# DIURNAL VERTICAL DISTRIBUTION OF THE LARVAE OF THE INDO-PACIFIC MACKEREL, RASTRELLIGER NEGLECTUS (VAN KAMPEN)

by

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ABSTRACT

The paper reports on the results of the study on the diurnal vertical distribution of Indo-Pacific mackerel postlarvae in the Gulf of Thailand. The postlarvae of Rastrelliger neglectus showed a positive phototaxis reaction in the early morning while the sun is rising. A large number of postlarvae was observed to concentrate at the depths of 5 - 10 m during daytime, and to drift downwards to greater depths from dusk through the night. This pattern is probably associated with the non-feeding action and/or resting periods.

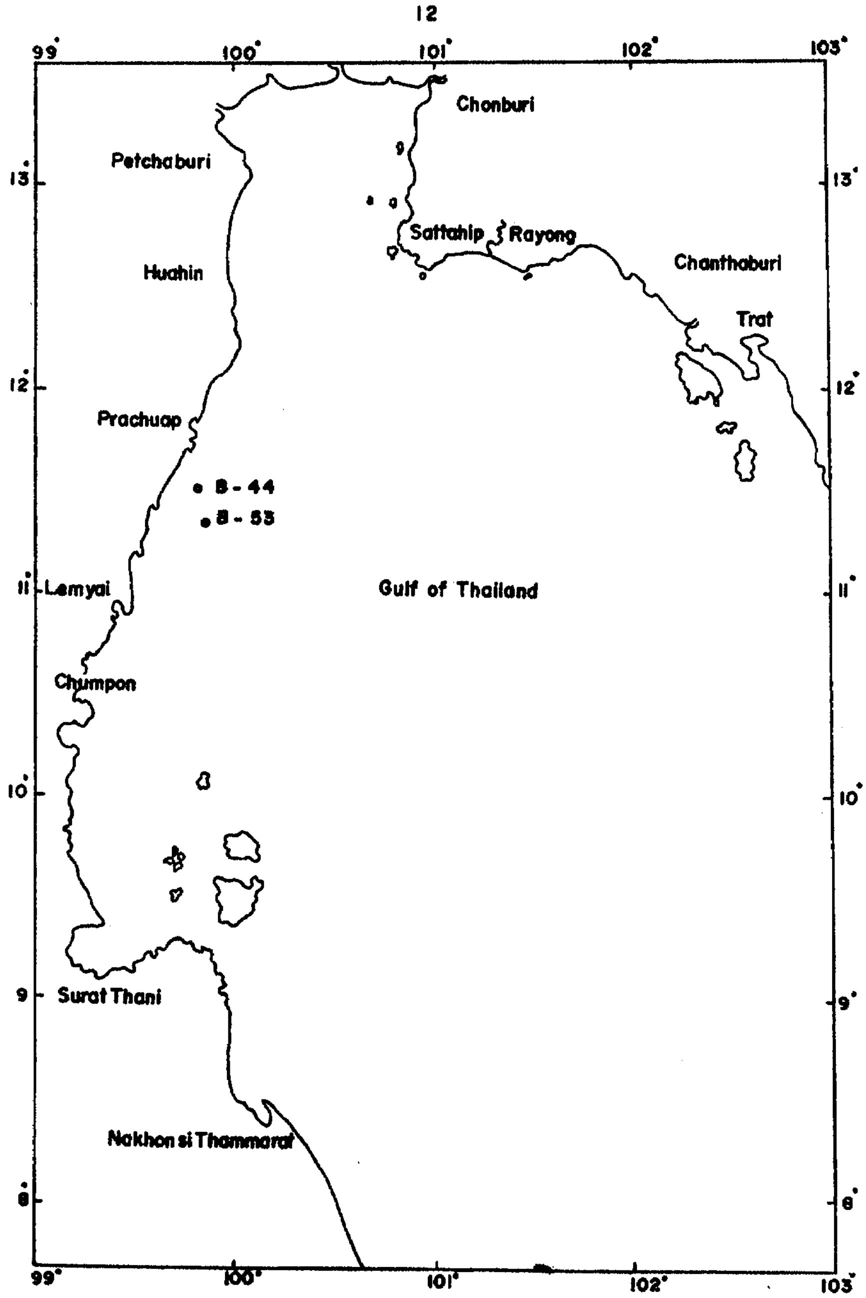


Fig. 1 The stations where the Indo-Pacific mackerel larvae were collected for the diurnal vertical distribution study

Since 1958, the Department of Fisheries of Thailand has carried out research on the
behaviour and life history of the Indo-Pacific mackerel, Rastrelliger neglectus (van Kampen),
5 in the Gulf of Thailand, as this species constitutes one of the economically important
fish resources of Thailand. The study on the diurnal vertical distribution of the larvae
of this fish is one of the projects currently being undertaken by the Pelagic Fisheries
Investigation Unit of the above-mentioned department.

Several fisheries biologists have studied the migratory and distributional behaviours
of the postlarval stages of various species of fish at different periods of the day
6 (Russell (1930); Silliman (1943); Bridger (1956); Ahlstrom (1959); Miller, Colton and
Marak (1963); Hempel (1970)). However, only a few papers reported on the diurnal vertical
movement and distribution of the mackerel (Sette (1943); Watanabe (1970)).

By towing obliquely a larval net, (mouth opening 1.50 m diameter) from 13 m depth
7 to the surface, Boonprakob (1968) found that a large number of the Indo-Pacific mackerel
larvae were caught both in day and in night-time. However, only a small number of the
larvae were caught when towing the net horizontally near the surface during the night-time.

Dhebtaranon and Boonprakob (1971) noted the different behavioural pattern of the
larvae of the Indo-Pacific mackerel in comparison with other zooplankters; they move
8 to the surface during the daytime and stay in the depth during night-time. However, the
results from the previous surveys were still unsatisfactory because the surveys were
conducted only from depths of 15 m, and the numbers of larvae obtained were very few.
Thus, further experiments were carried out to ascertain the behaviour of the postlarvae
of mackerel with respect to their diurnal movement and distribution.

## 2. MATERIAL AND METHODS

The surveys of the spawning grounds of this species off the west coast of the Gulf of Thailand were undertaken during March 1-3, 1971. After completing the plankton tow the number of larvae caught at each station were counted and the stations where the larvae were found to concentrate were selected for the diurnal vertical migration study. The plankton collections were made by R.V. "Pramong I" and R.V. "Pramong VI" of the Department of Fisheries during 7-10 March, 1971. To complete the cycle of three-day investigation, the plankton tows were made at 03.00, 09.00, 15.00 and 21.00 hours by R.V. "Pramong I", and at 06.00, 12.00, 18.00 and 24.00 hours by R.V. "Pramong VI".

Station No. B-53 (Lat. 11°20'00"N; Long. 99°53'00"E; 39 m depth) (Fig. 1), was sampled at intervals from 15.00 hours of March 7, to 09.00 hours of March 8, but only a few mackerel larvae were found. Station No. 44 (Lat. 11°30'00"N; Long. 99°50'00"E; 31 m depth) was explored later at the set interval from 12.00 hours of March 8, until March 10.

The opening and closing net used has a mesh size of 330 microns and a mouth diameter of 60 cm. A flow meter was fixed at the middle of the opening for recording the volume of water passing through the net. The net was used at the following depths: 5-0 m, 10-5 m, 15-10 m, 20-15 m, and 25-20 m respectively.

The water from the depth of 25 m, 10 m, and 0 m was sampled for salinity and temperature determination. The plankton samples were kept in 4% formalin solution. The number of larvae obtained from different depths was standardised to 500 $m^3$ of water in order to have comparable data.

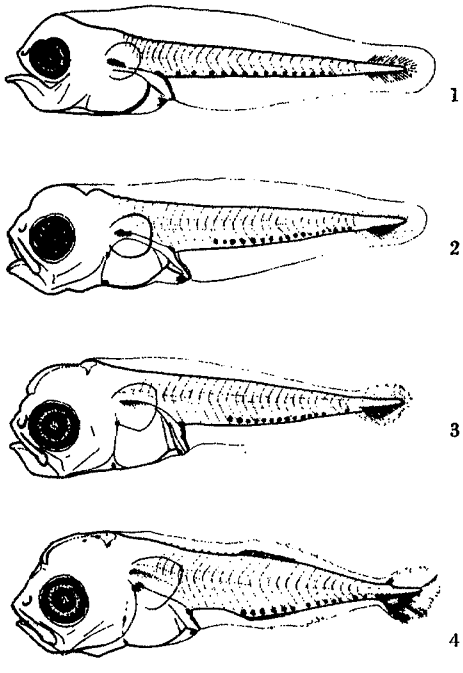


**Fig. 2 a.** Postlarval stages of *R. neglectus*
(Based on preserved specimens)

1 : $P_1$ – stage, T.L. 2.42 mm
2 : $P_2$ – stage, T.L. 3.06 mm
3 : $P_2$ – stage, T.L. 3.56 mm
4 : $P_3$ – stage, T.L. 4.10 mm

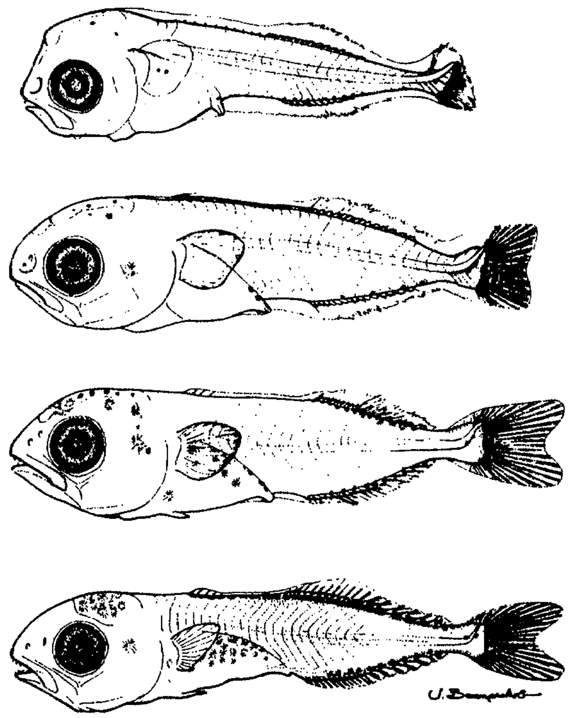

**Fig. 2 b** Postlarval stages of *R. neglectus*
(Based on preserved specimens)

5 : $P_3$ – stage, T.L. 4.71 mm
6 : $P_4$ – stage, T.L 6.62 mm
7 : $P_4$ – stage, T.L. 8.00 mm
8 : $P_4$ – stage, T.L. 11.80 mm

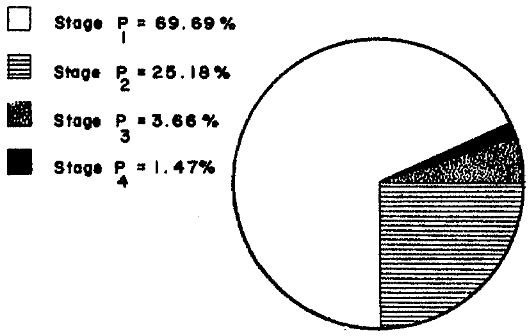


Fig. 3 Percentage of postlarvae at each stage found during the observation.

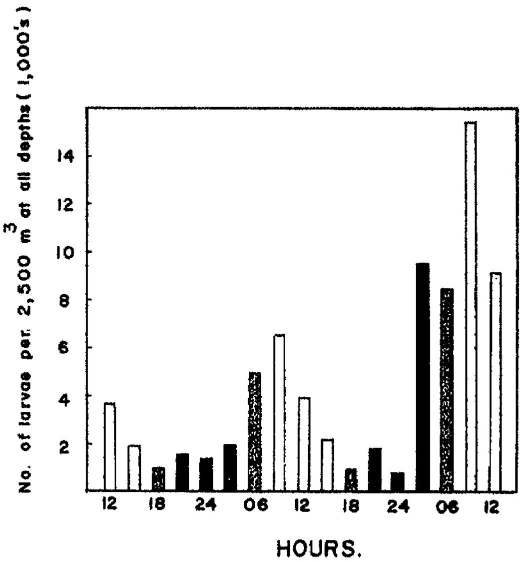


Fig. 4 Diurnal variation in number of the Indo-Pacific mackerel larvae at station B-44 over a 2-day period ( 8 - 10 March 1971 )

The stages of development of postlarvae were categorised as shown in another contribution by the authors to this Symposium (Boonprakob and Dhebtaranon (1972)).

## 3. RESULTS AND DISCUSSION

### 3.1 Diurnal variation in catches of postlarvae

6,100 postlarvae of the Indo-Pacific mackerel were sorted out from the plankton samples and analysed. Most of them were caught at Station No. 44, and only less than 100 larvae at Station No. 53 (Table I). The larvae at stages $P_1$ were found to be 69.69% of the total number of larvae caught, and those at more advanced developmental stages ($P_2$, $P_3$, and $P_4$) were caught in smaller numbers (Fig. 3).

The results of some studies on the distribution of larvae of various fish species collected by different types and sizes of gear (Russell (1930); Silliman (1943); and Bridger (1956)) showed that the numbers of fish larvae obtained during the night-time were higher than those in the daytime. However, our results differ from these previous observations. The average number of larvae collected during the night-time was lower than in the daytime and in the morning hours. Comparison of the number of larvae collected at different times of the day showed that the highest number of larvae was obtained at 09.00 hours, and the lowest at 18.00 hours (Fig. 4).

Differences were noticed in the numbers of the larvae of the various stages collected during different times of sampling. $P_1$-larvae were caught mostly in daytime, $P_2$ and $P_3$-larvae at dawn, and $P_4$-larvae during night-time (Fig. 5). Silliman (1943) has shown that California pilchard larvae of over 8 mm in length could avoid the net which was towed at 50 cm per second in daylight. Ahlstrom (1954) and Bridger (1956 and 1958) have demonstrated that the differences in the day and night catches were mainly due to the ability of many species to avoid slow-moving collecting gear during the daytime. This would explain the fact that the later stages were caught in larger numbers in night-time than in daytime (Fig. 5, stage $P_4$).

The $P_1$-larvae were caught in larger numbers in the daytime. This may be due to the following reasons:

(a) During this stage the eyes of the larvae are not well developed and it is difficult for the larvae to see and avoid the net;

(b) they are not active enough to move away from the net;

(c) they may move together in school; and,

(d) the water current might have a certain influence over the distribution of the larvae.

The total amount of larvae was highest at dawn and in the daytime when they are distributed in the upper layer, and lower at night when the larvae were found to concentrate in the deeper layers. Miller, Colton and Marak (1963) collected haddock larvae by using a high-speed plankton sampler towed at the speed of 7 knots, and reported that the numbers in day catches were almost the same in night catches.

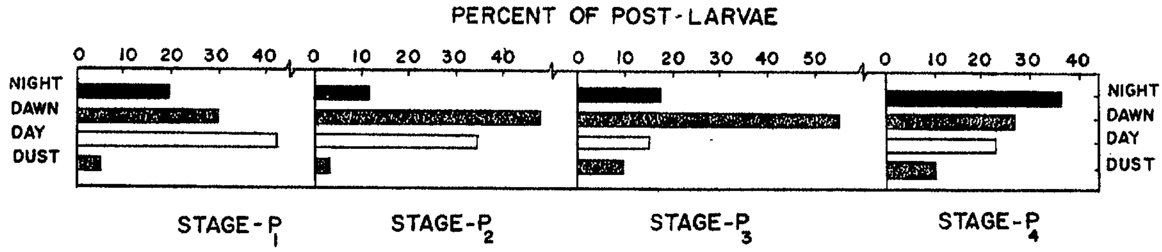


Fig. 5 Percentage of diurnal variation in catches of post-larvae at each stage.

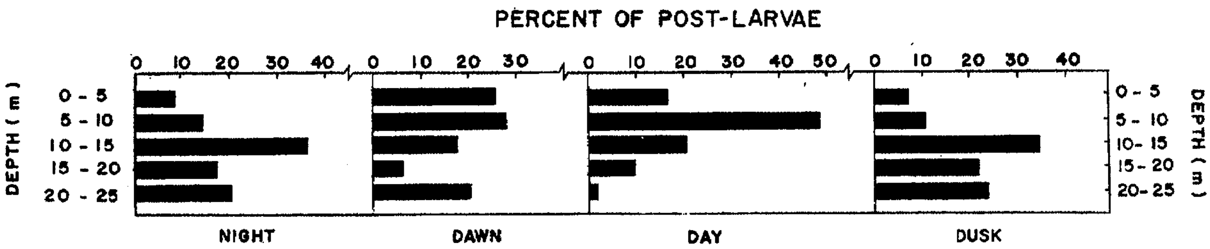


Fig. 6 Diurnal vertical distribution of the Indo-Pacific mackerel post-larvae.

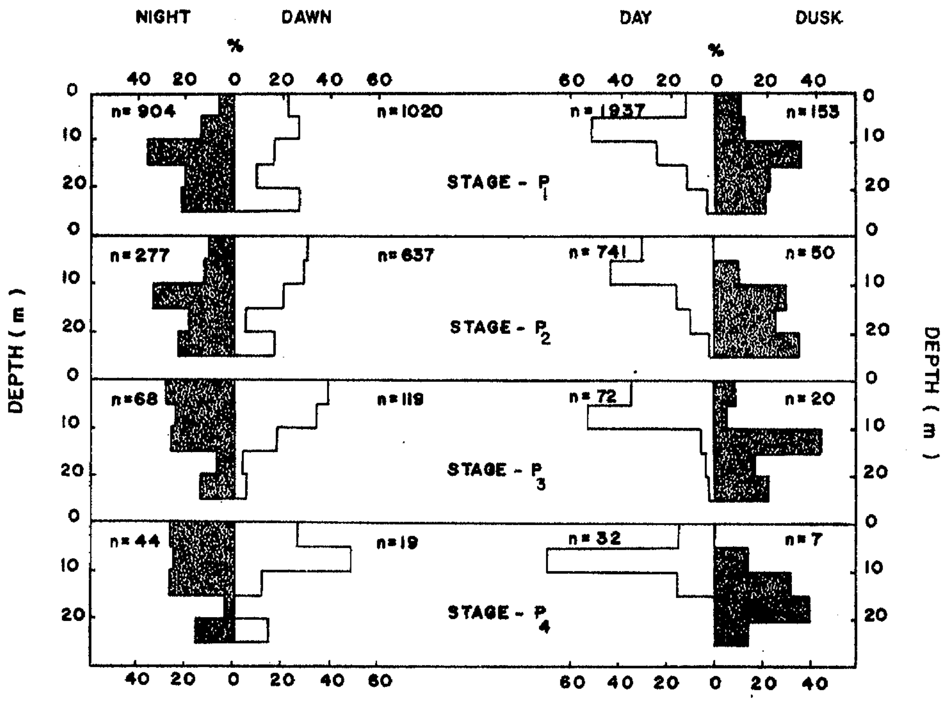


Fig. 7 Vertical distribution of the Indo-Pacific mackerel postlarvae in different stages.

## 3.2 Diurnal vertical distribution

Sette (1943) noted that the Atlantic mackerel larvae were found in abundance at depths of 10-20 m in the daytime, and near the water surface during the night-time. The results of sampling by using a larval net summarised by Watanabe (1970) indicated that the number of postlarvae collected near the surface at night was higher than during the daytime, and postlarvae scarcely inhabited the waters deeper than 25 metres. This is because the important prey animals of postlarvae such as eggs and nauplii of copepods are mainly distributed in the upper layer of the sea.

It was observed that the diurnal vertical distribution of the Indo-Pacific mackerel larvae was different from the behaviour described for the other species mentioned before; the larvae were found to concentrate in the deeper water at night and to move upwards gradually to the layer of 0-10 m at dawn (Fig. 6). The larvae inhabit the level of 5 - 10 m depth when the intensity of the sunlight is increasing. During this period the numbers of larvae collected seemed to decrease gradually with increasing depth. At twilight, the larvae seemed to rest, and as they do not move actively, they sank to deeper water; most of them were found at 10-25 m depth (Fig. 6).

Light is one of the important physical factors that control the vertical distribution pattern of aquatic animals. There are several reports dealing with the effects of light on the vertical distribution of aquatic organisms, among others Balls (1951); Beamish (1966); Hergenrader and Hasler (1966); Barrs (1970. It is believed that the effects of light may cause variations in the response among individual species of fish of different ages. For example, the herring larvae swim directly towards the light, showing a positive phototaxic reaction (Woodhead and Woodhead (1955)). Balls (1951) reported that the herring at the whitebait stage were always found near the water surface during daylight, the 1 to 2 years-old herring also did not escape from light, but the older herring showed a negative phototaxic reaction by moving downwards in the daytime and upwards in the night-time.

The rearing experiments of the larvae of Blennius pholis and Centronotus gunnellus conducted by Qasim (1955) showed that the larvae are inactive in the dark or dim areas. This was thought to be the resting time of the larvae when empty stomachs were always observed. The larvae became active and started to feed when light was given. Such a behaviour was observed in several species of fish larvae (Shelbourn (1953); Bhathacharyya (1957); Blaxter and Holliday (1958); Blaxter (1965)). These authors found that the feeding behaviour of the larvae, both those living in nature and under laboratory conditions, are affected by the light as it was observed that the volumes of stomach contents of the larvae in the daytime or in the lighted areas were much greater than those in the night-time or in dark areas.

It seems that the positive phototaxic behaviour of the Indo-Pacific mackerel larvae resembles that of the herring larvae. In this study, the larger number of larvae were collected at the surface water at dawn; however, some of them were found also in the deeper water, 20-25 m in the morning (Fig. 6). This might be due to the low intensity of light in the early morning which could not penetrate into the deeper layer; hence, the larvae living at that depth did not show positive phototaxic reaction. When the light intensity was gradually increased during late morning and penetrated through the deeper water, no larvae were found any more at the depths of 20-25 m (Fig. 8).

Our observations also indicated that the increased light intensity at noon caused the decrease in the number of larvae living near the water surface; they were abundant at 5-10 m during this period. This is probably due to two reasons, the first being the increase of the water temperature near the surface. From his experiments on the temperature tolerance of ten species of marine fish larvae, Kuthalingam (1959) concluded that eight of the species appeared to require lowest temperature conditions from the time of hatching up to the end of the postlarval period. The second reasons might be that the larvae choose a suitable light intensity for spotting and capturing their food. The results of the rearing experiments of herring larvae conducted by Blaxter and Holliday (1958), indicated that the feeding behaviour of the larvae was affected by the light intensity. They found that the optimum light intensity for feeding was in the range of 100-1000 mc (metre candle). The light intensity outside this range decreased the rate of feeding. This rate decreased to the lowest level when the light intensity was increased up to 30,000 mc; the larvae stopped also feeding at the low intensity of light of 0.25 mc (= light of full moon).

## 3.3 Vertical distribution among different stages of fish larvae

Hempel (1970), in summarising his studies on the behaviour of several species of marine fish inhabiting the subtropical Atlantic and coral waters, stated that the eggs and yolk-sac larvae were missing in the uppermost layer and that the young postlarvae stay permanently close to the surface whilst the old larvae and juveniles perform diurnal vertical migrations.

The Indo-Pacific mackerel larvae seem to show a distinct pattern of vertical distribution. It was observed that the distribution pattern of $P_1$ and $P_2$-larvae was the same, but differed from those of $P_3$ and $P_4$-larvae during night-time. After sunset the $P_1$ and $P_2$-larvae were abundant at depths of 10-25 m but most of the $P_3$ and $P_4$-larvae were found to concentrate in the uppermost layer, 15-0 m. In other periods, the distributional pattern of these larvae was the same: they moved upwards in the morning, inhabiting the 5-10 m levels at noon, and moved downwards to deeper levels at twilight time (Fig. 7).

The examination of the stomach contents of the larvae has not yet been completed, therefore we cannot yet ascertain whether the light intensity or the feeding habit of these larvae influence their vertical distribution pattern.

## 3.4 Temperature, salinity and distribution of the larvae

In general, the cold water and tropical fish are less tolerant to temperature changes than those living in the temperate sea. Blaxter (1960) noted that herring larvae of about 6-8 mm in length acclimatised to temperatures between 7.5 - 15.5°C; the upper lethal temperature for this fish varies from 22° to 24°C and the lower lethal temperature from 0.75° to -1.8°C. This shows how much the larvae can adapt themselves to survive in such different water temperatures during the different seasons.

As in the tropical waters the temperature changes only slightly during the year, the fish of this zone are stenothermal. Kuthalingam (1959) found that the tolerance ranges for the larvae of ten species of tropical fish were very narrow, the upper lethal temperature varying from 30° - 31°C and the lower from 27° to 29°C. In our investigations the water temperature changed also only slightly during the day (Fig. 8), and might be considered as an unimportant factor for the distributional pattern of the larvae. However, it is believed that the increase of temperature at the surface at noon or afternoon may cause the moving away of the larvae from the sea surface.

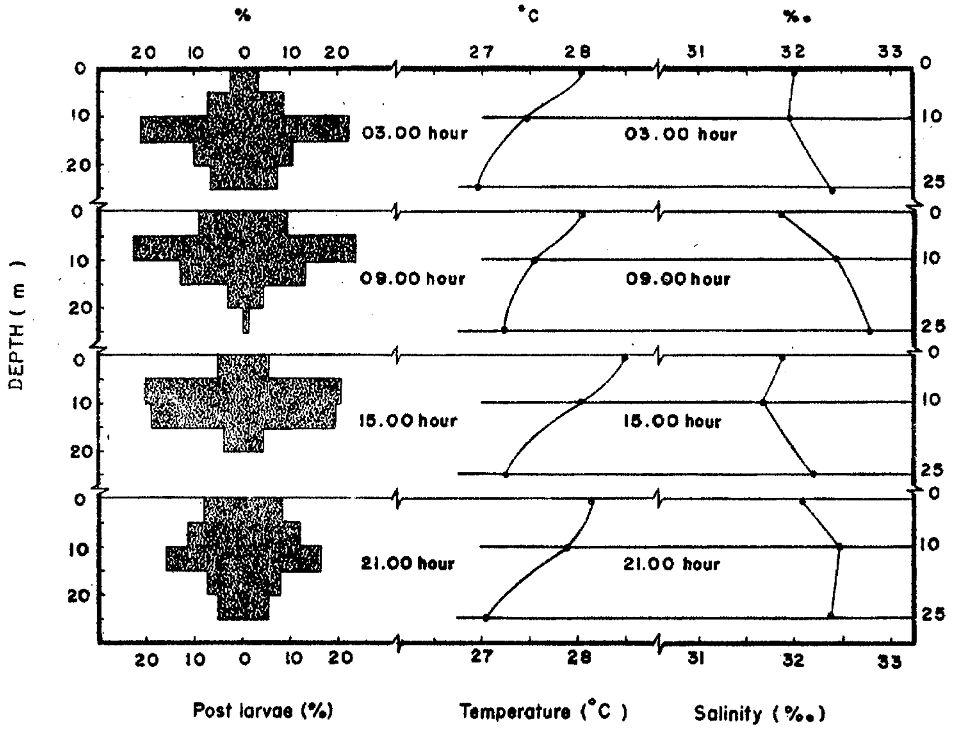


Fig. 8 Distribution of postlarvae in relation to temperature and salinity at four times in the diurnal cycle.

Several species of marine fish show a considerable range of salinity tolerance. Herring larvae can survive in salinities ranging from 1.4 to 60.1‰ for 24 hours (Holliday and Blaxter (1960)). The yolk-sac larvae of the plaice, Pleuronectus platessa, survive in water with salinities ranging from 5 to 65°/oo for one day (Holliday and Jones (1967)). Hourston (1959) reported that herrings at the juvenile stage were abundant between 17.23 and 29.39°/oo salinity. In our studies, the salinity of the water at depths of 0 m, 10 m, and 25 m, ranged from 31.86 to 32.15°/oo; 31.63 to 32.99°/oo; and 32.18 to 33.39°/oo respectively; the average salinity shows in small differences between depths (Fig. 8). It is presumed that the salinity is not an important factor for the distributional pattern of the larvae.

Another interesting result presented by Rudjakov (1970) indicated that the downward migration of planktonic populations may be attributed entirely to passive sinking. This conclusion, along with other data from voluminous literature devoted to circadian rhythms, supports the assumption that diurnal vertical migration is the result of the animal's alternation of phases of high and low activity. Thus, the fact that the $P_1$ and $P_2$-larvae are concentrated in the lower depths during dusk and might-time may be the result of low activity or resting.

## 4. SUMMARY

1. A total of 6,100 Indo-Pacific mackerel larvae were collected during the investigation; 69.69% were $P_1$-larvae, 25.18%, 3.66%, and 1.47% were $P_2$, $P_3$, and $P_4$-larvae respectively.

2. The larger numbers of $P_1$-larvae were found during daytime, $P_2$ and $P_3$-larvae at dawn, and $P_4$-larvae in the night-time. The average catches at dawn and daytime were higher than the catches at dusk and night-time.

3. The Indo-Pacific mackerel larvae show a pattern of vertical distribution similar to those of other positive phototaxic animals. They move downwards during the low light-intensity period (low activity or resting).

4. Temperature and salinity conditions of the water during the period of investigation were not the causal factors of the diurnal vertical migration and distribution of the larvae.

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TABLE I. The numbers of postlarvae of the Indo-Pacific mackerel collected by an opening/closing net at different depths during the surveyed period, 7 - 10 March 1971

| Station | Date Mar. '71 | Time | No. of postlarvae found in each depth | | | | | Estimated No. of postlarvae per 500m$^3$ in each depth | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0-5m | 5-10m | 10-15m | 15-20m | 20-25m | 0-5m | 5-10m | 10-15m | 15-20m | 20-25m |
| B-53 | 7 | 1515-1623 | - | - | - | 1 | - | - | - | - | 8 | - |
| " | 7 | 1730-1858 | - | - | - | - | - | - | - | - | - | - |
| " | 7 | 2034-2156 | - | - | - | - | 1 | - | - | - | - | 11 |
| " | 7-8 | 2330-0138 | 1 | - | - | - | 4 | 7 | - | - | - | 32 |
| " | 8 | 0343-0528 | 7 | 3 | 4 | 3 | - | 42 | 24 | 80 | 24 | - |
| " | 8 | 0536-0641 | 1 | 3 | 4 | 1 | 2 | 5 | 17 | 28 | 9 | 20 |
| " | 8 | 0845-0959 | - | 1 | 1 | 33 | - | - | 6 | 8 | 548 | - |
| B-44 | 8 | 1213-1335 | 100 | 241 | 5 | 79 | 72 | 676 | 1700 | 90 | 616 | 648 |
| " | 8 | 1446-1618 | 18 | 48 | 4 | 12 | - | 132 | 887 | 84 | 187 | - |
| " | 8 | 1730-1850 | 11 | 25 | 56 | 1 | 10 | 106 | 210 | 572 | 20 | 63 |
| " | 8 | 2024-2153 | 48 | 25 | 27 | 24 | 9 | 521 | 503 | 388 | 391 | 128 |
| " | 8-9 | 2330-0123 | 28 | 33 | 31 | 25 | 20 | 255 | 325 | 370 | 226 | 194 |
| " | 9 | 0247-0340 | 58 | 35 | 49 | 8 | 87 | 664 | 509 | 636 | 103 | 1718 |
| " | 9 | 0530-0635 | 239 | 223 | 81 | 1 | 1 | 3009 | 1215 | 731 | 19 | 19 |
| " | 9 | 0834-1035 | 133 | 70 | 151 | 44 | 1 | 1874 | 1056 | 2744 | 792 | 18 |
| " | 9 | 1130-1229 | 56 | 91 | 83 | 136 | 38 | 340 | 669 | 601 | 1100 | 278 |
| " | 9 | 1432-1526 | 34 | 40 | 48 | 9 | - | 427 | 1019 | 642 | 183 | - |
| " | 9 | 1742-1845 | 5 | 1 | 13 | 57 | 51 | 35 | 6 | 110 | 409 | 399 |
| " | 9 | 2045-2147 | 8 | 18 | 39 | 12 | 14 | 128 | 385 | 828 | 232 | 244 |
| " | 9 | 2330-0028 | 9 | 5 | 8 | 42 | 54 | 42 | 65 | 70 | 320 | 386 |
| " | 10 | 0245-0341 | 9 | 65 | 241 | 145 | 94 | 108 | 1297 | 4394 | 2307 | 1544 |
| " | 10 | 0605-0735 | 46 | 451 | 219 | 57 | 466 | 406 | 2434 | 1551 | 816 | 2732 |
| " | 10 | 0848-0933 | 157 | 325 | 188 | 33 | 4 | 2100 | 9435 | 3098 | 586 | 63 |
| B-44 | 10 | 1135-1222 | 105 | 326 | 76 | 14 | 5 | 1475 | 5747 | 1531 | 294 | 83 |
| | | TOTAL | 1073 | 2029 | 1328 | 737 | 933 | 12322 | 27509 | 18556 | 9191 | 8570 |