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THALIACEA OF THE BERMUDA AREA

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ABSTRACT

A large number of samples of Salpidae, Doliolidae and Pyrosomatidae, collected by the U. S. Ocean Acre Project, are studied. A new record for the Bermuda area of *Doliopsis rubescens* (Vogt, 1817) is given. Dominant species are *Iasis zonaria* (Pallas, 1766), *Salpa fusiformis* Cuvier, 1804, and *Salpa aspera* Chamisso, 1819. Seasonal peak occurrences are observed for several species. The seasonal and vertical variation of the number of muscle fibres of aggregate *Salpa fusiformis* and aggregate *Salpa aspera* is studied and discussed.

INTRODUCTION

In a series of papers (Van Soest, 1973a, 1973b, 1974a, 1974b, 1975a and 1975b) the present author recently revised the family Salpidae. Part of the material used for this revision originated from the Bermuda area. It was collected during the U. S. Ocean Acre Project, financed by the U. S. Navy, and carried out by the Smithsonian Institution at Washington, in 1967-1972.

The salp material collected during cruises 1, 6, 10, 11, 12, 13 and 14 was sent to Amsterdam for identification and a separate treatment of it is given in the present paper. Simultaneously, material of both other Thaliacean groups (Doliolidae and Pyrosomatidae) will be reported upon, although part of the Pyrosomatid material has been treated already in a recent paper of the present author (cf. Van Soest, 1974c).

The Bermuda area has been subject to several zooplankton investigations in which Thaliacea were treated, e.g. Apstein (1894), Moore (1949), and Deevey (1971). Still, the area proved to be insufficiently known as far as Thaliacea are concerned, as shown for instance by the discovery of several new species from the area (*Salpa younti* Van Soest, 1973, *Brooksia berneri* Van Soest, 1975a). Moreover, the sophisticated sampling program carried out during the U. S. Ocean Acre Project has yielded a unique series of samples in depth as well as time from roughly the same location.

MATERIAL

The material consisted of salp samples collected during Ocean Acre Project cruises 1, 6, 10, 11, 12, 13 and 14. The individual stations are given below; for the station data one is referred to Gibbs et al., 1971. All stations were located between 31°-34° N and 62°-65° W, at depths varying from 0 to 1500 m. Sampling was executed with an IKMT net (either 2 m or 3 m in diameter at its open end), provided with a discrete depth sampler described by Aron et al., 1964. Samples of salps were mostly small; only occasionally more than a hundred individuals (of the smaller species) were collected.

Stations:

ACRE cruise 1 (26-X/1-XI, 1967): 1B, 1M, 4M, 7C, 7M, 8B, 9B, 9C, 11B, 11C, 12A, 12B, 12M, 13A, 13B, 13M, 15A, 15M, 16C, 16M, 17A, 18A, 18C, 18M, 19A, 19C, 19M, 20P, 22A, 22C, 24N, 26N, 27N, 28N.

ACRE cruise 6 (25/30-IV, 1969): 10C+D, 16A, 16D, 17C+D, 23.

ACRE cruise 10 (1/10-VI, 1970): 1N, 2A, 2B, 2C, 2M, 3A, 3B, 3C, 3M, 4A, 4B, 4C, 4M, 5A, 5B, 5M, 6A, 6B, 6M, 7B, 7M, 8A, 8B, 8M, 9A, 9B, 9M, 10A, 10M, 11A, 11B, 11M, 13B, 13M, 14B, 14M, 15A, 15B, 15C, 15M, 16A, 16B, 16M, 17A, 17B, 17C, 17M, 18A, 18B, 18P, 19C, 19M, 20B, 20C, 20M, 21N, 23B, 23C, 23M, 24M, 26P, 27C, 27M, 27N, 28M, 28P, 29A, 29M, 31B, 31M, 32C, 33A, 33M, 34C, 34M, 35C, 36A, 36M, 37M, 37N, 38N.

ACRE cruise 11 (12/15-I,1971): 1B, 1M, 1S, 2A, 2B, 2M, 3A, 3C, 3M, 4C, 5A, 5B, 5C, 5M, 7A, 7M, 8C, 8M, 9M, 11C, 12B, 12M, 13A, 13B, 13C, 13M, 31B.

ACRE cruise 12 (26-VIII/8-IX, 1971): 1A, 1B, 1C, 1M, 8B, 8C, 8M, 10M, 13B, 13M, 14M, 16M, 19B, 21M, 23M, 28C, 28M, 31B, 31C, 31M, 34B, 34C, 35M.

ACRE cruise 13 (23-II/3-III, 1972): 1B, 1C, 1M, 2A, 2M, 3M, 4C, 4M, 5B, 5M, 6B, 6M, 7M, 9P, 10C, 10M, 11A, 11C, 11M, 12M, 13M, 15B, 15C, 16M, 18M, 21M, 22B+C, 24M, 25M, 27B, 28B, 28C, 28M, 29B, 29C, 29M, 30A, 30C, 31B, 32A, 32B, 32C, 32M, 33M, 35C, 36M.

ACRE cruise 14 (4/11-VI, 1972): 3B, 3P, 8M, 10C, 12C, 13C, 17M, 20M, 21A, 23B, 23C, 24B, 24M, 26A, 28C.

NEW RECORDS

Authors reporting on the Thaliacea of the Bermuda area (Apstein, 1894; Moore, 1949) did not distinguish a number of taxa described recently by the present author (Van Soest, 1973a, 1973b, 1974a, 1975a). For that reason a number of species could not have been reported by these authors: *Salpa younti*, *Thalia orientalis* Tokioka, 1937, *Thalia cicar* Van Soest, 1973, *Cyclosalpa foxtoni* Van Soest, 1974, and *Brooksia berneri*. Other species already well-known from other areas have been reported newly for the Bermuda area by the present author: *Salpa aspera* Chamisso, 1819, *Salpa maxima* Forskål, 1775, *Pegea bicaudata* (Quoy & Gaimard, 1833), *Ritteriella retracta* (Ritter, 1906), *Cyclosalpa polae* Sigl, 1913, *Helicosalpa virgula* (Vogt, 1854), *Pyrosoma atlanticum* Péron & Lesueur, 1804, *Pyrostremma agassizi* (Ritter & Byxbee, 1905) and *Pyrostremma spinosum* (Herdmann, 1888). A remarkable new record is that of *Doliopsis rubescens* (Vogt, 1854), a rare species of apparently cosmopolitan distribution. Other Doliolid specimens occurring in the Bermuda area could not be identified due to the very poor state of preservation; among the dozens of "old nurses" captured during the various cruises a fair number of *Doliolum denticulatum* Quoy & Gaimard, 1824, were present.

SEASONAL OCCURRENCE OF THE SPECIES

The various cruises were made during different months of the year: January (cruise 11), February/March (cruise 13), April (cruise 6), June (cruises 10 and 14), August/September (cruise 12) and October (cruise 1). In table I the Thaliacea species encountered in the material are listed together with their occurrence and abundance during the different months of the year; the effect thus created is considerably artificial as the various cruises have not been executed in one and the same year. Cruise 6 samples have been omitted as they were few in number and contained *Salpa aspera* only.

From table I the following conclusions may be drawn:

1. Dominant species occurring all the year round are *Iasis zonaria* (Pallas, 1766), *Salpa aspera* and *Salpa fusiformis* Cuvier, 1804, although the latter is conspicuously less well represented during the months of June, August and October.
2. Less abundant species occurring (almost) all year round are *Pegea confoederata* (Forskål, 1775), *Ritteriella retracta* (only solitary zooids have

been found), *Traustedtia multitentaculata* (Quoy & Gaimard, 1833), *Weelia cylindrica* (Cuvier, 1804), and *Pyrosoma atlanticum*.

3. Species with a distinct seasonal peak occurrence are *Thalia democratica* (Forskål, 1775) - June -, *Cyclosalpa floridana* (Apstein, 1894) - June -, *Pyrostremma spinosum* - February/March -, and *Pyrostremma agassizi* - October -. *Salpa younti* has a peak occurrence in February/March (cruise 13), but it also occurred with 17 specimens in a sample of August/September (cruise 12). *Thalia orientalis* seems to be most abundant in the first three months of the year, (cf. also Deevey (1971) who reports "*Thalia longicauda*" (= probably *T. orientalis*) from January and February), while *Thalia cicar* occurs only in the samples of August-October; care should be taken in drawing conclusions from this, as both are not well represented in the material. In the southern Caribbean *Thalia cicar* and *T. democratica* have been reported to show both their peak occurrences simultaneously in June at the same location (cf. Van Soest, 1975b: figure 5). Moore (1949) reports a peak of *Thalia democratica* in the Bermuda area in the winter months, but as he did not distinguish other *Thalia*-species, he may have studied *Thalia orientalis* or *T. cicar*. *Pegea bicaudata* has two peak occurrences - January and June -.

4. A large number of species has been encountered quite sporadically: *Salpa maxima, Brooksia berneri, Ihlea punctata* (Forskål, 1775), *Thetys vagina* (Tilesius, 1802), *Cyclosalpa polae, Cyclosalpa foxtoni* and *Doliopsis rubescens*.

SEASONAL AND VERTICAL VARIATION OF THE NUMBER OF MUSCLE FIBRES OF SOME SALP SPECIES

In previous papers the present author has reported upon the latitudinal variation of the number of muscle fibres in many salp species distributed in tropical as well as in temperate waters (Van Soest, 1972, 1975b). A similar variation has been found by Winkler (1975), in the number of muscle fibres of the oral muscles of *Salpa fusiformis*. It has been contented that this latitudinal variation is the expression of small genetic differences between tropical and temperate populations, rather than mere ecophenotypical adaptation of the individuals. This contention has been largely based on circumstantial evidence (cf. Van Soest, 1975b). The present collection of salp samples allows us to investigate this problem from still another angle. The Bermuda area exhibits tropical sea-water temperatures (26°-27° C) in summer, but winter temperatures may be as low as 19° C (cf. Schroeder & Stommel, 1969), thus presenting a fair seasonal fluctuation, which could be expected to influence muscle fibre numbers of salp populations, should this character be determined directly by ecological circumstances.

The vertical distribution of sea-water temperatures exhibits also a large variation (from 26° C (summer) at the sea surface to about 4° C at 1500 m (cf. Schroeder & Stommel, 1969)). If salp species have real deep water populations - evidence presented by Van Soest (1975b) do not support this presumption - and again if the muscle fibre variation is merely an ecophenotypical adaptation, then it may be expected that a variation similar to the previously described latitudinal variation in this character will occur in a vertical column of water at one location.

From figure 1, in which the mean muscle fibre numbers of solitary and aggregate *Salpa fusiformis* samples from different depths and different seasons are given, and from figure 2, in which the same are given for *Salpa aspera*, it is clear that neither seasonally, nor vertically a clear clinal variation can be found. It is concluded from this, that a more or less stationary population of both species is present in the Bermuda area, and that these populations exhibit their own number of muscle fibres in which a random but limited variation is present.

DISCUSSION

Although the fact that the various cruises were held in different years, diminishes the value of the comparison of the abundance of the species in different parts of the year, this is compensated to some extent by the large number of samples taken during most of the cruises, which has considerably increased the chance of getting a fair impression of the species composition at the times of sampling.

The different seasonal occurrence of Thaliacean species is an interesting, though still not very well studied phenomenon. Some studies have been done on the seasonal cycles of Mediterranean

Thaliacea (e.g. Braconnot, 1971). It is not quite clear why certain species seem to occur only in a short period of the year, while others seem to be present all the year round without sharp peaks in abundance. Likewise, it is not quite clear why species showing peak occurrences, do so in different parts of the year (e.g. *Thalia democratica* in June, *Salpa younti* in February/March). These questions should continue to be subject of extensive field observations.

The absence of a seasonal or vertical clinal variation in the number of muscle fibres of *Salpa fusiformis* and *Salpa aspera* once again points strongly to genetic differences as the cause of the previously observed latitudinal variation of the number of muscle fibres. Moreover, it once again renders the existence of real deep water populations in salps unlikely.

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TABLE I

THE NUMBER OF SPECIMENS OF THALIACEAN SPECIES CAPTURED IN VARIOUS MONTHS OF THE YEAR DURING THE OCEAN ACRE PROJECT

	January	Febr./March	June	Aug./Sept.	Oct.
Salpa fusiformis	> 50	> 50	14	15	13
Salpa aspera	> 50	12	> 50	20	32
Salpa maxima	-	-	-	1	-
Salpa younti	> 50	-	-	17	-
Iasis zonaria	> 50	20	> 50	> 50	> 50
Thalia democratica	1	-	> 50	1	3
Thalia orientalis	20	25	1	1	-
Thalia cicar	-	-	-	1	6
Pegea confoederata	2	-	4	20	-
Pegea bicaudata	30	-	> 50	-	-
Ritteriella retracta	6	7	5	1	7
Traustedtia multitentaculata	3	1	25	9	5
Brooksia berneri	10	7	1	1	-
Ihlea punctata	1	-	2	-	-
Thetys vagina	-	-	1	-	-
Weelia cylindrica	4	-	2	1	5
Cyclosalpa polae	-	1	6	1	-
Cyclosalpa floridana	-	-	> 50	-	-
Cyclosalpa foxtoni	-	-	6	5	-
Helicosalpa virgula	2	-	1	-	-
Pyrosoma atlanticum	> 50	3	15	1	3
Pyrostremma agassizi	2	-	1	-	> 50
Pyrostremma spinosum	-	(> 50)*	2	-	3
Doliopsis rubescens	-	-	2	-	-
Doliolidae "old nurses"	6	15	2	20	2

* A few small colonies and fragments and a large number of loose zooids.

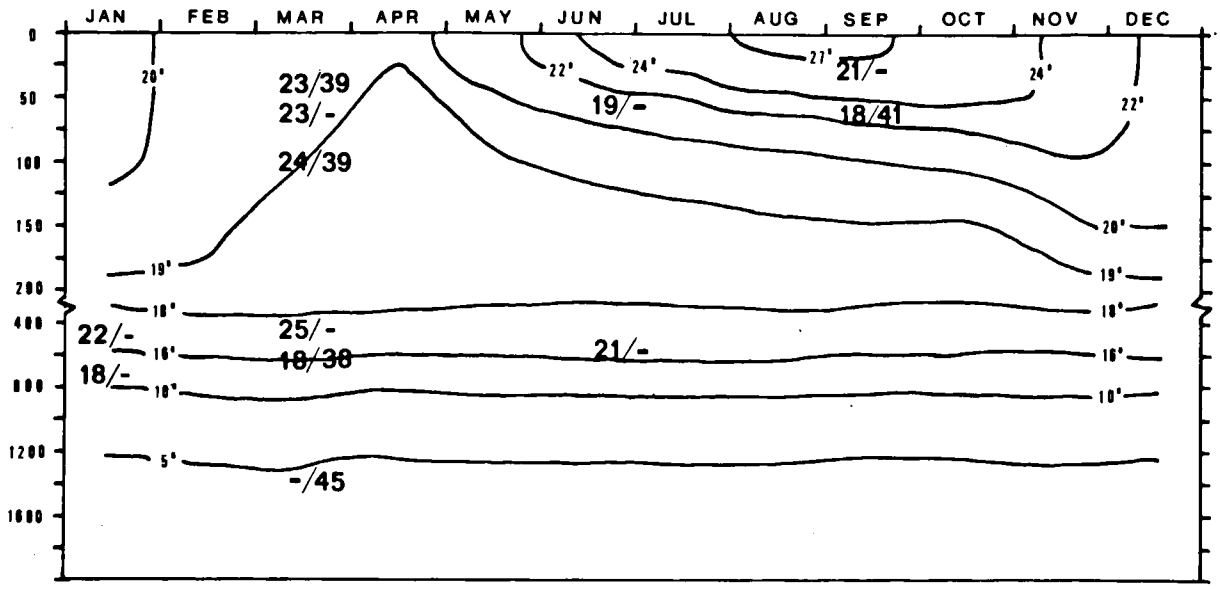

Fig. 1 Muscle fibre variation in time and depth of *Salpa fusiformis* in the Bermuda area. Horizontal axis: months of the year; vertical axis: depth in metres. Horizontal lines: 10-year-average isotherms (°C), derived from Schroeder & Stommel, 1969. Bold figures: mean number of muscle fibres of M IV of solitary (left of virgule) and of M I - VI of aggregate individuals (right of virgule).

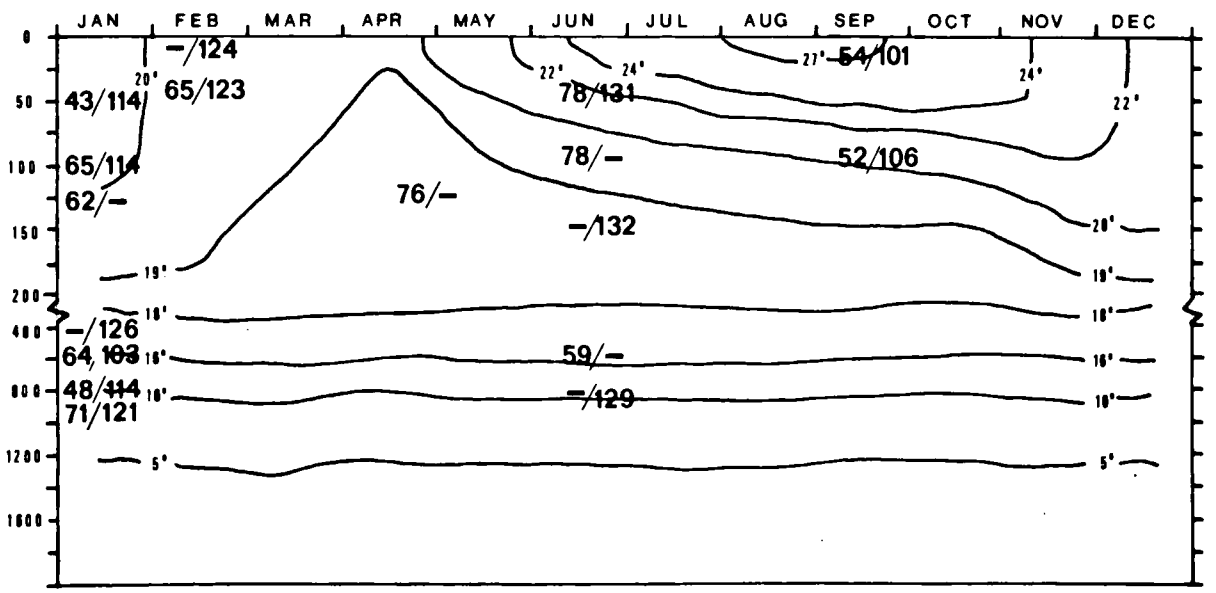

Fig. 2 Muscle fibre variation in time and depth of *Salpa aspera* in the Bermuda area. Further details as in fig. 1.