PLANKTON OF THE FLORIDA CURRENT. II. SIPHONOPHORA[1]

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ABSTRACT

Siphonophores present in the Florida Current off Miami have been studied for 18 months. The seasonal distribution of each species is described together with its vertical distribution, diurnal migration and cycle of alternation of generations. When comparison has been possible, results agree fairly well with those from the Bermuda area. It was shown that, superimposed on seasonal fluctuations in numbers, most species vary somewhat in relation to the water mass present. In this locality, water mass change is associated with temperature changes. The siphonophores as a whole adjust their day level in relation to the temperature.

Since 1950, a study of the plankton of the Florida Current off Miami, Florida, has been in progress with the assistance of a grant from the National Geographic Society. A first report on the hydrographic conditions encountered during the work has already appeared (Miller, Moore and Kvammen, 1953). Methods used in the collection of the plankton have also been described in that report. The present paper is one of a series on different groups of the zooplankton. The only previous study of the seasonal distribution of oceanic zooplankton in the North Atlantic is that for the Bermuda area (Moore, 1949). The siphonophores from Bermuda, a representative series of which had been identified by Dr. A. K. Totton, were available in the present work and were taken as a standard of comparison, the only species encountered here, but not in Bermuda being *Enneagonum hyalinum*. A few changes in nomenclature have, however, been made at the suggestion of Dr. M. Sears.

It was hoped that the present study would provide an amplification of the Bermuda work and allow the verification of some of the generalizations that were made there on such relationships as vertical distribution and illumination. For much of this comparison, it will be better to await publication of the results on other groups, and thus utilize a greater number of species. The data necessary for such

[1]Contribution No. 86 from the Marine Laboratory, University of Miami.

comparison is therefore presented briefly here and will not be discussed at present. Complete tabulation of the results from all hauls is filed in the library of the Marine Laboratory. The results discussed more fully here are those which are characteristic of particular species rather than of zooplankton as a whole.

List of Species

The following species were recorded during the work. Details with regard to the commoner ones are given later, but some notes are appended here to those which were found only in small numbers.

Amphicaryon acaule Chun

Agalma spp.

Detached bracts and nectophores were taken occasionally but were not specifically identified. They were not common.

Hippopodius hippopus Forskål

Abyla trigona Quoy and Gaimard

Small numbers were taken in the autumn and winter of both years.

Abyla leuckartii Huxley

Abylopsis eschscholtzii Huxley

A. tetragona Otto

Enneagonum hyalinum Quoy and Gaimard

Bassia bassensis (Quoy and Gaimard)

Diphyes dispar Chamisso and Eysenhardt

D. bojani (Eschscholtz)

Eudoxoides spiralis (Bigelow)

E. mitra (Huxley)

Chelophyes appendiculata (Eschscholtz)

What was presumed to be the eudoxid generation of this species was taken fairly commonly in Bermuda but was seen on only one or two occasions in Florida waters, despite the comparative abundance of the polygastric generation there.

Lensia subtilis (Chun)

L. fowleri (Bigelow)

L. campanella (Moser)

L. cossack Totton

Sulceolaria monoica (Chun)

Single specimens occasionally throughout the year.

Galetta australis (Quoy and Gaimard)

Single specimens occasionally in winter and spring.

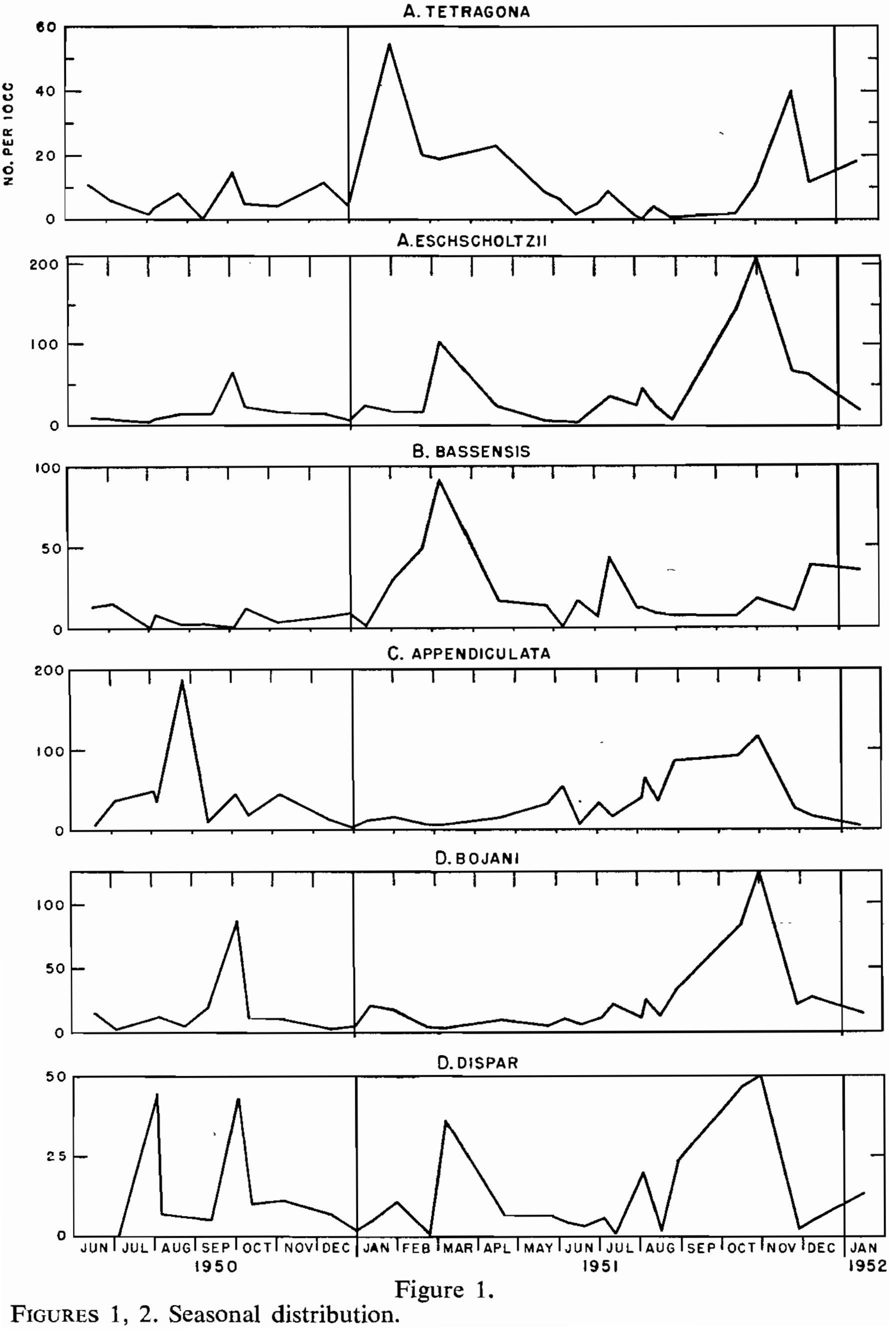

Figure 1.

FIGURES 1, 2. Seasonal distribution.

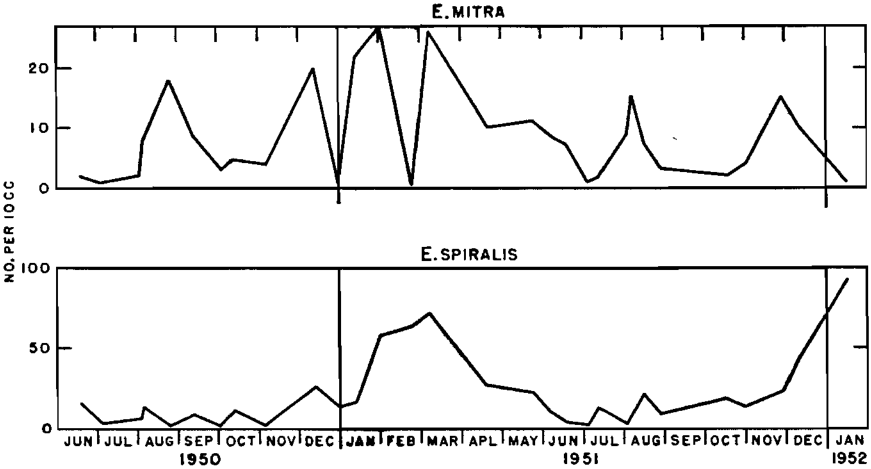

Figure 2.

Seasonal Distribution

Seasonal distribution of those species which were present in sufficient numbers, is presented in Figures 1, 2. The results are expressed as numbers per ten cubic centimeters of drained plankton, averaging that taken from all levels at a particular station. Owing to the inconsistent vertical distribution of the net hauls on different occasions, this has proved the simplest method of presentation. It is made on the assumption that there is no marked seasonal fluctuation in the quantity of zooplankton present, a fact which was demonstrated in Bermuda, and confirmed here (Miller, *et al.*, 1952). In Bermuda, *Diphyes bojani* and *Abylopsis eschscholtzii* showed definite winter maxima, while *A. tetragona* was probably a winter form, *Bassia bassensis* was winter or spring, and *Eudoxoides spiralis* was winter or autumn and spring. *E. mitra* and *Chelophyes appendiculata* showed no marked seasonal maximum, and *Diphyes dispar,* although not well defined, tended to be a summer form. Other species were not taken in sufficient numbers to define their season of maximum abundance. The Florida results agree fairly well with those from Bermuda. *E. spiralis, B. bassensis* and *A. tetragona* were definitely winter forms, *D. bojani* an autumn one and *D. appendiculata* a summer or autumn one. *D. dispar, E. mitra* and *A. eschscholtzii* were more sporadic. The remaining three common species were sporadic in their occurrence, but *D. dispar* and *A. eschscholtzii* may have been spring and autumn forms, and *E. mitra,* a winter or spring form.

In both the Bermuda and Florida areas, fluctuations in numbers are believed to be in part due to inherent seasonal changes within a given water mass, but in part also to seasonal changes in the water mass present. In Bermuda, it appears that the summer water has a more northerly origin and brings with it forms typical of rather colder waters, while the winter water is more southerly in origin (Moore, Hela and Owre, in MS.). In the Florida current off Miami, there is a fluctuating amount of water of Gulf of Mexico origin intruding into the main water mass which comes through the Yucatan Channel. During the period of these observations, there was a general tendency for the Gulf water to predominate at the station being studied throughout the spring and summer, with Yucatan water taking its place in autumn and winter. However, the condition was complicated by short period fluctuations in the two water masses. As a further complication, in August 1951, and again in January 1952, a third water mass appeared briefly. This agreed in character with neither of the others, and its origin has not yet been definitely determined. If, as seems probable, some of our species are relatively more abundant in

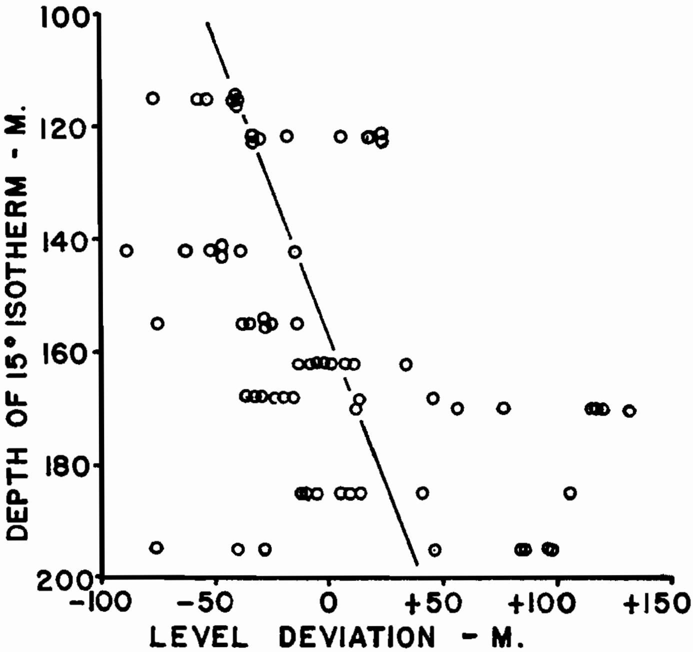

FIGURE 3. The deviation, on different occasions, of each species from its mean day level for the whole period of observation, plotted against the depth of the 15°C. isotherm.

one water mass than in the other, then some of the observed fluctuations in abundance might be due to this, rather than to a seasonal cause. Correlation coefficients were calculated between abundance of the various species and the percentage of Gulf of Mexico water present (Table I).

TABLE I

Species	*r*
D. dispar	+ .47
D. appendiculata	+ .64
E. spiralis	— .46
Significant value at P = 5%	.468
Significant value at P = 1%	.542

For the remaining species the correlations were not significant. The seasonal variation was, however, so great, that it would obscure the water mass relationship in such a small series, and the following method was therefore used to eliminate seasonal effect. It was assumed that the same seasonal cycle occurred in the two water masses. The values for numbers and for percentage of Gulf water were expressed as percentage deviations from the mean of the three readings of which they were the center. Correlations were then worked out for these percentage values with the following results.

TABLE II

Species	*r*
D. dispar	+ .49
E. mitra	— .47
E. spiralis	— .57
C. appendiculata	+ .58
A. eschscholtzii	+ .45
A. tetragona	+ .49

The same values of significance apply here, and the remaining two species did not show a significant correlation. One further species, *Enneagonum hyalinum,* also appeared to be an indicator of Gulf water, but was present in too small numbers to be of value. Its occurrence in relation to type of water is shown below.

TABLE III

% Gulf water	0 — 20	20 — 40	40 — 60	60 — 80	80 — 100
Occurrence of	— —	—	—	—	— — — — — —
E. hyalinum		++	+++	+	+++++++

Regression equations indicated that the change in numbers due to water mass was, with one exception, only 15 - 45% of the change in concentration of Gulf water, and so relatively small in comparison with the large seasonal fluctuations. *E. spiralis*, however, appeared to be mainly a Yucatan water form. An attempt was made to apply a correction for water mass effect to the observed seasonal curves for numbers, but in no case was a significant shift in the peaks produced. It is felt, therefore, that the observed peaks represent genuine seasonal

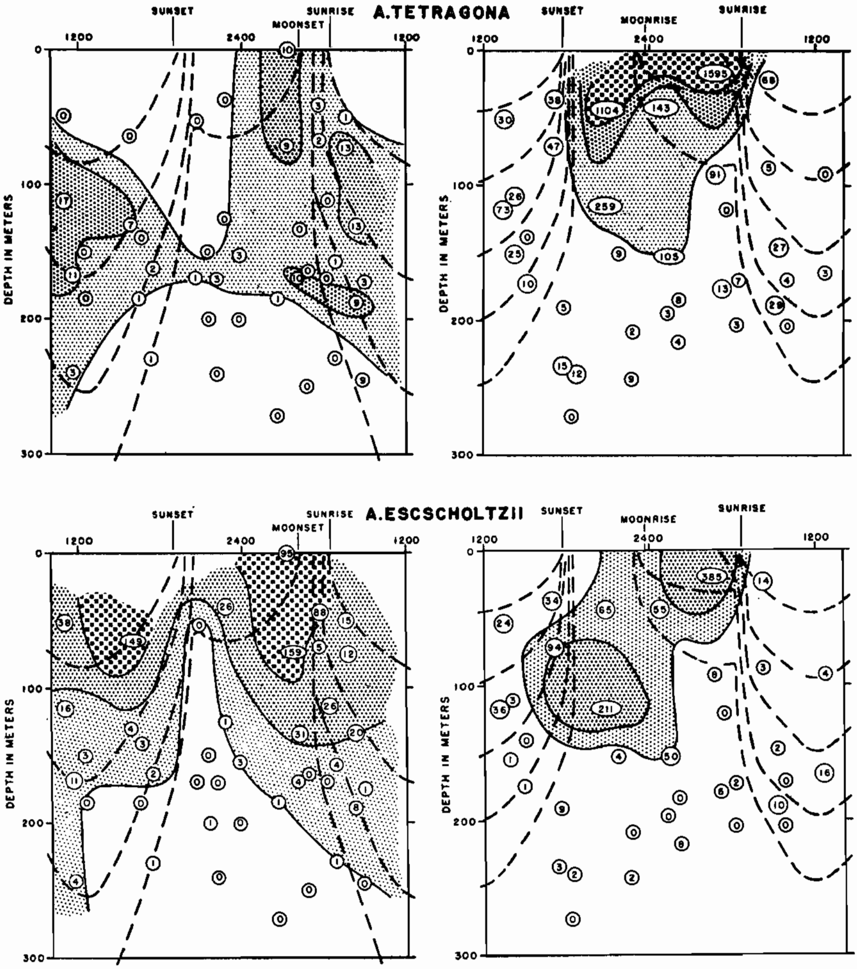

Figure 4.

FIGURES 4-7. Diurnal migration. Numbers represent catch scaled to a standard tow of one mile. The superimposed isolumes, reading from the top, represent illumination values of 10^0, 10^{-2}, 10^{-4}, etc., based on an arbitrary value of 10^2 for surface light with the sun direct overhead.

changes in abundance of the species, and that even the subsidiary fluctuations are likely to be due to some cause other than the changes in proportions of Gulf and Yucatan waters.

The occurrence of a third water mass on two occasions has already been referred to. Since its siphonophore population showed no striking peculiarities, it will not be discussed here. The stations at which it occurred were omitted from the above calculations.

Vertical Distribution

The mean day level of a species has been expressed as the level

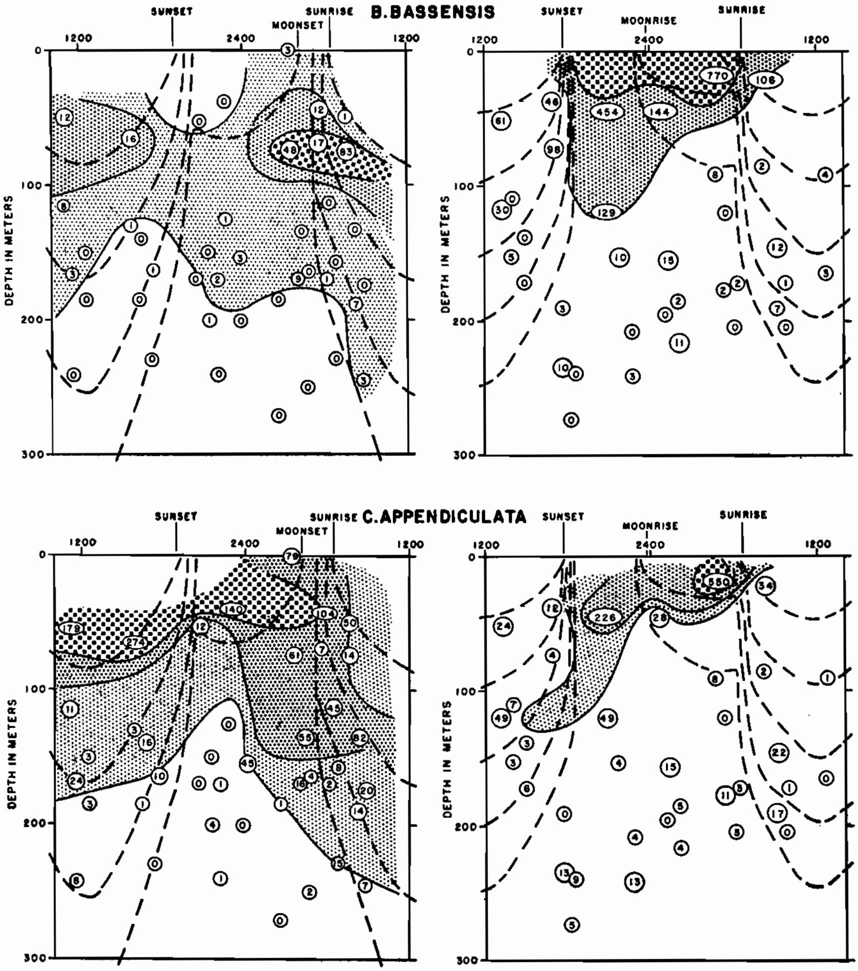

Figure 5.

above which 50% of the population occurs. The over-all mean for the whole period has been arrived at by two methods. In the first method, the mean day level has been calculated for each station at which a sufficient series of hauls was made, and in which the species was sufficiently represented. The over-all value was then obtained as the mean of these various station values. This appears to be the better method. A second method was used where the species was present always in small numbers only. Here, all results for the entire period were grouped together, averaged for 50 meter intervals, and the mean

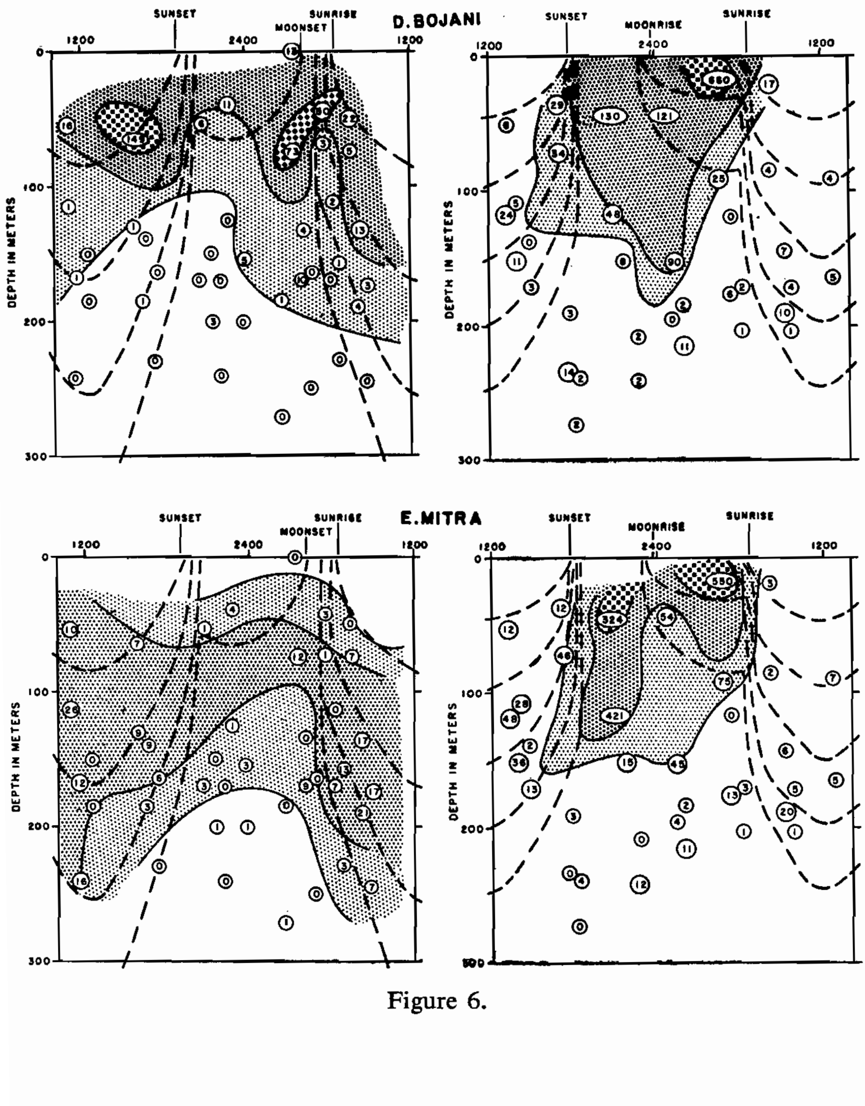

Figure 6.

day level then calculated in the usual way. The second method, because of the nature of these particular hauls, tends to give shallower values and can be taken as little more than an indication of the general level occupied. Table IV shows the values obtained by the two methods, together with Bermuda values for a comparison.

TABLE IV

Species	*Mean Day Level—M.*			*Spread—M.*		
	Florida		*Bda.*	*Florida*		*Bda.*
	Method I	*Method II*		*Method I*	*Method II*	
Diphyes bojani	72	29	40	43	88	25
D. dispar	59	40	*ca.* 10	76	104	10
Eudoxoides spiralis	75	50	65	45	69	65
E. mitra	134	68	125	65	134	105
Chelophyes appendiculata	74	48	75	81	100	130
Lensia cossack	—	35	—	—	43	—
L. campanella	—	17	60	—	25	25
L. subtilis	—	32	140	—	30	150
L. fowleri	—	100	165	—	102	70
Galetta australis	—	58	—	—	84	—
Abyla leuckartii	—	102	—	—	105	—
Abylopsis eschscholtzii	58	12	*ca.* 40	51	78	80
A. tetragona	104	85	55	63	122	25
Bassia bassensis	59	13	50	29	75	40
Enneagonum hyalinum	—	100	—	—	28	—
Amphicaryon acaule	—	92	80	—	100	75
Hippopodius hippopus	—	110	140	—	92	75

There is, on the whole, a good agreement between the results from Florida and Bermuda. A detailed comparison must, however, await the availability of data for species from other groups. It is possible, though, to examine the effects of varying water mass on the day level of the siphonophores. The Gulf of Mexico water is, throughout the levels sampled for plankton, about 5°C. colder than the water of the Yucatan channel. Since temperature, as well as illumination, may control the depth of zooplankton, it is to be expected that some species at least will tend to descend deeper during the daytime in the Yucatan water than in the Gulf of Mexico water. In Figure 3, the deviations of level of the various siphonophore species from their overall means for the entire period, are plotted against the depth of the 15°C. isotherm, and it is apparent that the expected adjustment of level to temperature conditions does in fact take place. In fact the regression line indicates that the change in level of the organisms is 95% of the change in level of the 15° isotherm. Studies of additional species will be required before this can be pursued further.

Table IV also shows the Florida and Bermuda values for the spread—that is, the vertical distance between the 25% and 75% levels of the species. There is little agreement between the figures for the two regions.

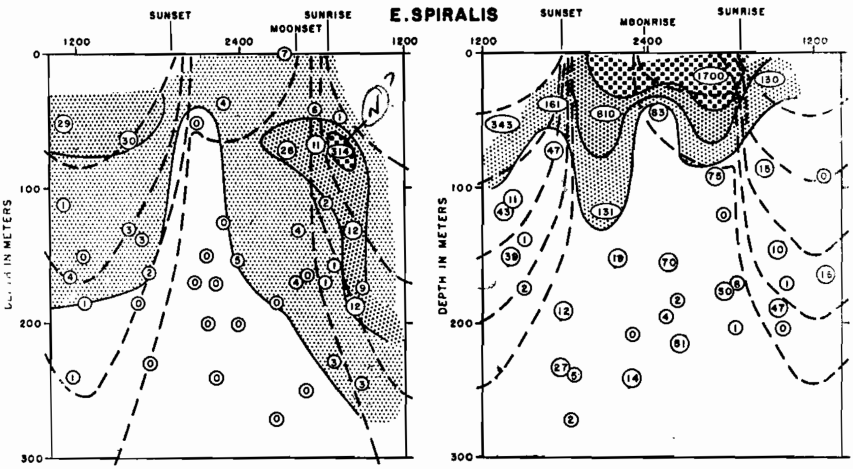

Figure 7.

Diurnal Migration

Two 24 hour stations were occupied for diurnal migration studies, and the results of these are shown in Figures 4-7. Superimposed on the figures are isolumes calculated for the particular periods which

TABLE V

	Day-night range—M.			*Day-night ratio*		
	Florida		*Bda.*	*Florida*		*Bda.*
Species	NG. 16	NG. 32		NG. 16	NG. 32	
Diphyes bojani	—59	—16	—	18	24	—
D. dispar	—38	+49	—	9	100	—
Eudoxoides spiralis	—33	—30	—	40	93	60
E. mitra	—50	—44	—	12	100	41
Chelophyes appendiculata	—48	— 5	—87	29	100	78
Lensia cossack	—	—	—	—	0	—
L. campanella	—	—	—	—	20	—
L. fowleri	—32	—	—	3	21	—
Abyla leuckartii	—92	—	—	6	0	—
Abylopsis eschscholtzii	— 6	—48	—	29	28	—
A. tetragona	—70	—80	—89	8	80	61
Bassia bassensis	—28	—41	—	12	100	—
Enneagonum hyalinum	—19	—	—	28	—	—
Amphicaryon acaule	—	—	—77	0	49	83
Hippopodius hippopus	—50	—	—	28	42	—

differed considerably both in the extent of penetration of the light and in the duration of moonlight during the night period. All those species present in sufficient numbers showed some diurnal migration. Values for the day-night range, and day-night ratio are shown in Table V and compared with the available figures from Bermuda. The day-night ratio is an indication of the extent of the night increment into the top 250 meters from deeper water. A value of 100 indicates no increment, while a value of 0 indicates that the whole population retreats below 250 meters in the daytime.

There are too few species for which Bermuda figures are available to allow a useful comparison of the two regions, so this will be deferred until data on other groups is available.

Alternation of Generations

In Bermuda, a cyclic alternation of preponderance of the polygastric and the eudoxid generations was observed in several species. In *Bassia bassensis* there were probably five cycles during the year, in *Eudoxoides spiralis,* four, and in *E. mitra,* six. The variation in water mass in the Florida area no doubt complicates the observed pattern, but the three species shown in Figures 8, 9 show at least some measure of cyclic change. *Abylopsis tetragona* is the most clearly defined, with probably five cycles during the year and with good agreement between the two years. *A. eschscholtzii* showed a clear cut peak of eudoxids in the spring and either an extended eudoxid period in the summer and fall, or a period of rapid fluctuation. No definite cycles were observed in this species in the Bermuda material. *Bassia bassensis* showed summer and autumn eudoxid peaks in both years in the Florida material and showed the same at Bermuda. The Bermuda winter peak was, however, missing in Florida, and the two Bermuda spring peaks are represented here by a single extended period, possibly appearing as such on account of too widely spaced sampling. On the whole, though, the agreement between the two regions is surprisingly close. *Diphyes bojani* is included to show the possibility of this species having a double cycle during the year, but the data are too erratic for this to be definite.

Discussion

The purpose of the present survey has been twofold. A survey of the local population of siphonophores, with indications of the seasonal and vertical distribution of the commoner species, has been presented. This survey extended for about a year and a half, and since some of the characteristics observed in the first year were repeated in the second, it may be assumed that the results are reasonably representa-

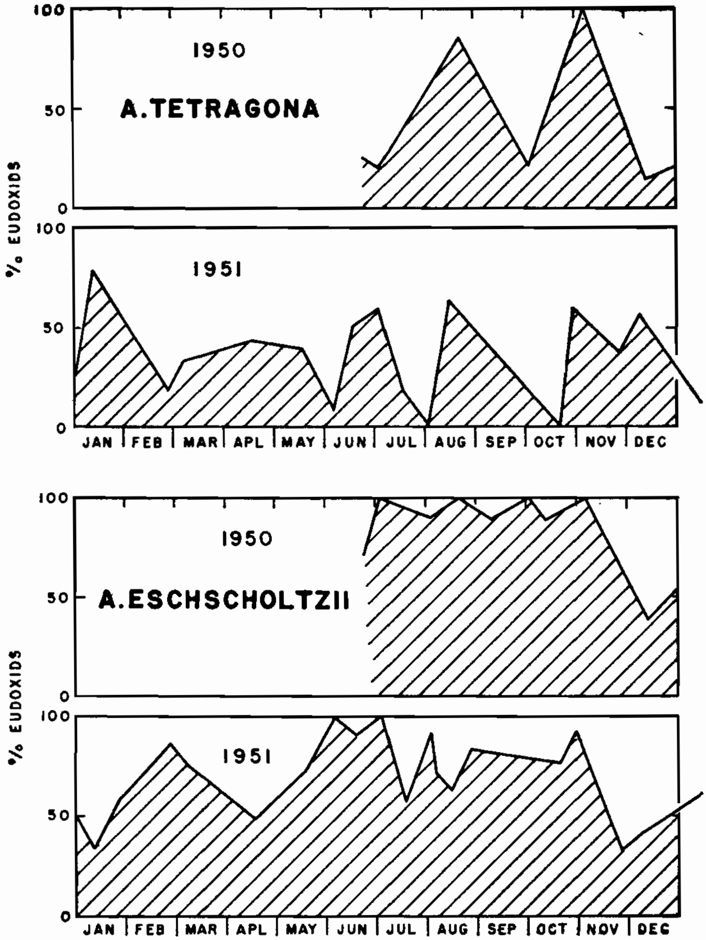

Figure 8.

FIGURES 8, 9. Seasonal changes in percentage of eudoxids present.

tive of typical conditions in the area. Furthermore, the seasonal and vertical distribution of the several species agrees as well as can be expected with similar observations in the Bermuda area, and so lends support to the belief that the results are applicable to a wide area of the western North Atlantic. From the local point of view, it was hoped that some species would be found to be good indicators of the water masses present in the Miami area, and this has, unfortunately, not proved to be true. Although the abundance of several has been shown to be different in the Yucatan and Gulf of Mexico waters, none are completely restricted to one mass, and so readily useable as indicator species.

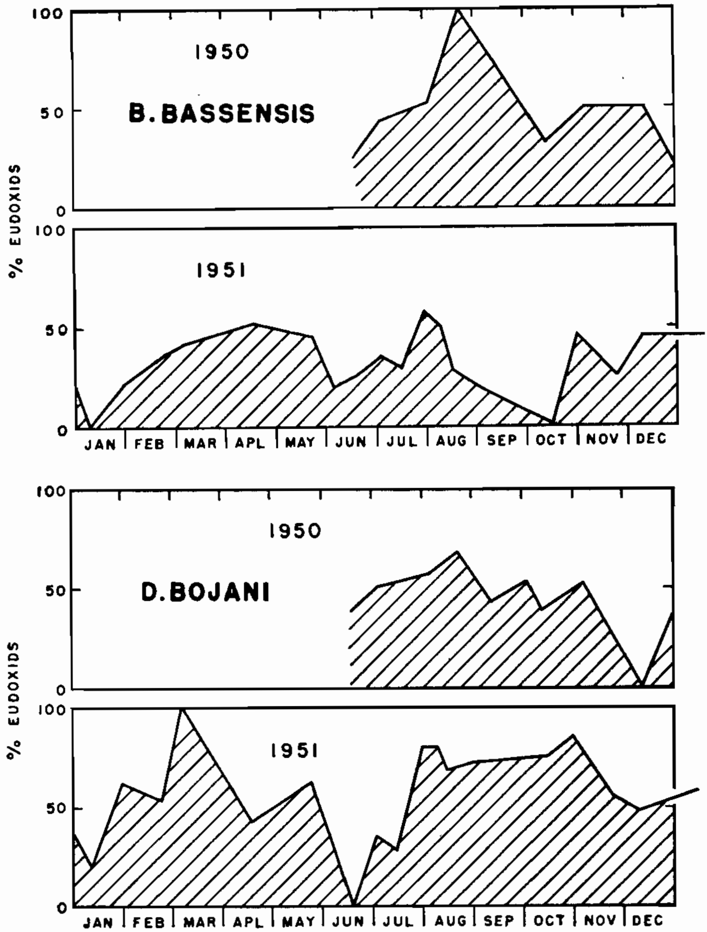

Figure 9.

The second purpose of the survey was a study of the reaction of the plankton species to temporary changes in such conditions as illumination and temperature. This is more readily done when a large number of species can be used for comparison, and will therefore be postponed until results for other groups have been completed. The only generalization noted here is that among the siphonophores there is a tendency for a change in day level in relation to temperature, the animals moving upward when cold water comes closer to the surface, as it does when there is an influx of Gulf of Mexico water.

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