



## Checklist of the salps (Tunicata, Thaliacea) from the Western Caribbean Sea with a key for their identification and comments on other North Atlantic salps

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### Abstract

In waters of the Northwestern Atlantic pelagic tunicates may contribute significantly to the plankton biomass; however, the regional information on the salp fauna is scarce and limited to restricted sectors. In the Caribbean Sea (CS) and the Gulf of Mexico (GOM) the composition of the salpid fauna is still poorly known and this group remains among the less studied zooplankton taxa in the Northwestern Tropical Atlantic. A revised checklist of the salp species recorded in the North Atlantic (NA, 0–40° N) is provided herein, including new information from the Western Caribbean. Zooplankton samples were collected during two cruises (March 2006, January 2007) within a depth range of 0–941 m. A total of 14 species were recorded in our samples, including new records for the CS and GOM area (*Cyclosalpa bakeri* Ritter 1905), for the CS (*Cyclosalpa affinis* (Chamisso, 1819)), and for the Western Caribbean (*Salpa maxima* Forskål, 1774). The number of species of salps known from the CS and GOM rose to 18. A key for the identification of the species recorded in the region is provided. Studies on the ecological role of salps in several sectors of the NA are scarce and deserve further attention.

**Key words:** pelagic tunicates, Yucatan Peninsula, North Atlantic, gelatinous zooplankton, taxonomy

### Introduction

Pelagic tunicates, comprising appendicularians and thaliaceans (doliolids, pyrosomids and salps) are conspicuous members of the gelatinous zooplankton; they inhabit both coastal and oceanic waters. Their distribution and ecology have received more attention in the last decades as they feed closer to the base of the food webs than copepods do and can consume directly a wide size range of preys, thus conferring them a significant role in marine ecosystems (Alldredge & Madin 1982; Andersen 1998; Sutherland *et al.* 2010). In the Northwestern Tropical Atlantic (NWTA), as in other tropical areas where gelatinous zooplankton is highly diverse, pelagic tunicates contribute significantly to the plankton biomass (Michel & Foyo 1976; Longhurst & Pauly 1987; Okolodkov 2003; Bernal *et al.* 2004). However, the regional information on the thaliaceans is scarce and limited to certain sectors of the NWTA (Esnal 1978; Esnal & Simone 1982; Suárez-Morales & Gasca 1996) as compared to appendicularians and other relatively well known gelatinous taxa (Segura-Puertas *et al.* 2003; Sanvicente-Añorve *et al.* 2007; Castellanos & Suárez-Morales 2009; Gasca 2009b; Pugh & Gasca 2009; Flores-Coto *et al.* 2010).

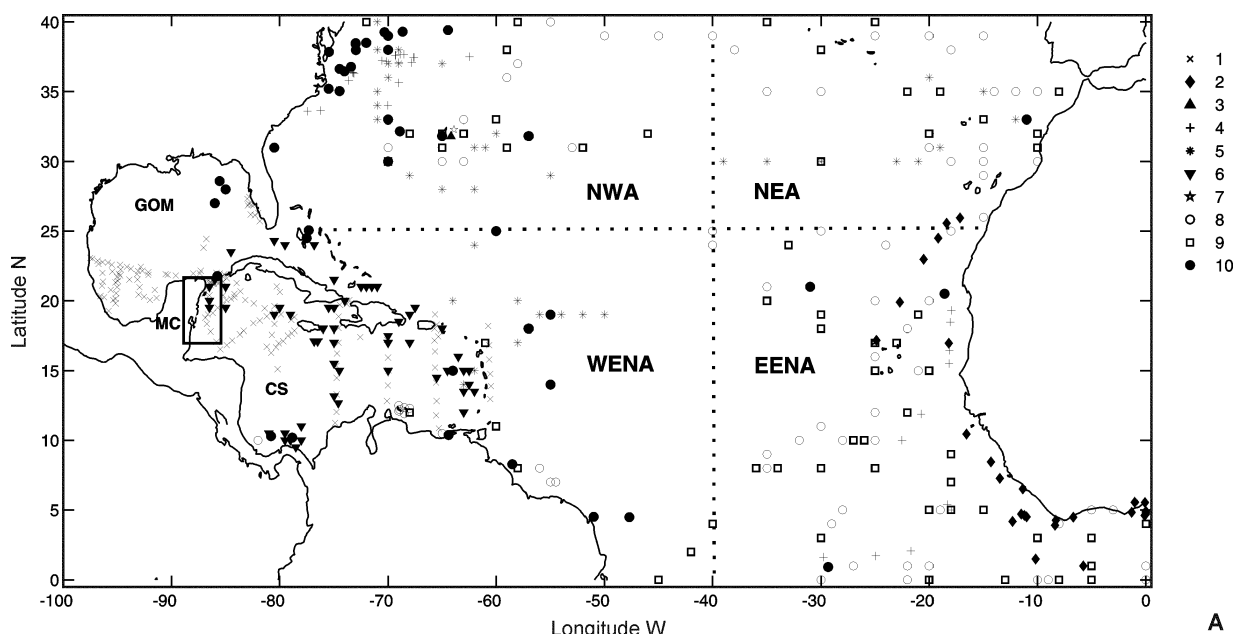
Salps are among the most diverse groups of pelagic tunicates (Van Soest 1998) and, similarly to other thaliaceans, they can form seasonal blooms or swarms. Relatively few species of salps account for most of the reported blooms, related to seasonal increases of local productivity at mid and high latitudes (Madin *et al.* 2006; Deibel & Paffenhofer 2009). Blooms occur more intermittently in tropical-subtropical systems (Madin *et al.* 1996; Hereu *et al.* 2010).

The order Salpida comprises one family (Salpidae) and two subfamilies (Salpinae Yount 1954 and Cyclosalpininae Yount 1954), with eleven and two genera, respectively. In a comprehensive biogeographical survey of the salps (Van Soest 1975a, 1998) no data were included from most of the CS and the GOM. The salpid fauna of these two

basins of the NWTA was studied in some detail by Esnal (1978); however, the oceanic waters off the western Caribbean were poorly represented. Surprisingly, a recent compilation of salp species inhabiting the GOM made reference to five species only (Cole & Lambert 2009) while Esnal (1978) reported 11 species from the GOM (excluding the Yucatan Strait area).

Due to the oceanographic connection between the western CS and the GOM (Richardson 2005) and the relevance of swarming salps in the GOM (Esnal 1978; Deibel & Paffenhofer 2009), a revision of the current knowledge of the salpid fauna is urgently needed; however, the lack of basic data on the composition and the identification of the species is still hindering the ecological study of this group in the region. We provide a revised updated checklist of salps from the Northwestern Atlantic including new data from the Caribbean Sea. The list includes also previous records from the North Atlantic sector from the equator to 40° N and from the Greenwich meridian to the east coast of America. A key for the identification of these salp species is also included together with a basic set of morphological data useful to follow the key.

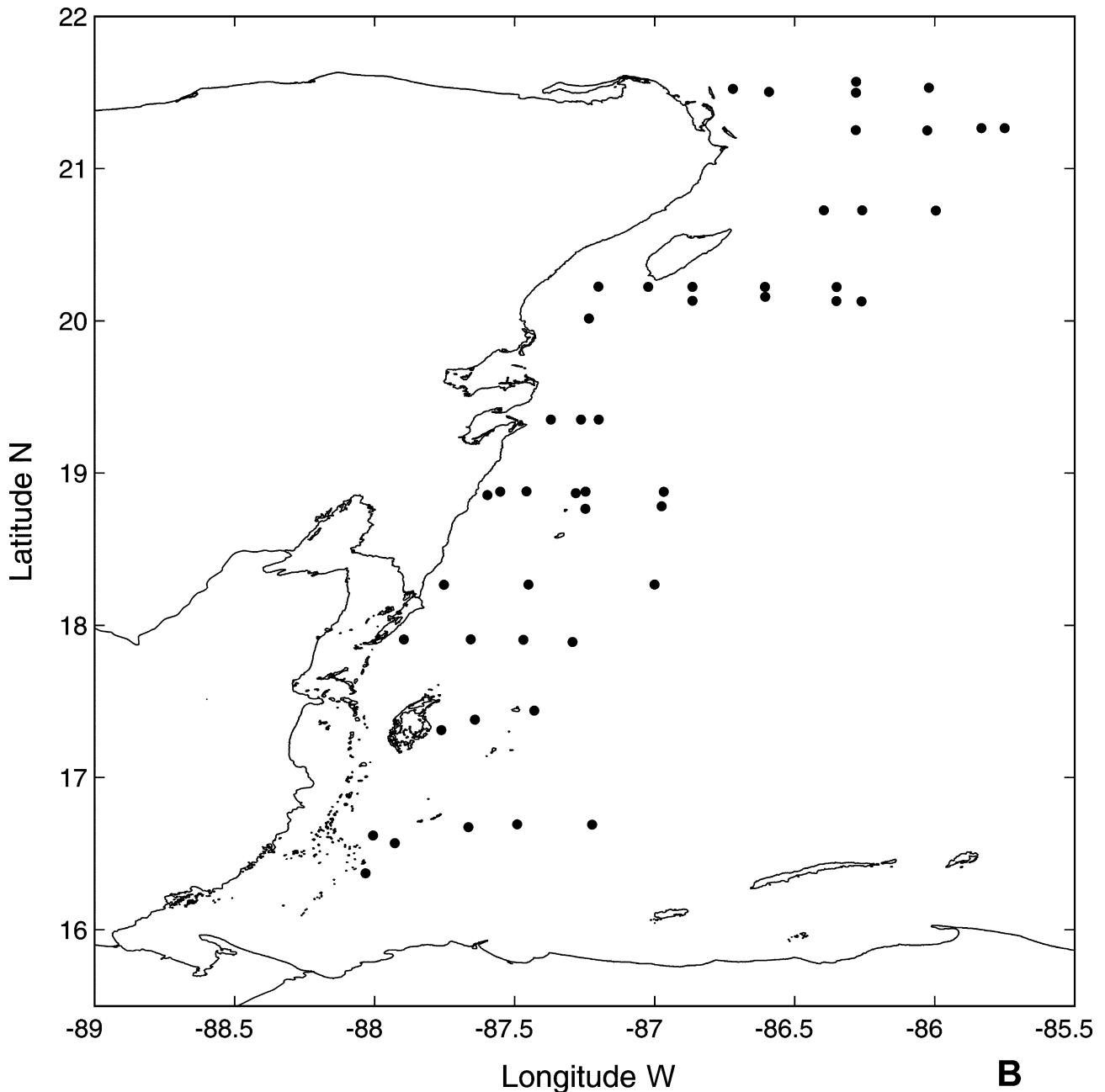
## Material and methods



**FIGURE 1.** A) Location of salp records in the North Atlantic obtained from different sources. Northeastern Atlantic region (NEA) comprises 25°–40°N and 0°–40°W, Northwestern Atlantic (NWA) comprises 25°–40°N and west 40°W, Eastern Equatorial North Atlantic (EENA) comprises 0°–25°N and 0°–40°W, Western Equatorial North Atlantic (WENA) comprises 0°–25°N and west 40°W to the eastern margin of the Caribbean Sea (CS) and Gulf of México (GOM). The Mexican Caribbean region (MC) is denoted within rectangle and amplified in Figure 1 B. References are: 1, Esnal 1978; 2, Godeaux 1977; 3, Madin *et al.* 1996; 4, Madin & Cetta 1984; 5, Madin & Harbison 1978; 6, Michel & Foyo, 1976; 7, Van Soest 1975a; 8, Van Soest 1973, 1974a,b; 9, Van Soest 1975b; 10, Other studies: Metcalf & Bell 1918; Meurice 1970; Owre & Foyo 1972; Tokioka & Bhavanarayana 1979; Wiebe *et al.* 1979; Paffenhofer *et al.* 1995; Johnsen & Widder 1998; Yoon *et al.* 2001; Vargas & Madin 2004; Steinberg *et al.* 2004; Madin *et al.* 2006; Márquez *et al.* 2006; Wiebe *et al.* 2006; Ambler *et al.* 2008; Díaz *et al.* 2008; Cole & Lambert 2009; Cortés 2009.

**Salp records.** The list of species presented here was obtained from the revision of the existing literature on the salpid fauna from the North Atlantic Ocean. Records were obtained from different sources containing salps data in waters from the equator to 40° N. The geographic position of records (not shown here) was obtained mainly from the reference itself; otherwise, it was inferred from visual inspection of the corresponding distribution map in the original source. Localities from which salp records were obtained are plotted in Fig. 1a. Additionally, new data are presented for waters of the Western Caribbean (Fig. 1b). These data were generated from the examination of zooplankton samples collected during two oceanographic cruises (NOAA- ECOSUR) carried out during March-April 2006 and January 2007 on board NOAA's R/V "Gordon Gunter". The sampling gear used was a Multiple Opening/Closing net (MOCNESS, 1 m<sup>2</sup> of mouth area, mesh size 0.3 mm) hauled between the surface and 100 m. During the

2006 cruise, additional deeper (0–941 m) hauls were performed at 3 stations. In 2007, vertical stratified tows every 25 m from 100 m to the surface were performed at 4 stations, with a larger MOCNESS net (10 m<sup>2</sup> mouth area, mesh size 2 mm). Samples were fixed in 4% formalin and later on preserved in Steedman solution. Some samples were fixed and preserved in ethanol for genetic studies. Salps were sorted from the whole original samples and identified following Van Soest (1973, 1974a), Godeaux (1998) and Esnal and Daponte (1999). Based on these references we prepared a key for the identification of salps occurring in the Caribbean Sea and the Gulf of Mexico. Some specimens from the Mexican Caribbean are deposited in the collection of zooplankton held at El Colegio de la Frontera Sur, Chetumal, Mexico (ECO-CHZ).



**FIGURE 1.** B) Stations within the Mexican Caribbean (MC) visited on March/April 2006 and January 2007.

**TABLE 1.** List of salp species from different sectors of the North Atlantic as depicted in Figure 1A, B: Mexican Caribbean (MC), Caribbean Sea (CS) and Gulf of Mexico (GOM), Western Equatorial North Atlantic (WENA), Eastern Equatorial North Atlantic (EENA), Northwestern Atlantic (NWA) and Northeastern Atlantic (NEA).

Species / Region	MC	CS & GOM	WENA	EENA	NWA	NEA
<i>Cyclosalpa affinis</i> (Chamisso, 1819)	X	X	X	X	X	X
<i>Cyclosalpa polae</i> Sigl, 1912	X	X	X	X	X	X
<i>Pegea confoederata</i> (Forskål, 1775)	X	X	X	X	X	X
<i>Ritteriella retracta</i> (Ritter, 1906)	X	X	X	X	X	X
<i>Thalia democratica</i> (Forskål, 1775)	X	X	X	X	X	X
<i>Thalia orientalis</i> Tokioka, 1937	X	X	X	X	X	X
<i>Weelia cylindrica</i> (Cuvier, 1804)	X	X	X	X	X	X
<i>Salpa fusiformis</i> Cuvier, 1804	X	X	X	X	X	X
<i>Salpa maxima</i> Forskål, 1774	X	X	X	X	X	X
<i>Salpa aspera</i> Chamisso, 1819	-	X	X	X	X	X
<i>Thalia cicar</i> Van Soest, 1973	X	X	X	X	X	- <sup>1</sup>
<i>Brooksia rostrata</i> (Traustedt, 1893)	X	X	X	X	X	X
<i>Ihlea punctata</i> (Forskål, 1775)	X	X	X	X	X	X
<i>Traustedia multitentaculata</i> (Quoy & Gaimard, 1834)	X	X	X	X	X	X
<i>Iasis zonaria</i> (Pallas, 1774)	-	X	X	X	X	- <sup>1</sup>
<i>Cyclosalpa floridana</i> (Apstein, 1894)	-	X	-	X	X	-
<i>Thetys vagina</i> Tilesius, 1802	-	X	-	X	X	- <sup>1</sup>
<i>Helicosalpa virgula</i> (Vogt, 1854)	-	-	X	X	X	X
<i>Pegea bicaudata</i> (Quoy & Gaimard, 1826)	-	-	X	-	X	X
<i>Cyclosalpa bakeri</i> Ritter, 1905	X	-	-	X	- <sup>1</sup>	-
<i>Cyclosalpa pinnata</i> (Forskål, 1775)	-	-	-	-	X	X
<i>Pegea socia</i> (Forskål, 1775)	-	-	-	-	X	X
<i>Cyclosalpa foxtoni</i> Van Soest, 1974	-	-	-	-	X	- <sup>1</sup>
<i>Ritteriella amboinensis</i> (Apstein, 1904)	-	-	-	X <sup>2</sup>	-	X
<i>Salpa younti</i> Van Soest, 1973	-	-	-	X	X	- <sup>1</sup>
<i>Cyclosalpa danae</i> Van Soest 1975	-	-	-	X	-	- <sup>1</sup>
Total number of species	26	14	17	22	23	18

1-reported north from 40° N; 2-doubtful record from Gulf of Guinea, according to Van Soest (1974a)

## Results and discussion

A revised checklist of salps records from the Caribbean Sea (CS) and the Gulf of Mexico (GOM) is presented in Table 1. It includes previous records from the literature and those resulting from our samples. Other salps species that have been reported from North Atlantic (0–40° N) are also listed considering a division of regions (see Fig 1). The names used in the table are those currently recognized as valid (Van Soest 1998; but see also Govindarajan *et al.* 2010).

The total number of species recorded from the northwestern CS during both cruises was 14, with 11 and 14 species occurring during 2006 and 2007, respectively. These surveys allowed an increase of the number of species previously reported from both the CS (15 species) and the GOM (14 species) to 18 (Table 1). The occurrence of *Brooksia rostrata* (Traustedt, 1893), *Cyclosalpa affinis* (Chamisso, 1819) and *Thalia orientalis* Tokioka, 1937 marked the difference between the cruises.

*Cyclosalpa bakeri* Ritter, 1905 is a new record for both sectors (CS and GOM) with another record only at the EENA (Godeaux 1977). Our records of *C. bakeri* are for the aggregate form. The morphological differences between the aggregates of *C. bakeri* and the closely related *C. foxtoni* (Van Soest, 1974) are subtle. *Cyclosalpa foxtoni* was described from the Bermuda area; however, the possibility of *C. bakeri* occurring in the tropical Atlantic and the Caribbean is high (R. W. M. Van Soest, pers. comm. to C.H.). This species seems to be scarce in the Atlantic

Ocean (Van Soest 1974a; Esnal & Daponte 1999) though it is not uncommon in other areas such as North Pacific where it occasionally blooms (Madin *et al.* 1997; Lavaniegos & Ohman 2003).

The record of *Cyclosalpa affinis* is new for the CS; hitherto, it was known to occur west from Florida (Johnsen & Widder 1998). It is considered a rare salp mainly found in warm and temperate waters (Yount 1958; Esnal & Daponte 1999). In the surveyed area it was recorded from one station south-east to Cozumel Island during a stratified sampling.

The occurrence of *Salpa maxima* Forskål, 1774 in our samples represents a new record for the northwestern CS; there are only two previous records of this species in the region at about 12° N–68° W (Van Soest 1974b). It is a moderately abundant species in the North Atlantic but is less common in the Caribbean Sea according to Van Soest (1974b) and data from our surveyed area. These three species (*Salpa maxima*, *Cyclosalpa bakeri* and *C. affinis*) have been reported also in the South Atlantic from 0 to 20° S (*C. affinis*) and to about 40° S (*C. bakeri* and *S. maxima*) (Esnal & Daponte 1999) where they are also scarce.

We did not find *Cyclosalpa floridana* (Apstein, 1894), *Iasis zonaria* (Pallas, 1774), and *Salpa aspera* Chamisso, 1819, which have been previously recorded in the area and in other sectors of the North Atlantic as well (Table 1). Within the CS and the GOM basins, only the former species have been deemed as frequent (Esnal 1978) probably due to its warm water affinity (Van Soest 1974b). Despite being considered among the species most widely distributed (Van Soest 1998), the other two have been recorded only from a few locales at the southern GOM (*I. zonaria*) and at one of the eastern Caribbean (*S. aspera*) (Esnal 1978).

The dominant species in our samples of the Western Caribbean waters were *Thalia cicar* Van Soest, 1973, *T. democratica* (Forskål, 1775), *Weelia cylindrica* (Cuvier, 1804), and *S. fusiformis* Cuvier, 1804. Similar results were obtained by Esnal (1978) and Michel and Foyo (1976). These species are widely distributed and are usually reported as swarming forms worldwide (Andersen 1998). They are known to swarm in the CS and GOM (Michel & Foyo 1976; Esnal 1998), but they had moderate abundances in our surveys.

Of the 44 known species of salps (Van Soest 1998), 30 occur in the Atlantic Ocean, with 23 species within the tropics (20° S to 20° N) and 26 (25) species dwelling in subtropical and temperate waters at northern (southern) hemisphere (Van Soest 1998; Esnal & Daponte 1999). Of the 26 species known to occur in the North Atlantic (0–40° N), up to 12 were found in the surveyed area (CS), including the new records (Table 1, Fig. 1). *Thalia cicar*, dwelling the equatorial and northwestern region, is absent from the northeastern sector, though it may occur north of 40°N (Van Soest 1998; Van der Land & Van Soest 2000). Nine species reported from the North Atlantic have not been reported in the CS and GOM. Two of them, *Helicosalpa virgula* (Vogt, 1854) and *Pegea bicaudata* (Quoy & Gaimard, 1826), are known to occur in the neighboring WENA, so those species could also be distributed in the CS because of the oceanographic connections of these areas (Richardson 2005). *Cyclosalpa pinnata* (Forskål, 1775), *C. foxtoni* Van Soest, 1974, and *P. socia* (Forskål, 1775) appear to be restricted to higher latitudes. However, the former species has also been reported in low latitudes from the South Atlantic, (0° to 20°S) (Esnal & Daponte 1999).

The incorporation of data of more recent studies and new samplings (Table 1) within this area has not increased the list of species known in the North Atlantic (Van Soest 1998), but the number of records has increased for the Caribbean Sea sector. Sympatric occurrence of related species of *Salpa* and *Cyclosalpa* in temperate and tropical waters of the Atlantic are not uncommon, so it could be expected that other species may also occur within the CS and the GOM. For example, *S. younti* Van Soest, 1973, described from specimens collected in the Bermuda area (NWA) and also found in the Equatorial Atlantic (Van Soest 1973) co-occurs with *S. aspera*. Similarly, *C. foxtoni* Van Soest 1974 and *C. danae* Van Soest 1975 (both described from samples collected in the Atlantic) have been found in co-occurrence with *C. bakeri* and *C. affinis*, respectively (Van Soest 1975b).

The use of complementary sampling devices may become an important factor to increase the local and regional lists of species. *Cyclosalpa affinis* was collected in the GOM area by SCUBA diving (Johnsen & Widder 1998) and in the surveyed area it was collected during a stratified sampling with a MOCNESS net. *Salpa maxima* and *Cyclosalpa bakeri* were also collected in our surveyed area by using different MOCNESS nets systems. Similarly, the use

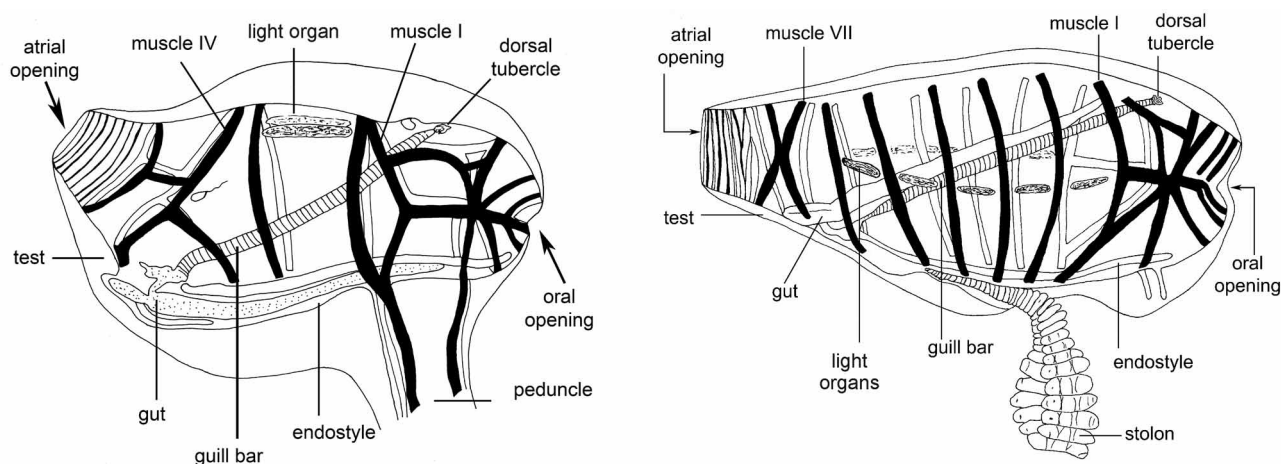
of different methods of collection complemented the list of species of salps of the WENA sector (Wiebe *et al.* 2006). Most of our knowledge of the zooplankton in the Western Caribbean derives from collections of the epipelagic layers; it has been proved that deeper samplings provide new records of different zooplankton groups (Gasca 2009a,b). This is probably true for salps since some species are known to perform extended vertical migrations (Van Soest 1975a). Furthermore, a new species of salp is reported to be limited to the meso- and bathypelagic depths (Govindarajan *et al.* 2010). Overall, the knowledge of the salpid fauna of the North Atlantic, and particularly within the GOM, the southwestern Caribbean and the WENA is still limited and deserve further attention.

### General morphology and structures useful for identification of salps

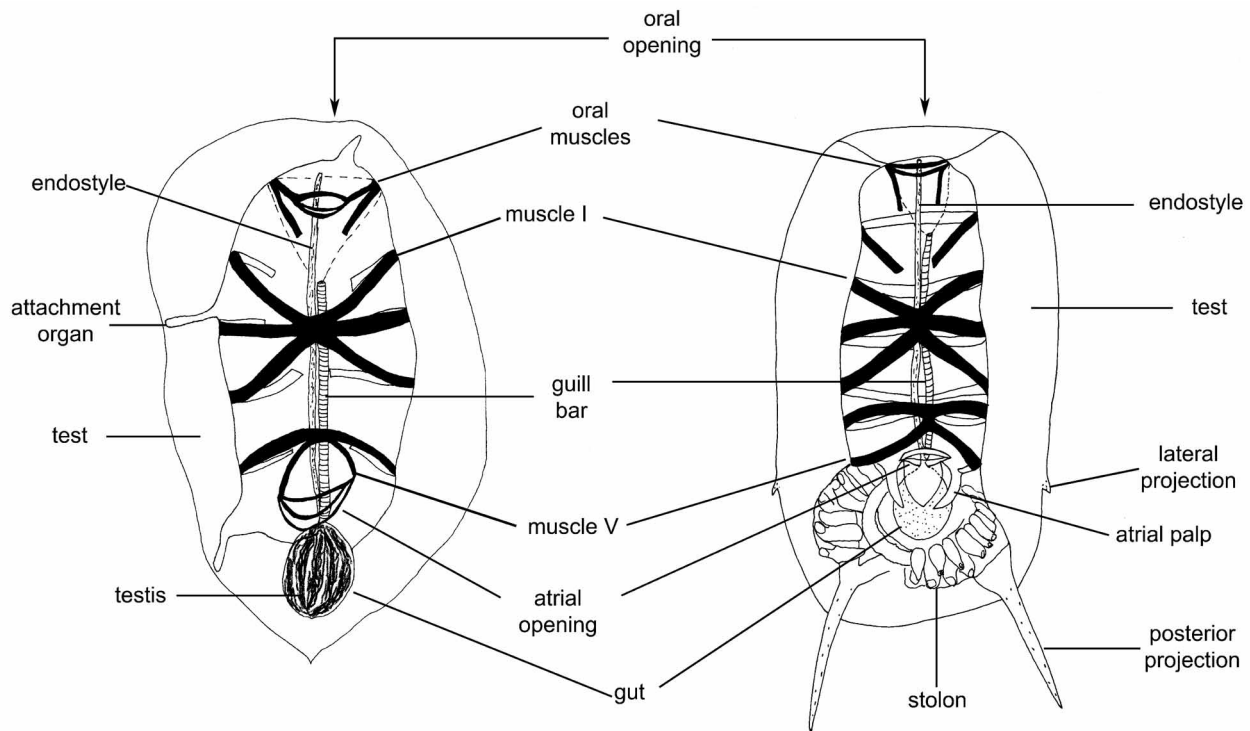
The life cycle of salps characterizes by the alternation of two forms. An aggregate (blastozoid) sexual generation alternates with a solitary (oozoid) generation of asexual reproduction, without mediating a larval phase. Both solitary and aggregate zooids are recognized by their transparent barrel-shaped test and the presence of an anterior oral opening and a posterior cloacal (atrial) opening located dorsally or terminally (Figs. 2 and 3). Body muscles encircling the body are arranged forming whether complete or interrupted bands, running parallel, touching or fusing. The atrial and branchial cavities, almost continuous, are interrupted by a large ciliated branchial bar lying obliquely across the cavity. The endostyle stretches ventrally. The alimentary canal (gut) is a straightened tube overlying the branchial bar (Fig. 2), a tube bent into a broad loop, or else into a more or less dense loop at the posterior end of the body (Fig. 3). One or more pairs of light organs may be present (Fig. 2). In the aggregate form, gonads lie posteriorly; in the solitary form, a stolon protruding from test mid-ventrally may be present, holding the aggregates in whorls or in double rows.

The most frequently used morphological features for the taxonomic identification of salps, are: the arrangement of the body muscles; the number of fibers per muscle; the presence of projections or ornaments in test; the structure of light organs and the morphology of the dorsal tubercle. The determination of salps species is easier considering separately the two forms of their life cycle, *i.e.* the aggregate form or blastozoid, normally identified by the presence of one or more eggs, and the oozoid or solitary form, normally identified by the presence of the stolon.

The following account of the classification for the salp species found in Mexican waters of the Caribbean Sea follows the arrangement by Ihle and Ihle-Landenberg (1933). The key includes the species recordered in the Caribbean samples analyzed and also other species that could also occur in the area, *i.e.* species previously found in the CS and the GOM, but not present in our samples (Table 1). The references cited under the previous section present figures and details remarks for the species in the key, and will be not reproduced here. Figures 2 and 3 represent the general morphology and structures position useful to discriminate between subfamilies (*Cyclosalpinæ* and *Salpinæ*) and zooids (aggregate and solitary). Though *Cyclosalpa pinnata* has been not reported for the CS or the GOM, it was chosen as the most suitable species to depict general features of the subfamily *Cyclosalpinæ*.



**FIGURE 2.** General morphology of *Cyclosalpinæ*. Lateral view of *Cyclosalpa pinnata* aggregate zooid (left) and solitary zooid (right). Redrawn from Metcalf & Bell (1918).



**FIGURE 3.** General morphology of Salpinae. Dorsal view of *Thalia democratica* aggregate zooid (left) and solitary zooid (right). Redrawn from Esnal & Daponte (1999) with permission of authors.

### Key to salp species from the Caribbean Sea and Gulf of Mexico

- 1 Animals bearing gonads, one or more eggs or embryos, stolon always absent, blastozooid or aggregate form . . . . . (19)
- Animals bearing a stolon ventrally or posteriorly, gonads always absent, oozooid or solitary form . . . . . (2)
- 2 Gut straight overlying the branchial bar, light organs usually present, seven annular body muscles generally interrupted ventrally . . . . . Cyclosalpinae... (3)
- Gut not accompanying the branchial bar, gut usually bent into a more or less compact loop posteriorly, light organs always absent. . . . . Salpinae... (6)
- 3 Dorsal longitudinal muscles absent . . . . . (4)
- Dorsal longitudinal muscles present . . . . . (5)
- 4 Light organs absent, muscles M I and M II interrupted dorsally, dorsal tubercle strongly convoluted. . . . . *Cyclosalpa affinis*
- Light organs weakly developed between M II and M VI, dorsal tubercle C-shaped, M I to M V fused ventrally into a single mass, M VI interrupted ventrally but M VII continuous ventrally . . . . . *Cyclosalpa floridana*
- 5 Dorsal longitudinal muscles fused in only one; five pairs of light organs; dorsal tubercle moderately convoluted . . . . .
- . . . . . *Cyclosalpa polae*
- Two dorsal longitudinal muscles running parallel; six pairs of light organs; dorsal tubercle G-shaped. . . . . *Cyclosalpa bakeri*
- 6 Ten or more body muscles. . . . . (7)
- Less than ten body muscles. . . . . (8)
- 7 Ten to 20 body muscles, all interrupted ventrally and continuous dorsally, fusing or exchanging fibers; gut straightened longitudinally, test thin and flabby . . . . . *Ritteriella retracta*
- Test firm and thick with spines scattered on its surface; at least 16 (16 to 22) body muscles, all interrupted dorsally and ventrally, zooid attaining a large size . . . . . *Thetys vagina*
- 8 Nine body muscles . . . . . (9)
- Less than nine body muscles. . . . . (12)
- 9 Longitudinal muscles on each side of the body present, nine broad body muscles continuous around the body except M VIII, interrupted ventrally . . . . . *Ihleia punctata*
- No longitudinal muscles on each side of the body . . . . . (10)
- 10 All body muscles parallel to each other, test smooth. . . . . *Salpa maxima*
- Some body muscles fusing or approaching dorsally . . . . . (11)
- 11 Muscles I to III and M VIII to M IX strongly fused dorsally, test entirely smooth . . . . . *Salpa fusiformis*
- Muscles I to M III fused or closely approaching dorsally, M VIII and M IX parallel or converging but not fusing, test ridges longitudinal and serrated. . . . . *Salpa aspera*
- 12 Eight body muscles; M I to M IV fused or closely approaching dorsally, test smooth. . . . . *Weelia cylindrica*<sup>1</sup>
- Less than eight body muscles . . . . . (13)

- 13 Seven body muscles continuous in two dorsal groups (M I–M III and M IV–M VII), M III and M IV touching or fusing laterally, a long proboscis bearing longitudinal muscles . . . . . *Brooksia rostrata*  
 - Four or five body muscles . . . . . (14)
- 14 Five broad parallel body muscles interrupted dorsally and ventrally . . . . . *Iasis zonaria*  
 - Four or five narrow body muscles, continuous dorsally . . . . . (15)
- 15 Four short body muscles firmly fused dorsally in two groups, M I–M II and M III–M IV, test barrel-shaped without projections . . . . . *Pegea confoederata*  
 - Five body muscles, test bearing projections . . . . . (16)
- 16 Body oval, numerous projections protruding into the test, some of them beyond it, muscles widely interrupted ventrally . . . . . *Traustedia multitentaculata*  
 - Body cylindrical with two posterior projections . . . . . (17)
- 17 Cloacal palps simple . . . . . *Thalia democratica*  
 - Cloacal palps bifurcate . . . . . (18)
- 18 Posterior projections very long, no lateral projections . . . . . *Thalia orientalis*  
 - Posterior projections short, two lateral projections long, test bulky and smooth . . . . . *Thalia cicar*
- 19 Four body muscles arranged asymmetrical or symmetrical, gut forming either an extended tube or loose loop, never forming a compact nucleus; one pair of light organs may be present . . . . . Cyclosalpinæ (20)  
 - Gut always forming a more or less compact nucleus, four or more body muscles; light organs always missing . . . . . Salpinæ... (23)
- 20 Body muscles arranged asymmetrical (there are dextral and sinistral individuals like mirror images), dorsal tubercle C-shaped, intestine loop swelling outwards from the body wall; two posterior projections, one bearing a caecum on the right ventral side and another bearing a testis on the left dorsal side posteriorly to the intestine; a pair of light organs may be present between M I and M II . . . . . *Cyclosalpa bakeri*  
 - Body muscles arranged symmetrical . . . . . (21)
- 21 Light organs absent . . . . . (22)  
 - One pair of light organs present, muscles I and II and muscles III and IV fused dorsally, dorsal tubercle W-shaped, peduncle very long . . . . . *Cyclosalpa polae*
- 22 Body muscles free dorsally, dorsal tubercle strongly convoluted, gut loose coiled protruding strongly posteriorly, testis within the loop of the gut . . . . . *Cyclosalpa affinis*  
 - Body muscles I and M II, and M III and M IV strongly fused dorsally, both groups approaching dorsally, M II and M III touching ventrally; a simple C-shaped dorsal tubercle; testis beyond the intestine swelling the body wall outwards . . . . . *Cyclosalpa floridana*
- 23 Four body muscles . . . . . (24)  
 - Five or six body muscles . . . . . (26)
- 24 Body muscles symmetrically arranged, fused in two groups: muscles I–II and MIII–IV, interrupted ventrally . . . . . (25)  
 - Body asymmetrical, body muscles conjoining ventrally and dorsally as a simple mass, body oval . . . . . *Brooksia rostrata*
- 25 Body muscles very short, body plump, nucleus reddish-brown; mean number of muscles fibers: MI: 14; MII: 1; MIII: 13; MIV: 12 . . . . . *Pegea confoederata*  
 - Body muscles strongly fused in two groups, MIV branching laterally, test soft, globular, nucleus protruding between two long posterior projections . . . . . *Traustedia multitentaculata*
- 26 Five body muscles . . . . . (27)  
 - Six body muscles . . . . . (32)
- 27 Five body muscles parallel or approaching dorsally . . . . . (28)  
 - Body muscles continuous, fusing or touching dorsally . . . . . (29)
- 28 Body muscles broad and parallel, interrupted ventrally, M I interrupted dorsally; test very firm, with a posterior projection; three or more embryos between M IV and M V . . . . . *Iasis zonaria*  
 - Body muscles narrow and short, interrupted dorsally and ventrally; test firm and thick, with longitudinal rows of spines, zooid reaching a large size . . . . . *Thetys vagina*
- 29 Two groups of body muscles, M I–III and M IV–V fusing or closely approaching dorsally; body fusiform. . . . . *Weelia cylindrica*  
 - Two groups of body muscles, MI–III and MIV–V separately dorsally, total number of muscles fibers MI–MV: 15 to 17, usually 16; body oval . . . . . (30)
- 30 Posterior part of the test rounded, not pentagonal . . . . . *Thalia cicar*  
 - Posterior part of the test pentagonally pointed . . . . . (31)
- 31 Nucleus bearing a posterior projection . . . . . *Thalia democratica*  
 - No posterior projection on nucleus, anterior attachment organs protruding beyond body wall . . . . . *Thalia orientalis*
- 32 Body muscles asymmetrical; M I and M II, sometimes M III, fused dorsally, M IV and M V parallel, M V and M VI fused dorsally but largely separated laterally; test flabby, dolioliform. . . . . *Ihlea punctata*  
 - Body muscles symmetrically arranged into three dorsal groups: M I–II, M III–IV and M V–VI, test thick and firm, body fusiform . . . . . (33)
- 33 Muscles I and II more strongly fused than M III–IV, muscles fibers in M I: 12 (overall M I to M VI: 60–119) . . . . . *Ritteriella retracta*  
 - Muscles I–II and M III–IV equally fused dorsally, both groups touching or approaching dorsally . . . . . (34)

1. According to Van Soest (1975b) the number of body muscles in the solitary zooid of *Weelia cylindrica* is either 8 or 9. For the Atlantic Ocean the author found only specimens with 8 body muscles, as we have also observed in specimens collected from Mexican Caribbean Sea.



- 34 Anterior and posterior projections echinated, posterior projection with a bifid appearance . . . . . *Salpa aspera*  
 - Test completely smooth . . . . . (35)  
 35 Groups of muscles I–II and III–IV closely approaching dorsally; M IV and V not approaching laterally . . . . . *Salpa maxima*  
 - Groups of muscles I–IV fused dorsally; M IV and V fused laterally. . . . . *Salpa fusiformis*

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## References

- Allredge, A.L. & Madin, L.P. (1982) Pelagic Tunicates: Unique Herbivores in the Marine Plankton. *Bioscience*, 32, 655–663.
- Andersen, V. (1998) Salp and pyrosomid blooms and their importance in biogeochemical cycles. In: Q. Bone (Ed), *The biology of pelagic tunicates*. Oxford University Press, Oxford, pp. 125–138.
- Ambler, J.W., Aulenbach, D.L., Peck, A.T., Winsor, M.A. & Makinen, C.P. (2008) Interannual variability in summer cladoceran-tunicate blooms in coastal waters of Wallops Island, VA. In: *2008 Ocean Science Meeting*, Orlando, Florida.
- Bernal, Á., Werding, B. & Zea, S. (2004) Variación espacial y temporal de biomasa zooplanctónica en el sector nerítico del mar Caribe colombiano. In: N.F. Campos & P.A. Acero (Eds), *Contribuciones en ciencias del mar en Colombia: investigación y desarrollo de territorios promisorios*. Universidad Nacional de Colombia, Bogotá, p. 262.
- Castellanos, I. & Suárez-Morales, E. (2009) Appendicularia (Urochordata) of the Gulf of Mexico. In: D.L. Felder & D.K. Camp (Eds), *Gulf of Mexico. Origin, Waters, and Biota. Vol. 1, Biodiversity*. Texas A&M University Press, USA, pp. 841–869.
- Cole, L. & Lambert, G. (2009) Tunicata (Urochordata) of the Gulf of Mexico. In: D.L. Felder & D.K. Camp (Eds), *Gulf of Mexico Origin, Waters, and Biota. Volume 1, Biodiversity*. Texas A&M University Press, USA, pp. 1209–1216.
- Cortés, J. (2009) Other Taxonomic Groups (Fungi, Kinorhynchs, Invertebrate Chordates). In: *Marine Biodiversity of Costa Rica, Central America*, pp. 497–500.
- Deibel, D. & Paffenhofer, G.A. (2009) Predictability of patches of neritic salps and doliolids (Tunicata, Thaliacea). *Journal of Plankton Research*, 31, 1571–1579.
- Díaz, X.F.G., Gusmão, L.M.d.O. & Neumann-Leitão, S. (2008) New record of *Thalia cicar van Soest 1973* (Urochordata: Thaliacea) in the Equatorial Atlantic. *Biota Neotropica*, 8, 99–104.
- Esnal, G.B. (1978) Los salpidos (Tunicata, Thaliacea) del Golfo de Mexico y Mar Caribe. *Physis, Buenos Aires, sección A*, 38, 59–66.
- Esnal, G.B. & Daponte, M.C. (1999) Salpida. In: D. Boltovskoy (Ed), *South Atlantic Zooplankton*. Backhuys Publisher, Leiden, pp. 1423–1444.
- Esnal, G.B. & Simone, L.C. (1982) Diliolidos (Tunicata, Thaliacea) del Golfo de Mexico y Mar Caribe. *Physis, Buenos Aires, sección A*, 40, 51–57.
- Flores-Coto, C., Sanvicente-Añorve, L. & Sánchez-Ramírez, M. (2010) Appendicularian distribution and diversity in the southern Gulf of Mexico. *Revista Mexicana de Biodiversidad*, 81, 123–132.
- Gasca, R. (2009a) Diversity of Hyperiid Amphipods (Crustacea: Peracarida) in the Western Caribbean Sea: News from the Deep. *Zoological Studies*, 48, 63–70.
- Gasca, R. (2009b) Diversity of Siphonophora (Cnidaria: Hydrozoa) in the Western Caribbean Sea: new records from deep-water trawls. *Zootaxa*, 2095, 60–68.
- Godeaux, J. (1977) Thaliacea from the coast of tropical West Africa. *Atlantide Repport*, 12, 7–24.
- Godeaux, J. (1998) The relationships and systematic of the Thaliacea, with keys for identification. In: Q. Bone (Ed), *The biology of pelagic tunicates*. Oxford University Press, Oxford, pp. 273–294.
- Govindarajan, A.F., Bucklin, A. & Madin, L.P. (2010) A molecular phylogeny of the Thaliacea. *Journal of Plankton Research*, 33, 843–853.
- Hereu, C.M., Lavaniegos, B.E. & Goericke, R. (2010) Grazing impact of salp (Tunicata, Thaliacea) assemblages in the eastern tropical North Pacific. *Journal of Plankton Research*, 32, 785–804.
- Ihle, J.E.W. & Ihle-Landenberg, M.E. (1933) Anatomische Untersuchungen über Salpen IV. Allgemeine über den Darmkanal der Salpen. *Zoologische Anzeiger*, 104, 194–200.
- Johnsen, S. & Widder, E.A. (1998) Transparency and Visibility of Gelatinous Zooplankton from the Northwestern Atlantic and

- Gulf of Mexico. *Biological Bulletin*, 195, 337–348.
- Lavaniegos, B.E. & Ohman, M.D. (2003) Long-term changes in pelagic tunicates of the California Current. *Deep Sea Research Part II: Topical Studies in Oceanography*, 50, 2473–2498.
- Longhurst, A. & Pauly, D. (1987) *Ecology of Tropical Oceans*. Academic Press, Sand Diego, California, 407 pp.
- Madin, L.P. & Cetta, C.M. (1984) The use of gut fluorescence to estimate grazing by oceanic salps. *Journal of Plankton Research*, 6, 475–492.
- Madin, L.P. & Harbison, G.R. (1978) Salps of the genus *Pegea* Savigny 1816 (Tunicata: Thaliacea). *Bulletin of Marine Science*, 28, 335–344.
- Madin, L.P., Kremer, P. & Hacker, S. (1996) Distribution and vertical migration of salps (Tunicata, Thaliacea) near Bermuda. *Journal of Plankton Research*, 18, 747–755.
- Madin, L.P., Kremer, P., Wiebe, P.H., Purcell, J.E., Horgan, E.H. & Nemazie, D.A. (2006) Periodic swarms of the salp *Salpa aspera* in the Slope Water off the NE United States: Biovolume, vertical migration, grazing, and vertical flux. *Deep Sea Research Part I*, 53, 804–819.
- Madin, L.P., Purcell, J.E. & Miller, C.B. (1997) Abundance and grazing effects of *Cyclosalpa bakeri* in the subarctic Pacific. *Marine Ecology Progress Series*, 157, 175–183.
- Márquez, B., Marín, B., Zoppi, E. & Moreno, C. (2006) Zooplankton del Golfo de Cariaco. *Boletín del Instituto Oceanográfico de Venezuela, Universidad de Oriente*, 45, 61–78.
- Metcalf, M.M. & Bell, M. M. (1918) The Salpidae: a Taxonomic Study. *Bulletin of the United States National Museum*, 100, 5–193.
- Meurice, J.C. (1970) Contribution à l'étude du genre *Ritteriella* : *Ritteriella* Amboinens Apstein. *Annales de la Société Royale Zoologique de Belgique*, 100, 191–214.
- Michel, H.B. & Foyo, M. (1976) Caribbean Zooplankton. Part I. Siphonophora, Heteropoda, Copepoda, Euphausiacea, Chaetognatha and Salpidae. Government Printing Office, U.S. Department of the Navy. 549 pp.
- Okolodkov, Y.B. (2003) Una revisión de investigaciones rusas de plancton en el Golfo de México y Mar Caribe en los 1960–1980's. *Hidrobiológica*, 13, 207–221.
- Owre, H.B. & Foyo, M. (1972) Studies on Caribbean Zooplankton. Description of the Program and Results of the First Cruise. *Bulletin of Marine Science*, 22, 483–521.
- Paffenhöfer, G.A., Atkinson, L.P., Lee, T.N., Verity, P.G. & Bulluck, L.R. (1995) Distribution and abundance of thaliaceans and copepods off the southeastern U.S.A. during winter. *Continental Shelf Research*, 15, 255–280.
- Pugh, P.R. & Gasca, R. (2009) Siphonophorae (Cnidaria) of the Gulf of Mexico. In: D.L. Felder & D.K. Camp (Eds), *Gulf of Mexico. Origin, Waters, and Biota. Vol. 1, Biodiversity*. Texas A&M University Press, USA, pp. 395–402.
- Richardson, P.L. (2005) Caribbean Current and eddies as observed by surface drifters. *Deep Sea Research Part II: Topical Studies in Oceanography*, 52, 429–463.
- Sanvicente-Añorve, L., Alatorre, M.A., Flores-Coto, C. & Alba, C. (2007) Relationships between fish larvae and siphonophores in the water column: effect of wind-induced turbulence and thermocline depth. *ICES Journal of Marine Science*, 64, 878–888.
- Segura-Puertas, L., Suárez-Morales, E. & Celis, L. (2003) A checklist of the Medusae (Hydrozoa, Scyphozoa and Cubozoa) of Mexico. *Zootaxa*, 194, 1–15.
- Steinberg, D.K., Nelson, N.B., Carlson, C.A. & Prusak, A.C. (2004) Production of chromophoric dissolved organic matter (CDOM) in the open ocean by zooplankton and the colonial cyanobacterium *Trichodesmium* spp. *Marine Ecology Progress Series*, 267, 45–56.
- Suárez-Morales, E. & Gasca, R. (1996) Introducción al estudio del zooplankton marino. In: R. Gasca & E. Suárez (Eds), *Introducción al estudio del zooplankton marino*. El Colegio de la Frontera Sur, Mexico, pp. 665–711.
- Sutherland, K.R., Madin, L.P. & Stocker, R. (2010) Filtration of submicrometer particles by pelagic tunicates. *Proceedings of the National Academy of Sciences of the United States of America*, 107, 15129–15134.
- Tokioka, T. & Bhavanarayana, P.B. (1979) Notes on the occurrence of a swarm of *Salpa cylindrica* Cuvier (Tunicata: Salpidae) in Sardinera Lagoon, Puerto Rico. *Proceedings of the Biological Society of Washington*, 92, 572–576.
- Van der Land, J. & Van Soest, R.W.M. (2000) Thaliacea. In: M.J. Costello, C. Emblow & R. White (Eds), *European Register of Marine Species. A check-list of the marine species in Europe and a bibliography of guides to their identification*. Courier Forschungsinstitut Senckenberg, pp. 337–338.
- Van Soest, R.M.W. (1973) The genus *Thalia* Blumenbach, 1798 (Tunicata, Thaliacea), with descriptions of two new species. *Beaufortia*, 20, 193–212.
- Van Soest, R.M.W. (1974a) A revision of the genera *Salpa* Forskål, 1775, *Pegea* Savigny, 1816, and *Ritteriella* Metcalf, 1919 (Tunicata, Thaliacea). *Beaufortia*, 22, 153–191.
- Van Soest, R.M.W. (1974b) Taxonomy of the subfamily Cyclosalpininae Yount, 1954, with descriptions of two new species. *Beaufortia*, 22, 17–55.
- Van Soest, R.M.W. (1975a) Zoogeography and speciation in the Salpidae (Tunicata, thaliacea). *Beaufortia*, 23, 181–215.
- Van Soest, R.M.W. (1975b) Observations on taxonomy and distribution of some salps (Tunicata, Thaliacea), with description of three new species. *Beaufortia*, 23, 105–130.
- Van Soest, R.W.M. (1998) The cladistic biogeography of salps and pyrosomas. In: Q. Bone (Ed), *The biology of pelagic tunicates*. Oxford University Press, Oxford, pp. 231–249.

- Vargas, C.A. & Madin, L.P. (2004) Zooplankton feeding ecology: clearance and ingestion rates of the salps *Thalia democratica*, *Cyclosalpa affinis* and *Salpa cylindrica* on naturally occurring particles in the Mid-Atlantic Bight. *Journal of Plankton Research*, 28, 827–833.
- Wiebe, P., Madin, L., Haury, L.R., Harbison, G.R. & Philbin, L.M. (1979) Diel vertical migration by *Salpa aspera* and its potential for large-scale particulate organic matter transport to the deep-sea. *Marine Biology*, 53, 249–255.
- Wiebe, P., Madin, L., Pagès, F., Lindsay, D., Hansen, H.Ø., Panampunnayil, S., *et al.* (2006) RV/Ronald H. Brown Cruise 06-03 to the Western Subtropical and Tropical North Atlantic 10 April to 30 April, 2006. In: *A Census of Marine Zooplankton (CMarZ) Report*, p. 164 pp. (available online from <http://www.cmarz.org>).
- Yoon, W., Kim, S. & Han, K. (2001) Morphology and sinking velocities of fecal pellets of copepod, molluscan, euphausiid, and salp taxa in the northeastern tropical Atlantic. *Marine Biology*, 139, 923–928.
- Yount, J.L. (1958) Distribution and ecologic aspects of Central Pacific Salpidae (Tunicata). *Pacific Science*, 12, 111–130.