists of a heap of stones with a rope, the ‘Dol’ operated on the konkan coast has wooden anchors of two types. The main type is an anchor-pole or spike of about 8 to 10 feet popularly known as ‘sus’ driven in the mud at the bottom of the sea. The other type is a very long pole or ‘pylon’ known as ‘khamba’ fixed to the bottom and jutting out about the 10 feet above the surface of water at the highest of the high tides.

Zone 4 – Andhra – Orissa coast: The fisherman of Baruva, Pundi, and Calingapatnam in Andhra harvest Bombay duck in boat seine catches. At Junput in Orissa Bombay duck is caught in fixed bag nets.

During the months of July to November Bombay duck is caught by boat-seines on the Andhra coast and in November-December fairly large quantities occur in the catches of fixed bag nets operated along the Orissa coast.

The boat-seines are locally known as ‘Iraga valai’ and are operated by two catamarans. In all, seven persons are engaged in the two catamarans, one having three and the other four fishermen.

Zone 5 – the estuaries of Bengal : The Bombay duck is landed in sizeable quantities along the Midnapore coast and in the estuaries of Bengal. In Matlah river Bombay duck are caught by 'Behundi jal' a fixed type of bag net.

Innumerable bag nets are fixed for fishing in the estuaries of Bengal depending upon the force of current and the turn of the tide. Their frequency of operation depends upon the force of tidal currents and on th richness of the fishery.

The 'Behundi jal' is a fixed type of bag net and is employed in all the months of the year except from the middle of July to the end of October. It is admirably adapted for use in the fast tidal currents of the spring tides of each fortnight. Between November January they are usually fixed during flow tides and between January and April mainly at the time of ebb currents. From April to the middle of July they are fixed in strong currents of both the ebb and flow-tides.

CATCH

The catch data presented here in respect of Bombay duck fishery are drawn from this Institute's Bulletin No.13 on the Marine Fish Production in India for the period 1950-1968 (CMFRI – 1969).

Table 11 Bombay duck landings during 1950 – 1968 in tonnes

Year	Bombay duck	Total catch	% age of Bombay duck
1950	14,161	580,021	2.44
1951	7,262	533,916	1.36
1952	24,647	528,348	5.34
1953	45,261	581,463	7.78
1954	36,051	588,258	6.13
1955	104,117	595,725	17.48
1956	128,618	718,779	17.89
1957	119,567	875,176	13.66
1958	67,311	755,994	8.90

Table (Contd.)

Year	Bombay duck	Total catch	% age of Bombay duck
1959	57,242	584,587	9.79
1960	108,564	879,681	12.34
1961	93,844	683,569	13.73
1962	83,934	644,244	13.03
1963	91,853	655,484	14.01
1964	81,342	859,582	9.46
1965	73,893	832,777	8.87
1966	77,363	890,311	8.69
1967	74,883	863,879	8.67
1968	82,407	902,772	9.13

An examination of Table 11 brings out the following :

(1) there is substantial increase in the landings of Bombay duck over a period of 19 years from 2.44 % in 1950 to 9.13 % in 1968; (2) the fishery was extremely good during 1955, 1956 1957 and 1960 when more than one lakh tonnes of Bombay duck were landed; (3) there was a steep fall in the landings during 1958 and 1959 but the fishery again stabilised at 8-9 % of the total marine fish catch, with Bombay duck landings between 73,893 – 82,407 tonnes, the highest yield ever recorded was in 1956 when 128, 618 tonnes of this fish were landed.

Data in respect of Bombay duck landings from the east and west coast landing centres of India from 1956-1968 were sorted out and tabulated below:

Table 12 Landings of Bombay duck along the east and west coasts of India from 1956-1968.

Year	East coast	West coast	% from West coast
1956	3,320	125,298	97.41
1957	2,108	117,489	98.24
1958	590	66,721	99.80

Table 12 (Contd.)

Year	East coast	West coast	% from West coast
1959	688	56,554	98.80
1960	841	107,723	99.22
1961	717	93,127	99.23
1962	645	83,289	99.23
1963	2,284	90,231	97.53
1964	702	80,640	99.13
1965	661	73,233	99.10
1966	730	76,633	99.05
1967	1,953	72,930	97.39
1968	3,023	79,384	96.33

It would be seen from the above that the catches varying from 96.33–99.80% of the total Bombay duck landings came from the west coast of India. The Bombay duck landing from the commercial fisheries point of view are exclusively from the states of Gujarat and Maharashtra. The seasonal distribution of the species in respect of these two states from 1956-1968 is given in the following two statements. An overall examination shows that the Bombay duck fishery in Gujarat is more abundant than in Maharashtra. The highest catch of 74,046 tonnes in Maharashtra was in 1956 as against 78, 129 tonnes in Gujarat in 1960.

Table 13 Quarter-wise distribution of Bombay duck landings in Gujarat from 1956-1968 in tonnes

Year	I Quarter	II Quarter	III Quarter	IV Quarter	Total
1956	5,435	3,494	2,525	39,798	51,252
1957	5,625	14,951	3,282	34,915	58,773
1958	3,365	5,496	1,310	17,046	27,217
1959	3,641	3,515	235	21,875	29,266
1960	1,309	3,691	2,136	70,993	78,129
1961	5,426	221	18	60,570	66,235
1962	28,006	324	176	25,948	54,454
1963	10,167	1,239	295	54,188	65,889
1964	14,977	681	82	43,879	59,619

Table 13 (Contd.)

Year	I Quarter	II Quarter	III Quarter	IV Quarter	Total
1965	17,468	825	1,442	29,612	49,347
1966	9,777	845	1,673	33,439	45,734
1967	9,483	354	1,393	33,076	44,806
1968	9,733	1,056	2,007	40,880	53,676

Table 14 Quarterwise distribution of Bombay duck landings in Maharashtra from 1956-68 in tonnes

Year	I Quarter	II Quarter	III Quarter	IV Quarter	Total
1956	4,300	9,817	7,091	52,838	74,046
1957	6,638	25,736	4,717	21,595	58,686
1958	5,348	9,475	1,988	22,593	39,504
1959	5,077	5,999	3,030	13,182	27,288
1960	4,787	1,166	5,924	17,715	29,592
1961	4,397	5,465	2,369	14,661	26,892
1962	3,590	5,562	1,451	18,232	28,835
1963	3,753	6,248	1,013	13,310	24,324
1964	2,686	3,593	3,278	11,463	21,020
1965	1,980	6,978	4,252	10,675	23,885
1966	1,506	7,835	3,504	18,054	30,899
1967	2,028	5,846	2,925	17,324	28,123
1968	1,436	5,385	1,604	17,279	25,704

In Maharashtra the Bombay duck are taken throughout the year but the highest yield is in the IV quarter, but gradually diminishing in the order of abundance in quarters I, II and III. In Gujarat also the landings are the highest in the IV quarter followed by the II quarter in order of abundance.

Regarding quarterly trends of Bombay duck landings on the east coast of India, Rao (1969) for the period of 1956-1965 has shown that they were the highest in the fourth Quarter, moderate in the first quarter and poor in the second and third quarters.

VII. **GENERAL REMARKS**

In the forties the Bombay duck landings accounted for just 2-3 % of the marine fish landings of India. In the fifties, with the impetus the fishing industry received with the mechanisation of the craft, the Bombay duck landings reached a maximum of 1 lakh tonnes. In the sixties the total landings showed a downward trend but have stabilised around 75-80 thousand tonnes, although no reduction in effort is apparently visible. Studies on Bombay duck conducted in the Institute also show some change in the pattern of the catch composition, the younger fish dominating the catches now and relative decline in the availability of higher sizes in the commercial catch. These facts suggest that either the present level of fishing has probably attained or the availability has changed due to some fishery-independent environmental factors. So the future course of investigations must be directed towards answering these question.

Long term and annual stock assessment : In case of the exploited stocks, it is essential to find out the current fishing intensity and determine the level of fishing intensity to obtain a maximum sustained yield. The yield from the stock depends on the intensity of fishing and number of fish that are recruited to the fishable stock. If the minimum size of capture is altered, there will be changes in recruitment; thus the minimum age of capture has a direct bearing on the yield as well. The rate of growth, the natural mortality rate as well as the life span of fish influence the yield for a given fishing intensity which may be considered proportional to the fishing mortality rate. Thus the yield from an exploited stock is a function of vital parameters like recruitment, minimum age of capture, growth rate, natural mortality rate, fishing mortality rate as also the fishable life span of the species. Only two of the above parameters, namely, fishing mortality rate which is proportional to fishing intensity and the minimum age of capture can be controlled by suitable regulation of mesh size of the gear. Thus the other parameters have to be estimated by collecting suitable data and express the yield per recruit in terms of fishing intensity and minimum size of capture. The resulting yield per recruit will have a maximum value at some level of fishing effort corresponding to a fixed minimum value at some level of fishing effort corresponding to a fixed minimum size of capture and vice versa. We may also allow variation in both an obtain the direction leading to increase in yield per recruit. The technique of determining the maximum yield per recruit has to be adopted since the recruitment fluctuates from year to year. This type of assessment of fishing only furnishes the average level of fishing intensity which is expected to give the optimum yield and is thus a long term average assessment. The actual yield in any year will vary considerably depending on the strength of recruitment. For short term fishing prospects, it will be necessary to have some knowledge of the age structure of the population from year to year and particularly the strength of the year class.

Thus for an efficient management and rational exploitation of the Bombay duck fishery, we will have to collect suitable data leading to accurate estimated of the parameters involved, viz., catch, mortality rate, effort, are groups in the catch, natural mortality rate, rate of growth etc. Future investigations will have to be directed towards these objects.

In case of the Bombay duck fishery there is bound to be some difficulty in obtaining the effort put in. At present, the 'dol' nets are operated round the clock at the turn of the tide and the catch is brought to the shore by mechanised boats which function as carrier boats. Each carrier boat brings the catch of 3-4 'dol' net units. Methods have to be evolved by which the date in respect of each 'do' net unit has to be collected taking the single 'dol' operation as the unit of effort.

Biological investigations carried out so far on Bombay duck give us a for knowledge on the bionomics of the species, i.e. minimum size at maturity, maturation, the spawning season and spawning periodicity, rate of growth, etc. We also know that the fishery is supported by at least three stocks, two on the west coast and one on the east coast. The delimitation of stocks has to be dealt with in greater detail both statistically and serologically to establish the identity of stocks on the coasts of India. Only which delimitation of stocks will permit as a fuller and more accurate assessment of the Bombay duck fisheries as a whole. The future biological investigations will be directed to fill up gas in the available knowledge. Some special emphasis is necessary on the following aspects of research:

Spawning survey: The gap in our knowledge on the eggs and larvae of Bombay duck and the area of spawning required urgent steps to take up the spawning survey on priority basis. Identification and delimitation of spawning areas will make important contributions to the solution of the problem of stock delimitation apart from its value on recruitment research and life-history studies.

Recruitment research : We find some annual fluctuations in the catches which are mainly traceable to the variations in the magnitude of recruitment. The study of its fluctuations will be helpful in predicting fishing success on short term basis. This researhc will also aim at finding out whether there is any relation between the abundance of spawners and subsequent recruitment. If any relation is found, our efforts should be direct towards keeping the spawners at a level which would ensure maximum recruitment. This can be done by regulating fishing of spawners.

Environmental studies : It is well known that fishery environmental factors affect a fish stock in several ways. The brood strength is determined in the main by one or more critical factors in the environment affecting subsequent recruitment. The availability of the fish in the fishing ground may again depend on these leading to fluctuations.

Availability and migration studies : At present fishing is restricted to certain areas in the inshore belt and the fishery depends on the Bombay duck shoal entering the area. If the availability changes, the fishery prospects also change. To understand the true nature if present availability, it is necessary to undertake exploratory surveys in areas beyond the present fishing zone in and outside the fishing seasons. Such exploratory surveys will also throw light on migration. Mark release experiments are also essential.

Thus an integrated programme of stock assessment together with biological and environmental studies will be necessary for a proper and rational exploitation of the valuable fisheries of Bombay duck.

SUMMARY

1. Taxonomy and distribution of the Bombay duck, *Harpodon nehereus* have been described. The species presents a discontinuous distribution on the Indian coasts.

2. A study of the sex-ratio showed that females predominated the catches throughout the period of study except in the months of July and August. The overall sex-ratio was for every 100 males, 171 females. From the condition of maturity of the ovaries it appears that *H. nehereus* breeds throughout the year, with a peak breeding season extending over a period of four months from December to March. The ova diameter measurements indicate that each individual fish spawns only once in a year.

The major recruitment to the stocks takes place during the post-monsoon months of September-December. Continuous recruitment to the stocks is also indicated which further confirms the continuous breeding habit of the species.

3. The minimum size of maturity has been determined to be 210mm in total length.

4. The values for ponderal index in female indicate an inflexion at 210 mm which coincides with the minimum size of maturity. It is also seen that the 'K' values are generally lower in the female than the male and particularly so during the peak spawning season.

5. Fecundity studies in specimens varying between 229-318 mm in total length have shown that the number of ova produced by an individual varied between 14,600 to 1,46,400.

6. The length frequency studies show that the fish attain an average total length of 127 mm at the end of the first year and 217 mm at the end of the second year. From these data, it can be inferred that *H. nehereus* attain maturity when it completes two years. The average monthly rate of growth appears to be 11 mm in the first year and 8 mm in the second year.

7. Length-weight relationship for the two sexes has been determined and the formulae dervied are:

Male $W = 0.0000009795\ L.^{3.7169}$

Female $W = 0.\ 0000002268^{\ 3.4444}$

The observed and calculated values, when plotted, show a very close agreement and the curves for the two sexes cut each other at 210 mm which again confirms the minimum size of maturity in *H. nehereus*.

8. An examination of the stomach contents of 582 specimens of *H.nehereus* during 1958-1959 clearly shows that it is a carnivorous fish mainly subsisting on fish and crustacean diet.

From the percentage of empty, full and gorged stomachs it appears that the feeding activity is at a higher level during January to April which incidentally are the months coming after the peak spawning period. The percentage of empty stomachs was the highest during November.

9. Morphometric measurements and meristic counts of a Large number of specimens were carried out, from Jaffrabad, Versova, Janjira-Murud and Masulipatnam.

No significant differences were noticed in respect of the regressions of total length and inter-orbital space on standard length from all the four localitites. Similarly, among the meristic characters, the analysis of variance in respect of anal fin count did not show significant results. On the other hand, the regression of diameter of eye on standard length showed highly significant results in respect of all the localities. Therefore, it appears that these four characters are not likely to be useful in the delimitation of stocks.

The analysis of covariance of sample from Versova indicates that they are derived from a homogeneous stock.

From an examination of samples from the four localities, it appears that the Bombay duck fishery is supported by three independent stocks. The fishery at Versova Janjira-Murud is supported by a single, or closely related stocks, whereas the fisheries off Jaffrabad and Masulipatnam are supported by two independent stocks.

From the results obtained it appears that greater the distance between two places, more significant are the difference among the characters.

Sets of formulae for all the four localities have been derived for determining the various body measurements when the standard length is known.

10. The data on surface temperature and surface salinity of sea water along the coasts of India and the food and feeding habits of the species show that the low surface temperature in the areas of occurrence is probably responsible for the peculiar distribution of the species to a greater extent than other factors.

11. The Bombay duck catch statistics indicate a remarkable increase in the landings from 7262 tonnes in 1951 to 1,28,618 tonnes in 1956. 1958 and 1959 recorded poor landings. The fishery revived in 1960 and since then it has more or less stabilised around 80,000 tonnes. In view of the fact that 80% of the catch is comprised of immature fish, it is necessary to keep a close watch on the size composition of the catch and catch statistics to prevent undue destruction of the juveniles.

12. The need for a well integrated programme of stock assessment together with biological and environmental studies for a proper and rational exploitation related to the Bombay duck fishery has been emphasised.

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