ON THE OIL SARDINE FISHERY OF THE MANGALORE ZONE DURING THE YEARS 1957-1963.

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In the Mangalore zone extending from Malpe to Kasaragod, the season for oil sardine (*Sardinella longiceps* Val.) is roughly the same as in the Calicut area, *viz.*, October-March. Work on the fishery of this zone was started in 1957. The first season's study was of a preliminary nature but later the programme was expanded to include detailed observations at Ullal, an important centre near Mangalore, and regular visits to other fishing villages for collection of samples. During this investigation special emphasis was laid on catch trends, environmental variations and size and age composition. The results for the period 1957-'63 are presented here. The fishery of part of this zone for the years 1925-'52 has been discussed by Nair (1952).

METHODS

The zone referred to here, Malpe-Kasaragod, has a coast-line of about 100 km. The fishing range is normally within about 4 miles from shore, although occasionally some of the boats venture even further. The following were the main types of gear operated.

TABLE .I

Types of Fishing Units

Name of Unit	No. of boats required	Type	Operational range
1. *Cast net*	1	..	1–2 miles from shore.
2. *Kollibale*	2	Boat-seine	1–4 miles from shore.
3. *Paithubale*	2	Do.	Do.
4. *Chalabale*	1–2	Gillnet	Do.
5. *Idabale*	3	Do.	1–3 miles from shore.
6. *Manangubale*	1	Do.	1–2 miles from shore.
7. *Kairampani*	1	Shore-seine	Up to about ½ mile from shore.
8. *Rampani*	1 big boat & 6–8 auxiliary ones.	Do.	1–1½ miles from shore.

Experimental purse-seines were also operated. On rare occasions oil sardine in small numbers were landed by trawl-net and also by *Kanthabale*, a bottom gill-net.

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Catch and effort at Ullal

From 1958 onwards, observations were conducted at Ullal on all working days and the catches of 25-50% of each type of operated units observed. The total catch of each type of unit on each observation day (Y_d) was estimated as

$$\frac{N}{n}\Sigma y_i \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and the monthly total (y) as

$$\frac{D}{d}\Sigma y_d \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where N=the total number of nets of each type operated, n=the number of nets observed, y_i=the catch of the ith observed unit, D=the number of the fishing days in the month and the number of days of observation.

The monthly effort (g) expressed in terms of the number of each type of operated unit was estimated as

$$\frac{D}{d}\Sigma g_d \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where g_d is the number operated on the observation day.

The catch-per-unit of effort then is obtained as $\frac{y}{g}$.

Size composition at Ullal

Samples were collected at least twice a week in respect of each type of gear. Samples from units of the same type were pooled on each observation day. The number of fish of a particular length group (l_d) landed on each sampling day by a particular fishing unit was estimated by the formula,

$$l_d=\frac{l_i}{s_i}y_d \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and the monthly total (l_n) by the formula

$$l_n=\frac{y}{\Sigma y_d}\Sigma l_d \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where l_i is the number of fish of a particular length group in the sample of a day and s_i the sample weight.

Then $\frac{l_n}{g}$ gives the catch-per-unit of effort in numbers.

Size-composition at other centres

At least two to three other centres were also visited every week and samples collected. The monthly total number of fish of a particular length group landed by all the observed fishing units of the same type was then estimated by the formula,

$$\Sigma \frac{l_i}{s_i} Y_i \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where l_i is the number of fish of a particular length group in each sample, s_i the sample weight and Y_i the catch of the ith observed unit. This when divided by the number of units observed gave an estimate of the catch-per-unit-of effort.

In Fig. 3—10, the catch-per-unit of effort is plotted.

THE FISHERY

For purposes of the discussion here, this zone has been divided into two sections—the southern section extending from Kasaragod to Ullal and the northern one from Ullal to Malpe. The year referred to is July-June.

1957—58 :

This season was very good in this zone as on other sections of the Mysore and Kerala coasts. The fishery commenced in September and attained the peak in October-November. The longer season of heavier catches was limited to the Moolki-Kasaragod region. The fishery weakened considerably after the first half of February.

1958—59 : (TABLE II)

The fishery was a failure at Mangalore and other northern centres. At Ullal, the total annual catch was only about 0·18 metric tons, the entire quantity having been landed in October. The fishery was localised mainly to the centres south of Ullal, where moderate catches were reported.

1959—60 : (TABLE III)

This season was also poor, although the total catch was higher than that of the last year. The fishery started in the southern centres (Kanhangad, Kasaragod etc.) in the second half of October and gradually extended to the northern centres (Ullal, Panambur, Baikampady, Malpe etc.). Large catches were recorded from middle of November to end of December, after which there was hardly any oil sardine fishery.

The first catch at Ullal was on 29th October. The annual total catch amounted to about 55·8 m. tons of which as much as about 55·7 m tons were landed in November. By the end o this month the season came to a close here. *Chalabale* had the highest catch this year and cast net the highest catch-per-unit of effort.

During November and December, the FAO experts conducted experimental purse-seine operations off Mangalore and very good catches were recorded especially on 15th November and 12th December.

TABLE II

Monthly Catch and Effort at Ullal in 1958-59

Month	Cast net		
	g	y	y/g
October	474	0·18	0·38
November	15	..	..
December	..	..	..
TOTAL	489	0·18	0·38

There was no fishing for sardine after November.

g=Effort (No. of Units operated);

y=Catch (in Metric tons);

y/g=Catch-per-unit of Effort (in Kg.).

TABLE III

Monthly Catch and Effort at Ullal in 1959-'60

Month	Cast net			*Chalabale*			*Kairampani*			*Manangubale*			Monthly total catch
	g	y	y/g	g	y	y/g	g	y	y/g	g	y	y/g	
July	..	..	..	..	..	..	..	..	..	..	..	..	..
August	..	..	..	..	..	..	..	..	..	..	..	..	..
September	..	..	..	..	..	..	..	..	..	..	..	..	..
October	..	..	..	..	..	..	1	0·14	136·00	..	..	..	0·14
November	329	23·18	70·46	518	32·51	62·76	..	..	..	..	..	..	55·69
December	..	..	..	..	..	..	..	..	..	..	..	..	..
January	..	..	..	..	..	..	..	..	..	..	..	..	..
February	..	..	..	..	..	..	..	..	..	..	..	..	..
March	..	..	..	..	..	..	..	..	..	..	..	..	..
April	..	..	..	..	..	..	..	..	..	91	0·02	0·22	0·02
May	..	..	..	..	..	..	..	..	..	150	..	..	..
June	..	..	..	..	..	..	..	..	..	..	..	..	..
TOTAL	329	23·18	70·46	518	32·51	62·76	1	0·14	136·00	241	0·02	0·08	55·85

g=Effort (No. of units operated).
y=Catch (in Metric tons).
y/g=Catch-per-unit of Effort (in Kg.).

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1960—61 (TABLE IV)

Catches were much better this year than in 1959-60 . The fishery commenced in the second week of July at the southern centres, later becoming active at the northern centres as well. Landings were especially high in October and December. In the *Rampani* centres north of Mangalore, heavy catches were recorded in the last week of December; 8 *Rampani* hauls were observed during field trips undertaken at this time, and their landings totalled about 282 m. tons (catch-per-haul of more than 35,000 kg.). The fishery was poor after February.

At Ullal, the first catch of the new season was noted on 21st August. The total annual catch was about 94 m. tons. October-December was the most productive quarter (about 48 m. tons). Also October recorded the highest monthly total (about 28 m. tons) followed by December, the November catch being negligible. The bulk of the October catch was made by cast net and that of the December catch by *Chalabale*. There was no catch in February, but a recovery was noted in April. *Chalabale* ranked first both in regard to annual catch and annual catch-per-unit of effort. It did not land sardine in July-September. The next three quarters showed a rising trend in its c.p.u.e., the maximum being noted in April-June. On the other hand cast net had the highest c.p.u.e. in October-December.

1961—62 (TABLE V)

An important feature of this year's fishery was its concentration in a 15-mile section of the coast-line extending from Ullal to Suratkal.

The commencement of the season was normal, many of the centres recording catches in the first week of August, but with the advance of the season and especially from November to February the fishery was localised in the Ullal-Suratkal section. Large dense shoals appeared in the 3-8 fathom area off this region and heavy landings were made by *Rampani*, many of which had come from centres outside this section. Altogether 66 *Rampani* hauls were observed this year and the catch-per-haul amounted to 10,191 kg. Similarly the catch-per-net for *Kollibale* observed in centres other than Ullal was about 619 kg. These are, of course, on the high side since they refer only to operations that had oil sardine catch.

At Ullal, the annual estimated catch was about 432 m. tons. The new season commenced here on 3rd August. The data showed yield peaks in October, December and February. January-March was the most productive quarter. Unlike in previous years, *Rampani* net was operated at this centre this year. It landed about 354 m. tons which formed about 80% of the total and accounted for the major part of the five-fold increase in landings recorded this year, as compared to 1960—61. The other nets, among which cast net, *Kollibale* and *Chalabale* were the more important, landed about 78 m. tons. It was also seen that during periods of high catches the fishermen curtailed effort so that the landings might not become unmanageable. The October peak was accounted for mainly by cast net and the December and February peaks by *Rampani* catch. Both in regard to total catch and catch-per-unit of effort, *Rampani* ranked first, followed by *Kollibale*.

1962—63 (TABLE VI)

The sardine season was good this year also. The fishery was more evenly spread out than during last year, and all centres had good catches, although generally speaking, landings were better in the south than in the north.

TABLE IV.

Monthly Catch and Effort at Ullal in 1960-61

Month	Cast net			*Kollibale*			*Chalabale*			*Manangubale*			*Idabale*			Monthly total catch
	g	y	y/g	g	y	y/g	g	y	y/g	g	y	y/g	g	y	y/g	
July	87	..	..	..	..	..	27	..	..	59	..	..	..	..	..	..
August	315	0·07	0·22	..	..	..	..	..	..	32	..	..	38	4·43	116·58	4·50
September	328	3·07	9·36	..	..	..	10	..	..	..	..	..	63	2·10	33·33	5·17
October	400	17·72	44·30	..	..	..	99	10·87	109·80	..	..	..	..	..	..	28·59
November	34	..	..	..	..	..	69	1·46	21·16	..	..	..	..	..	..	1·46
December	19	3·40	178·95	1	..	..	243	14·79	60·86	..	..	..	..	..	..	18·1
January	20	0·79	39·50	..	..	..	220	16·53	75·14	..	..	..	..	..	..	17·32
February	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
March	..	..	..	..	..	..	63	3·00	47·62	..	..	..	..	..	..	3·00
April	..	..	..	..	..	..	105	15·84	150·86	..	..	..	..	..	..	15·84
May	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
June	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
TOTAL	1,203	25·05	20·82	1	..	..	836	62·49	74·74	91	..	..	101	6·53	64·65	94·07

g=Effort (No. of units operated);

y=Catch (in Metric tons);

y/g=catch-per-unit of Effort (in Kg.).

TABLE V

Monthly Catch and Effort at Ullal in 1961-62

Month	Cast net			*Kollibale*			*Chalabale*			*Kairampani*			*Rampani*			*Menangubale*			*Idabale*			Total monthly catch
	g	y	y/g	g	y	y/g	g	y	y/g	g	y	y/g	g	y	y/g	g	y	y/g	g	y	y/g	
July	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
August	297	2·15	7·25	..	..	..	102	2·03	19·90	..	..	..	..	..	..	..	..	..	..	..	..	..	4·18
September	326	0·19	0·58	..	..	..	367	3·62	9·86	16	..	..	..	..	..	..	..	..	7	0·13	18·57	3·94	
October	561	11·69	20·84	4	..	..	159	..	..	14	0·16	11·43	..	..	..	..	..	..	10	0·16	16·00	12·01	
November	83	1·24	14·94	8	1·96	245·00	36	0·46	12·78	1	..	..	..	..	..	..	..	..	33	..	..	3·66	
December	18	1·05	58·33	61	9·57	156·89	206	1·11	5·39	..	..	..	2	40·82	20410·00	1	0·01	10·00	..	..	..	52·56	
January	10	0·24	24·00	149	35·19	236·17	30	0·01	0·33	..	..	..	..	..	..	..	..	..	15	2·27	151·33	37·71	
February	..	..	..	34	0·95	27·94	..	..	..	..	..	..	25	307·58	12303·20	..	..	..	2	..	..	308·53	
March	..	..	..	..	..	..	..	..	..	..	..	..	6	6·07	1011·67	..	..	..	2	..	..	6·07	
April	..	..	..	..	..	..	234	3·62	15·47	..	..	..	..	..	..	..	..	..	..	..	..	3·62	
May	..	..	..	..	..	..	56	..	..	..	..	..	..	..	..	32	..	..	..	..	..	..	
June	5	..	..	..	..	..	..	..	..	42	..	..	..	..	..	17	..	..	..	..	..	..	
TOTAL	1300	16·56	12·74	256	47·67	186·33	1190	10·85	9·12	73	0·16	2·19	33	354·47	10741·52	50	0·01	0·20	69	2·56	37·10	432·2	

g=Effort (No. of units operated).

y=Catch (in Metric tons).

y/g=Catch-per-unit of Effort (in Kg).

TABLE VI

Monthly Catch and Effort at Ullal in 1962-63

Month	Cast net			*Kollibale*			*Chalabale*			*Kairampani*			*Manangubale*			*Idabale*			*Kuthabale*			Total catch
	g	y	y/g	g	y	y/g	g	y	y/g	g	y	y/g	g	y	y/g	g	y	y/g	g	y	y/g	
July	125	1·27	10·16	..	..	..	..	..	..	4	..	..	126	..	..	..	..	..	..	..	..	1·27
August	88	0·23	2·61	2	1·36	680·00	370	2·45	6·62	4	..	..	274	0·10	0·36	..	..	..	..	..	..	4·14
September	257	..	..	..	..	..	20	..	..	30	0·65	21·57	193	..	..	..	..	..	..	..	..	0·65
October	175	2·44	13·94	16	4·69	293·13	23	0·24	10·43	23	1·39	6·04	..	..	..	..	..	..	..	..	..	8·76
November	256	8·47	33·09	..	..	..	5	..	..	5	0·07	14·00	51	1·65	32·35	..	..	..	..	..	..	10·19
December	127	2·89	22·76	112	11·36	101·43	59	..	..	..	..	..	17	..	..	..	..	..	..	..	..	14·25
January	71	4·54	63·94	43	4·44	103·26	76	1·26	16·58	..	..	..	..	..	..	..	..	..	..	..	..	10·24
February	35	2·32	66·28	81	18·98	234·32	61	0·79	12·95	..	..	..	..	..	..	21	0·13	6·19	..	..	..	22·22
March	..	..	..	5	..	..	104	1·28	12·31	..	..	..	..	..	..	14	0·37	26·43	298	0·01	0·03	1·66
April	..	..	.	..	..	..	402	7·16	17·81	..	..	..	..	..	..	..	..	..	..	..	..	7·16
May	..	..	..	..	..	..	65	..	..	1	..	..	15	..	..	57	..	..	..	..	..	..
June	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
TOTAL	1134	22·16	19·54	259	40·83	157·64	1185	13·18	11·12	67	2·11	31·49	676	1·75	25·89	92	0·50	5·44	298	0·01	0·03	80·54

g = Effort (No. of units operated).

y = Catch (in Metric tons).

y/g = Catch per-unit of Effort (in Kg.)

Altogether 28 *Rampani* hauls with oil sardine were observed this year and the catch-per-haul was estimated as 7958 kg. In regard to *Kollibale*, taking into account only those units that landed oil sardine, the catch-per-net was 387 kg. for centres other than Ullal.

About 81 m. tons of oil sardine were landed at Ullal. The first catch of the new season here was recorded on 25th July in cast net. Monthly totals had two peaks, one in December and the other in February. After the third week of February the fishery was poor for some time, but improved again in April. *Kollibale* recorded the highest total catch and catch-per-unit of effort. An interesting feature noted this year was the occurrence of oil sardine in *Kanthabale*, a bottom gill net operated in the 10-25 meter area, and also in the catches of trawl nets.

Of the seasons referred to here, 1958-59 was the poorest while 1957-58, 1960-61 and 1962—63 were very good. Apart from total catch, the duration of the season had also varied between years. It will be seen that beginning from 1958-59, the duration of the fishery had been increasing steadily every year. At Ullal, oil sardine were caught for one month in 1958-59, eight months in 1960-61 and ten months in 1962-63. Of course, a longer season need not necessarily result in a higher catch as the latter depends also on the level of abundance of the fish. An important feature of the sardine fishery is the high level of abundance it maintains for short periods. In 1959-1960, the seasonal total at Ullal was almost entirely accounted for by the November catch of 55 m. tons. Even though it was not a good season, none of the monthly totals here attained that level in other years except when the *Rampani* net was operated in 1961-62 due to the peculiar nature of that year's fishery. But again, it has often been seen that catch level is limited, not by the level of abundance of the fish, but by economic considerations. On a number of occasions with the catch-per-unit of effort rising to high values, the fishermen had to curtail production on account of market conditions. It is evident that in good years the maximum catch possible under the prevailing conditions is not taken.

Though the length of the season varies from year to year, it has been seen that the fishery remains active for more time in the south than in the north. Normally the season commences earlier in the south and also ends later. Chidambaram (1950) and Panikkar (1952) also have discussed this phenomenon, as it applies to the West Coast as a whole.

At Ullal, cast net, *Chalabale* and *Kollibale* were the important gear operated for oil sardine. But the relative importance of these nets has been changing in recent years. *Kollibale* assumed greater prominence during the last two seasons, whereas, prior to 1961 it has rarely been operated at this centre.

LENGTH FREQUENCY

The length frequency distributions are shown in Figs. 1-10. From 1958 onwards the samples were weighted according to catches and the catch-per-unit of effort estimated, as stated earlier. For the sake of convenience, the frequencies are plotted in terms of percentages for the years 1959-63. The figures for Ullal and other centres have also been drawn separately. When discussing modes, only non-selective gear (*Rampani*, *Kairampani*, *Kollibale* and cast net) have been considered.

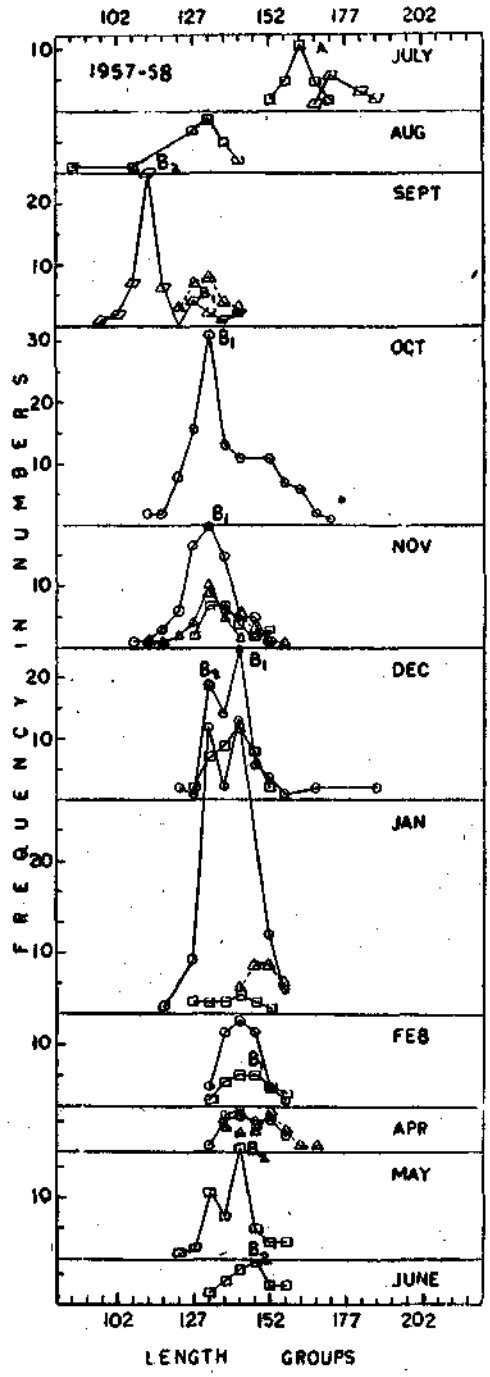


Fig. 1. Size-composition of the catches of oil sardine in 1957-58.

△——△ Cast net; △- - -△ *Chalabale*; □——□ *Kollibale*;
□- - -□ *Idabale*; ▱——▱ *Kairampani*; □- - -□ *Kanthabale*;
○——○ *Rampani*; ○- - -○ *Manangubale*; ◇——◇ *Paithubale*;
⊛——⊛ Trawl net; ⊠——⊠ Purse-seine.

1957—58 :

The catch was very high this year and was supported mainly by the 12-14 cm. size groups, the contribution by larger fish being negligible, as will be seen from Fig. 1. The modes for the younger fish varied from 127-147 mm. during the season; even among them two separate groups or batches could be recognised. It will be seen that in the *Kairampani* catch of September there were two modes at 127 and 112 mm. respectively. The first one (B_1) could be traced to 132 mm. in November and 142 mm. in January in the *Kollibale* and *Rampani* catches. The other one (B_2) moved to 132 mm. and 142 mm. in the *Rampani* catches of January and April respectively and to 147 mm. in June landings of *Kollibale*.

It will be seen that B2 attained the value of 147 mm. four months after B_1.

1958—59 :

Young fish less than 15 cm. in length were absent from the nearshore waters this year. The catch was composed of larger fish, the modes of which could be traced back to the groups B_1 and B_2 of the previous season (Fig. 2). As stated earlier, the fishery failed this year.

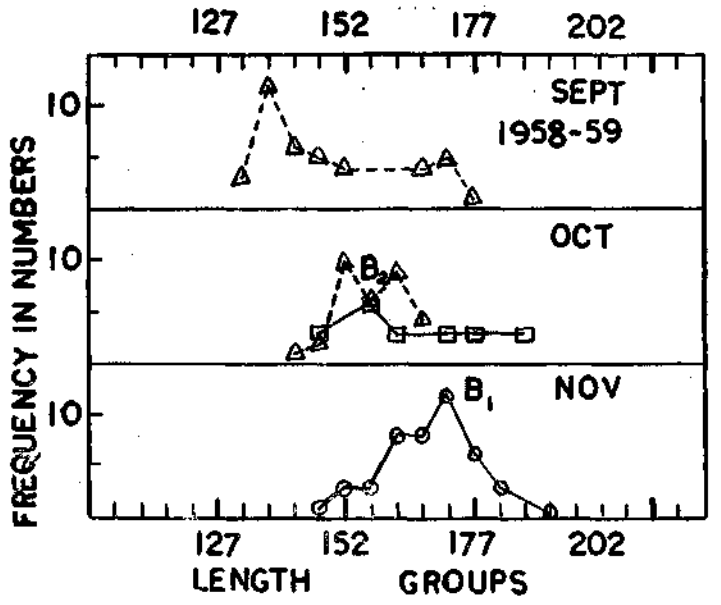


Fig. 2. Size-composition of the catches of oil sardine in 1958-59. (For explanation see Fig. 1).

1959—60 :

Young sardine again appeared in large numbers this year and the catch also improved considerably. Among the large fish four separate groups were noted. Of these the one at 177 mm. in August appeared to be B_2 and this moved to 182 mm. in November after which it could not be traced. The other three groups varied from 152 mm. to 182 mm.

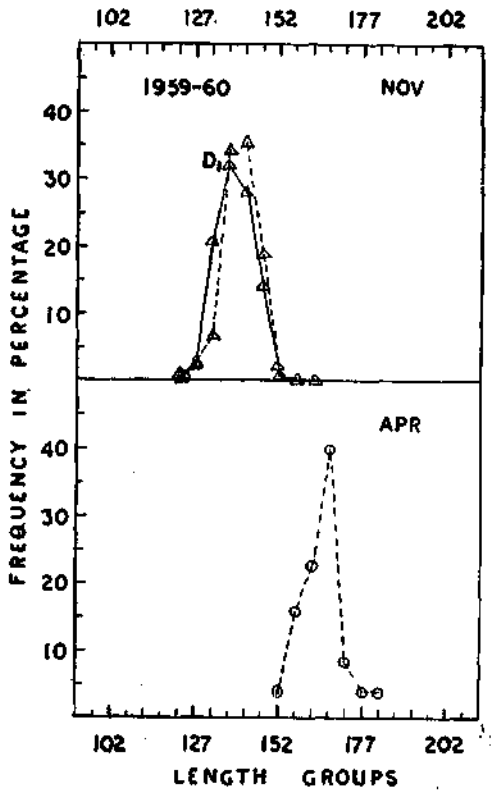


Fig. 3. Size-composition of the catches of oil sardine at Ullal in 1959-60. (For explanation see Fig. 1)

during the October-April period. The group designated as C_2 was at 162 mm. in October and November (in the *Kollibale* and *Rampani* catches respectively). Another group (C_3) was at 152 mm. in the November catches of *Kollibale* and at 162 mm. in the January catches of *Rampani*, from which the time lag between C_2 and C_3 could be put as roughly 2 months. Again in the *Rampani* catch of January there were two modes (C_1 and C_4) at 177 mm. and 152 mm., which moved to 182 mm. and 162 mm. respectively in April. The groups C_1-C_3 would most probably have measured 100—150 mm. in the previous season. As far as the smaller sardine of this year were concerned, two groups were again evident. The first one (D_1) moved from 132 mm. in October to 152 mm. in April in the catches of various nets. But the other (D2) was seen only in the catches of December and January when it measured 117 and 127 mm. respectively. The fishery was supported mainly by group D1 (See Fig. 4)

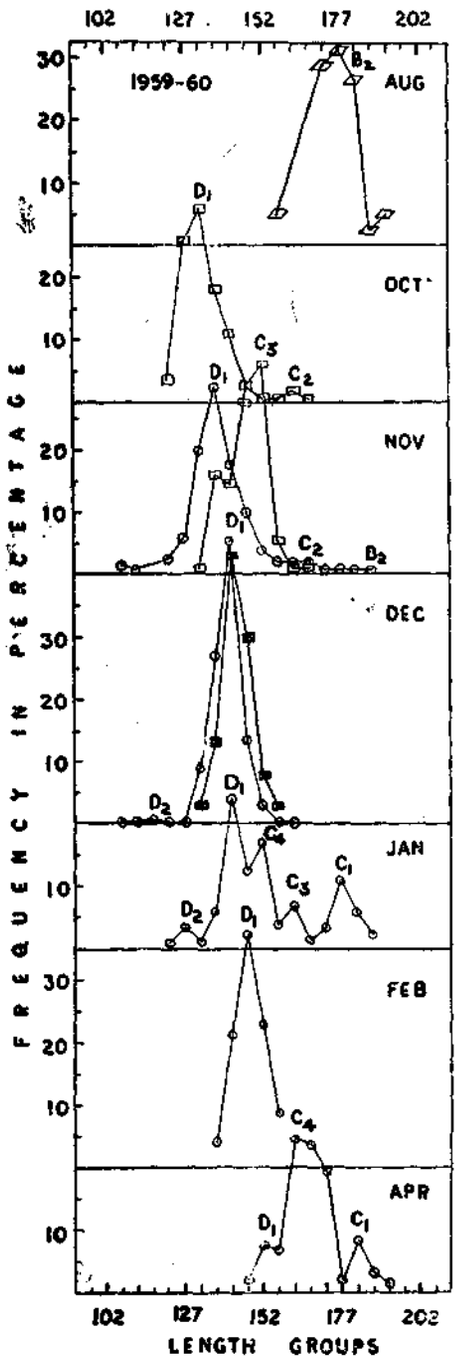


Fig. 4. Size-composition of the catches of oil sardine at other centres in 1959-60. (For explanation see Fig. 1).

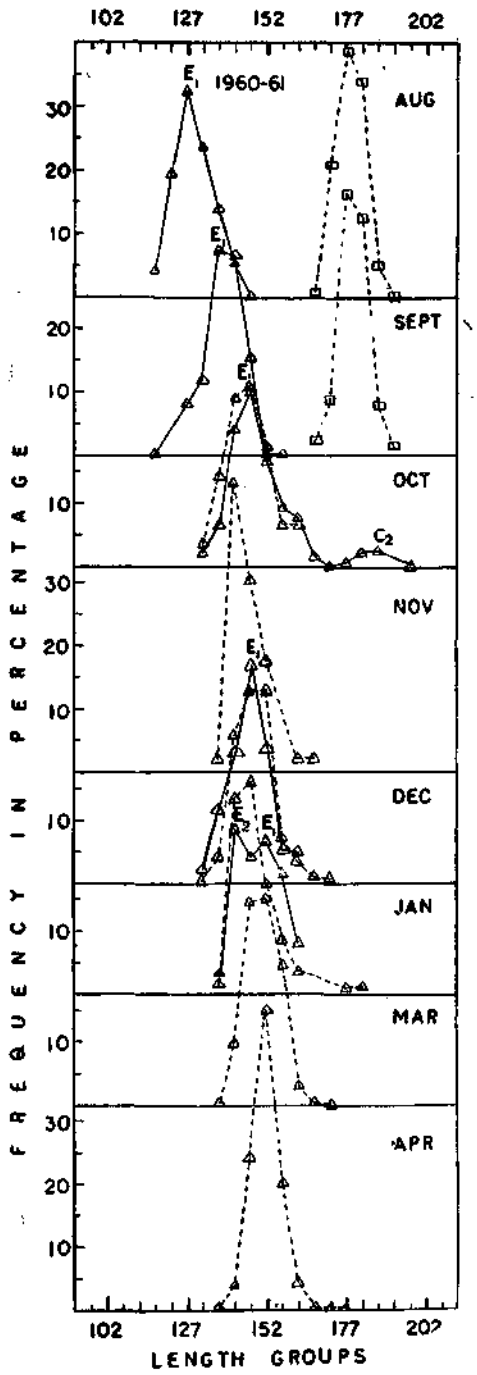


Fig. 5. Size-composition of the catches of oil sardine at Ullal in 1960-61. (For explanation see Fig. 1).

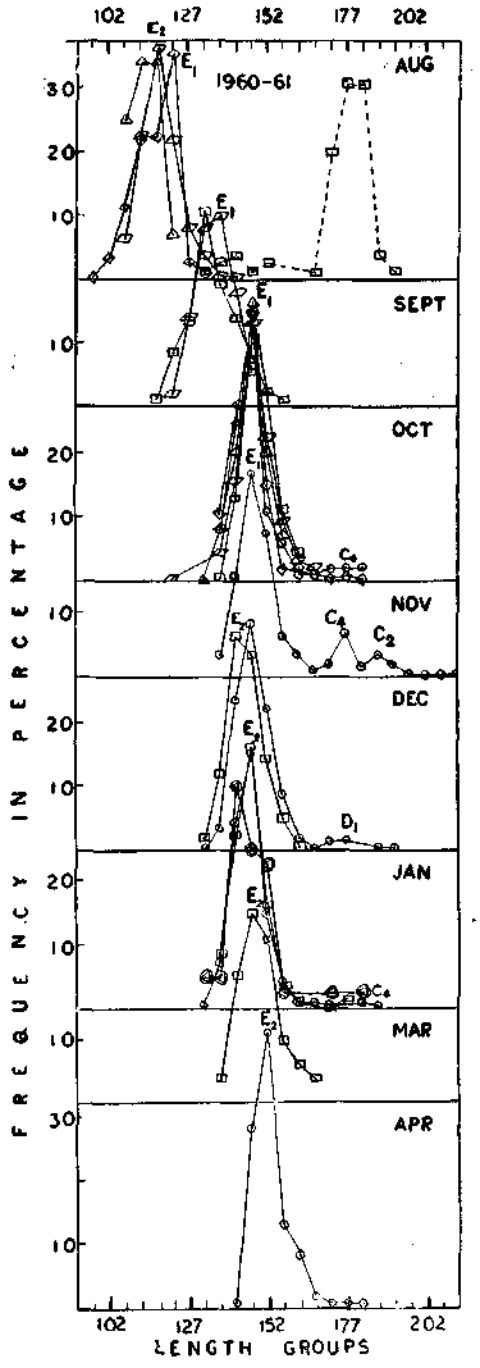


Fig 6. Size-composition of the catches of oil sardine at other centres in 1960-61. (For explanation see Fig. 1).

1960—61 :

The group D_1 which formed the mainstay of the previous season was again seen during December in the *Rampani* and *Kollibale* catches at 177 mm. Also in November C_2 was at 187 mm. Again C_1 was evident at 177 mm. in October and November and at 182 mm. in January. The bulk of the catches was, however, supported by the groups E_1 and E_2 (Figs. 5 and 6). E_1 moved from 122 mm. in August to 147 mm. in December and E_2 from 142 mm. in December to 152 mm. in April in the catches of various nets.

1961—62 :

The groups E_1, E_2 and E_3 were again recorded at 162-167 mm. from August to March as may be seen from Figs. 7 and 8.

Among younger fish, four groups were apparent. The first one (F_1) was noted at 147 mm. in December at Ullal and 152 mm. in March at other centres, in the *Kollibale* catches. The *Kollibale* catch at Ullal had another mode at 132 mm. (F_2) in November and December. The same group (F_2) was seen at values ranging from 112-137 mm. in the landing of other nets at Ullal from October to December, but it could not be traced further during this year. F_2 was seen again in July 1962 at 152-157 mm. (Figs. 9 and 10) from which the time lag between F_1 and F_2 could be estimated as roughly four months. The third group (F_3) varied from 102 mm. in October to 132 mm. in March in the catches of various nets. Lastly another mode (F_4) was seen at 92 mm. in October in the cast net catch of Ullal which moved to 107 mm. in December. Between F_3 and F_4, the difference in age is perhaps roughly two months. The fishery was supported mainly by the 10-15 cm. group this year also.

1962—63 :

Among fish more than 15 cm. in length, five groups E_2, E_3, F_1, F_2 and F_3 could be traced. E_3 was seen at 172 mm. in the July catches of cast net and *Kollibale* both at Ullal and other centres (Figs. 9 and 10). It was again seen at 182 mm. in the October catch of *Kollibale* at Ullal. F_1 was noted at 172 mm. and F_2 at 152 mm. in August in *Kollibale* at Ullal. F_3 was seen 162-167 mm. in the catches of various nets in January-March.

For the young sardine which contributed to the bulk of the landings, two distinct groups could be seen. In *Rampani* landings the first one (G_1) varied from 142 mm. to 147 mm. during October-February and the other (G_2) from 122 to 137 mm. during October-March. The same two groups were also present in the cast net and *Kollibale* catches at Ullal (Fig. 9). From the movement of the modes, the time interval between the two groups would appear to be 4-5 months. G_1 can also perhaps be traced back to 62 mm. and 77 mm. respectively in the catches of *Kollibale* of Septemer and October 1961.

The study of size-composition shows that the catches depend mainly on the 10-15 cm. groups as at Calicut. But within this range 2-3 distinct batches or groups could be recognised in certain years, the time interval between the first and the last being about 4-6 months. Hence they were apparently broods of the same year-class. From the analyses of modal progression it would also appear that the size of one year and two-year-olds can be regarded as roughly 10 and 15 cm. respectively as mentioned by Nair (1952).

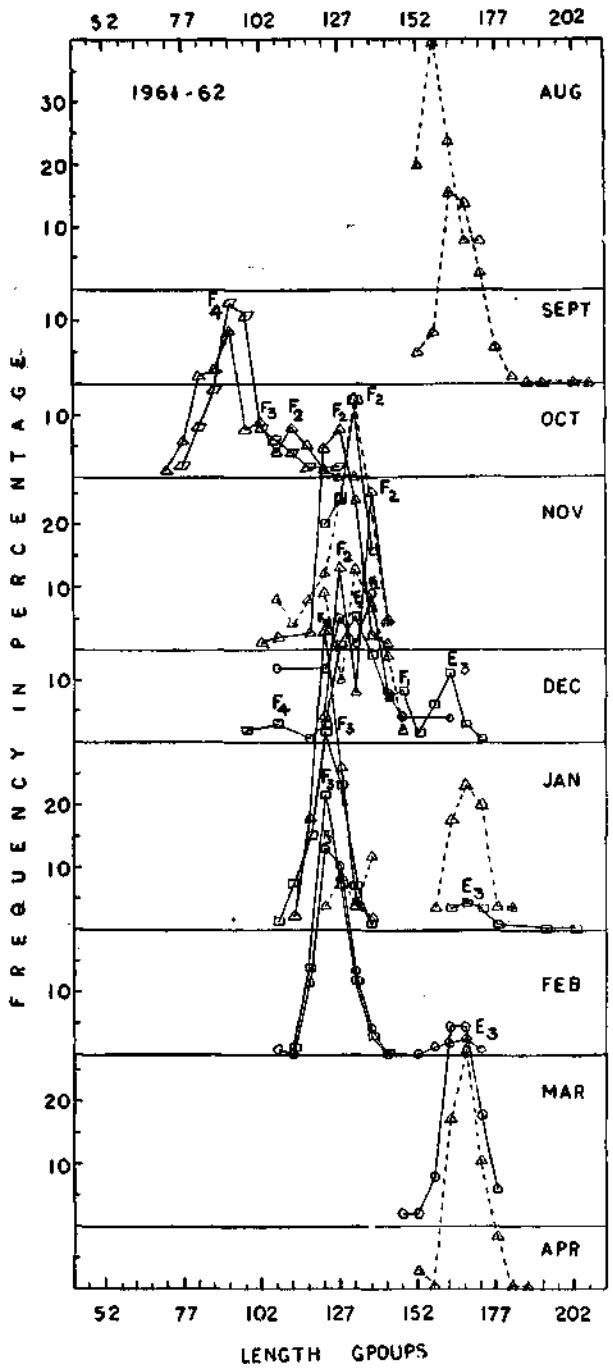


Fig. 7. Size-composition of the catches of oil sardine at Ullal in 1961-62 (For explanation see Fig. 1).

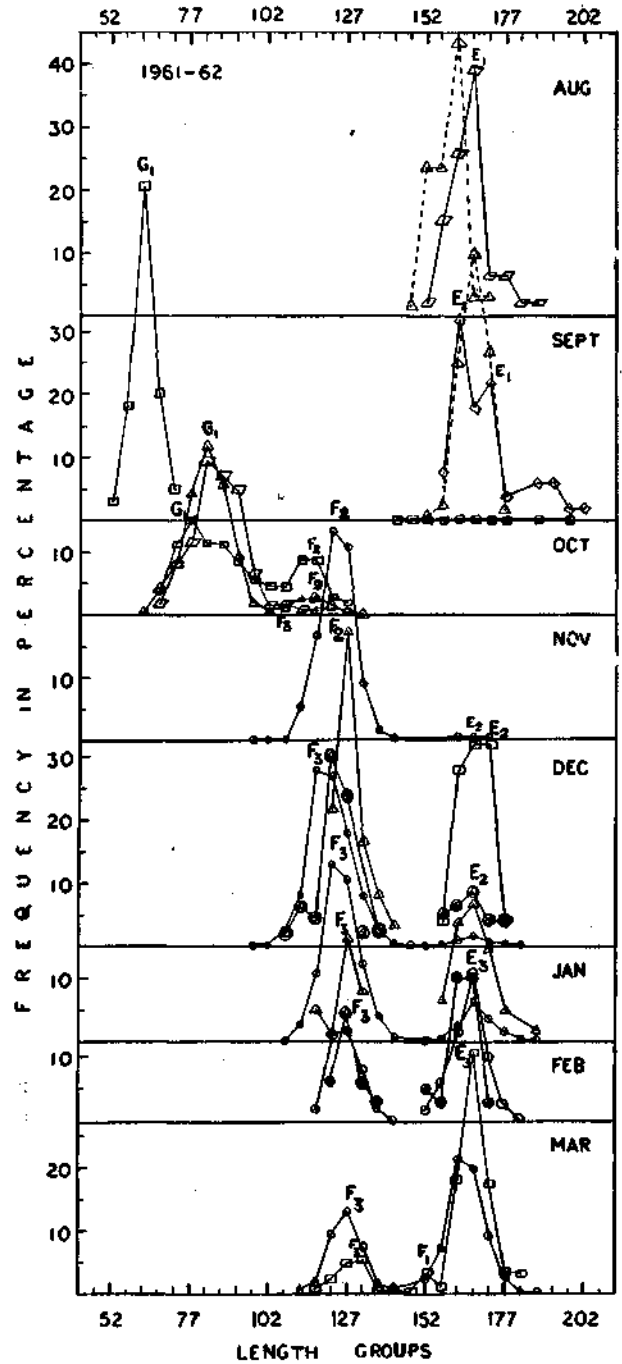


Fig. 8. Size-composition of the catches of oil sardine at other centres in 1961-62. (For explanation see Fig. 1).

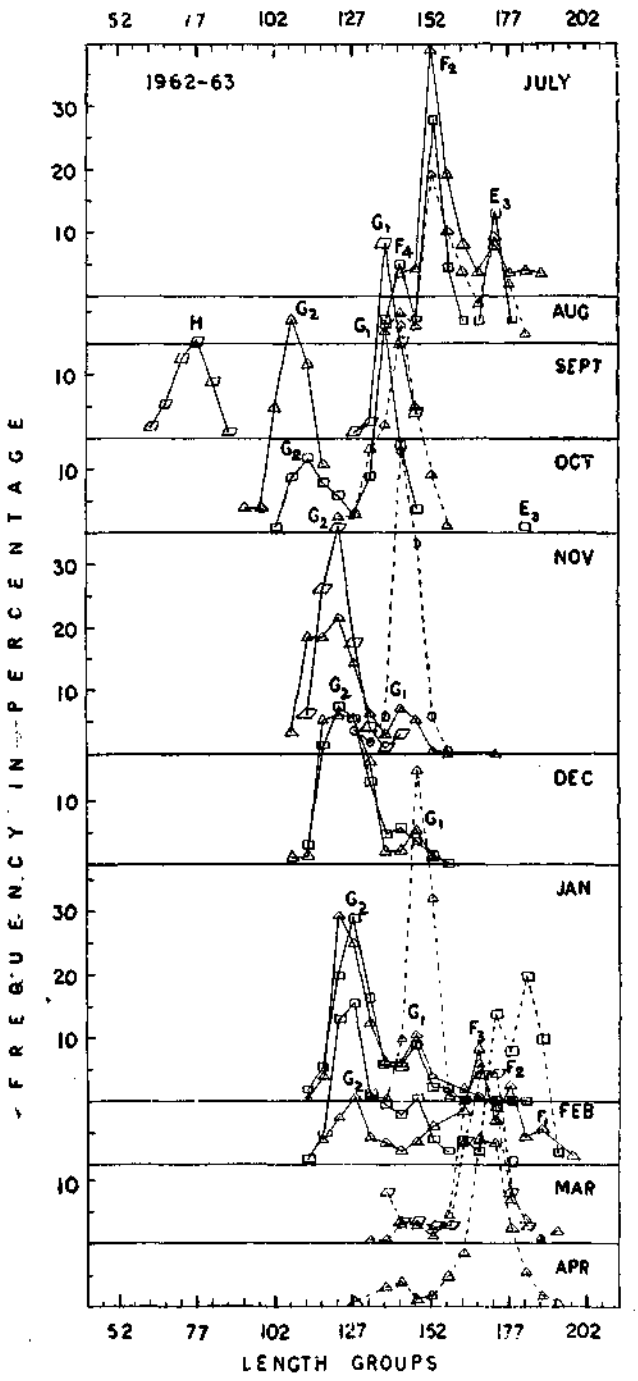
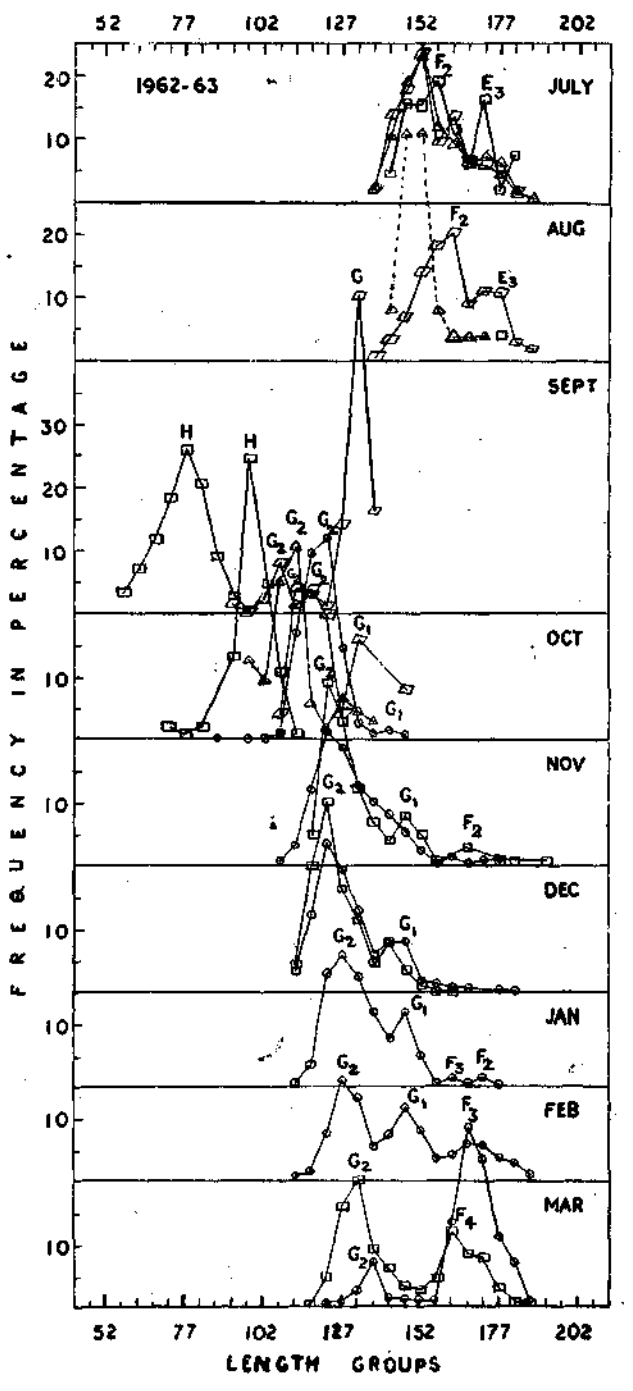


Fig. 9. Size-composition of the catches of oil sardine at Ullal in 1962-63. (For explanation see Fig. 1)



F g. 10. Size-composition of the catches of oil sardine at other centres in 1962-63. (For explanation see Fig. 1).

AGE-COMPOSITION

Figs. 1-10 show that during July-September, the catches are composed mainly of sardine more than two years old. Their numbers decrease during the next two or three months, but increase again from December or January onwards. But during October-March, the period of high catches, the fishery is supported mainly by one-year-olds. After March, in certain years, two-year-olds were observed to outnumber one-year-olds.

A rough estimate of the contribution (in numbers) of one and two-year-olds to the fishery from 1959 to 1963 was made by breaking the monthly length frequency curves for total catch at the lowest point between successive modes and summing up the values for each separate curve (age group) thus obtained (Table VII). Values for the different broods of the same year class were pooled. The estimation was confined to one- and two year-olds, as they formed the bulk of the catches.

The following limitations will have to be taken into account in regard to these data :

1. For centres other than Ullal, only nets with catches have been used in these estimates as stated earlier. Therefore the estimates of the catch-per-unit of effort for these nets are probably higher than the true values.

2. Sampling at centres other than Ullal has not been very satisfactory. This also explains the anomaly of the *Kollibale* data for 1961-'62.

From the data in Table VII, estimates of the annual rates of decrease of the year classes, as measured by the various nets were obtained. These are given in the Table VIII.

TABLE VII

Estimates of One and Two-year-olds in the Catches

Year	CATCH-PER-UNIT OF EFFORT											
	at Ullal				at other centres							
	Cast net		*Kollibale*		*Cast net*		*Kollibale*		*Kairampani*		*Rampani*	
	I†	II†	I†	II†	I†	II†	I†	II†	I†	II†	I†	II†
1959-60	3142	..	..	..	..	..	9,504	210	..	4	196,644	11,548
1960-61	1787	66	..	..	2,114	..	9,643	61	6,236	..	216,750	8,617
1961-62	1709	—	406	62	1,703	310	7,863	10,243	1,083	583	466,425	117,375
1962-63	1212	49	9,245	110	814	881	17,825	996	6,978	528	366,387	24,762

The averages for all centres in the zone based on the results for different nets are also given in the Table. The grand average for the entire period 1959-63 comes to 0·81 (i e. 1·66 in terms of instantaneous rate). It has to be stressed here that these are only preliminary estimates. More refined estimates should be possible in future.

TABLE VIII

Estimated Annual Rates of Decrease in Number of the Oil Sardine (between the Second and Third Years of Life).

Year	At Ullal		At Other Centres				Average for the Zone
	Cast net	*Kollibale*	Cast net	*Kollibale*	*Kairam-pani*	*Rampani*	
1959-60/60-61 . .	0·93	..	..	0·99	..	0·96	0·98
1960-61/61-62 . . .	..	..	0·85	..	0·91	0·46	0·74
1961-62/62-63 . . .	0·97	0·73	0·48	0·87	0·51	0·95	0·75

TABLE IX

Monthly Oil Sardine Catch and Average Surface Salinity, and Temperature at Ullal.

Month	1957-58			1958-59			1959-60			1960-61			1961-62			1962-63		
	S‰	T°C	Y*	S‰	T°C	Y	S‰	T°C	Y	S‰	T°C	Y	S‰	T°C	Y	S‰	T°C	Y
July . . .	11·57	27·6	..	..	..	..	10·06	25·5	..	..	..	..	..	..	..	9·60	25·9	1·27
August . . .	12·44	25·8	..	..	..	..	4·02	25·8	..	16·32	23·4	4·50	..	..	4·18	11·34	25·2	4·14
September . .	32·58	26·1	..	20·63	25·7	..	16·70	26·2	..	13·39	24·3	5·17	13·60	26·7	3·94	13·48	25·7	0·65
October. . .	33·21	28·2	..	29·01	25·9	0·18	28·48	27·9	0·14	27·69	26·2	28·59	28·12	28·2	12·01	20·21	28·1	8·76
November . .	33·47	28·7	..	35·49	29·1	..	32·68	28·6	55·69	32·07	29·1	1·46	32·04	28·1	3·66	33·10	27·9	10·19
December . .	33·34	28·5	..	35·38	28·2	..	31·99	28·3	..	33·14	27·3	18·19	33·23	28·1	11·74	30·51	28·3	14·25
January. . .	33·61	28·5	..	34·18	28·5	..	32·28	28·0	..	33·75	26·8	17·32	34·40	27·1	37·71	31·83	27·7	10·24
pebruary . .	34·54	28·7	..	34·37	28·9	..	33·48	28·4	..	33·88	28·0	..	35·12	28·1	0·95	32·26	27·6	22·22
March . . .	35·07	29·6	..	35·06	30·0	..	33·95	29·2	..	34·56	29·4	3·00	35·23	29·9	..	33·07	29·5	1·66
April . . .	36·12	30·8	..	35·08	31·1	..	33·46	30·0	0·02	32·33	29·6	15·84	35·35	31·1	3·62	34·02	29·8	7·16
May . . .	33·73	30·6	..	33·34	29·5	..	32·14	30·0	..	34·37	29·1	..	35·33	31·4	..	34·06	30·6	..
June . . .	32·26	30·8	..	33·41	..	..	18·37	28·8	..	..	..	..	..	..	..	..	..	..

S‰ = Salinity.
T° C = Temperature (in degrees centigrade).
Y = Monthly total catch (The *Rampani* net was operated only in 1961-62 and hence the catch of this net has not been included here).
*Catch data for this year were not available.

MATURITY

During the July-September period sardine are in advance stages (Stage III, IV and V) of maturity. Spent fish are recorded during these months and also up to the end of December. These are large sardine which have completed more than two years of life. On the other hand one-year-olds are in stage I and II (immature) from October to April. Fish in stage III are usually found from March onwards. Therefore, it would appear that the spawning period is roughly July to November, as observed by Nair at Calicut (1952 and 1959).

FOOD

Observation on the food of oil sardine shows that the diet consists mostly of phytoplankton, especially diatoms. The important forms were *Fragilaria oceanica* and species of *Coscinodiscus, Biddulphia, Pleurosigma, Nitzschia* and *Rhizosolenia*. A detailed study on this aspect will be published elsewhere by one of us (M.H.D.).

SALINITY AND TEMPERATURE

In Table IX are given the following data in regard to the four-fathom area off Ullal (fishing grounds).

1. Monthly mean values of surface salinity and temperature.
2. Monthly total catches.

As at Calicut (See Chidambaram, 1950; Nair, 1952; Sheshappa, 1953; George 1953) surface salinity and temperature are low during monsoon months. During monsoon months the catches are composed mainly of mature fish which are more than two years old. On the other hand, from October to March, when salinity and temperature have intermediate values, one-year-olds comprise the bulk of the catches. This pattern of age-composition has also been noted at Calicut by Nair (1952).

The 1958-59 season was the shortest among those considered here. It will be seen from the Table IX that salinity rose to more than 35%. very early in the season *i.e.* by November, while such high values are normally expected only after March. This can partly explain the shortness of the duration of that year's fishery. Again in 1961-62, the catches at Ullal dwindled after January, salinity values after this month being more than 35‰. Such high values were not observed during the other years.

But although the above relation may hold good as a general rule, still a high salinity value (more than 35‰.) may not always be a limiting factor for one-year olds (the dominant age-group of the October-March period), for one of us (K.V.S.) had observed high catches at Calicut during a month having an average salinity of more than 35‰.

During November-April of 1958-59, temperature values were higher than those of the corresponding months of the later years. This was also perhaps one of the factors responsible for the shortness of this season. Again temperature was lower but catches higher during the February-April periods of 1960-61 and 1962-63 than during the corresponding periods of 1959-60 and 1961-62. The table also shows that generally speaking catches were comparatively better during the months having mean temperature within the range of 27·1°—29·6° C. It was only rarely that sardine were landed during the periods when the temperature rose above 30° C.

DISCUSSION

This study has shown that over the years considered here, age-composition has followed a regular pattern. From July to September or October, the fishery is composed mainly of mature and maturing fish as observed by Nair (1952) at Calicut, who also states that August-November is the spawning period. The spawning period of oil sardine in the Mangalore zone is roughly the same as that at Calitcut. From size-composition it was seen that the mature sardine of this period are more than two-years old. With the warming up of the coastal waters and increase in salinity after September, they forsake the nearshore waters but reappear from December or January onwards. During the intervening period, normally the time of heavy landings, one-year- olds enter the fishery. From January onwards, the fishery is supported mainly by one-and two-years-olds, although older sardine also may be present in smaller numbers. Even during this phase, yearlings from the dominant group. The number of two-year-olds increases from February onwards and they even form the dominant group after March in certain years. But normally the landings decline considerably after March, with the rise of salinity and temperature to high values.

It is, of course, likely that hydrological conditions affect different age-groups in different ways. Low salinity and temperature are perhaps favourable for spawners (See also Nair 1952), which explains the preponderance of mature fish in the catch of the monsoon months. But they reappear as spents or recovering spents from December onwards. However, of greater significance is the influence of hydrological conditions on one-year-olds whose abundance in the nearshore waters determines the success of a season. The most important period in regard to these fish as well as to the total seasonal catch is October-March. Here the data suggest that the catch fluctuations of this period are largely independent of normal salinity and temperature variations except when they rise to high values (temperature to more than 29·5° C and salinity more than 35‰). It can be seen from the Table IX that over the various seasons, fairly good catches have been recorded in months having average temperature within the range (25.9°) C—29·6° C and salinity within the range 29‰ —35·‰. On the other hand above these values they probably act as limiting factors. This was perhaps what happened in 1958-59 season and also in the February-April period of 1961-62.

The problem of catch fluctuations has therefore to be related mainly to that of variations in the numerical strength of the year-classes themselves. That they vary considerably is shown by Table VII. In this regard the hydrological conditions of the spawning period will be of great significance and this aspect will have to be considered in greater detail in future studies. Related to this problem is also the occurrence of more than one brood in a year.

The annual rates of decrease as measured by different nets varied from 0·46 to 0·99 in various seasons, from which an average of 0·81 has been estimated. These are only rough estimates and have to be treated with some reservations but are still of interest in view of the present-day age-composition of the catches.

SUMMARY

In the Mangalore Zone, the oil Sardine season is October-March as in the Calicut area. The fishery starts in the southern centres and gradually extends to the northern centres. There were very high catches in 1957-58. The 1960-61 and 1962-63 seasons were also very good.

But the 1958-59 season was a failure. The landings in 1959-60 were also poor, though better than in 1958-59. The 1961-62 season was peculiar in that the fishery was confined mainly to a 15-mile section of the coastline extending from Ullal to Suratkal.

From July to September or October (monsoon months), when surface salinity and temperature are low, the catch consists mainly of mature fish more than two years old. They are scarcely seen during the next 2-3 months, but reappear from December or January onwards. From October to March, normally a period of intermediate values of salinity and temperature, the fishery is supported mainly by the one-year-olds. The older age-groups occur in increasing numbers from February onwards, and even form the dominant group after March in certain years. However catches decline after March with increase in salinity and temperature.

The catch fluctuations of October-March appear to be largely independent of the normal temperature and salinity variations of the period, except when they rise to more than 29·5° C and 35·0‰ respectively. Above these values, they appear to act as limiting factors. Temperature and salinity during October-March of 1958-59, a poor season, were higher than during the corresponding periods of the other years, salinity rising to more than 35·0‰ as early as in November. Likewise, the drop in catch during the February-April period of 1961-62 was perhaps related to these factors.

The catch fluctuations appear to be related mainly to fluctuations in year-class strength. More than one brood could be recognised in certain years. The annual rate of decrease of a year-class has been estimated as roughly 0·81.

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SOIL NUTRIENTS AND PLANKTON PRODUCTION IN FISH PONDS
A. AVAILABLE SOIL PHOSPHORUS

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Studies on the correlations between different levels of major nutrients like nitrogen, phosphorus and potassium in pond soil and production of plankton in water is an essential pre-requisite for a judicious planning of fertilisation programme in pond management. As a part of the comprehensive programme to study the effect of these nutrient elements on the productivity of fish ponds, an investigation on the possible response of available soil phosphorus to plankton production was taken up first, since this element is known to play a dominant part in determining the productivity of fish ponds (Nees 1949). A general survey of about sixty piscicultural ponds in Orissa, West Bengal, Assam and Madhya Pradesh and also a regular observation on eighteen selected ponds in Orissa and Madhya Pradesh by Banerjea and Chatterjee (unpublished) showed that for slightly acidic or slightly alkaline soils with a fair concentration of available nitrogen, available soil phosphorus seems to play an important role in determining the production of fish in these ponds. Based on these observations a detailed laboratory experiment was taken up to study the effect of different levels of available phosphorus in the soil on plankton production and to find the optimal ratio between the available phosphorus and available nitrogen, as the main physiological function of phosphorus is to encourage the assimilation of nitrogen by the organisms into cellular matter (Hasler and Einsele, 1948).

The field experiment was taken up in small size nursery ponds the bottom soils of which were deficient in phosphorus, sandy in texture and slightly acidic in reaction; the same soil was used for laboratory experiment. The results obtained from these experiments are described in the present note.

MATERIAL AND METHODS

The soil for the laboratory experiment was collected from ponds in the Lingipur fish farm (Orissa) in which the field experiment was conducted. It was air dried, ground into powder, sieved through a 2 mm. sieve and two kilograms of this air dried soil were used as substratum in each of twelve cylindrical glass jars of 10 litre capacity. The twelve jars were grouped into four sets, of three jars each. Keeping one set with 4·0 mg./100 gms. of available P_2O_5 as control without any treatment, the available phosphorus level of other three sets were artificially raised to 8·0, 12·0 and 16·0 mg/100 gms. by treating the soil with calculated quantity of superphosphate (32 % P_2O_5). The jars were then filled with 8 litres of distilled water and after allowing sufficient time for establishing the chemical equilibrium between soil and water each jar was inocculated with 0·2 cc. of concentrated plankton samples (*Anabaena, Pediastrum, Euglena, Brachionus, Keratella, Moina, Cyclops*). Samples for water and plankton analysis were collected every week. As the total vo ume of water was small

(8 litres), only a small volume (20 cc.) was collected from the different portions of the body of the water and mixed into a representative sample. A complete analysis of the soil was made before the treatment. For soil analysis, the methods as recommended by International Bureau of Soil Science were followed with slight modifications as necessary (Piper 1947). Standard methods of water analysis by American Public Health Association were followed for water analysis (A.P.H.A. 1946). Total count of plankton was determined microscopically by analysing a concentrated sample of 20 cc. of water (Alikunhi *et al.* 1955). The field experiment was conducted in six small size nursery ponds at Lingipur (Orissa). These ponds were all dry during early June when the experiment was started. All the pond bottoms were brought to uniform soil condition by scraping off a thin layer of the soil as necessary and then analysing the sample. The six ponds were grouped into two sets of three. Keeping one set as control, the bottom soils of the ponds in the other set were treated with requisite amount of superphosphate (32% P_2O_5) so that the available soil phosphorus was raised to 8 mg/100 gms. P_2O_5 to a depth of 15 cms. Weekly samples for water and plankton analysis were collected from the end of June when rain water accumulated in these ponds. The duration of the field experiment was six months and the laboratory experiment was continued for one year (April 60—March 61). The data collected for both laboratory and field experiments are presented in Tables I-VI.

TABLE I

Showing results of physical and chemical analyses of Lingipur soils

Clay %	Silt %	Sand %	pH.	Total N	Total P_2O_5 (mg/100 gms)	Total K_2O (mg/100 gms)	Available N	Available P_2O_5 (mg/100 gms)	Available K_2O (mg/100 gms)	Organic-Carbon %
5·2	22·5	70·3	6·6	24·0	41·0	341·0	16·1	4·0	13·1	0·27

TABLE II

Showing dissolved phosphorus in water at different soil-phosphorus levels (laboratory experiments)

Soil phosphorus (mg/100 gms)	Dissolved phosphorus in water (P_2O_5 p.p.m.)												
P_2O_5	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	AVE-RAGE
4·0 . . .	·090	·160	·101	·160	·196	·100	·075	·072	·076	·080	·060	·145	·109
8·0 . . .	·070	·300	·130	·210	·135	·080	·080	·093	·071	·075	·065	·140	·120
12·0 . . .	·190	·410	·135	·180	·184	·110	·090	·094	·120	·120	·100	·170	·158
16·0 . . .	·120	·465	·173	·260	·213	·113	·140	·140	·130	·060	·070	·120	·167

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TABLE III

Showing plankton concentrations (Total number/litre) at different phosphorus levels (laboratory experiments)

Months	SOIL P_2O_5 (mg/100 gms.)											
	4·0			8·0			12·0			16·0		
	Phyto	Zoo	Total	Phyto	Zoo	Total	Phyto	Zoo	Total	Phyto	Zoo	Total
April . .	350	1,150	1,500	1,450	1,950	3,400	1,850	2,150	4,000	2,650	3,350	6,000
May . .	2,850	1,150	4,000	5,750	1,350	7,100	11,200	1,800	13,000	11,350	2,150	13,500
June . .	2,000	1,000	3,000	2,800	1,700	4,500	6,700	3,800	10,500	6,250	3,250	9,500
July . .	300	400	700	500	600	1,100	1,200	1,400	2,600	1,050	1,350	2,400
August . .	250	650	900	700	1,000	1,700	6,700	2,150	8,850	8,400	4,150	12,550
September .	550	300	850	400	700	1,100	250	750	1,000	300	700	1,000
October .	100	500	600	100	550	650	150	950	1,100	250	900	1,150
November .	1,450	850	2,300	3,150	1,450	4,600	2,650	2,400	5,050	4,900	1,550	6,450
December .	2,400	1,100	3,500	3,550	3,450	7,000	7,250	1,250	8,500	5,400	3,600	9,000
January .	1,650	950	2,600	4,400	1,700	6,100	5,100	2,400	7,500	5,900	2,800	8,700
February .	1,350	1,150	2,500	2,950	1,750	4,700	4,600	2,700	7,300	4,750	3,050	7,800
March . .	450	750	1,200	1,300	2,100	3,400	1,950	2,350	4,300	2,200	2,900	5,100
Average .	1,142	829	1,971	2,254	1,525	3,779	4,133	2,008	6,141	4,450	2,479	6,929

TABLE IV

ho w ing dissolved phosphorus in water and plankton concentrations at different phosphorus levels in Lingipur ponds (field experiment)

P_2O_5 (mg/100 gms)

	4·0				8·0			
	Plankton (No./litre)		P_2O_5 (in water)		Plankton (No./litre)		P_2O_5 (in water	
	Phyto	Zoo	Total	(ppm.)	Phyto	Zoo	Total	(ppm.)
July . . .	1,866	1,289	3,155	·200	4,622	1,378	6,000	·180
August . . .	977	1,600	2,577	·090	2,155	3,667	5,822	·100
September . .	665	2,378	3,043	·030	689	4,244	4,933	·040
October . .	3,689	2,555	6,244	·040	4,178	2,244	6,422	·055
November . .	4,222	4,000	8,222	·032	4,689	4,311	9,000	·038
December . .	2,889	1,711	4,600	·045	3,977	1,889	5,866	·063
Average . .	2,385	2,255	4,640	·073	3,385	2,955	6,340	·079

TABLE V

Showing pH and available nutrients of treated and nutreated soil in Lingipur ponds

Pond No.	Treatment	Initial Soil P_2O_5 (mg/ 100 gm)	Before treatment			3 months after treatment			6 months after treatment		
			pH	N (mg/ 100 gm)	P_2O_5 (mg/ 100 gm)	pH	N (mg/ 100 gm)	P_2O_5 (mg/ 100 gm)	pH	N (mg/ 100 gm)	P_2O_5 (mg/ 100 gm
31 .	(Control)		6·6	17·4	3·9	6·6	13·4	3·6	6·4	16·0	4·0
32 .	No treatment	4·0	6·7	16·0	4·2	6·5	14·6	4·0	6·4	14·8	4·3
34 .			6·4	15·0	3·9	6·6	20·7	4·0	6·3	15·6	4·0
	Average		6·6	16·1	4·0	6·6	16·2	3·9	6·4	15·5	4·1
33 .	Treatment with superphosphate.	8·0	6·7	14·8	4·0	6·4	15·1	5·0	6·5	15·9	4·6
35 .			6·7	17·0	3·9	6·3	17·4	5·7	6·3	17·3	5·0
36 .			6·5	14·3	4·2	6·3	16·2	5·8	6·4	16·8	4·8
	Average		6·6	15·4	4·0	6·3	16·2	5·5	6·4	16·7	4·8

TABLE VI

Showing dissolved phosphorus in water, plankton concentrations and available nitrogen: phosphorus ratio at different soil phosphorus levels (laboratory experiments)

Available soil phosphorus (P_2O_5) (mg/100 gms.) . . .	4·0	8·0	12·0	16·0
Dissolved phosphorus in water (P_2O_5 p.p.m.)	·109	·120	·158	·167
Plankton concentration (number per cc)	1·97	3·78	6·14	6·93
Available nitrogen: phosphorus ratio	4·03	2·01	1·34	1·00

RESULTS AND DISCUSSIONS

The importance of soil phosphorus in determining the productivity of fish ponds is well recognised. Its apparent success as a fertiliser has made it the centre of interest and experiment. The extensive work done by different workers on this aspect has been reviewed by (Nees 1949), Mortimer (1954) and Maciolek (1954). In most of the work however the physical and chemical qualities of the bottom soil were not taken into consideration. The present work was taken up to study the response of a sandy and slightly acid soil of low available nutrients to treatment with a single phosphatic fertiliser by raising the available phosphorus levels and also to find out the optimal ratio of available nitrogen and available phosphorus using the production of plankton as index of response. The detailed physical and chemical analysis of the soil is given in Table I. Physically the soil is reddish brown in colour with a sandy texture and a very low percentage of clay and silt. So far the total nutrients are concerned the soil may be considered rich in potash, average in phosphorus but poor in nitrogen. The available potash in soil is quite fair but available nitrogen and available phosphorus are very low; organic carbon is also poor. It may be noted that while available potassium and available phosphorus represent only a small fraction of the total amount of the nutrient elements, more than 60% of the total nitrogen in the soil is in the available form. This may be due to the sandy texture and low organic content of the soil so that the fixation of soil nitrogen as bacterial protein is very low and most of the nitrogen is present as nitrate, nitrite, ammonium salts and amino-acids and easily decomposable peptides which can be converted to ammonia when heated with alkaline permanganate. The data presented in TablesII-IVshow the monthly averages of dissolved phosphorus and plankton concentration for the number of replicates for each treatment. Although the variation in the concentration of dissolved inorganic phosphorus from jar to jar for the same treatment and also for differently treated jars was not very regular, it will be seen from Table II that there was generally a rising trend of dissolved phosphorus content in water with increasing levels of available phosphorus in the soil. From an annual average for different treatments it was noted that for soil phosphorus levels 4·0, 8·0, 12·0 and 16·0 mg/100 gms., the phosphorus concentrations in water were ·109, ·120, ·158, ·167 p.p.m. respectively. In the field experiments the difference in the concentration of dissolved phosphorus is relatively less marked (Table IV). Results of the periodical examination of the pond soils, as presented in Table V, showed that available P_2O_5 content in the soil of the treated ponds, though decreased gradually from the initial value of 8·0/100 gms. remained all along higher than the same in the untreated ponds. It is well known that considerable amount of phosphorus, when added to the soil in water-soluble form, is readily fixed forming insoluble compounds mostly with iron, aluminium and calcium and is thus rendered unavailable. The decrease of available P_2O_5 content in this case is also possibly due to the above reaction taking place in the soil. The extent of fixation

depends largely upon the soil reaction, being minimum at a pH between 6·0 to 7·0 (Banerjea & Mandal—unpublished). In this particular soil the fixation perhaps was minimum owing to the favourable soil pH of 6·6, since it is observed that even more than 35% of the added phosphorus remained in the soil in available form after 3 months of its application. The available nitrogen content and the pH of the soil did not show any marked variation throughout the period of the experiment (Table V).

The plankton concentration varied considerably from jar to jar for the same treatment and also for differently treated jars but the average plankton concentration showed a trend of increase with increase of available soil phosphorus which was maintained throughout the period of experiment. The annual average of plankton concentrations for the increasing soil phosphorus levels (4·0—16·0 mg/100 gms.) were found to be 1971, 3779, 6141, 6929 per litre respectively. Among the phytoplankton, Chlorophyceae was clearly dominant followed by Bacillariophyceae and Myxophyceae. The forms generally encountered were *Pandorina*, *Eudorina*, *Pediastrum*, *Scenedesmus*, *Ankistrodesmus*, *Spirogyra* and *Chlamydomonas* of the Chlorophyceae; *Melosira*, *Cyclotella*, *Fragilaria* of the Bacillariophyceae; *Merismopedia*, *Microcystis* and *Anabaena* of the Myxophyceae. Occasionally *Phacus* and *Ceratium* of Euglenophyceae and Dinophyceae respectively were observed.

Of the zoo-plankton, the rotifers, cladocerans, copepods and ostracods preponderated. Ciliates were also noted occasionally. Of the rotifers, *Brachionus*, *Keratella*, *Conochilus* and *Filinia* were more common forms, while *Moina* and *Diaphanosoma*; *Cyclops* and *Cypris* represented the respective groups in general.

Summarised data for plankton concentration, available phosphorus in soil, solubles phosphorus in water and ratio of available nitrogen: available phosphorus are presented in Table V and Fig. 1. It will be seen from these that with rise of available phosphorus levels there

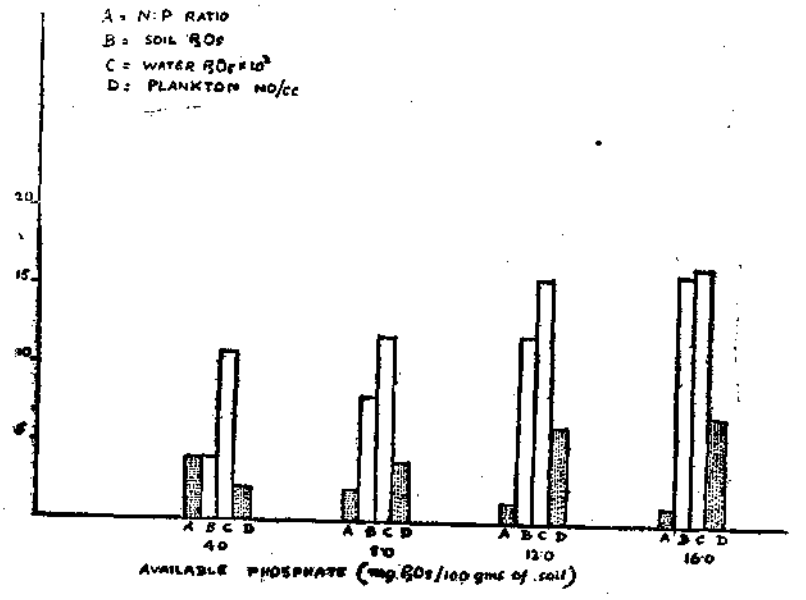

Fig. 1. Showing (1) N:P ratio (2) Soil phosphorus (3) Water phosphorus (4) Plankton concentrations at different soil phosphorus levels.

is definitely an increased trend of average plankton concentration but the rate of this increase is very low at phosphorus levels between 12·0 mg/100 gms. and 16·0 mg/100 gms. The corresponding nitrogen: phosphorus ratio being 1·34 and 1·00, showing that as the N:P ratio approaches from 1·34 to 1·00, the rate of increase of plankton decreases considerably. It is also significant to note that dissolved phosphorus in water showed a much less increase between the two soil phosphorus levels 12·0 and 16·0 mg/100 gms, so that this ratio of 1·00 for available nitrogen: available phosphorus corresponding to the phosphorus level 16·0 mg/100 gms. may be considered as optimal. From the data presented in this note it can be said that for slightly acidic sandy soil with low organic content of which available phosphorus is very low and available nitrogen is also poor but represents most of the total nitrogen of the soil, there is definitely a response to increased phosphorus levels for plankton production and the N:P ratio for maximum production of plankton is likely to be near about unity.

SUMMARY

It has been shown both by laboratory and field experiments that plankton concentration of pond water can be increased considerably by artificially raising the available phosphorus levels of the soil with which the water is in contact. Though a very generalised conclusion may not be drawn from the data presented, the results showed definitely that for a particular soil type, *viz.*, a slightly acid soil, sandy in texture with a very low percentage of clay and silt, and very low in available phosphorus and available nitrogen with a low organic content there is definitely a response to increased levels of available phosphorus for plankton production and the ratio for available nitrogen: available phosphorus for maximum plankton production is likely to be unity approximately.

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