

THE UNIVERSITY OF MIAMI

A STUDY OF SOME SIPHONOPHORES OF THE  
FLORIDA CURRENT

BY

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A THESIS

Submitted to the Faculty  
of the University of Miami  
in partial fulfillment of the requirements for  
the degree of Master of Science

Coral Gables, Florida

June 1954

THE UNIVERSITY OF MIAMI

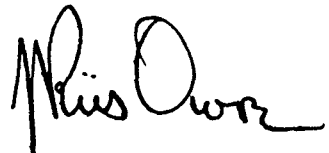
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Subject

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Florida Current

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This thesis has been  
approved by the Department  
of Marine Sciences and by  
the Committee on Graduate  
Study

A handwritten signature in dark ink, appearing to read "J. Riis Owre". The signature is fluid and cursive, with the first letters of the first and last names being capitalized and prominent.

J. Riis Owre  
Dean of the  
Graduate School

## PREFACE

I wish to express my many thanks to Dr. H. B. Moore for his guidance and inspiration in aiding me to complete this thesis and for the figures on diurnal migration.

I also wish to thank all the staff of the University of Miami Marine Laboratory who have assisted me in gathering data for this thesis, and especially Mr. Dave O'Berry, Mrs. Joan Feil Clancey and Mr. John B. Lewis.

Douglas Champe Roane

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## INTRODUCTION

Diurnal migration of planktonic animals has been observed for more than two hundred years. This migration of planktonic animals is important in at least three respects. First, some of these animals are known to be directly involved in the food chain of the oceans (Allen, 1934). This has commercial value in that these animals are the food source for many filter-feeding and predaceous fishes. Some of these fish exhibit a diurnal migration which may be a migratory feeding pattern on these planktonic animals and better understanding of this may lead to larger catches of these fish. Second, the understanding of this phenomenon will strengthen the ecological knowledge of planktonic animals and will provide another small step into a more complete knowledge of ocean life. Third, the ability of the scattering layer, which is thought to be migrating animals, to reflect high frequency sound waves, is of vital importance to the Navy's study of underwater sound.

Two methods of investigation were used by early writers. In the first method, observations at the surface throughout the night and day revealed that many animals were caught at the surface only during the night (Rang, 1828 and Laydig, 1862). The second method was the comparison of the vertical distributions obtained by net samplings at a given time during the day with that of a given time during the night (Chun, 1888). These comparisons showed that some animals climb to the surface at night and return to their day time level during the day.

Before 1900, the cause or causes of this nightly migration from depths occupied in the daytime toward the surface was a matter of speculation but light was assumed to be the mediating factor (Loeb, 1893). Weismann (1874) thought that the eyes of the planktonic animals were adapted to mid-value light and the animals would not be able to capture food if they remained at the surface during the day. Chun (1888) postulated that diurnal temperature changes drove the animals toward the surface during the night and downward during the day. Fuchs (1882) considered that planktonic animals preferred darkness and that diurnal migration was a feeding migration as the phytoplankton lay much nearer the surface.



Forel (1904) postulated that the offshore land breeze on the Lake of Geneva made a centripetal current which drove the animals into the center of the lake during the night and the animals evaded the centrifugal current produced by the onshore breeze during the day by staying lower in water. Strodtmann (in Forel, 1904) suggested that the diurnal temperature changes could cause convection currents which would account for ascent at night. Descent remained an active flight from the light. Ostwald (1902) suggested that many of the vertical movements might be related to viscosity changes in the water produced by diurnal temperature changes.

Experimentation began with Loeb's theory of tropisms (1894). He believed that the animals behaved heliotropically (orientation of sessile animals or plants to light), and assumed that only vertical light rays were significant in migration so that diffuse light was ruled out. He believed that in the case of free-moving animals, the animal is orientated by the light and is forced to move in this orientation. Consequently, if the animal is positively heliotropic, it moves toward the light and if the

animal is negatively heliotropic, it moves away from the light. Loeb's theory of diurnal migration was that positive heliotropism drew the animals to the surface at dusk and negative heliotropism drove them down in the morning. This change of sign of tropism was accredited to temperature and carbon dioxide by Loeb. The application of this term, tropism, to free moving animals was incorrect but did stimulate experimentation which adopted the more suited term, taxis (direct orientation of free moving animals).

Parker (1902) introduced the term "geotropism." He assumed that geotropism meant, when applied to diurnal migration, a directional response to light by movement, from which deviations are corrected in response to gravity.

Dice (1914) believed that diurnal migration was the interaction of two taxisms - geotaxis (geotropism of Parker) and phototaxis, and eliminated change of sign by the use of these two taxisms. Downward movement was the result of negative geotaxis being much stronger than positive phototaxis when stimulated by strong light. Upward movement was the result of

positive phototaxis being stronger than negative geotaxis when stimulated by low intensity light.

Rose (1929) introduced the theory of optimum intensity which limited the reactions of animals to a wide band of light intensities which is explored irregularly by the animals.

One of the latest theories of diurnal migration is that of Moore (1951) who postulates that illumination is the controlling factor during ascent and descent periods and temperature and illumination are the joint controlling factors during mid-day.

Previous to the Scattering Layer Stations (the stations on which this paper is based) only two surveys of the vertical distribution of the oceanic zooplankton in sub-tropical regions of the Western Atlantic had been made; others being only samples obtained from cruises of research vessels such as the Atlantis, Challenger and others. Both of the above mentioned surveys were made by Moore (1949, 1953) and were concerned with the seasonal distribution, diurnal migration, vertical distribution, cycle of alternation of generations and ecological

factors of the zooplankton from the Bermuda and Florida Current areas.

Moore (1950) found the diurnal migration of euphausiids in the Mediterranean Sea controlled by illumination; the control of temperature was minimized by extremely slight thermal stratification. In the North Atlantic, where more extreme thermal stratification is present, the lower limits of the euphausiids were under the control of temperature.

The same principle of reaction to light and temperature is found in the sub-tropical regions of the Western Atlantic. Moore (1953) found the diurnal migration of four groups, pteropods, siphonophores, chaetognaths and copepods to be under the joint control of illumination and temperature; illumination the controlling factor during the ascent and descent of the zooplankton and temperature and illumination the controlling factors during mid-day.

This paper presents a continuation of such studies as mentioned before of eight common species of siphonophores found in the eastern portion of the Florida Current and compares the findings of the author with those of Moore when possible. These eight

species of siphonophores were chosen for two reasons. First, they were the most common species of siphonophores in all three areas (88% in the 10 Mile Station) and second, they provide a unit of comparison amongst themselves and between the three areas under study. The problem of diurnal migration in relation to temperature and illumination was completed only to the extent of recording data from eleven of the thirteen stations and the analysis of mid-day levels. A final report on diurnal migration and effecting factors will be published later under joint-authorship of Dr. H. B. Moore and the author.

This paper does not intend to prove any theory but provides another small series of observations that eventually may be combined to establish some generalized law or laws for all migrating planktonic animals.

This siphonophore work was an independent study carried out under the Bureau of Ships contract number Nobs-57146. The stations began in September 1952 and continued to January 1954. A total of thirteen stations was completed during

this period. Complete records of all hauls are filed in the library of the Marine Laboratory.

## BIOLOGY

Siphonophores are wholly planktonic, polymorphic colonial animals which belong to the phylum Cnidaria, class Hydrozoa and order Siphonophora. They range in size from a few millimeters to one foot or more. Most are transparent but some range in color from red to blue.

Each colonial animal is composed of several individuals. The polygastric (asexual) generation is composed of two major forms, the superior and inferior nectophores (medusoid swim bells) and in addition to these, dactylopolyps and gastropolyps (polypoid individuals) which contain tentacles and nematocysts. The eudoxid (sexual) form is also composed of two major forms, the bract for protection and the gonophore for reproduction and locomotion (medusoid swim bell) and also dactylopolyps and gastropolyps (polypoid individuals) which contain tentacles and nematocysts.

By definition, siphonophores feed, move, and reproduce by specialized polyps: dactylozooids for tentacular functions of protection and food gathering, gonozooids for reproduction and locomotion and gastrozooids for digestion of food.

Throughout the class reproduction is in the form of alternation of sexual and asexual generations. The sexual form is the eudoxid (medusoid) and its gonozooid produces eggs and/or sperm. The union of these gametes produces a zygote which develops into a free-swimming planula larva. After a time, the planula metamorphoses into a polygastric (polypoid) asexual form. The polygastric form grows or buds off the sexual or eudoxid form.

Thus the cycle of alternation of generations may be expressed:

polyp --> medusa --> egg + sperm --> planula --> polyp

Digestion is carried out by the specialized polyps called gastrozooids which both generations possess. Dactylozooids and nematocysts capture food and tentacles pass it into the gastrozooid. Siphonophores are strictly carnivorous and feed on

food ranging in size from the smallest planktonic animals to medium sized fish.

Locomotion is facilitated by specialized medusoid individuals; gonophores in the eudoxid form and medusoid swim bells (nectophores) in the polygastric form. These individuals contain muscle fibers which upon contraction force water from the cavity of the gonophore and swim bell. Motion is the result of the expulsion of this water from the cavity. By alternate contraction and relaxation of these individuals, the animal is propelled through the water.

Siphonophores possess a sub-epidermal nervous system to the extent of a very diffuse scattering of neurites. These neurites form a nerve net which covers the entire animal. Three types of receptors are present: photoreceptors, sensory cells and statocysts. The photo-receptors contain pigments which are light sensitive and are connected to the nerve net. Sensory cells are presumed to be general receptors of temperature, touch, chemical qualities, etc. and are connected to the nerve net. Statocysts are cells which contain a round concretion



(statolith) above a row of sensory cells. These are organs of equilibrium and are connected to the nerve net.

This discussion of the biology of siphonophores has been limited to that which is applicable to the work in this paper. Further facts concerning this order may be found in Hyman (1940) and Lang (1891).

#### METHODS AND MATERIALS

Stations were scheduled once a month but some were not completed due to either mechanical breakdown of equipment or severe meteorological conditions. Eleven of the stations were made four miles west of Gun Cay ( $25^{\circ} 21'-26'$  N.,  $79^{\circ} 29'-40'$  W.), two were made approximately ten miles east of the flashing red light marking the entrance to Miami Harbor ( $25^{\circ} 43'$  N.,  $79^{\circ} 56'$  W.), and all were designated as Scattering Layer Stations.

To prevent misunderstanding of collecting areas, the Scattering Layer Stations will be referred to as the 40 Mile Station; these were made 40 nautical miles east of Miami, and Moore's work in the Florida Current will be referred to as the 10 Mile Station; these were

made 10 nautical miles east of Miami. The stations included the taking of plankton samples from depths ranging from 800 meters to the surface, hydrographic data, illumination data, weather data and sound data. All stations were made on board the Marine Laboratory's research vessel T-19. The crew consisted of four to eight members of the Marine Laboratory and worked alternate shifts for a period of twenty-four hours.

Equipment on board the T-19 consisted of hydrographic instruments, power winch, ca. 1800 meters of 7/32 inch steel cable, nets, stops, net attaching mechanisms, meter wheel and necessary blocks and frames to place the cable in towing position.

Cable stops, nets, and net attaching mechanisms were of the Discovery type (Kemp, et al., 1929) which were slightly modified for the manufacturer's convenience and are described by Jones in an unpublished Master of Science thesis at the Marine Laboratory (1952):

The mouth, lashed to a hoop of one-half inch iron, was about sixty-nine [seventy] centimeters in diameter. The first third of the net consisted of a canvas collar followed by one-quarter inch (not stretched) mesh netting. Behind this, a wide canvas collar contained a series of brass rings. The next third of the net consisted of

stramin netting similar in weave to burlap. [aperture 1.0 mm.] The small end of the net consisted of silk bolting cloth of No. 10 mesh. [aperture 0.158 mm.] The entire net was about twelve feet long. ....A bridle of three lines was attached to the large hoop in the net's mouth. A throttle line was threaded through the brass rings of the canvas collar midway. This line then passed through a thimble in its own end to form a noose. The free end of this line and the bridle were engaged in a closing mechanism which was fastened to the steel cable by means of a cylindrical stop which allowed the mechanism to revolve freely about the cable. This closing mechanism was a modified version of the Discovery type (Kemp, Handy and Mackintosh, 1929). The small end of the net received a jar for retaining the plankton....At the end of the tow, a brass messenger was sent down the cable and this released the net bridle from the closing mechanism and allowed the choke line to gather the middle of the net and cause it to double back and prevent the escape or entrance of plankton. The nets were lowered to the desired depth open, but Moore (1950) found that little plankton was captured during this descent.

The percentage that the captured plankton constitutes of the total population in situ is not known. Winsor and Clarke (1940) have shown that plankton nets do sample populations consistently within the limits of sampling error. Robert (1922) compared the results of plankton nets and pumps and found that they were quite constant. The type

of plankton net used for collection was the same in all three areas.

The cable was weighted by a 100 pound lead "fish." Two nets towed at the same time constituted a flight and were placed 100 meters apart on the cable. This flight was repeated every 200 meters until 800 meters of water was sampled. The depths of the nets were calculated from the depth-distance recorder (Miller et al., 1953) which was placed 15 meters below the deepest net.

This instrument records depth as a function of pressure by a Bourdon element. The Bourdon rotates an arm which carries a stylus across a smoked slide held by a standard Bathythermograph slide holder. The slide holder travels along a slide bar and also along a driving screw. The driving screw is rotated through two successive worm drives by a central shaft which is driven by an external propeller. The distance scale was calibrated by towing the instrument over a measured nautical mile four times, at a speed of two knots, two times against the current and two times with the current, and taking an average of four runs.

Pressure (depth) calibration was made in a pressure tank at Woods Hole Oceanographic Institute. A small solenoid was attached which moved the stylus arm at predetermined pressures. A master grid was prepared for the above ranges. Depth could be read to the nearest ten fathoms and horizontal distance to one-eighth of a nautical mile.

Distance towed was measured on the smoked slide from the point where the stylus stopped recording vertical distance and began to record horizontal distance to the point where it stopped recording horizontal distance and began to record vertical distance.

To remedy the inconsistency of hauls which varied from one-half mile to two miles, counts of siphonophores were multiplied by the reciprocal of the distance registered on the smoked slide to bring them up to or down to the correct calculated number of siphonophores per horizontal mile.

Hauls varying from the surface down to 200 meters were towed at a speed of two knots for a

period of twenty minutes. Deeper hauls were made by drifting with the current for a period of thirty minutes. These deep hauls made use of the high velocity of the surface currents to tow the nets and to keep them at a fairly constant depth. After each flight was completed, the vessel steamed south for fifteen to thirty minutes to regain its original position.

The plankton strained by the nets was collected by a 500 cc. bottle attached at the end of the net. The plankton was then drained of excess sea water and then preserved in a 7% solution of formalin and sea water buffered with a teaspoon of borax and appropriately labeled.

At the Laboratory the wet volume of the plankton was measured by water displacement in a 100 cc. calibrated graduate cylinder. Accuracy was  $\pm 1.0$  ml. or 5 to 15% of the total plankton per haul. These values were used in the seasonal distribution and alternation of generations graphs and notable changes in these graphs were of the value of three or four times the per cent error; consequently the margin of error in volume

determination was negligible in the plotting of these graphs. Various workers counted or removed the euphausiids, cephalopods, fish larvae, chaetognaths and copepods.

The author identified and counted the siphonophores by decanting excess fluid and pouring the remaining plankton and fluid into a petri dish and examined under a binocular microscope. Some night surface hauls contained too many siphonophores to be counted in this way. An aliquot, usually  $1/10$  of the total volume of the container, was taken after the contents were thoroughly mixed and the siphonophores present in this identified. After identifying a critical number (ca. 50), the number counted was multiplied by the reciprocal of the fraction of the total sample. Some species never reached this number and the entire haul was then scanned for their presence.

All counts were standardized to a nautical mile (Miller et al., 1953) and all depths converted to meters to facilitate comparison of data.

The identification of the eight species of siphonophores was aided by the notes and drawings of Dr. H. B. Moore and also from the works of Bigelow (1913), Totton (1929) and Lens et al. (1905). Due to their small size and similar anatomical structures, the eudoxid generations of C. appendiculata and E. spiralis were difficult to separate. The author was able to identify correctly only those bracts which were connected to the gonophores, the gonophores being different in both genera.

Identification was made only on mature individuals by means of bracts for the eudoxid generation and superior nectophores for the polygastric generation. Immature forms were recorded to supply data for seasonal distribution figures.

#### TERMS

The terms defined here are used in the description of each species:

Mean day-level: The depth in meters above which  
50% of the siphonophores of the



entire study were found during the day. This for a given species is the mean of the 50% levels of all stations in which counts were sufficiently abundant. This was calculated by the method described in diurnal migration, below.

**Spread:** The distance in meters between the 25% and the 75% levels of the siphonophores of the entire study found during the day. This for a given species is the mean of the 25% and the 75% levels of all stations in which counts were sufficiently abundant. This, too, was calculated by the method described in diurnal migration, below.

**Seasonal distribution:** The counts for all stations of a given species were combined for all depths sampled and are expressed as number per 10 cubic centimeters (cc.) of wet plankton. The mean of the above is used as an index of

the relative abundance of a species.

**Diurnal migration:** The depth that a percentage level rises or sinks during a period of twenty-four hours. This method is that described by Moore (1953):

Generally, six or seven depths were sampled on each occasion. Owing to the strong currents in the area, it was not possible to hold the nets very close to a desired depth, but in general the water column was well-sampled by a series of oblique hauls. The mid-depth of each haul was calculated, and from these, the depths half-way between each pair of hauls. It was assumed that each count was representative of the water column between two such half-way depths. The uppermost haul was assumed to extend to the surface, and the lowest, to the deepest recorded depth reached. For each species, and on each day, the total content of the water column was then integrated by cumulative multiplication of the counts and the lengths of the section of water column to which they applied. A second integration was then performed from the top down, using the same figures, and the depths were noted at which 25, 50 and 75 per cent of the above total were reached.

Rather than calculate the depths of the 25, 50 and 75 per cent levels, the depths of the 10, 20, 30 etc. percentage levels were calculated. These figures can be converted into the conventional kite distribution graphs by dividing a

thousand by the range of each net. These diurnal migration calculations were made by Dr. H. B. Moore and are averages for five stations except for D. dispar, which is taken from only one station.

### OBSERVATIONS

Only those species that were sufficiently abundant during the entire year were recorded and are:

Chelophyes appendiculata (Eschscholtz, 1829)

Eudoxoides mitra (Huxley, 1859)

Eudoxoides spiralis (Bigelow, 1911)

Diphyes dispar Chamisso and Eysenhardt, 1821

Diphyes bojani (Eschscholtz, 1825)

Bassia bassensis (Quoy and Gaimard, 1833)

Abylopsis eschscholtzii (Huxley, 1859)

Abylopsis tetragona (Otto, 1823)

#### Chelophyes appendiculata

The polygastric generation was very common during the entire study and the eudoxid generation was sporadic with a possible maximum in the spring (Fig. 1). There was possibly a seasonal maximum

between late summer and early fall (Fig. 2).

The mean day-level (Table I) of the polygastric generation was 221 meters and its spread (Table II) was 203 meters. The eudoxid generation had a mean day-level (Table III) of 221 meters and a spread (Table IV) of 166 meters. The average number per 10 cc. for the entire study was 37.2 (Table V). Diurnal migration was moderate (Fig. 3).

#### Eudoxoides mitra

Both generations were rather uncommon throughout the study and there was a tendency for the polygastric generation to be the more common form. There was very little seasonal fluctuation in the cycle of alternation of generation during the study (Fig. 4). A seasonal maximum was found between late summer and late fall (Fig. 5).

The mean day-level (Table I) of the polygastric generation was 249 meters and the spread was 133 meters (Table II). The eudoxid generation had a mean day-level of 291 meters (Table III) and a spread of 285 meters (Table IV). The average

number per 10 cc. for the entire study was 8.3 (Table V). Diurnal migration was slight (Fig. 6).

### Eudoxoides spiralis

The polygastric generation was very common during the entire study and the eudoxid generation was sporadic with two possible maxima (Fig. 7), one in winter and one in early summer. A seasonal maximum (Fig. 8) was found between early winter and early spring.

The mean day-level of the polygastric generation was 220 meters (Table I) and the spread was 227 meters (Table II). The eudoxid generation was not in sufficient numbers to determine mean day-level and spread. The average number per 10 cc. for the entire study was 20.8 (Table V). Diurnal migration was slight to absent (Fig. 9).

### Diphyes dispar

Both generations were rather uncommon during the study. The eudoxid generation was the more common form and had a very pronounced maximum which was found between early spring and mid-summer (Fig. 10). There were possibly two

seasonal maxima, one in winter and one in early spring (Fig. 11).

The mean day-level (Table I) and spread (Table II) of the polygastric generation were in 366 meters and 112 meters respectively. The eudoxid generation was not in sufficient numbers to determine mean day-level and spread. The average number per 10 cc. for the entire study was 13.2 (Table V). Diurnal migration was extensive (Fig. 12). Sufficient data for diurnal migration of this species was found in only one station.

### Diphyes bojani

Both generations were very common during the study with the eudoxid generation remaining constant except for a conspicuous drop between late winter and early spring (Fig. 13). Two seasonal maxima (Fig. 14) were found, one in the spring and one in the summer.

The mean day-level (Table I) of the polygastric generation was 305 meters and the spread was 243 meters (Table II). The eudoxid generation had a

mean day-level (Table III) of 298 meters and a spread of 260 meters (Table IV). The average number per 10 cc. was 23.2 for the entire study (Table V). Diurnal migration was moderate (Fig. 15).

### Bassia bassensis

The eudoxid generation was more common than the polygastric generation and both were rather uncommon. There was very little seasonal fluctuation in the cycle of alternation of generations during the study (Fig. 16). Three seasonal maxima were found and these occurred in the winter, spring and summer (Fig. 17).

The mean day-level (Table III) and spread (Table IV) of the eudoxid generation were 97 meters and 196 meters respectively. The polygastric generation was not in sufficient numbers to determine mean day-level and spread. The average number per 10 cc. for the study was 16.8 (Table V). Diurnal migration was slight to absent (Fig. 18).

### Abylopsis eschscholtzii

Both generations were rather uncommon and the eudoxid generation was the more common form.

The eudoxid generation possibly had five maxima during the year (Fig. 19). These occurred in mid fall, mid winter, early spring, late spring and early summer. Two seasonal maxima were found, one in the spring and one in late summer (Fig. 20).

The mean day-level (Table I) of the polygastric generation was 241 meters and the spread was 22 meters (Table II). The spread of the eudoxid generation was 216 meters (Table IV) and the mean day-level was 102 meters (Table III). The average number per 10 cc. was 11.0 (Table V). Diurnal migration was extensive (Fig. 21).

#### Abylopsis tetragona

Both generations were very common during the study with the eudoxid generation being more common than the polygastric generation. The eudoxid generation had two maxima, one in early winter and the other in early summer (Fig. 22). Two seasonal maxima were found, one in the spring and one in late summer (Fig. 23).

The mean day-level (Table I) and spread (Table II) of the polygastric generation was 170



meters and 260 meters respectively while the mean day-level (Table III) and spread (Table IV) of the eudoxid generation was 207 meters and 209 meters respectively. The average number per 10 cc. was 34.9 for the entire study (Table V). Diurnal migration was slight to absent (Fig. 24).

### Water Mass

Positive identification of the origin of the water at the sampled area was not possible from the data obtained on hydrographic stations made on the Scattering Layer Stations. The T-S curves (temperature and salinity) obtained from these hydrographic station data were not constant and were not of the type for Yucatan T-S curves as found by Iselin (1936) and Parr (1935). The T-S curve obtained from SL-21 is compared in Figure 25 with the T-S curves of Parr and Iselin for Yucatan water. Of all the stations this is the only one whose curve approximated the T-S curves for Yucatan Water, the others differing in having higher temperatures and lower salinities.

Hydrographic stations made by the Marine Laboratory have transected the sampled area and all T-S curves obtained from these stations fit the general T-S curve for Yucatan. The author can only surmise from this data that the water of the sampled area is Yucatan in origin with an influx of water from other regions.

## DISCUSSION

### Seasonal Distribution

Four species in the 40 Mile Station appear to have seasonal maxima in the spring and in the summer. These are: A. tetragona (Fig. 23), A. eschscholtzii (Fig. 20), D. bojani (Fig. 14), and D. dispar (Fig. 11). Two of these, A. eschscholtzii and D. bojani, agree fairly well with Moore's results in both areas. Moore also found the seasonal maximum for A. tetragona in the winter in both areas and the seasonal maximum for D. dispar in the winter in Bermuda and in the spring and autumn in the 10 Mile Station area. Both E. spiralis (Fig. 8), whose maximum was in

the winter, and B. bassensis (Fig. 17), whose maxima were in the winter, spring and summer, agree fairly well with Moore's results in Bermuda and in the 10 Mile Station area. C. appendiculata (Fig. 2), and D. mitra (Fig. 5) were found to have seasonal maxima in the summer to fall period in the 40 Mile Station area. Moore found no seasonal maxima for C. appendiculata and E. mitra in Bermuda but a maximum for C. appendiculata in the summer or fall and a maximum for E. mitra in the winter or spring in the 10 Mile Station.

The main cause of disagreement probably lies in the characteristics and in the origin of the water of the sampled area. The water of the area sampled by the author is thought to be of almost constant origin.

The origin of the water from the 10 Mile Station area varies seasonally and is threefold: Gulf of Mexico, Yucatan and an unknown water mass (Miller et al., 1953). During the fall and winter, Yucatan water is the dominant type and is replaced by Gulf of Mexico water during the spring and summer. The unknown water mass was present only

two times and occurred in August 1950 and January 1951.

The water composing the Bermuda area is from different regions (Hela et al., 1953). During the winter, the water found south and southeast of Bermuda is the south and westbound eddy of the Gulf Stream. In the summer, the water in the same area comes directly north and northwest from the North Equatorial Current.

These three water masses are defined by curves obtained by plotting salinity against temperature (Fig. 25). All three of these curves are different due to the differences in the salinity and/or temperature.

Such environmental differences may result in differing seasonal cycles in the different water masses, at least for some species. If there was no difference in seasonal cycles, then agreement might be expected between the 10 Mile Station, 40 Mile Station and Bermuda. If there was a difference, then change of water mass would be sufficient to account for observed differences in some species.

There is closer agreement of cycles from the 10 and 40 Mile Stations than between either of them and Bermuda. This again might be expected since the first two areas share a common water mass, whereas neither of the two water masses of Bermuda occur in unchanged form in the Florida Current Area.

#### Vertical Distribution and Spread

Tables I and II compare the mean day-levels and the spreads of the eight species studied with those of the Bermuda and 40 Mile Station areas. Method I is the mean for all stations at which sufficient hauls were made, and Method II was used where the species were present in small numbers only (Moore, 1953). The first method was that used by the author and was calculated for both generations. Moore calculated mean day-level and spread by combining both generations. Tables III and IV are the mean day-levels and spreads of eudoxid generation of the species studied and do not vary enough from those of the polygastric generation to make any appreciable difference in the final results.

The results from the Bermuda and the 10 Mile Station areas agree fairly well when compared as a whole. The results from the 40 Mile Station area show the mean day levels to be much deeper and the spreads to be greater than those of the other two areas.

Since both illumination and temperature may control the depth the zooplankton (Moore, 1953), and assuming water transparency to be the same in all three areas, the temperature distribution in the Bermuda and 10 Mile Station areas should be approximately the same and should be considerably different from that of the 40 Mile Station area. Table VII compares the depth of the  $15^{\circ}$  isotherm and its seasonal variation from the three areas. The  $15^{\circ}$  C. isotherm was taken as an arbitrary temperature and Moore (1953) found that the regression of change in level of the species on change in level of the  $15^{\circ}$  C. isotherm was 95%. The depth of the  $15^{\circ}$  C. isotherm for Bermuda is considerably greater than the depth of the  $15^{\circ}$  C. isotherm for the 10 Mile Station. These temperature data were taken from three hydrographic stations

made by Iselin (1936). These stations were from 15 to 45 miles south of the area sampled by Moore (1949) and may not be correct for Moore's northern area. Illumination data for the Bermuda area are taken from Hela et al. (1953). If temperature is the factor controlling the lower limits of depth and spread of these siphonophores, then there is some unknown factor inhibiting the zooplankton from penetrating deeper in the Bermuda area.

Returning now to water transparency, which was assumed to be constant in all three areas, we find the following:

	<u>Average depth of 15° C. isotherm</u>	<u>Average depth of mean-day levels</u>	<u>Average extinction coefficient</u>
10-Mile Station	151 meters*	79 meters***	0.062*
40-Mile Station	619 meters	253 meters	0.051
Bermuda	608 meters**	45 meters***	0.075****

\* Source: Miller et al. (1953)

\*\* Source: Iselin (1936)

\*\*\* Source: Moore (personal communication)

\*\*\*\* Source: Hela et al. (1953)

The transparency of the water of the Bermuda area is less than that for the other two regions. Thus this high extinction of light reduces the control of illumination from mid-depths and the zooplankton respond to this by having relatively shallow mean day-levels.

The observed differences in the mean day-levels of the three areas could therefore be accounted for in terms of observed temperature and illumination distributions if it is assumed that these two factors interact in regulating zooplankton depth. Treatment of the results designed to lead to an exact statement on separate and combined effects of these two factors is now in progress.

### Diurnal Migration

The diurnal migration of the siphonophores is presented in graph form and varies from species to species. The analysis of data is slow and has not been completed. A sample of five stations is included to show the control of illumination on diurnal migration. No correlations between mid-day illumination, cloud coverage, moonlight and diurnal



migration were made. Most species, C. appendiculata (Fig. 3), D. dispar (Fig. 12), D. bojani (Fig. 15), B. bassensis (Fig. 18) and A. eschscholtzii (Fig. 21) show moderate diurnal migration while E. mitra (Fig. 6), E. spiralis (Fig. 9) and A. tetragona (Fig. 24) show little or no diurnal migration.

The author was not able to make comparisons with the Bermuda and 40 Mile Station due to the lack of data on diurnal migration from these areas. The various modifying factors affecting diurnal migration are described by Cushing (1951). Much remains to be known concerning the factors but two generalizations may be made: illumination is the major factor controlling ascent and descent whereas mid-day and mid-night levels may be the result of a complex interaction of temperature, illumination and possibly pressure.

#### Cycle of Alternation of Generations

Table V compares the cycle of alternation of generations for the species studied from the three areas. There is little agreement between Bermuda

and the 10 and 40 Mile Stations and better agreement between the 10 and 40 Mile Stations.

The cycle of alternation of species is seen to vary from area to area. This variation may be explained by the differences in water masses discussed under seasonal distribution. Many more surveys must be conducted before any true cycle can be applied to any given species. The factors controlling maturation and reproduction are not known but are thought to be variable in different water masses. This is obvious from the variation in the cycles shown in Table VI.

Such estimates of cycles provide a measure of the life-span of individuals. In certain species, it has been shown that life-span decreases with increase in water temperature. Too few species have yet been studied to justify any generalizations of this, but the importance of recording such life-spans lies in the contribution that it will make in the future of an over all picture of zooplankton ecology.

## SUMMARY

Eight species of siphonophores in the 40 Mile Station were studied and their seasonal distribution, diurnal migration and alternation of generations presented.

Comparisons were made, when possible, between the 40 Mile Station area and the Bermuda and 10 Mile Station areas.

The mean day-levels of the siphonophores in the 40 Mile Station were much deeper than those of the siphonophores in both the Bermuda and 10 Mile Station areas. The differences in mean day-levels are attributed to the characteristics of the water of the sampled area, the origin of the water of the sampled area and to the transparency of the different water masses.

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## A P P E N D I X

TABLE I

Mean day-level in meters

Polygastric generation

	Bermuda*	(10 Mile Station)* Florida Current Method I    Method II		40 Mile station
<u>C. appendiculata</u>	75	74	48	221
<u>D. boiani</u>	40	72	29	305
<u>E. mitra</u>	125	134	68	249
<u>D. dispar</u> <u>ca.</u>	10	59	40	366
<u>E. spiralis</u>	65	75	50	220
<u>A. eschscholtzii</u> <u>ca.</u>	40	58	12	241
<u>A. tetragona</u>	55	104	85	170
<u>B. bassensis</u>	50	59	13	-

\* Source: Moore (1953).

TABLE II

Spread in Meters

Polygastric generation

	Bermuda*	(10 Mile Station)*		40 Mile Station
		Florida Current Method I	Method II	
<u>C. appendiculata</u>	130	81	100	203
<u>D. bojani</u>	25	43	88	243
<u>E. mitra</u>	105	65	134	133
<u>D. dispar</u>	10	76	104	112
<u>E. spiralis</u>	65	45	69	227
<u>A. eschscholtzii</u>	80	51	78	222
<u>A. tetragona</u>	25	63	122	260
<u>D. bassensis</u>	40	29	75	-

\* Source: Moore (1953).

TABLE III

Mean day-level in meters

Eudoxid generation

40 Mile Station

<u>C. appendiculata</u>	221
<u>D. bojani</u>	298
<u>C. mitra</u>	291
<u>D. dispar</u>	-
<u>E. spiralis</u>	-
<u>A. eschscholtzii</u>	102
<u>A. tetragona</u>	207
<u>B. bassensis</u>	97

TABLE IV

Spread in meters  
Eudoxid generation  
40 Mile Station

<u>C. appendiculata</u>	166
<u>D. boiani</u>	260
<u>E. mitra</u>	285
<u>D. dispar</u>	-
<u>E. spiralis</u>	-
<u>A. eschscholtzii</u>	216
<u>A. tetragona</u>	209
<u>B. bassensis</u>	196

TABLE V

Number per 10 cc.

	Bermuda*	(10 Mile Station)* Florida Current	40 Mile Station
<u>C. appendiculata</u>	15.9	3.1	37.2
<u>D. bojani</u>	8.0	1.7	23.2
<u>E. mitra</u>	7.1	50.2	8.3
<u>D. dispar</u>	1.7	1.2	13.2
<u>E. spiralis</u>	7.5	41.8	20.8
<u>A. eschscholtzii</u>	5.3	10.1	11.0
<u>A. tetragona</u>	19.9	2.5	34.9
<u>B. bassensis</u>	4.0	8.4	16.2
Average	8.7	14.9	20.6

\* Source: Moore (1953).

TABLE VI

## Cycle of Alternation of Generations per year

	Bermuda*	(10 Mile Station)* Florida Current	40 Mile Station
<u>C. appendiculata</u>	not definite	not definite	1-2 cycles
<u>D. bojani</u>	not definite	not definite	2 cycles
<u>E. mitra</u>	5-6 cycles	not definite	not definite
<u>D. dispar</u>	not definite	not definite	1-2 cycles
<u>E. spiralis</u>	3-4 cycles	not definite	not definite
<u>A. eschscholtzii</u>	not definite	2 cycles	4 cycles
<u>A. tetragona</u>	not definite	5 cycles	2 cycles
<u>B. bassensis</u>	5 cycles	2 cycles	not definite

\* Source: Moore (1953).

TABLE VII

Mean depth and spread of 15° C.  
isotherm in meters

	Bermuda*	(10 Mile Station)** Florida Current	40 Mile Station
Depth	608	151	619
Spread	15	87	137

\* Source: Iselin (1936).

\*\* Source: Miller et al. (1953).



## DESCRIPTION OF FIGURES

The dotted lines in the figures on seasonal distribution and cycle of alternation of generations indicate that no data were taken during this period of time. These lines connect two adjacent stations and are thought to represent approximately the true curve.

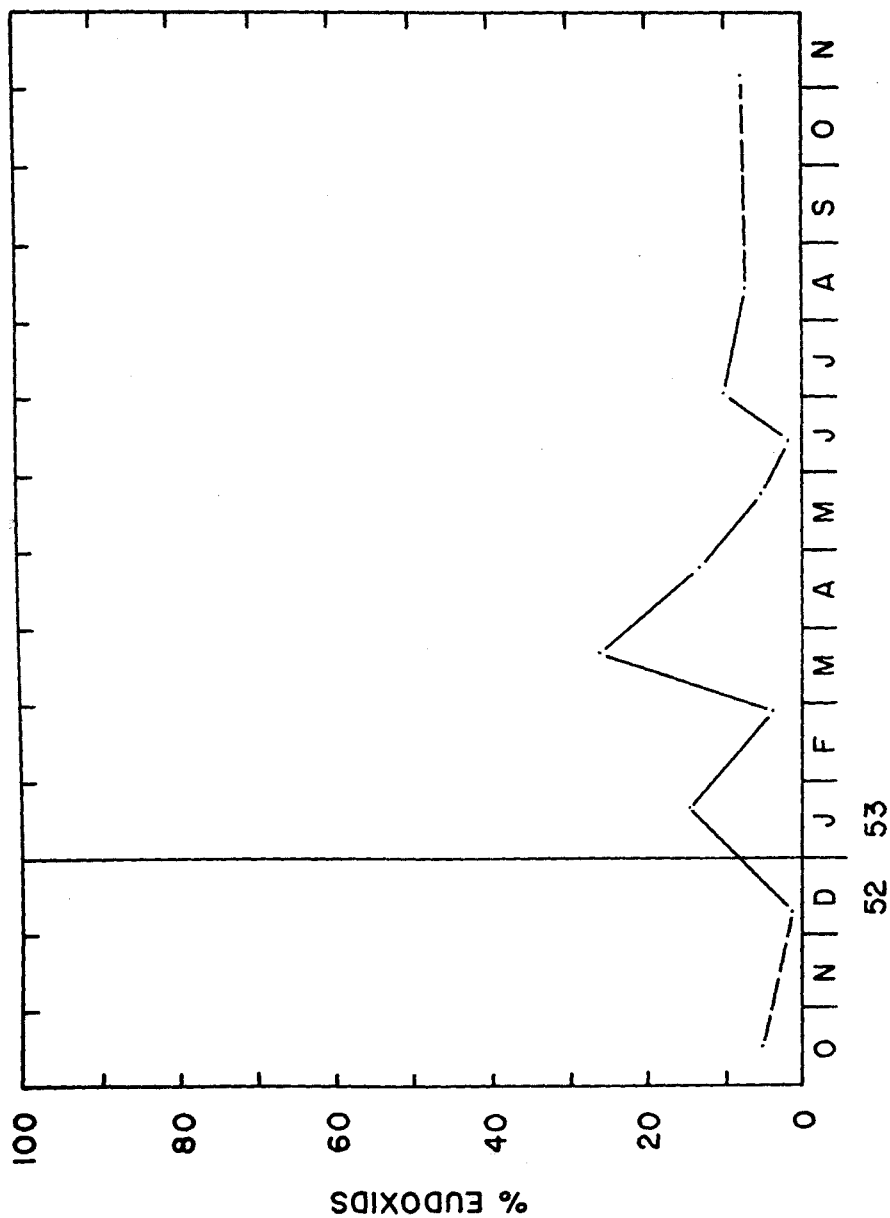


Fig. 1. C. appendiculata. Cycle of alternation of generations.

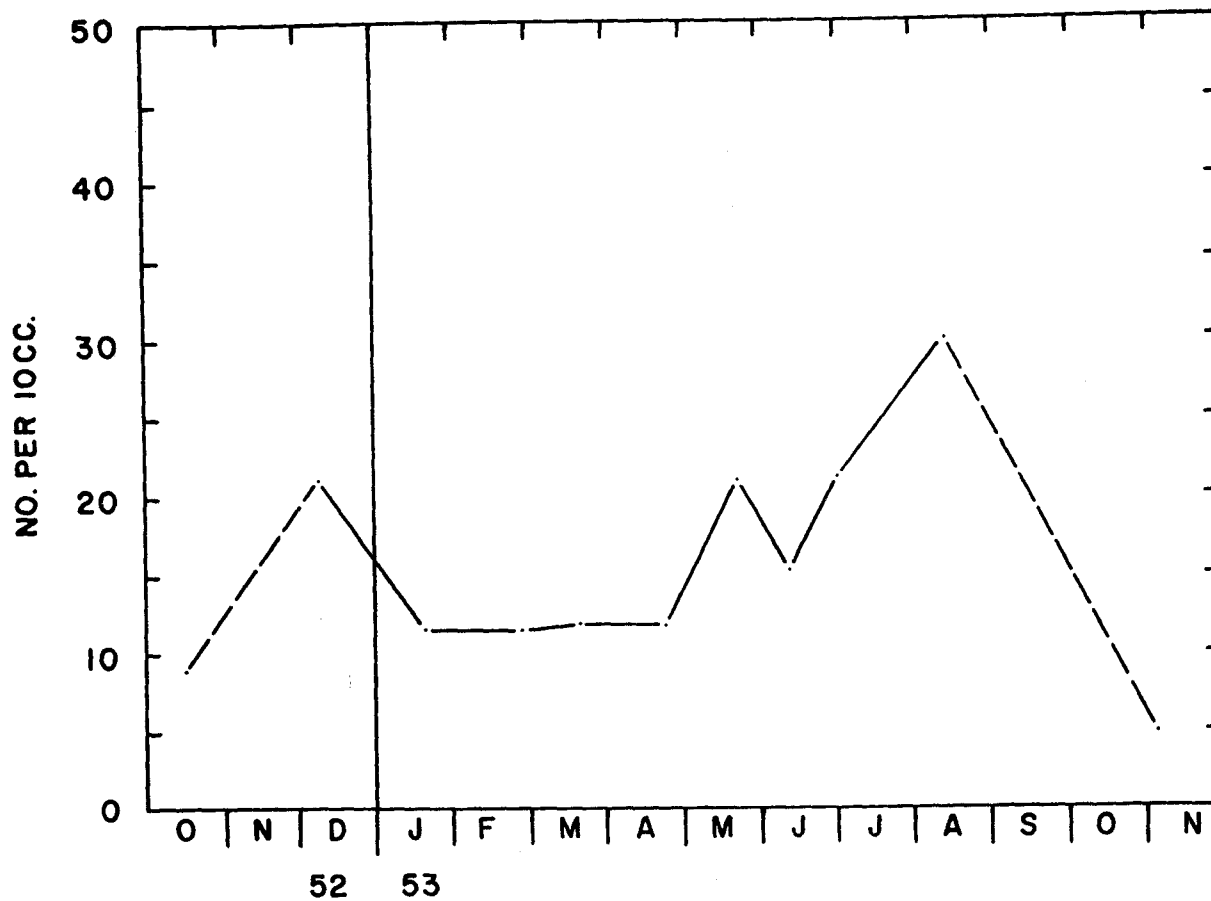


Fig. 2. C. appendiculata. Seasonal distribution.

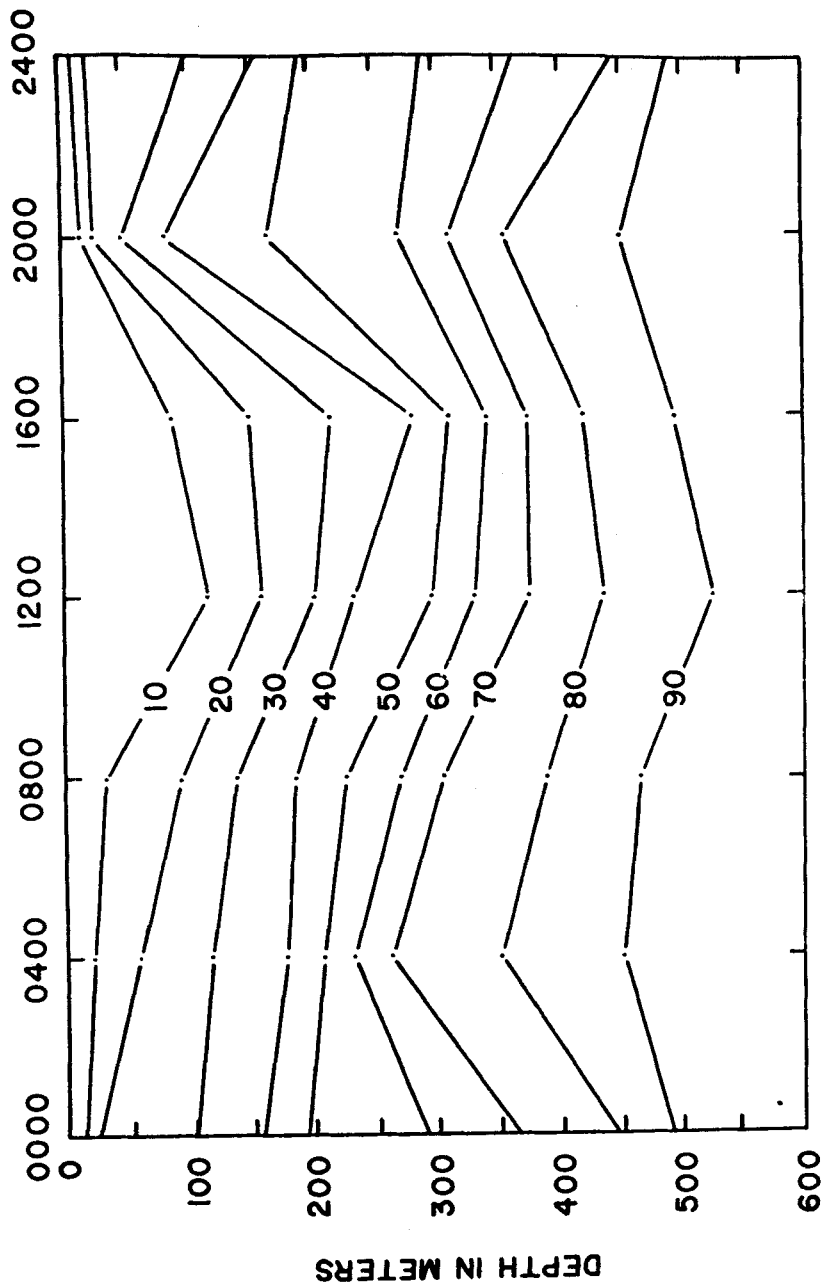


Fig. 3. *S. appendiculata*. Diurnal migration.

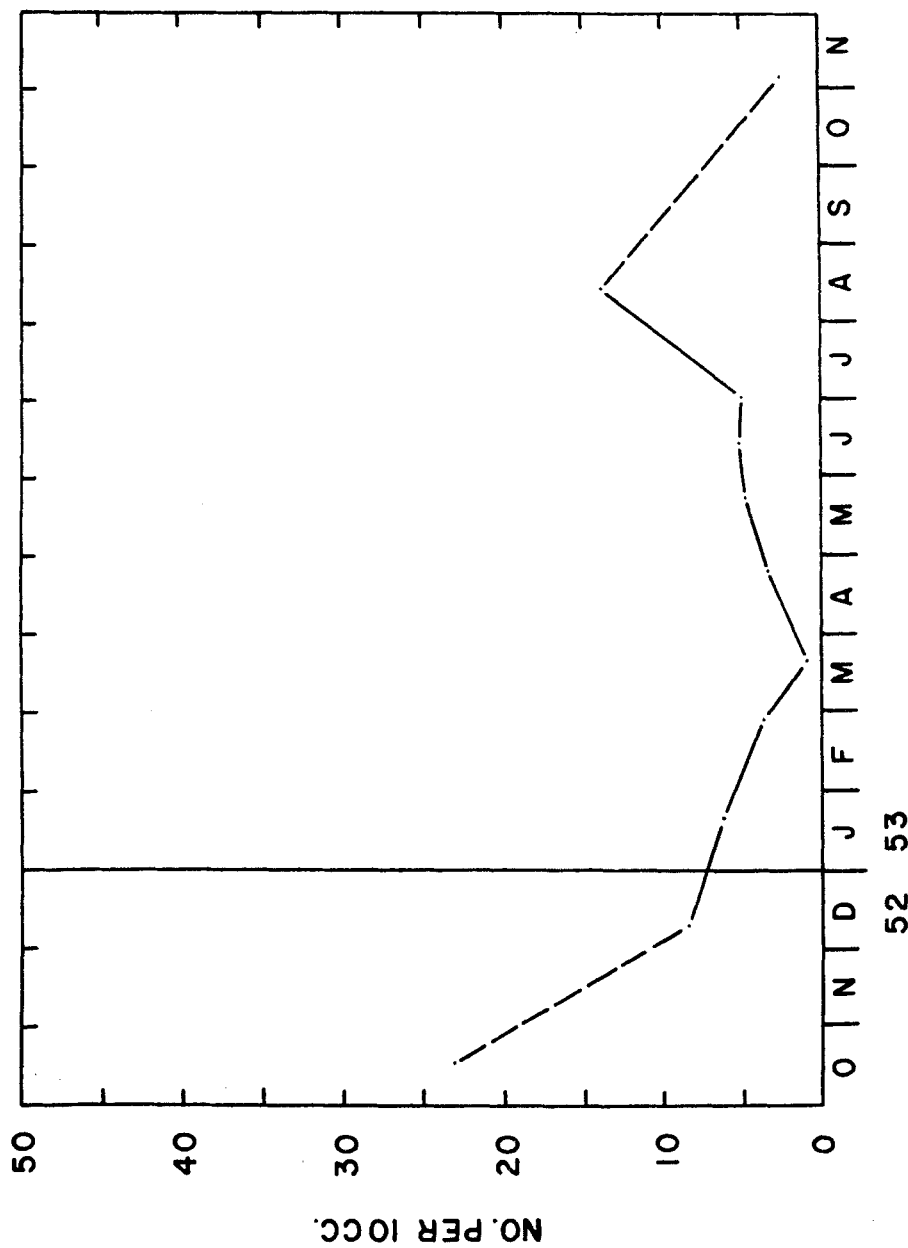


Fig. 5. *E. mitis*. Seasonal distribution.

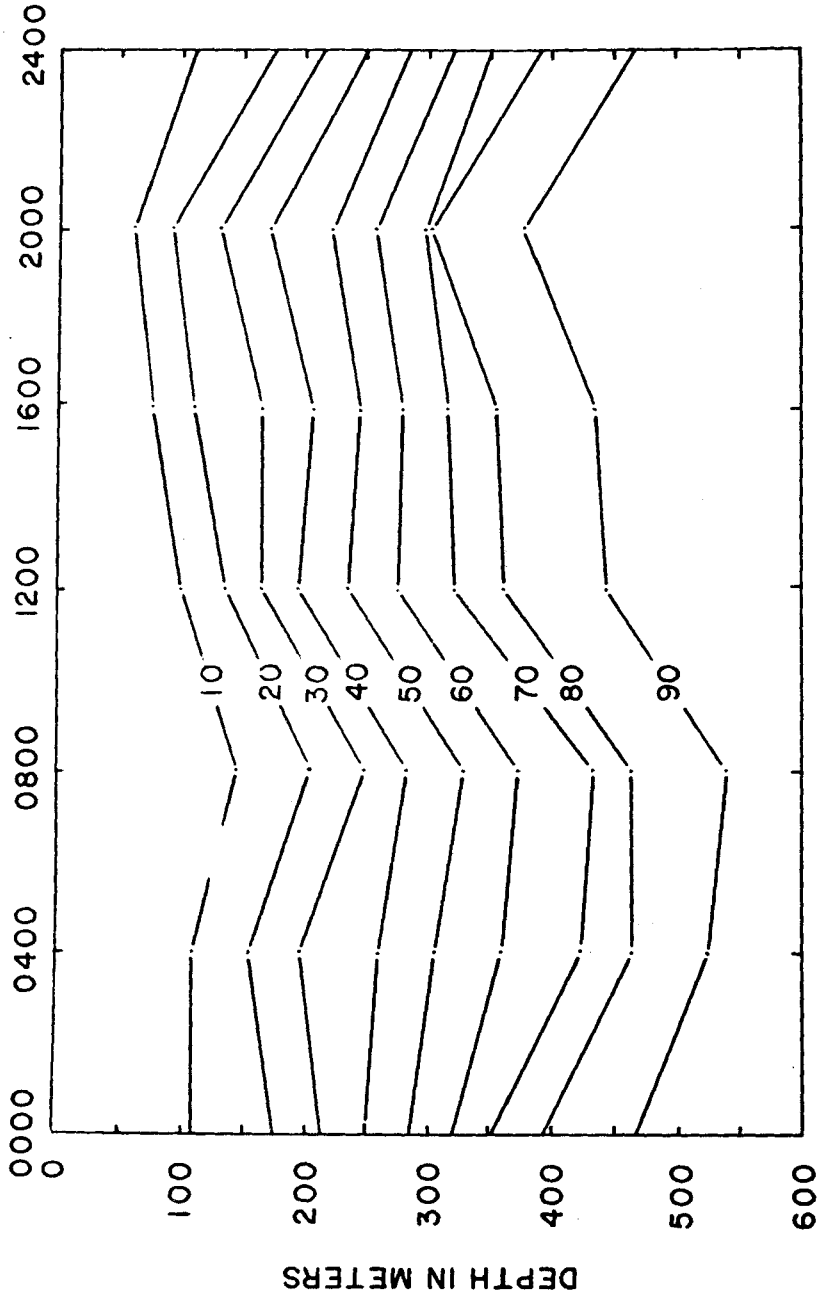


FIG. 6. *E. mitra*. Diurnal migration.

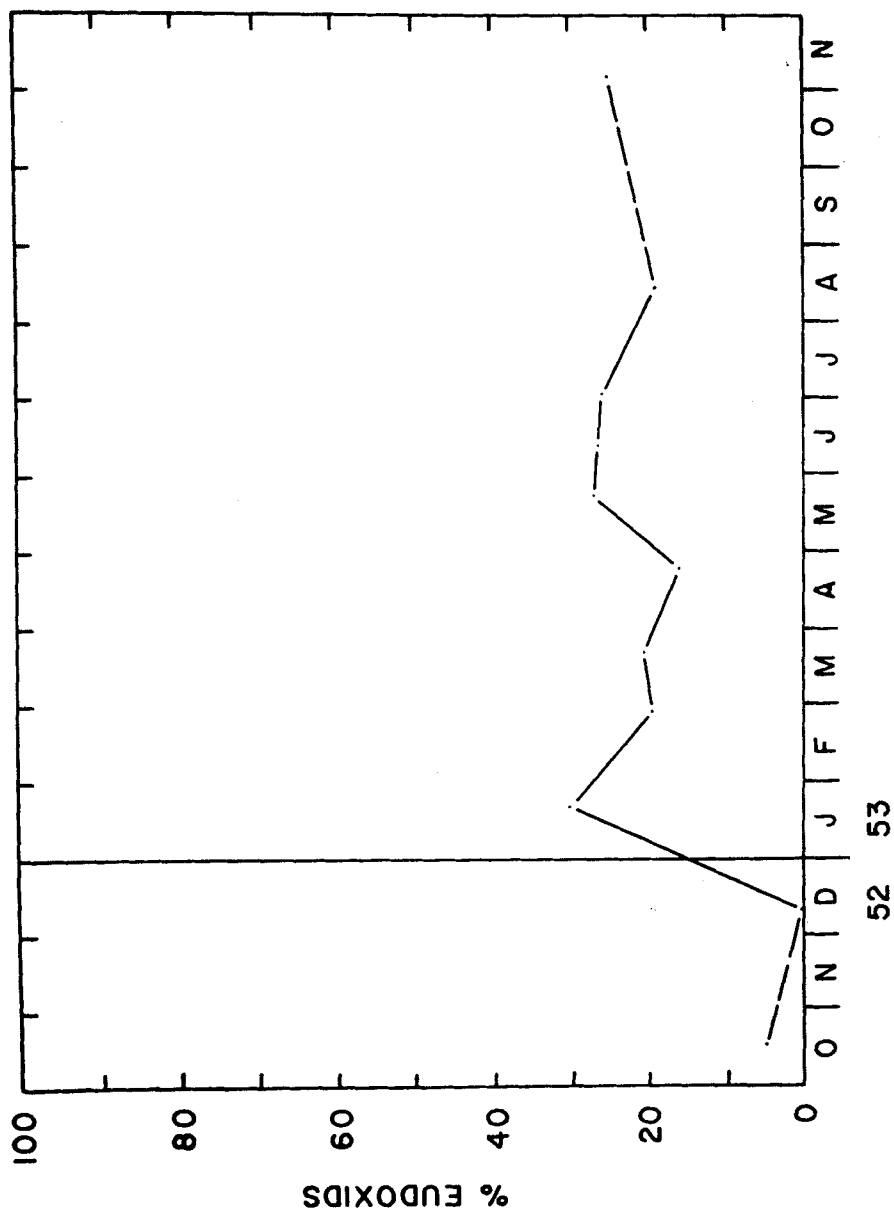


Fig. 7. *E. spiralis*. Cycle of alternation of generations.

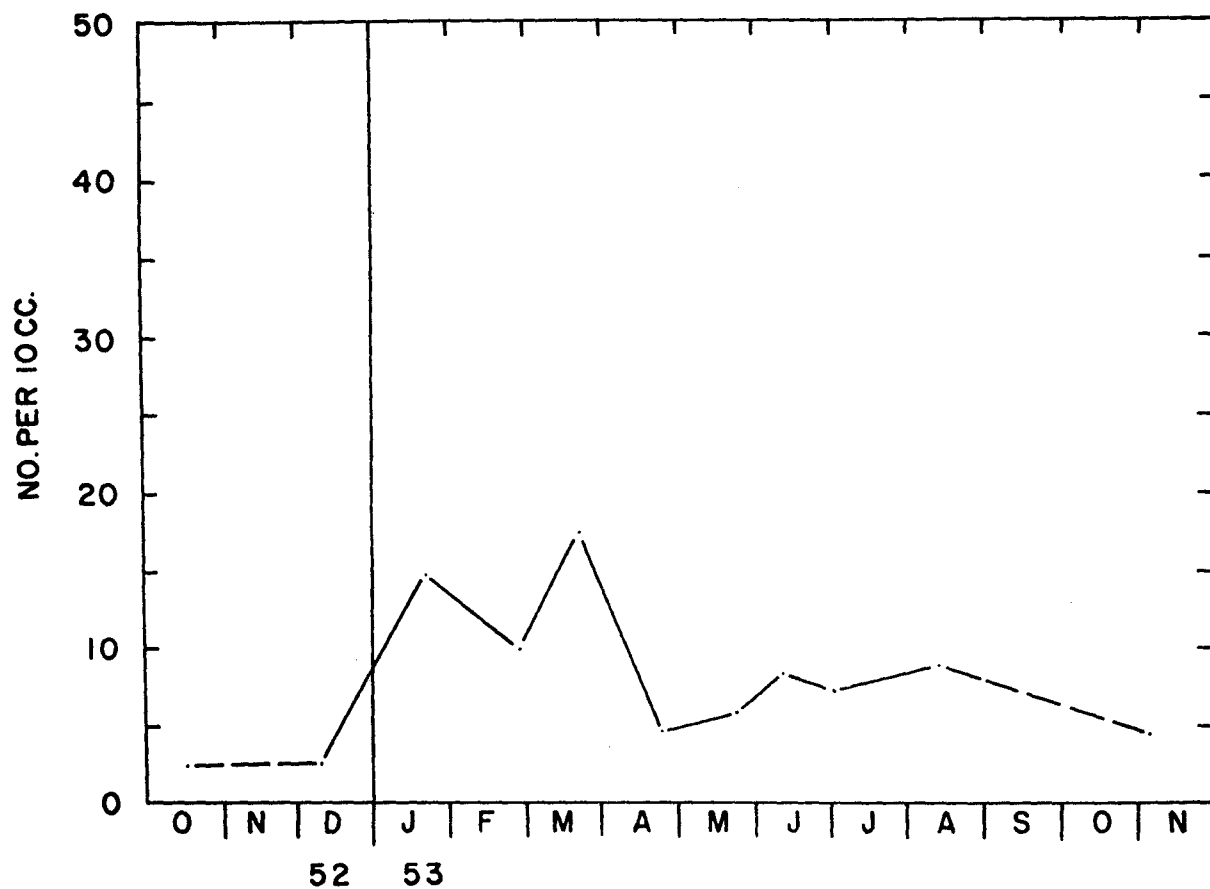


Fig. 8. E. spiralis. Seasonal distribution.



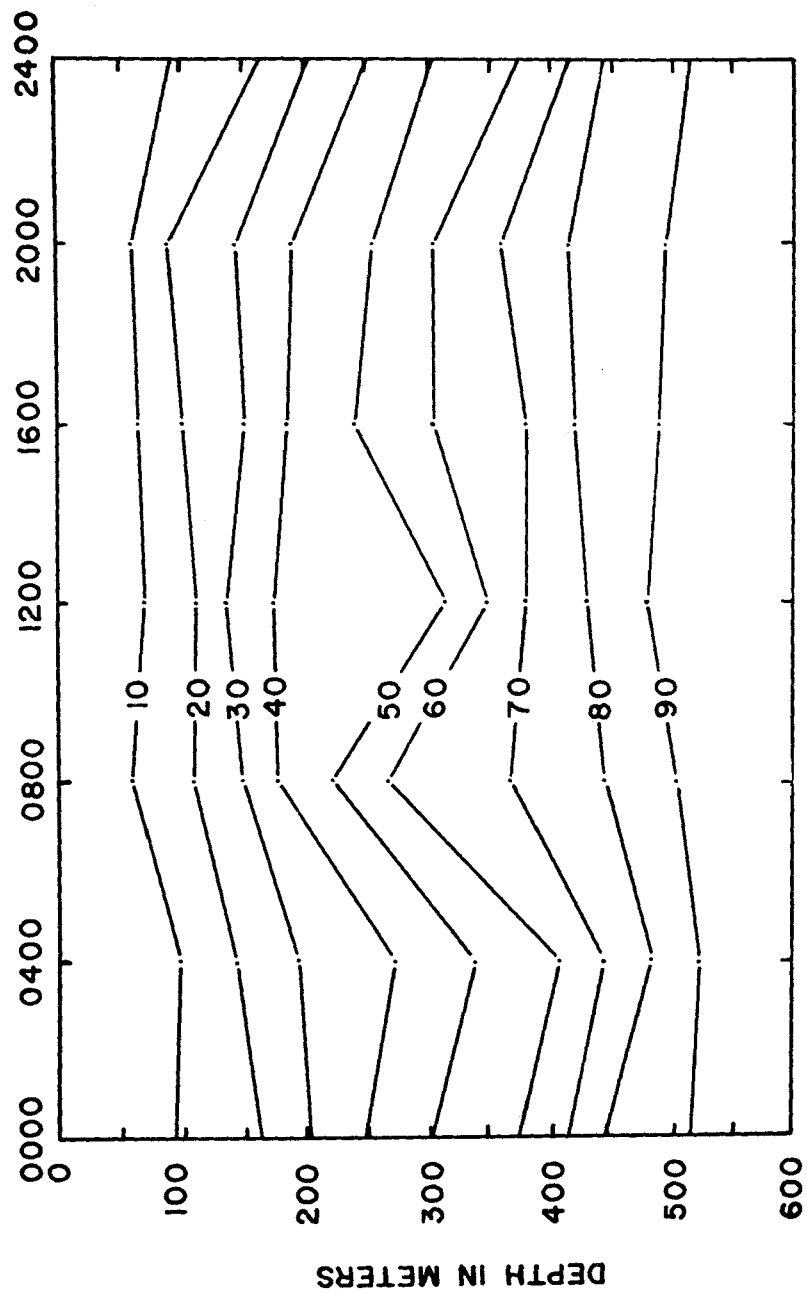


Fig. 9. *E. spiralis*. Diurnal migration.

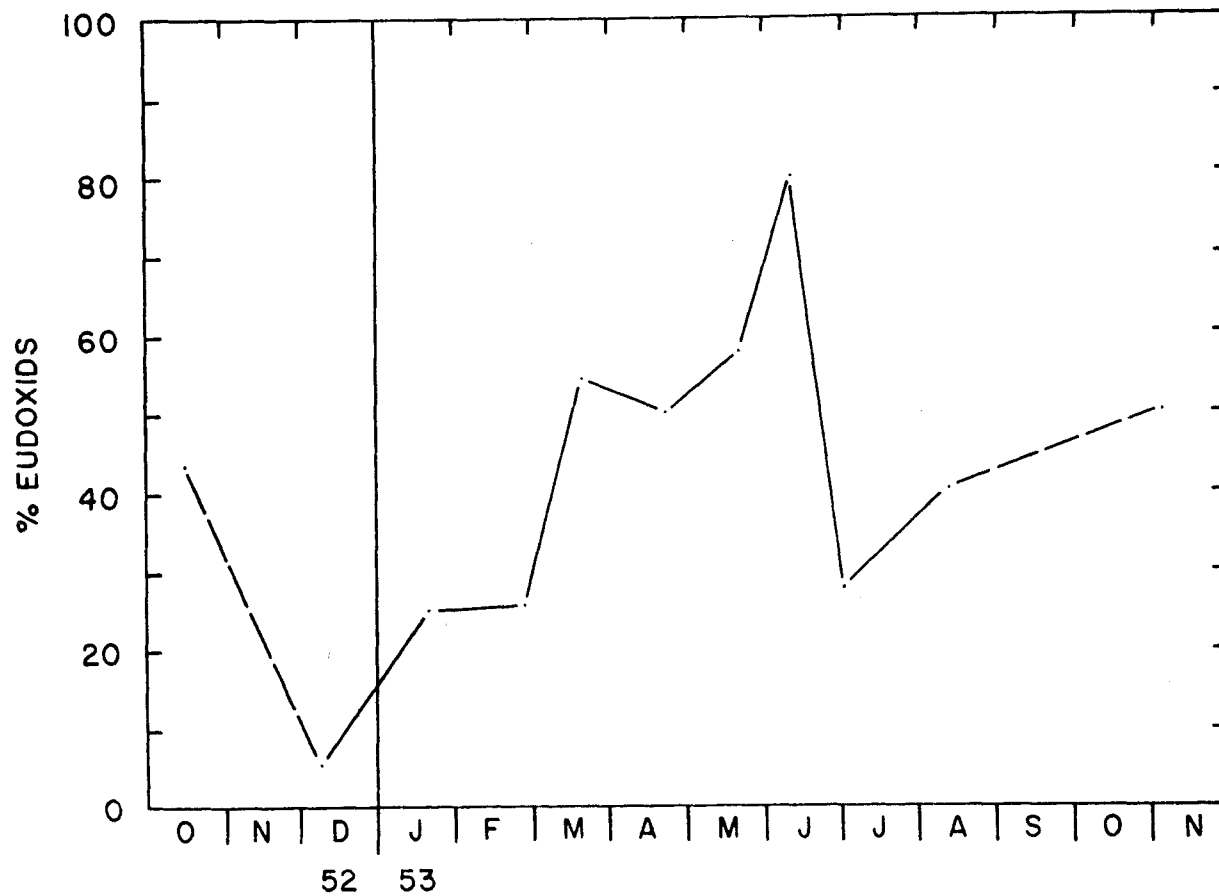
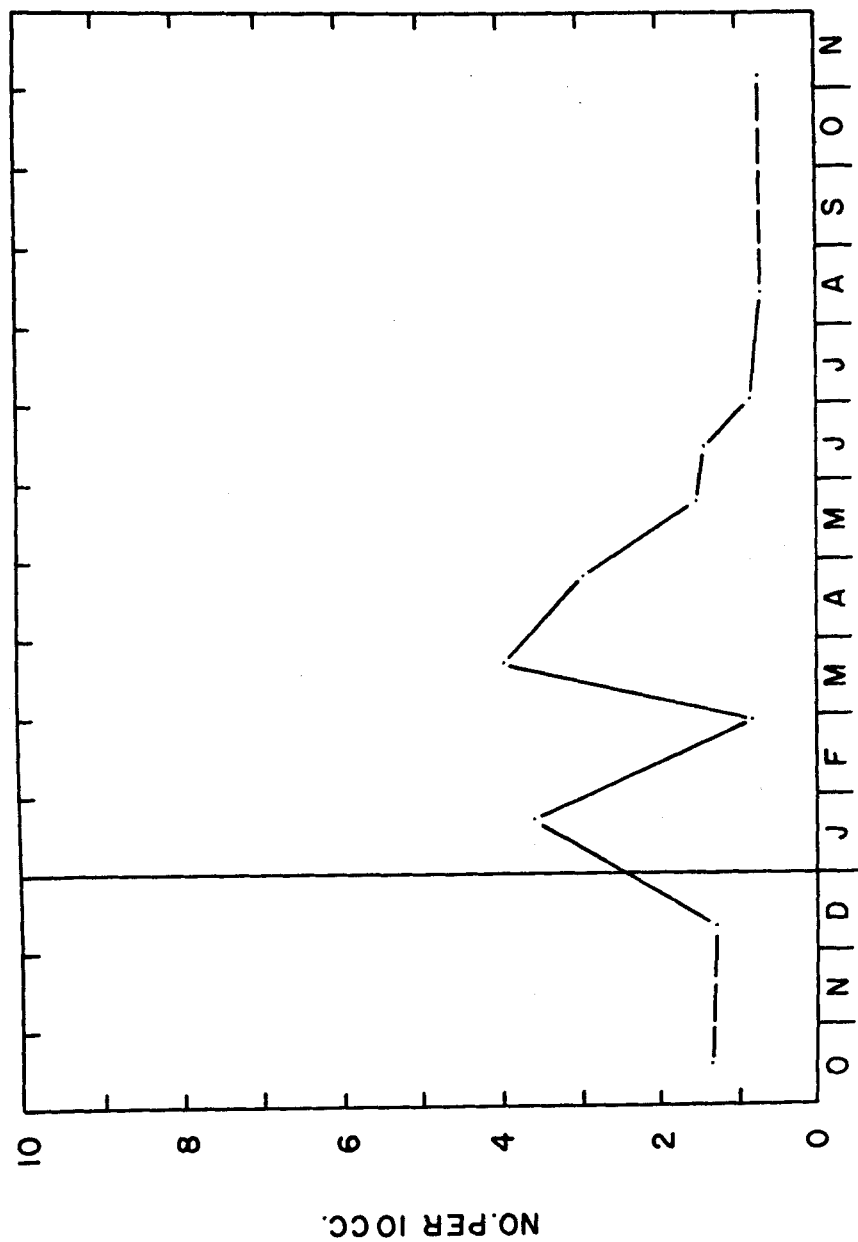


Fig. 10. D. dispar. Cycle of alternation of generations.



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Fig. 11. D. dispar. Seasonal distribution.

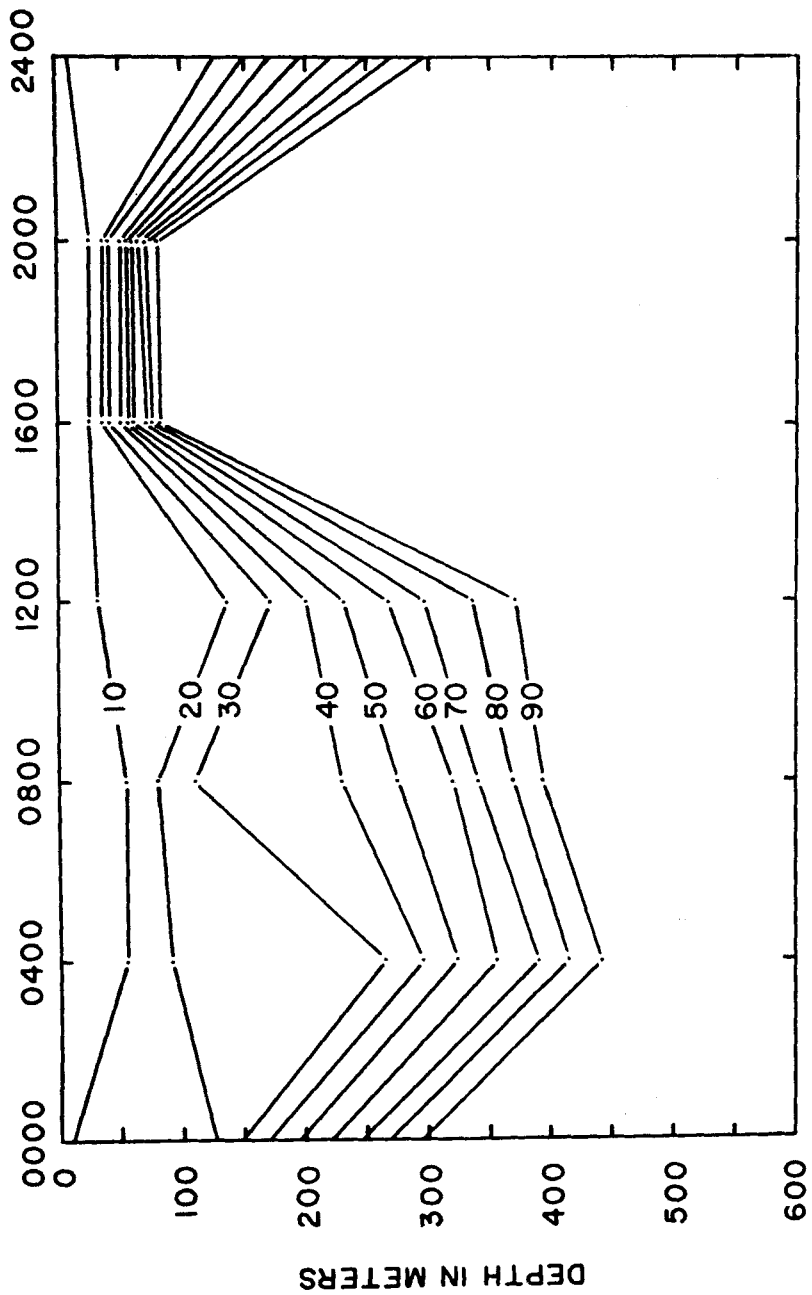


FIG. 12. *P. dispar*. Diurnal migration.

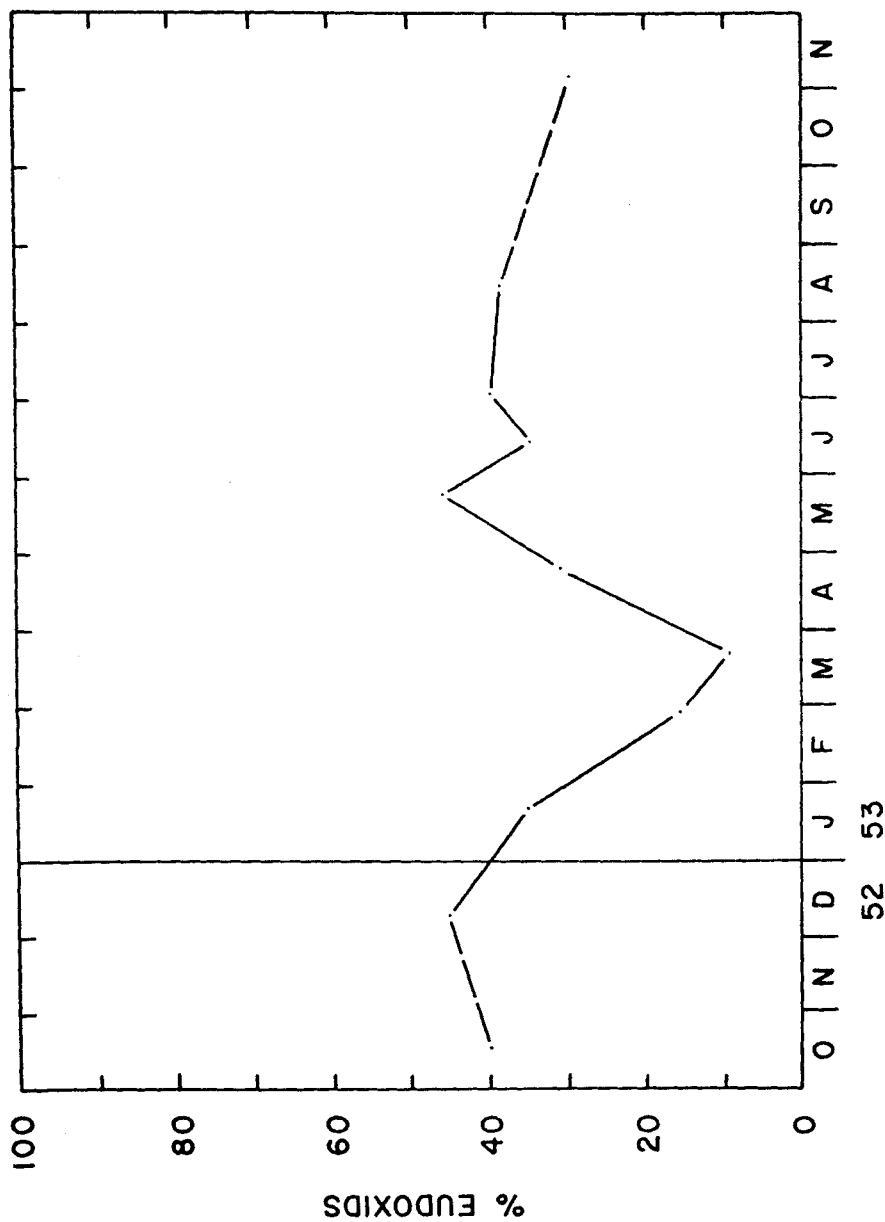


Fig. 13. *D. bolani*. Cycle of alternation of generations.

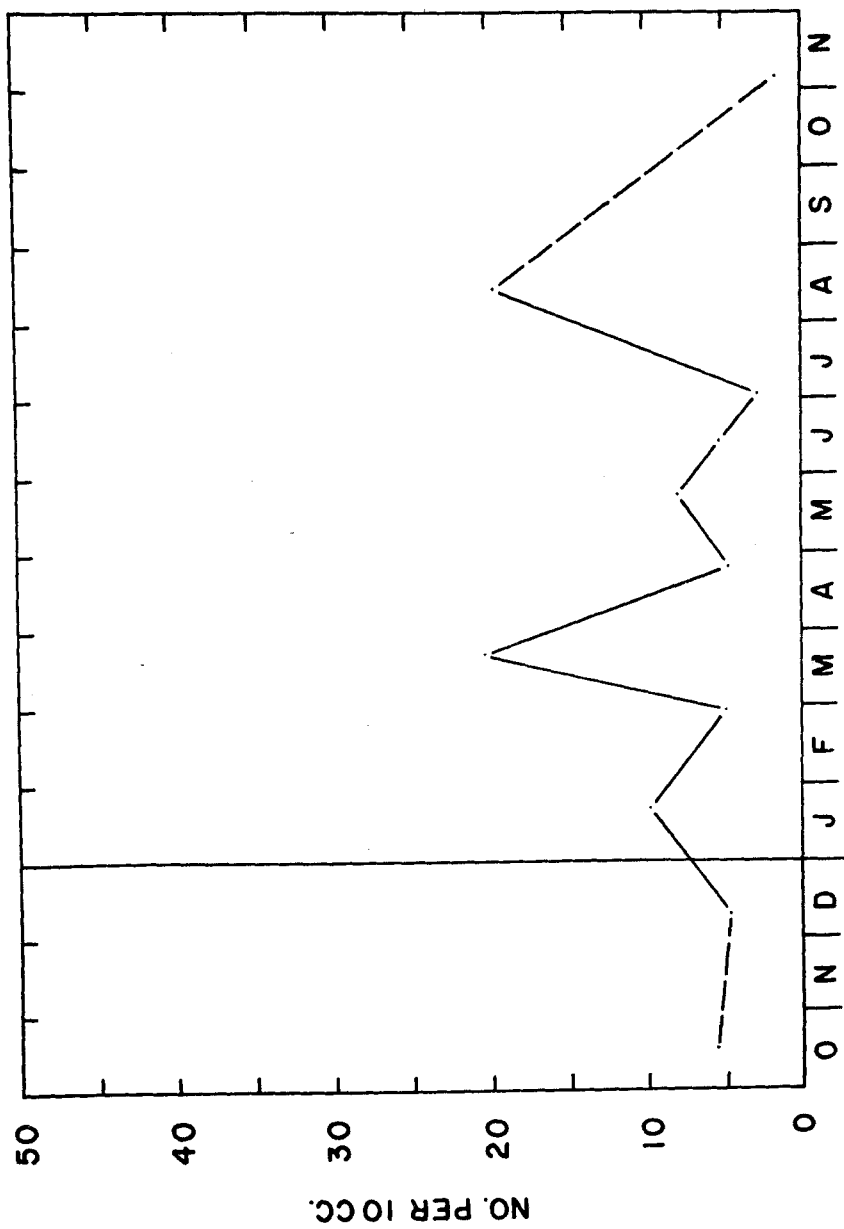


FIG. 14. *P. bofani*. Seasonal distribution.

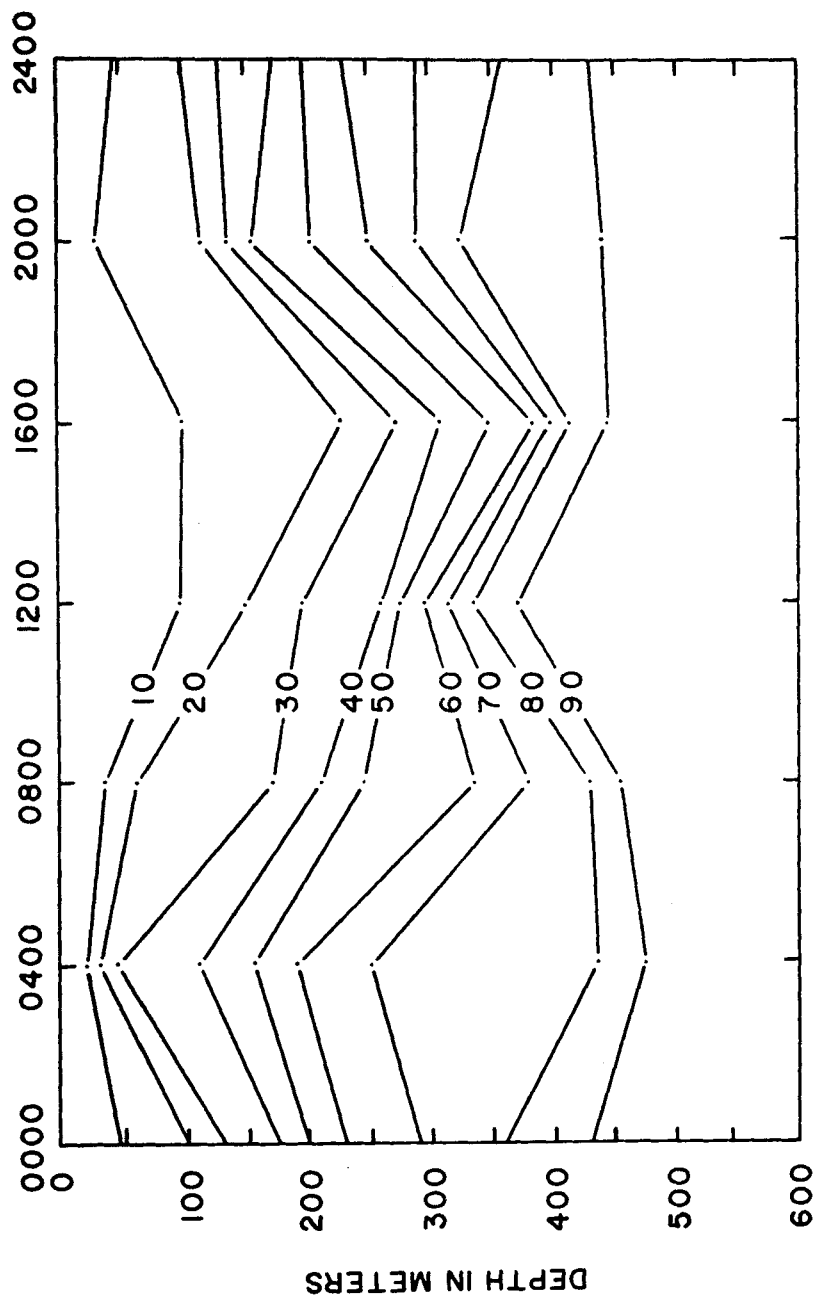


Fig. 15. *P. bolani*. Diurnal migration.

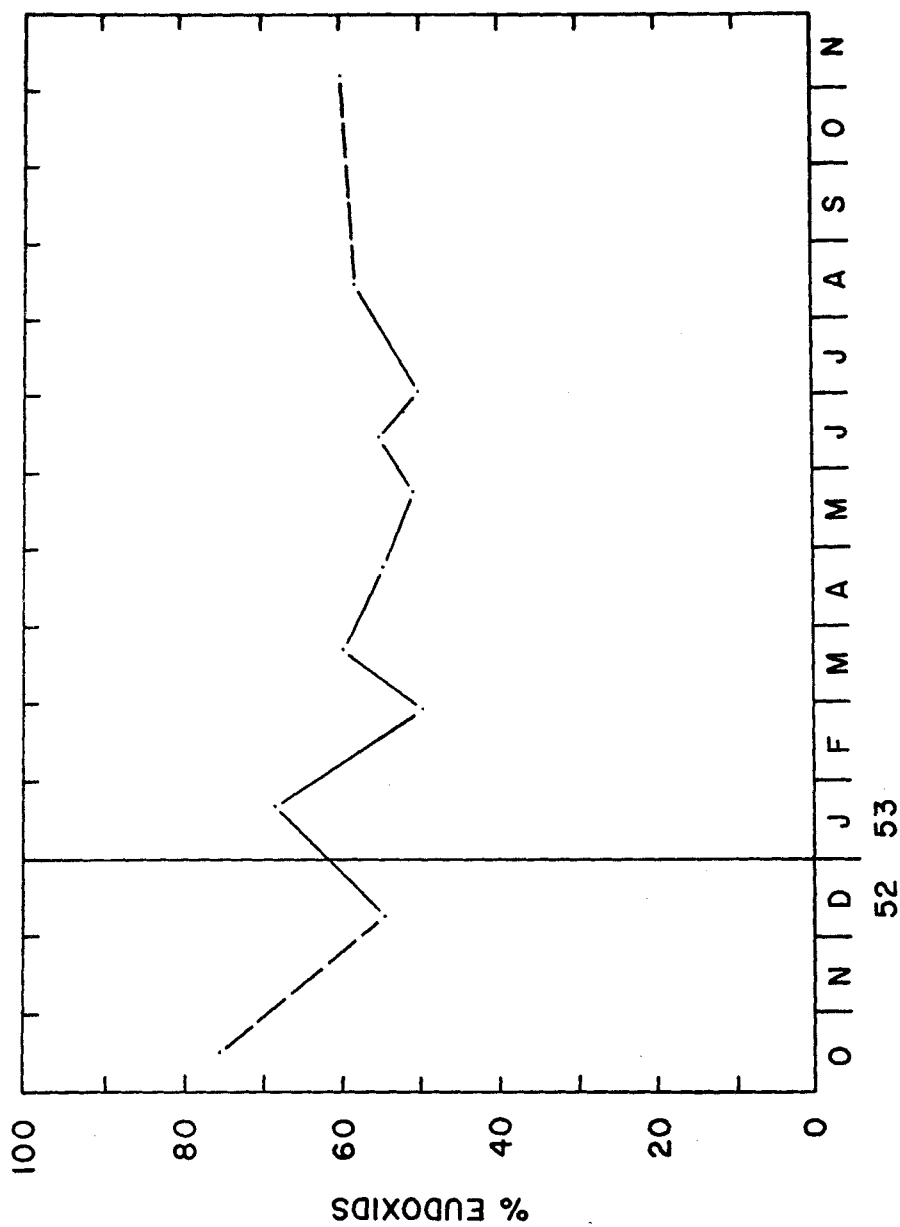
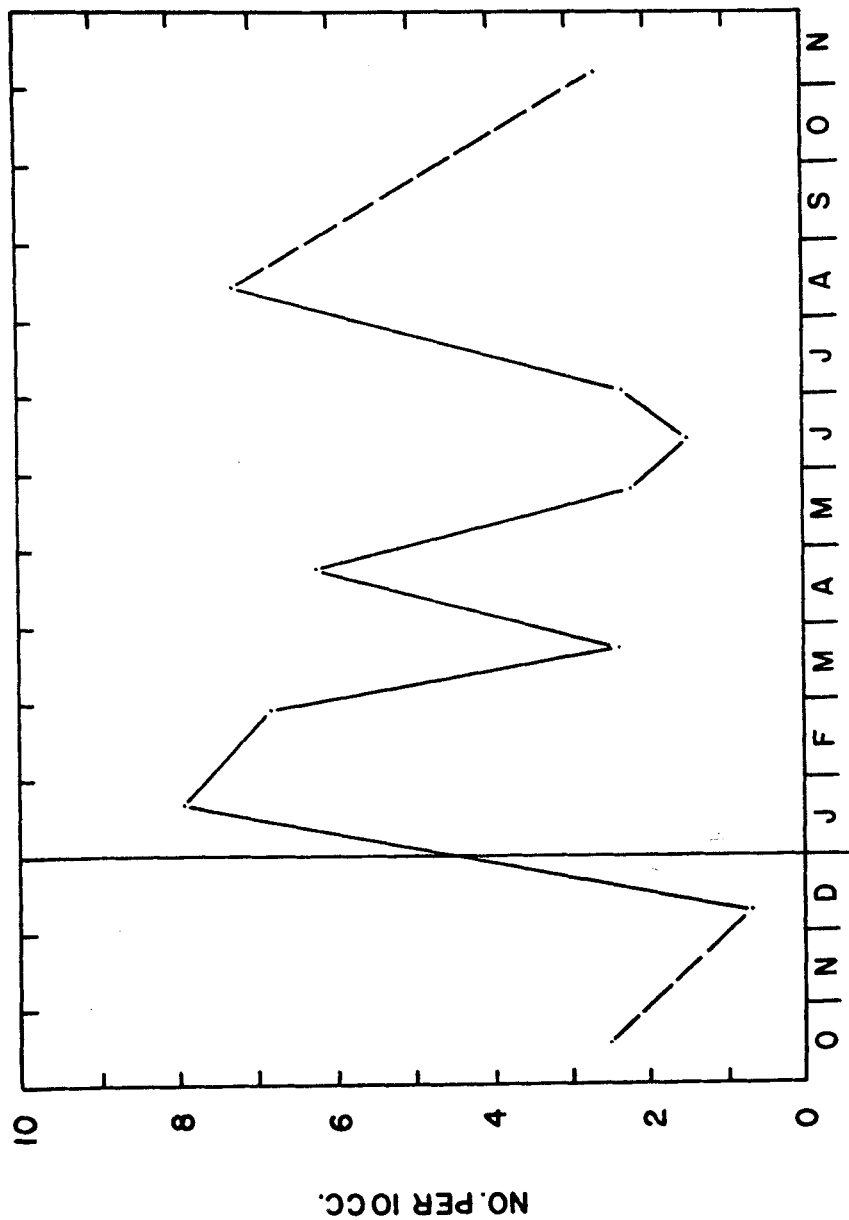


Fig. 16. *E. passensis*, Cycle of alternation of generations.





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FIG. 17. *B. bassensis*. Seasonal distribution.

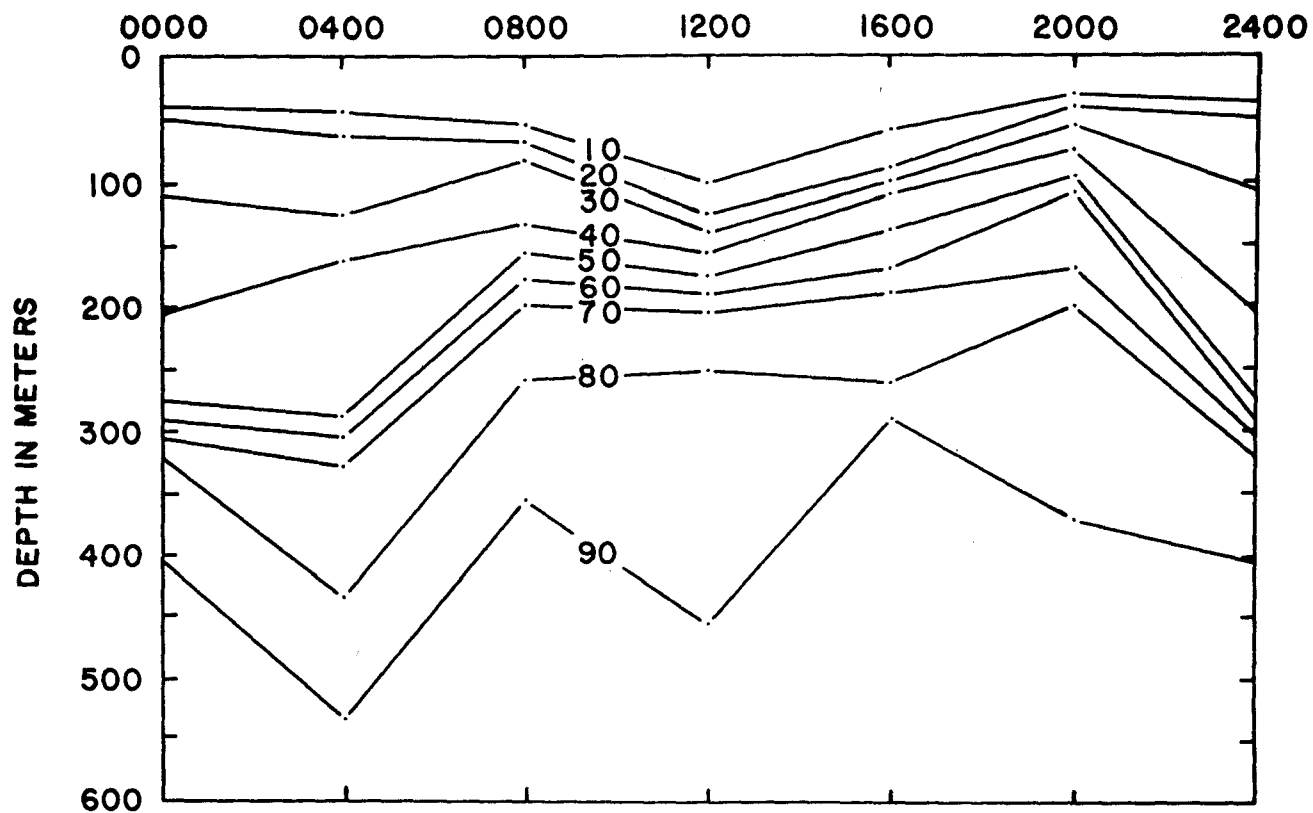


Fig. 18. B. bassensis. Diurnal migration.

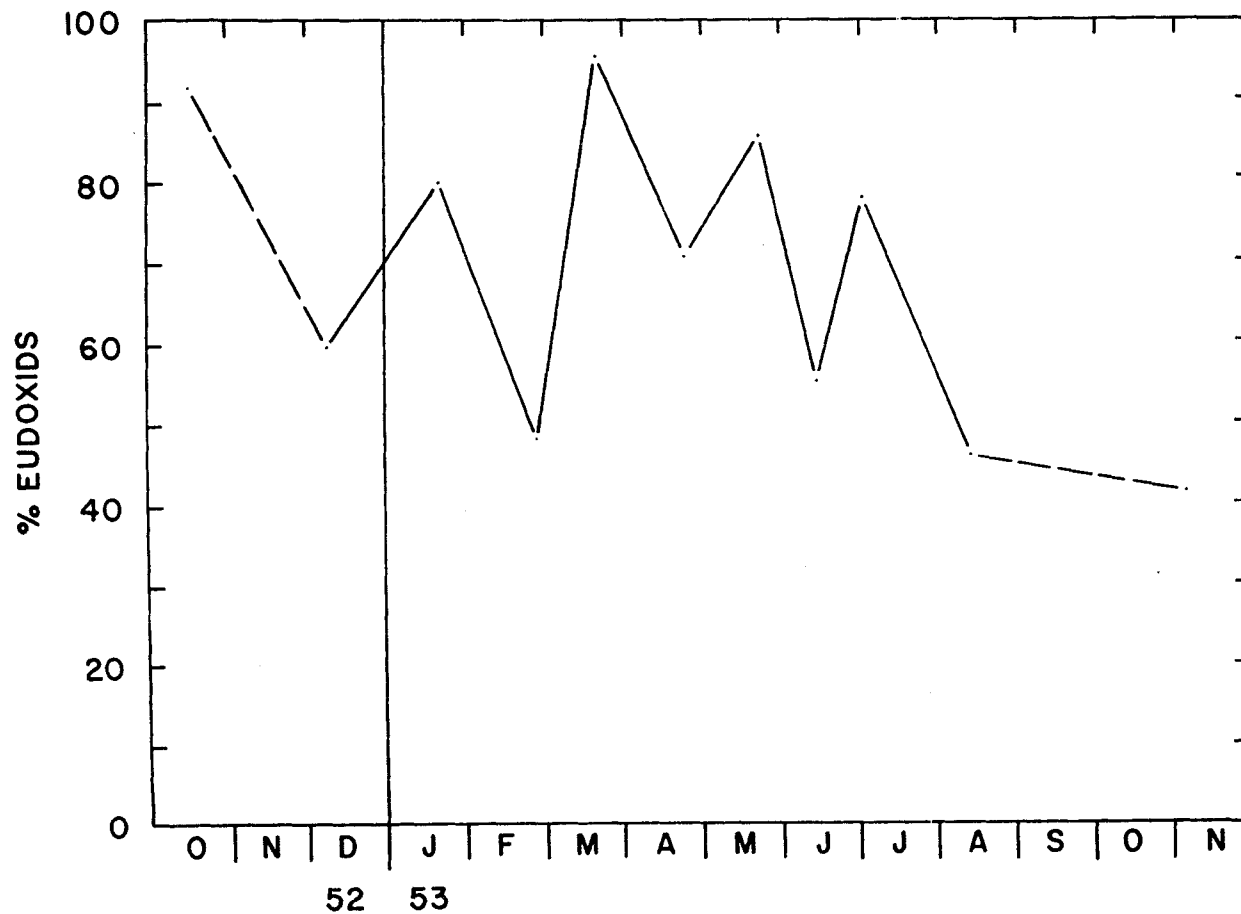


Fig. 19. A. eschscholtzii. Cycle of alternation of generations.

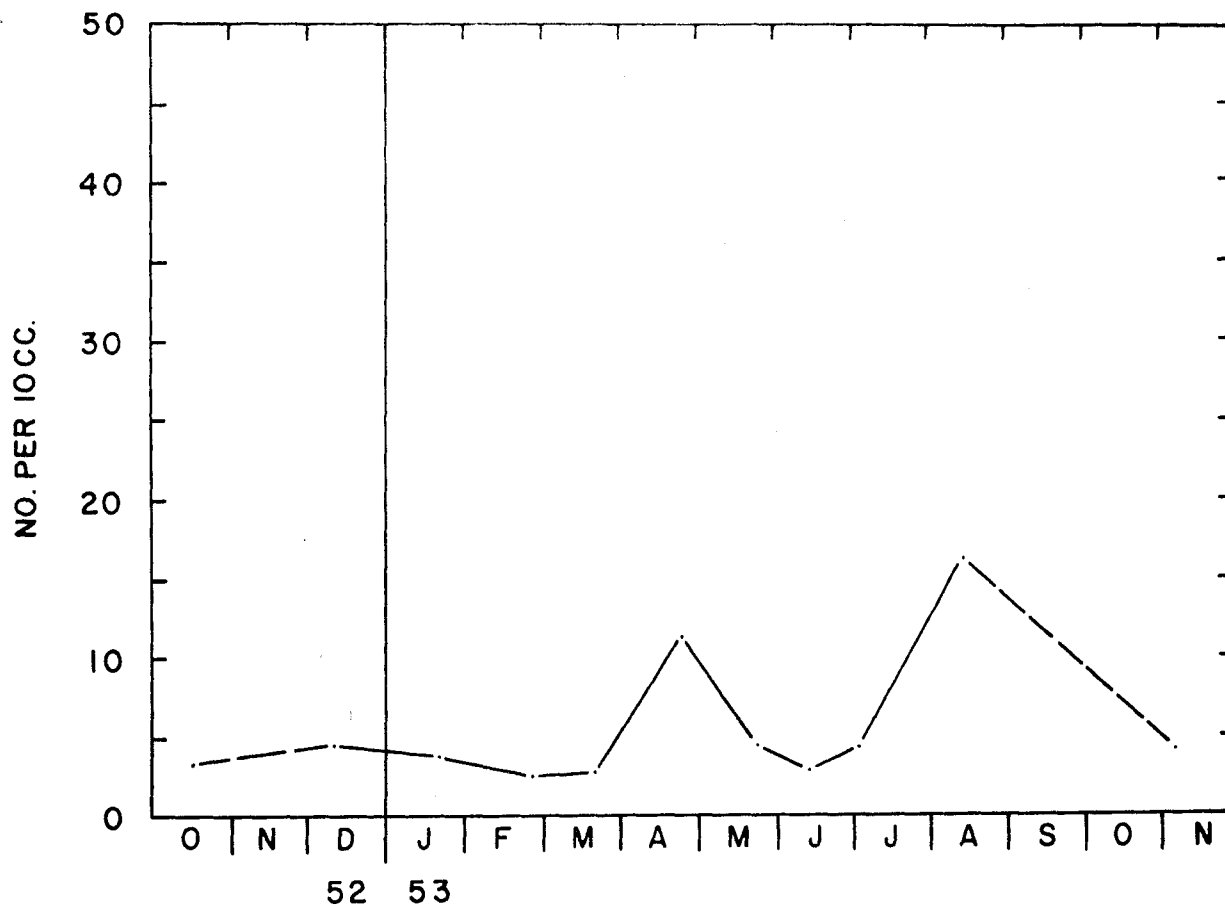


Fig. 20. A. eschscholtzii. Seasonal distribution.

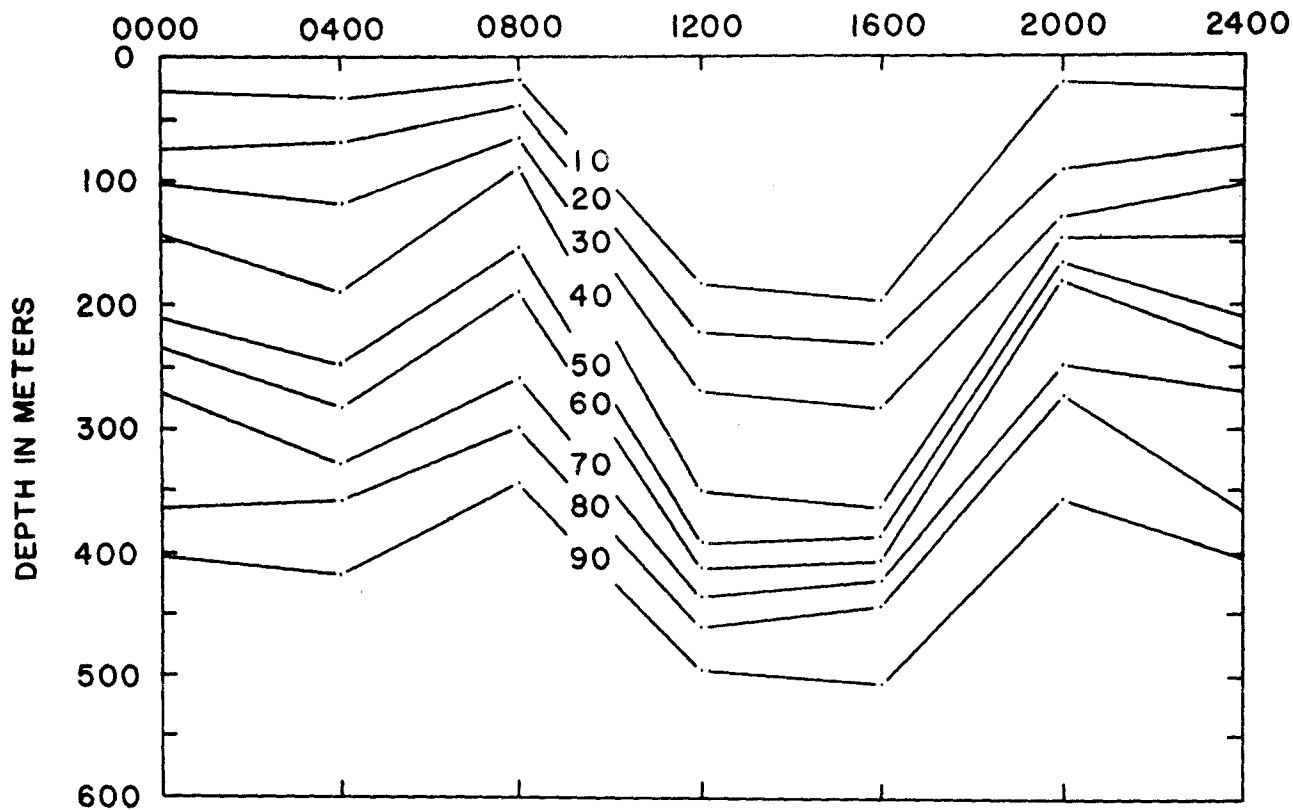


Fig. 21. A. eschscholtzii. Diurnal migration.

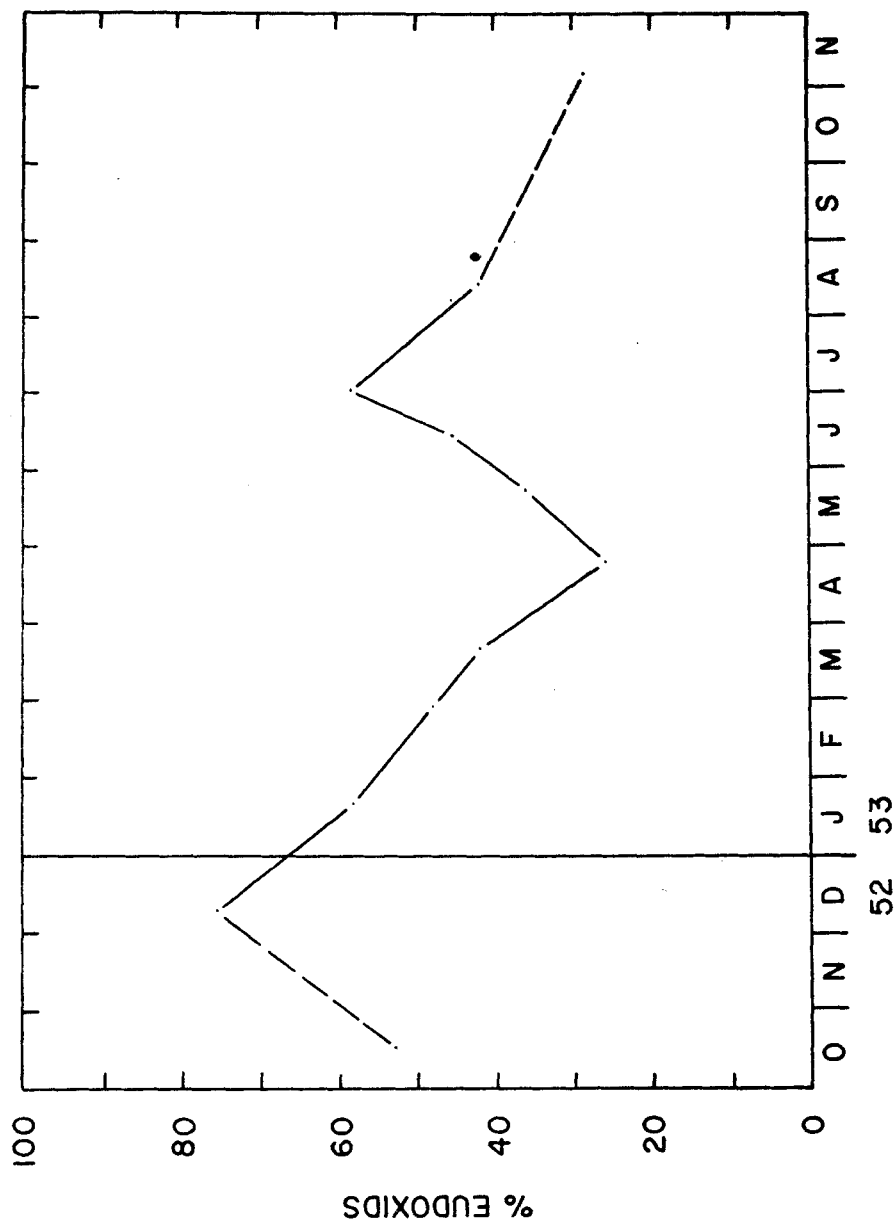
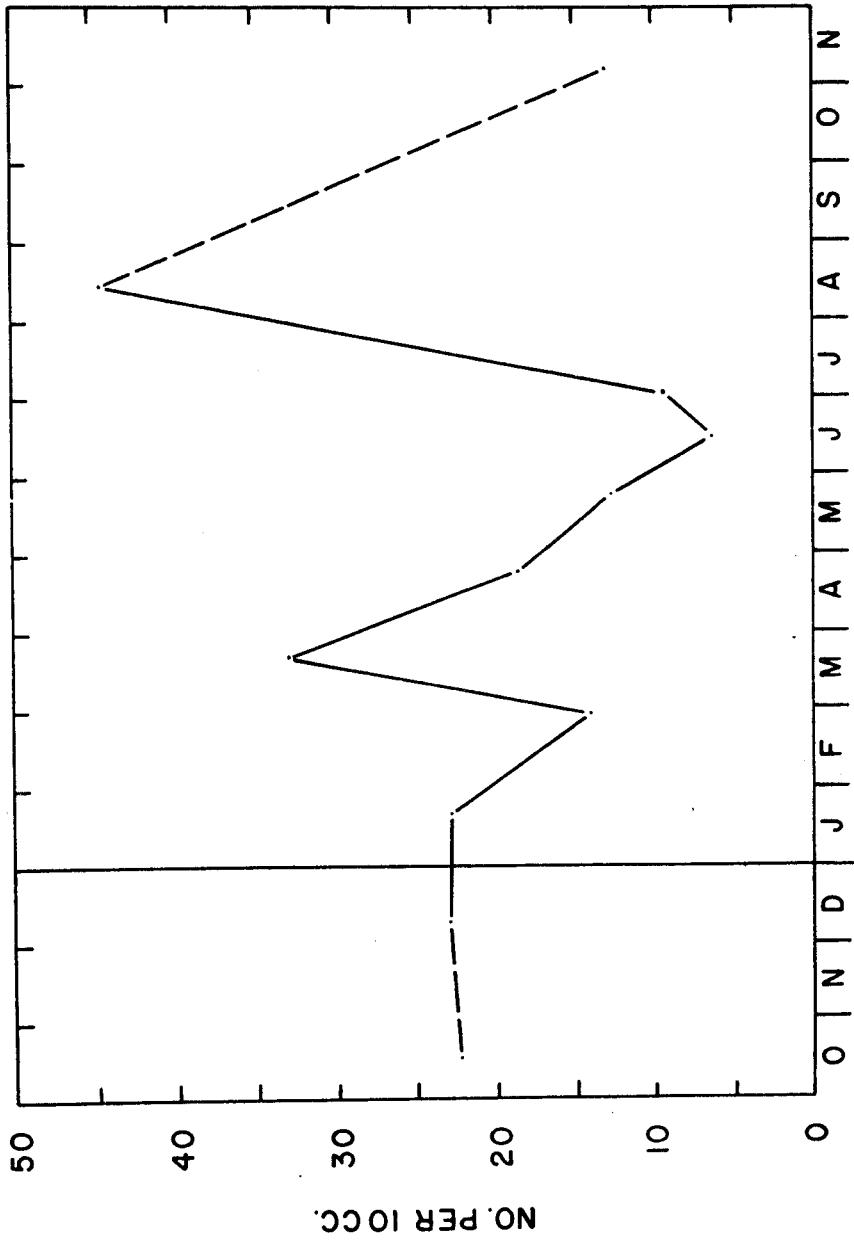


Fig. 22. A. tetraspora. Cycle of alternation of generations.



52 53

Fig. 23. *A. taeniorhynchus*. Seasonal distribution.

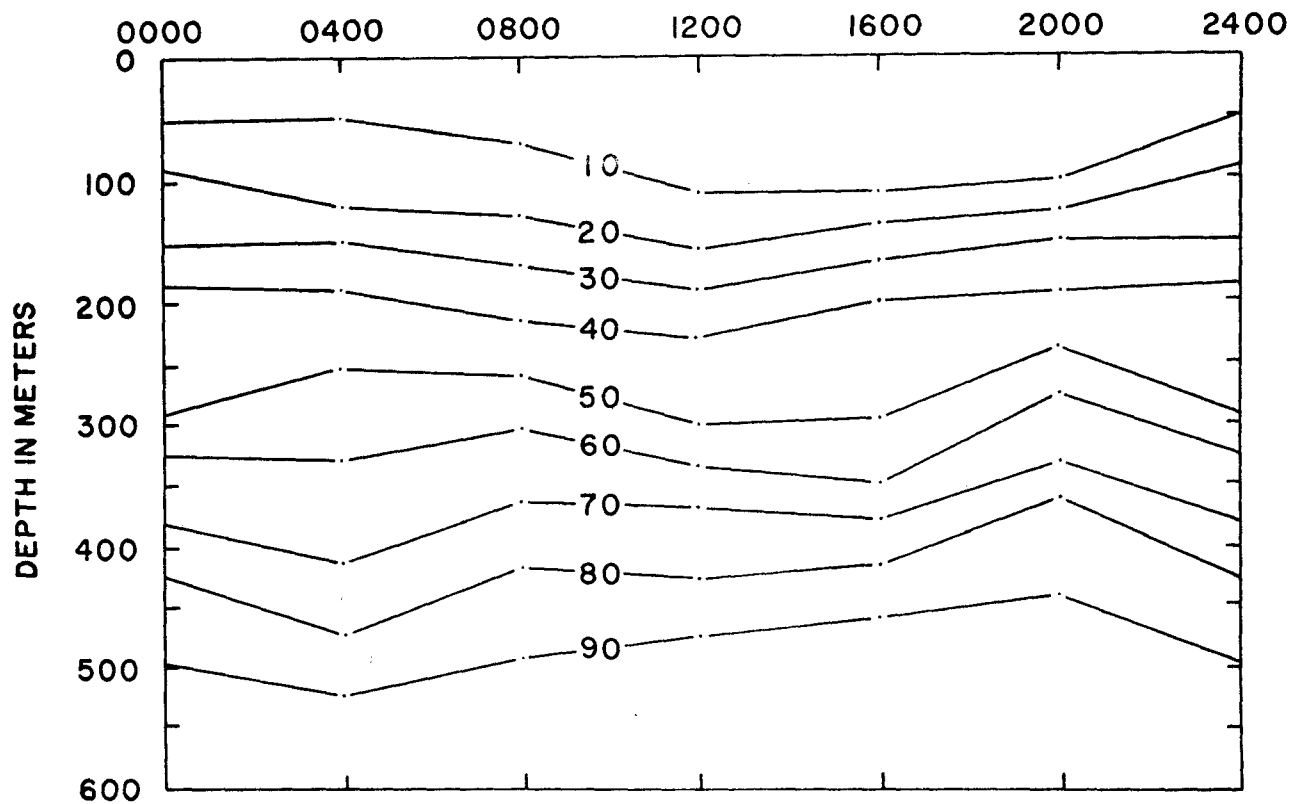


Fig. 24. A. tetragona. Diurnal migration.



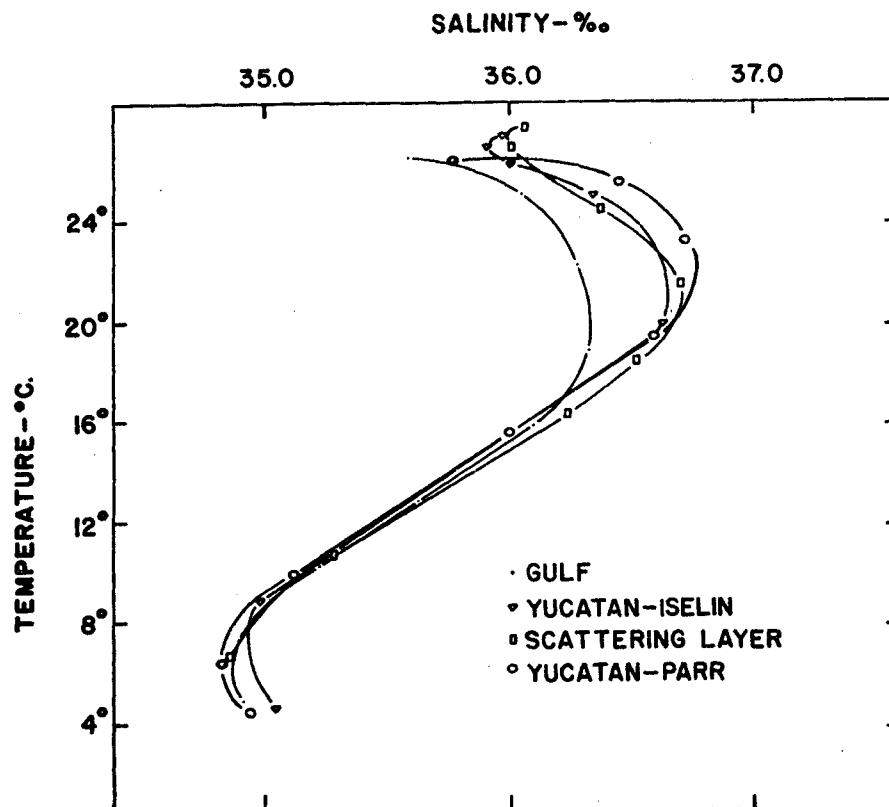


Fig. 25. T-S curves from a SL station, Yucatan water and Gulf of Mexico water.

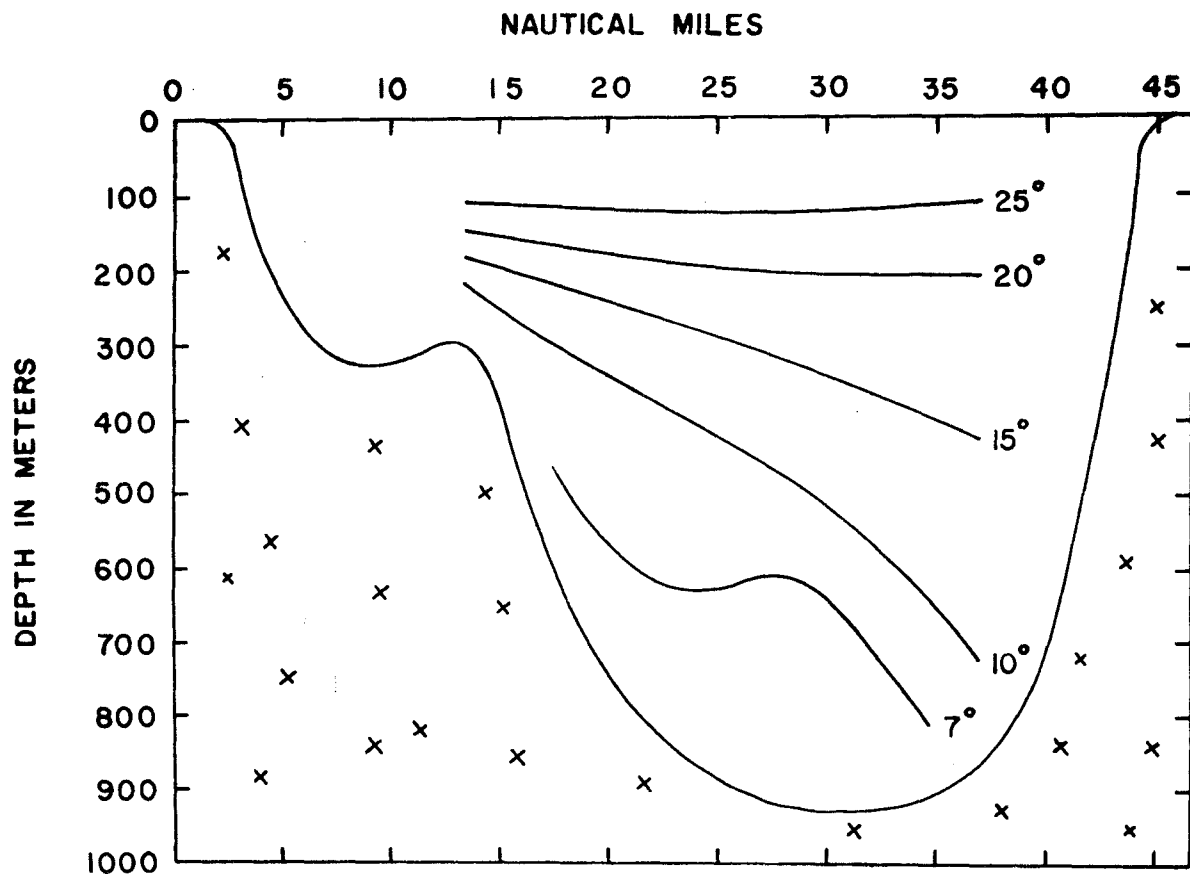


Fig. 26. Typical isotherm distribution between Miami and Cat Cay.

## VITA

Douglas Champe Roane was born in Norfolk, Virginia, on June 26, 1930. His parents are Carroll William Roane and Louise Champe Roane. He received his elementary education in Ocean View Elementary School, Norfolk, Virginia, and his secondary education in Granby High School, Norfolk, Virginia.

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