SOME OBSERVATIONS ON THE SHOALING BEHAVIOUR OF THE OIL-SARDINE *SARDINELLA LONGICEPS* VAL.

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Introduction

The importance of the knowledge of the behaviour of fish in their natural environment which enables their easier location, the devising of better gear and techniques of capture has long been realized by fishery workers. Studies of that nature already conducted have proved to be of considerable interest and value in the case of various fishes such as the Australian pilchard *Sardinops neopilchardus* (Blackburn, 1941; Blackburn and Tubb, 1950), the California sardine, *Sardinops cærulea* (Anon, 1952), the Japanese sardine, *Sardinops melanosticta* (Nomura, 1958), the " lemuru ", *Sardinella allecia* (Soerjodinoto, 1958), the Atlantic salmon (Keenleyside, 1958), the tunas, *Katsuwonus pelamis* (Strasburg and Yuen, 1958), *Neothunnus macropterus* and *Euthynnus yaito* (Tester *et al.*, 1955), the lajang, *Decapterus* spp. (Soemarto, 1958), the cichlid, *Tilapia esculenta*, the cat fish, *Clarias* (Beauchamp, 1958), and the minnow, *Phoxinus phoxinus* (Jones, 1958). Kesteven (1960) in an exhaustive review has lucidly dealt with almost all aspects of behaviour of fishes. No attempts have hitherto been made towards studies on the shoaling behaviour of fishes of Indian waters. In view of the importance of the fishery of oil-sardine *Sardinella longiceps* on the south-west coast of India, it was thought desirable to investigate the shoaling behaviour of this species.

Various definitions have been given for the term shoal or school by different authors. According to Blackburn and Tubb (1950) " A fish school is a dense concentration of fish very close to or actually breaking the surface of the sea, in such a way that the observer sees a circumscribed and, at any given moment, a fairly well-delimited area whitened with foam, or coloured by the fish themselves or both. " Keenleyside (1955) as quoted by Kesteven (1960) defined it as "an aggregate formed when one fish reacts to one or more other fish by staying near them (the chief factor common to all schools is a definite mutual attraction between individuals)". Tinbergen (1951) and Brown (1957) are in agreement with this definition. The latter further advanced the view that " the individuals within a school have an individual body odour

recognizable by each member of the school". The definition given by Messyazev* (1937) as quoted by Zusser (1958) is as follows: " A fish school is a biological category limited by the species—number and length composition of fishes. Further, fish aggregation is a local concentration of several separate schools and is composed of fishes of one or more species and of different sizes. Consequently, an aggregation is, generally, a temporary formation, heterogeneous and unstable in regard to its specific and size composition."

The term behaviour was used in the broadest sense by many authors to cover all the actions of an animal. Thus, according to Tinbergen (*loc. cit.*) behaviour is " the total of movements made by the intact animal ". Kesteven (*loc. cit.*, p. 8) stated, " In a physiological approach to behaviour, analysis is made in terms of receptors and affectors, stimulus intensity and responses; in the ethological approach analysis is made in terms of internal drive or motivation, releasing mechanisms, sign stimuli, and an hierarchy of behaviour patterns." In the present investigation, the term shoal is used to mean a dense or loose concentration of fish at the surface or sub-surface of the sea and also recognized by the presence of a faint colour caused by the fish themselves during the day, or by their luminescence during nights, with or without a definite shape, visible to the eye. The various actions of the fish, individual and collective, in the shoal, under natural conditions, are brought under the term shoaling behaviour here.

Material and Methods

Routine scouting trips were made from October 1957 to November 1958 in the inshore area off Calicut with the aid of a canoe about 8 metres in length. These operations were confined mostly to the 3·5–15·0 metre area (on one occasion such a trip extended up to 22·0 metre area also), covering a distance of about six miles, north to south. As soon as a sardine shoal was encountered, its direction of movement, shape, length, breadth and its other characteristic features were noted; then sardine samples were taken with the aid of a stringed cast net *Veechu Vala* to determine their size composition. Immediately after casting the net, the surface sea-temperature was noted. The direction of water flow was determined with the aid of a wooden float; the float was put in the sea and its direction of movement with reference to shore (while the boat was kept anchored) was noted. The current direction was also checked up by anchoring the boat and watching its position in relation to the flow of water. Simultaneously, turbidity of the sea was noted with the aid of a Secchi disc (measuring 20·0 cm. in diameter); the depth

* Reference not seen.

at which the disc was just visible and the depth at which it disappeared from view were noted and the average value was taken as the turbidity (or transparency) figure. The direction of the wind was noted down by rough observations. The presence of predators, when any, was also taken note of.

SHOALING BEHAVIOUR

(*A*) *Surface Shoals*

The characteristic features of different kinds of shoals encountered are described below. The terms flipping (Blackburn and Tubb, 1950) and pattering (Blackburn, 1941 and Blackburn and Tubb, 1950) were applied to particular types of behaviour of the shoals of *Sardinops neopilchardus*. These terms have been found applicable in the case of the Indian oil-sardine also.

Flipping shoals.—This trait of the sardine shoals is locally called *thōlum*. The characteristic feature of the flipping shoals is the occurrence of frequent splashing noises accompanied by jerking movement of the fish in the surface waters. In this type of shoals, some individual sardines are visible at the surface and they serve to reveal the identity of the shoal. This feature of the oil-sardine shoal is almost similar to the shoals of *Sardinella fimbriata* (as observed by the author). Though flipping shoals occur both during day and night, these are more frequently seen during morning hours and nights. It appears probable that flipping adds force or momentum to locomotion within a limited area. The cause of flipping act of the individuals in the shoal is not known. It may be seen from Table I that 13 such shoals were encountered only on one occasion during this investigation, namely on 4–1–1958.

Pattering shoals.—This feature of the sardine shoal is locally known as *Kotthapudi* and such shoals were observed from October to December; and 14 such shoals were observed. Pattering is characterized by frequent small noises either simultaneous or in quick succession, which resemble the sound of big rain drops falling on the sea. Unlike the flipping shoals, there is no jerking movement followed by splashing noises in this case. Pattering is more frequent during daytime than at nights. The individuals are not visible. It may probably be an act of behaviour towards attracting more individuals of the fish for dense aggregation. Fishermen say that the shoals of *Sardinella fimbriata* also exhibit a similar feature.

Rippling shoals.—The formation of ripples is a characteristic of shoals moving at the surface and is called by the local fishermen *polappu*. Rippling

is noticed even when the wind is heavy. Some individual fish from such shoals are at times clearly discernible from a distance. Rippling areas are more clearly delimited than in the case of other types of shoals, since they are actually in contact with the surface film of water. It was interesting to see that at times many such rippling shoals moving in different directions. From the boat, the size and the direction of movement of such shoals could easily be determined. The fish from such shoals are easily caught in nets. Tiny rippling shoals may attract similar ones occurring in their vicinity and thus form a large shoal. This type of shoal was observed (a total of over 177 shoals were noticed during the course of this investigation) from October to March (Table I). The conspicuously heavy rippling produced by shoals composed of the mature sardine occurring in June is called *kadavali* by local fishermen.

Leaping shoals.—Leaping is locally called *moolel.* Some individuals from the shoal sometimes resort to leaping above the water, covering short distance (a few feet). Apart from the normal behaviour of leaping exhibited by a number of individuals in the leaping type of shoals, leaping could also be observed practically in the case of any shoal when attacked by predators and disturbed by fishing operations. Thus the leaping act normally provides a temporary escape from predators besides enhancing the overall cruising speed. The season of occurrence of such shoals was from October to March; 39 leaping shoals were encountered during the course of the work.

In addition to the above characteristics of different shoals some shoals were also distinguishable by certain colour-effects associated with them. Two types of colour-effects were observed and they are described below.

(*a*) *Bluish colouration.*—Shoals having the bluish colour are common in occurrence. During the peak of the fishery such type of slow-moving shoals are invariably encountered in appreciable numbers. Such a colouration is a characteristic of compact shoals observed during daytime; and the individual fish are not visible. These shoals are easily fishable also. Probably, this colour-effect may be caused by the incidence of sunlight on the shoal. The season of occurrence of such shoals is from October to March. Over 169 numbers of shoals with this colouration were observed during this work.

(*b*) *Pinkish colouration.*—In addition to the above-mentioned colour-effect, often times, large shoals of the sardine display a pinkish tint also which is locally called *mariyam.* It is observed during daytime. Like the bluish shoals, the individual fish are not visible and the shoal is slow-moving in this case also. Heavy catches are often obtained from shoals exhibiting this

colour-effect. In addition to the sardine shoal, shoals of *Rastrelliger canagurta* also were reported by fishermen to display a similar colour-effect. The local fishermen express the opinion that this colour is caused when the shoal disturbs the bottom mud which consequently spreads out in the same area. It was found occurring during November and December. More than thirty-one shoals of this type were encountered during this work, one on 20–11–1957 and more than thirty on 14–12–1957.

Luminescent shoals.—Besides the above-said colour-effects, luminescence (locally called *thuyyu*) was also found useful for spotting the sardine shoals; the display of luminescence by the shoals is useful during nights particularly during the dark phase of the moon. A shoal, when luminescent, appears as a patch of light (delimited by the size of the shoal) moving in the surface seas. A similar feature has been mentioned in the case of the Australian pilchard (Blackburn, 1941 and Blackburn and Tubb, 1950) and the Indian mackerel (Paradhan, 1956) also. When luminescence of the shoal is moderate, generally, the sardines are easily caught in nets. Peak of intense luminescence, locally called *thuykālem*, is considered unfavourable for fishing. Intense luminescence might enable the fish to see and avoid predators and fishing gear. This explains the unsuccessful fishing during strong luminescence. Thirty-three luminescent shoals were encountered during the course of this work, and they were seen only in November and December.

(*B*) *Bottom Shoals*

(1) *Bubbling shoals.*—Bubbling is locally known as *nurakarachel.* Though the bottom shoals are not visible, their presence can often be judged by the emergence of chains of tiny bubbles from the sea bottom and these bubbles break up at the water-surface. It appears possible that these bubbles are released from the air-bladder of the sardine through its external opening situated behind the anal aperture. Bubbling was observed in many areas in October, December, January and February. Over 118 such shoals were noticed during the course of this work (Table 1). That this bubbling was associated with the sardine shoals was proved when a cast net operated in such areas invariably brought forth catches of the oil-sardine. It is noticed that the fishermen often look for this feature while trying to spot the sardine shoals; they believe that these bubbles are released by the fish from the muddy bottom while feeding at the bottom. Release of air-bubbles from air-bladder can practically facilitate the fish to sink towards lower strata of the sea. Detailed study of the air-bladder by the author has shown the occurrence of an external opening of air-bladder behined the anal aperture, and the application of gentle pressure on the bladder (when the fish is kept in water) brought

forth small air-bubbles. Whether there is any continuous release of air-bubbles through this aperture during any physiological phase of the fish is yet to be ascertained.

(2) *Fish odour.*—Sometimes, a strong fish odour locally known as *vedināttem* in an area indicated the occurrence of sardine concentrations in the bottom, while the fish were not at all visible; and the fish from such concentrations were generally netted in heavy quantities. A profuse discharge of mucus from thousands of the sardine may probably be the cause for this odour. The different individuals being attracted by the strong body odour may continue to stay together forming a compact large shoal. Such an odour occurred once during October (30–10–1957) during the present study.

Size and shape of shoals.—The sizes of various shoals encountered were only visually estimated and are hence approximate. The shoals were seen to range from 2 metres to 25 metres in length and 1 metre to 20 metres in breadth. (Two huge rippling shoals measuring about 500–800 metres in length and about 400 metres in breadth were observed on 26–10–1957.) The surface swimming shoals, being generally discernible, were studied as regards their shape and size. The front region of the shoal was usually somewhat narrow and slightly pointed; the hind end was rather blunt. It would appear that a few fish at the front portion of the shoal lead the rest, on most occasions in the case of the surface shoals especially the rippling ones. The shoals having the pattering behaviour were seen to be more or less oblong in shape. Tbe bluish shoals appeared to be somewhat narrow and long, and their boundaries were not quite clearly visible.

Movement of shoals.—Owing to practical difficulties, the rate of movement of the individual shoals could not be determined with any degree of accuracy. However, attempts were made to study their speed by observing the time taken by them to move from one fixed point to another situated on the shore, naturally this applies only to shoals swimming parallel to the shore.

Small shoals of the sardine swimming at the surface were generally quick. Certain surface shoals were observed to have moved at the rate of about three miles (about five kilometres) per hour. The speed of shoals having bluish and pinkish tints was considerably lower than that of the rippling ones.

The directions of movement of shoals were not the same during the different months and no apparent relation to the wind or water flow (Table I) had been noticed, within the limits of observations, during the course of this study.

Vertical distribution of shoals.—A large number of shoals is found to come to the surface layers of sea at about sunset. The presence of the invisible bottom shoals is known from the occurrence of bubbling and fish odour; and they are confined to the sea-bed and it would appear that their cruising speed is considerably low. The bluish and pinkish colour-effects associated with the various surface shoals are perhaps produced or influenced by the sunlight.

Length Composition of Shoals

Table I shows average and modal lengths of *Sardinella longiceps* based on the samples taken in the cast net on the different days during the period of investigation. It is interesting to note that throughout the year under observation, small-sized sardine ranging in modal lengths from 12·0–14·5 cm. occurred in the cast net catches (of which the 13·0 cm. mode dominated; next in importance was the fish having the mode at 14·5 cm.). The average length showed a range from 12·60–14·69 cm. Since no selective fishing is involved in this case it would be reasonable to assume that the catches procured with this net are fairly representative of the sardine populations which visited the inshore fishing grounds off Calicut during the year of observations. And, Table I shows that both the average and modal lengths of the fish are very near each other in all the samples examined. Therefore, it would appear that the fish belonging to the same size-group (and age-group)* tend to shoal together. Only a small percentage (less than 10%) was formed by the big-sized fish (16·0–19·0 cm. group) belonging to other age-groups. In the case of the shoals of the Indian mackerel, Pradhan (1956) stated that in a single mackerel shoal, the variation in size is very small and that different shoals may be formed by the fish having different size-groups.

Shoaling and Predators

The various predators associated with the sardine shoals were observed to influence shoaling to some extent, and the predators were terns, dolphins and gulls in the order of importance.

(*a*) *Terns.*—Terns were found invariably hovering around the sardine shoals and picking the fish uttering shrill cries. Two kinds of them were frequently noticed.

(1) *Sterna aurantia* ? Gray.—In this case the black bloch on its head is about 6 cm. long and 5 cm. wide. The rest of the body is white in colour.

* Studies on the age of the oil-sardine (Balan, 1959) have indicated that the fish having the 13·0 cm. modal length are one-year old.

TABLE

Some observations on the shoaling behaviour of Sardinella longiceps

Date	Time of observation	Depth in metres	Temperature ° C.	Turbidity cm.	Direction of water flow from	Direction of wind from	Direction of movement of shoal to	Shape of shoal
9-10-1957	12·00- 2·40 p.m.	15·0-22·0	30·00	..	S.E.	N.W.	N.E. & N.W.	Elongate and Rectangular
11-10-1957	5·00- 7·30 p.m.	10·8-15·0	29·2	..	N	do.	S & S.W.	Slightly pointed and attenuate
26-10-1957	6·50-11·15 a.m.	4·5- 5·5	29·2	..	W	E	W	Not quite distinct
30-10-1957	6·45- 9·45 a.m.	3·5- 5·5	..	..	N	do.	S & N	Elongate, slightly pointed and attenuate
8-11-1957	9·45-11·00 a.m.	5·5- 7·2	29·8	..	S.E.	S.E.	..	..
19-11-1957	9·00-11·00 p.m.	9·0-12·6	..	..	N	Calm	N	Not distinct
20-11-1957	6·40-10·45 a.m.	7·2- 9·0	29·9	..	do.	do.	W	Indistinct
21-11-1957	9·00-11·00 p.m.	9·0-15·0	..	..	do.	N	N.W.	do.
30-11-1957	8·15-10·15 a.m.	2·8-10·8	30·0	..	S.E.	S.E.	W	do.
7-12-1957	9·00-10·30 p.m.	5·5- 9·0	30·0	..	do.	do.	S	No definite shape
10-12-1957	9·00-11·00 a.m.	do.	30·0	..	do.	do.	do.	Indistinct
14-12-1957	do.	3·5- 9·0	29·0	..	do.	do.	N	do.
18-12-1957	do.	7·2-10·8	..	..	N	Calm	N.E.	do.

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Val. (No. of each type of shoal encountered is given in parenthesis)

Size of shoal	Length-groups composing shoal* cm.				Characteristics of shoals	Remarks
	Min. length	Max. length	Average length	Modal length		
10 m. long and 6 m. broad	11·1	13·5	12·61	12·5	Rippling (Plenty) Bluish (Plenty) and dense shoals, each about (100)	Shoals occurred in surface waters. Dolphins sighted
15–20 m. long and about 6–8 m. broad	11·0	13·5	12·60	13·0	Rippling about (20) Pattering (8)	Surface moving
About 10–800 m. long and 8–400 m. broad	11·8	15·3	13·52	13·0	Bubbling (50>) Rippling (3) being the largest. Leaping (2) Bluish colouration (50>)	Bubbling seen scattered in large zones
12 m. long and 4 m. broad	12·0	17·4	13·52	13·0	Rippling (20) and quick moving	Besides a fish odour prevailed and very good catches obtained
..	..	..	..	..	..	No shoal observed
..	..	..	..	..	Luminescent shoal (15)	Shoal luminescent and slow moving, catch not obtained
5–20 m. long and 1–4 m. broad	12·4	18·4	13·71	13·0	Rippling (1), Leaping (2), Bluish colouration (8), Pinkish colouration (1)	Very slow moving concentrated and surface shoals; Terns found associated
Each about 25 m. long and about 20 m. broad	..	..	..	..	Luminescent shoal (8)	Slow moving
..	12·1	18·0	13·65	13·0	Rippling (2), Pattering (5)	Dolphins seen
..	12·2	18·3	14·18	14·0	Leaping (4), Pattering (1)	Terns seen
..	12·6	18·4	14·28	14·5	Leaping (7), Bubbling (3)	do.
..	11·6	19·9	14·49	14·5	Bubbling (10), Leaping (5), Pinkish colouration (30>)	do.
Each about 20 m. long and 6–10 m. broad	..	..	..	..	Luminescent Shoal (10)	Slow moving

TABL

Date	Time of observation	Depth in metres	Temperature °C.	Turbidity cm.	Direction of water flow from	Direction of wind from	Direction of movement of shoal to	Shape of shoal
4-1-1958	8·15-10·30 a.m.	3·5- 5·5	29·5	..	do.	S.E.	N	Attenuate (Flipping Shoal)
25-1-1958	8·15-10·15 a.m.	3·5- 6·3	29·0	..	N.E.	do.	..	..
1-2-1958	8·30-10·15 a.m.	3·5- 5·5	29·0	55·0	do.	do.	..	Indistinct
15-2-1958	8·30-10·45 a.m.	3·5- 9·0	29·5	40·0	S	S	..	..
18-2-1958	9·00-10·45 a.m.	3·5- 5·5	30·0	..	S.E.	do.	..	..
25-2-1958	9·00-11·00 a.m.	5·5- 7·2	29·5	..	N.W.	..	N., N.E.	Elongate
4-3-1958	8·00-10·00 a.m.	3·5- 7·2	29·0	49·0	To S	To N	..	..
11-3-1958	9·00-10·35 a.m.	3·5- 6·3	31·0	..	From N	From N	..	..
15-3-1958	5·30- 7·30 p.m.	4·5- 9·0	..	..	do.	N.W.	From N	Elongate and attenuate
18-3-1958	9·00-10·20 a.m.	3·5- 6·3	31·0	..	do.	N	..	..
25-3-1958	9·00-11·00 a.m.	3·5- 8·1	31·0	69·0	N.W.	N.W.	To S.E., N & N.E.	"Oblong"
1-4-1958	9·00-11·00 a.m.	3·5- 9·0	31·0	68·0	N	N	To S	Narrow and elongate
8-4-1958	8·40-10·35 a.m.	3·5- 7·2	32·0	71·0	do.	do.	..	..

Note.—From the middle of April to November 1958, these observation trips were made in bidity, etc., were maintained (collected from the inshore area, 3·5-15·0 metres).

Temperature.—Temperature ranged from 24·8° - 32·8° C., the highest recorded being in

Turbidity.—These values ranged from 44·0-251·5 cm.; the highest value observed in

Direction of water flow.—On most occasions the direction of water flow was from North to

* All the samples consisted of 100 Nos.; those on 11-10-1957 and 18-3-1958 were repre-

I—(*Contd.*)

Size of shoal	Length-groups composing shoal* cm.				Characteristics of shoals	Remarks
	Min. length	Max. length	Average length	Modal length		
About 8 m. long each and 7–8 m. broad (Flipping shoals)	11·4	14·5	12·83	12·0	Bubbling (40>), Flipping (13)	Dolphins and plenty of terns observed
..	..	..	..	..	..	No shoal observed
..	12·0	17·0	13·60	13·0	Leaping (1)	Terns observed
..	11·1	17·5	13·19	13·5	..	Catch obtained from sea bottom
Leaping shoal about 3 m. long	12·1	15·7	13·62	13·0	Bubbling (15), Leaping (11)	Terns plenty
3–4 m. long and 1–2 m. broad	12·2	17·5	13·86	13·0	Bluish shoal (7)	Slow moving and sub-surface shoal. Tern, sea gull and dolphin noticed
..	13·1	16·2	14·64	14·5	..	Shoal occurred in the bottom area
..	..	..	..	..	..	No shoal observed
Each rippling shoal about 5 m. long and 3 m. broad	13·2	16·8	14·69	14·5	Rippling (30), Leaping (5)	Terns observed
..	11·9	14·5	12·91	12·5	..	Shoal occurred in the bottom area
4–5 m. long and 2–3 m. broad	No catch obtained			..	Bluish shoal (4), Rippling (1)	Bluish coloured and Ripping at surface waters, Terns observed
4–5 m. long and about 2 m. broad	13·0	16·0	14·5	14·0	Leaping (2)	Dolphin and Sea gull seen
..	..	..	..	..	..	No shoal observed

the forenoons only; and no shoal was observed; and the routine data on sea temperature, tur-

April and the lowest in August.
November and the lowest in April.
South.
sented by only 50 Nos. each.

(2) *Sterna* ? .—This tern is lean and blackish in colour and is locally known as *mathikākka* (this means the sardine crow). These terns are extremely predatory on the sardine stocks. From the diving of these birds, it was possible to locate the sardine shoals on many occasions.

(*b*) *Sea gull* (locally known as *kadal kākka*—this means the sea-crow).—*Larus brunnicephalus* Jerdon is the common sea gull of this coast. It was also found preying on the sardine.

(*c*) *Dolphin* (locally called *ādi*).—*Delphinus delphis* was often found scattering (breaking) or disturbing the shoals. Often times, it could be seen grabbing the netted sardine. In its role as a predator upon the oil-sardine, it is perhaps comparable to the porpoise (*Phocæna vomerina*) upon *Sardinops cærulea* (Fink, 1959).

General Considerations

As in the case of British herring fishermen (Graham, 1931) the Malabar fishermen also have many beliefs regarding the sardine fishery; the latter attribute the recent prolonged scarcity (before 1957) of the sardine to the cumulative effect of continued indiscriminate fishing with the boat seine, *mathikolli vala*. In other words, they feel that this net is perhaps destructive to the fishery in the long run. The sardine are caught in *mathikolli vala* under panic impulse, as in the case of herring (as described by Graham, *loc. cit.*).

The fishermen are of the opinion that if blood and other fish waste of the sardine are dumped into the sea (as is done after the extraction of the sardine oil), the shoals will show a tendency to disappear from the inshore areas. Such disappearance or the escape reaction of the sardine, if true, can, without doubt, be attributed to their sensitivity to olfactory stimuli.

During the course of this work, the turbidity (transparency of sea) values were found to range from 40·0–251·5 cm., the lowest value being recorded in February and the highest in November 1958 (reference to Table I). High sea-turbidity, locally called *neerkalakkam*, is generally considered favourable for fishing the sardine efficaciously, since the net is invisible to the fish; it is also in agreement with the view of Graham (*loc. cit.*) with regard to herring fishery.

The temperature data showed a range from 24·8°–32·8° C. in the course of this study; the lowest recorded was in July and August, and the highest in April.

The directions of water flow recorded during the different observations showed that on most occasions it was from north to south, in the course of this work; such a direction of the flow is generally considered by the fishermen as conducive to successful fishing.

It was found that there was no traceable correlation between some of these factors and the movements of the various shoals observed in the course of the work.

Perhaps, the sardine mortality due to various predators is of considerable magnitude, and is worth investigating. In the case of *Sardinops ocellata*, an approximate estimate of the fish consumed by various predators has been made by Davies (1956 and 1957).

It can be said with confidence that very useful results can be obtained from study of behaviour characteristics of other species under natural conditions, so that such knowledge could advantageously be applied for fish-finding and successful capture.

Summary

Certain observations have been made on the features of oil-sardine shoals of Calicut during the period October 1957 to November 1958. The various kinds of shoals encountered have been described. The surface shoals were grouped as flipping, pattering, rippling, leaping, bluish, pinkish and luminescent shoals. Two categories of bottom shoals have been recognized, *viz.*, those producing bubbling and those producing fish odour. Sardine shoals could also be recognized by the presence of predators such as terns, dolphins and gulls.

A study of the size composition of sardine shoals has indicated that the fish belonging to the same size-group and age-group shoal together.

Some beliefs of the fishermen associated with the sardine fishery are given. They opine that the dumping of sardine blood and its waste into the sea during the extraction of its oil may cause disappearance of the sardine shoals; if true, this must be ascribed to their sensitivity to olfactory stimuli.

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