

AN ABSTRACT OF THE THESIS OF

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(Name)

(Degree)

in OCEANOGRAPHY

(Major)

presented on

May 8, 1967

(Date)

Title: DISTRIBUTION AND OCCURRENCE OF THE SALPIDAE

OFF THE OREGON COAST

Abstract approved:

Redacted for privacy

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Salps from the Pacific Ocean off Oregon were examined from 317 midwater trawl and 86 one-meter net tows taken at stations ranging from 5 to 165 miles offshore along four hydrographic station lines from July 1961 to June 1964. Six species of salps were identified (Helicosalps virgula, Iasis zonaria, Salpa fusiformis, Pegea confoederata, Thalia democratica, and Thetys vagina).

The catches of salps were highly variable in time and space and few consistent distributional patterns were evident. Both the abundance and the frequency of occurrence of several species were higher off southern Oregon than northern Oregon. Largest catches of salps usually occurred in the spring and summer.

Salpa fusiformis and Iasis zonaria were the two most common species off Oregon. They were found during all seasons of the year, but largest numbers usually coincided with the season of upwelling

when northerly winds prevailed. Thalia democratica and Pegea confoederata, on the other hand, appeared to be warm-water species whose occurrence off Oregon is related to wind stress and advection from the south or west. All salps were collected in the upper 200 m of the water column.

Distribution and Occurrence of the Salpidae
Off the Oregon Coast

by

Lyle Turner Hubbard, Jr.

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1967

APPROVED:

Redacted for privacy

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Date thesis is presented

May 8, 1967

Typed by Gwendolyn Hansen for

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ACKNOWLEDGEMENTS

I wish to thank Dr. William G. Pearcy for the help, criticisms, and encouragement that made the completion of this study possible. Thanks are also extended to Dr. June Pattullo for her help on the physical oceanography and general comments, to Dr. Ivan Pratt for his comments and assistance, and to Ron Hill who did an excellent job of drafting for me. Special thanks are due to Dr. James L. Yount for his time and cooperation in checking my identification of the salps.

To the crews of the M/V Acona and M/V Yaquina is extended special appreciation for their very necessary cooperation and help at sea in the collection of the samples. I also wish to thank the many students who helped with the collections at sea and on the beach.

Finally, I wish to express my thanks and appreciation to my wife for her help and encouragement.

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
METHODS	4
RESULTS	8
Species Composition	8
<u>Salpa fusiformis</u> Cuvier 1804	8
<u>Iasis zonaria</u> (Pallas) 1774	11
<u>Pegea confoederata</u> (Forsk.) 1775	15
<u>Thetys vagina</u> Tilesius 1802	16
<u>Thalia democratica</u> (Forsk.) 1775	18
<u>Helicosalpa virgula</u> (Vogt) 1854	20
Depth Distribution	22
DISCUSSION	23
CONCLUSIONS	28
BIBLIOGRAPHY	29

LIST OF FIGURES

Figure	Page
1. Biological and hydrographic stations off the Oregon coast occupied during hydrographic-nekton cruises from July 1961 through June 1964.	5
2. Wind stresses and salp catches off the Oregon coast for the period July 1961 to June 1964.	11
3. The occurrence of <u>Salpa fusiformis</u> catches plotted in relation to temperature and salinity at 10 (●) and 50 (◐) meter depths.	26

LIST OF TABLES

Table	Page
1. Frequency of salp occurrence off Oregon.	7
2. Geographic distribution of <u>Salpa fusiformis</u> July 1961 June 1964.	9
3. Midwater trawl catches of <u>Salpa fusiformis</u> off Newport August 1961 to May 1964	12
4. Geographic distribution of <u>Iasis zonaria</u> July 1961 to June 1964.	14
5. Geographic distribution of <u>Pegea confoederata</u> July 1961 to June 1964.	17
6. Geographic distribution of <u>Thetys vagina</u> July 1961 to June 1964.	18
7. Geographic distribution of <u>Thalia democratica</u> July 1961 to June 1964.	21

DISTRIBUTION AND OCCURRENCE OF THE SALPIDAE OFF THE OREGON COAST

INTRODUCTION

Salps are pelagic tunicates (phylum Chordata, class Thaliacea). Their ecology, occurrence and abundance have seldom been studied. No systematic studies have been made off Oregon. Studies by Ritter and Byxbee (1905), Metcalf (1918), Thompson (1948), and Yount (1954, 1958) on the salps off Southern California, the Philippines, Australia, and the Central Pacific, respectively have provided much information on habitat, depth distribution, taxonomy and life cycles of Salpidae. More recently Berner (1954, 1955, and 1960) reported on three salp species found in the San Diego region.

Historically, salps have been known since 1756 when Browne first described them from the Mediterranean Sea. Pallas and later Forskal (as cited in Thompson, 1948, p. 101-102) revived interest in the salps with detailed studies of their structure. The poet Chamisso (as cited in Berrill, 1961, p. 150) wrote an outstanding report on the complex life cycle of the salps.

Ekman (1953, p. 329) discussing the zoogeographic distribution of salps, states that, "Species of Salps, Doliolum, and Pyrosoma are generally circumglobal warm water forms." According to Thompson (1948) salps are temperate and tropic in distribution and

their incursions into colder zones indicate the intrusion of warm tongues of water into northern and southern cold water zones.

Yount (1958) reiterates this statement: "The majority of salps are cosmopolitan warm water plankters, although they may be carried into high latitudes from time to time."

The ocean off Oregon, situated between 42° and 46° North latitude, is considered to be transitional between North Pacific Subarctic and Equatorial Pacific waters. The California Current, a part of the eastern North Pacific gyre, flows to the southeast all year (Sverdrup, et al., 1942, p. 724) about 700 km off the coast of Oregon and has a major influence on the oceanography. During the spring and early summer prevailing north-northwesterly winds create extensive upwelling which protrudes south and westward as eddies of cold water (Sverdrup, Johnson, and Fleming, 1942; Fleming, 1955; Maughan, 1963). In November, December and January, after upwelling has ceased, the northward flowing Davidson Current is found along the coast (Sverdrup, et al., 1942; Fleming, 1955; Maughan, 1963; Burt and Wyatt, 1964). Salinities below 32.5 ‰ are considered to be indicative of Columbia River Plume water, which lowers the salinity in the upper 50 m of water off Oregon, especially from June through September (Barnes and Gross, 1966).

Since equatorial waters do not predominate in the upper waters

off Oregon and salps are generally considered as warm-water plankton, the oceanic environment appears marginal for endemic salp populations. Therefore salps may be good indicators of intrusions of warm Equatorial or Central water off the Oregon coast.

The purpose of this study is to determine the occurrence of salps seasonally and geographically and, if possible, to correlate their occurrence with environmental conditions off Oregon.

METHODS

Collections of pelagic animals including salps were made from July 1961 through June 1964 along station lines perpendicular to the Oregon coast (Fig. 1). Four station lines extended from 5 to 165 nautical miles offshore, with stations at intervals of 10 or 20 miles. The lines are located off Astoria, Newport, Coos Bay, and Brookings, Oregon. A line off the Siuslaw River was sampled in November 1963.

The Coos Bay, Newport, and Astoria stations were usually sampled monthly and Brookings stations bimonthly from June 1962 through April 1964, weather permitting. In general, stations were sampled to a distance of 165 miles offshore.

Collections were made with a six-foot Isaacs-Kidd mid-water trawl (Isaacs and Kidd, 1953) and a one-meter diameter plankton net. After July 1962 the midwater trawl was lined throughout with 5 mm (square measure) knotless nylon mesh netting and had a 1/2 m plankton net (.571 mm aperture) for a cod-end. Before July 1962 the front half of the net consisted of .762 mm stretch mesh and the after half was lined with 13 mm mesh netting. The one-meter nets were made of nylon (Nitex) with mesh apertures of .571 mm. The vertical meter net was 4 meters and the oblique meter net 6 meters in length. A flow meter in the mouth of the meter net and a depth-distance recorder in the mouth of the midwater trawl provided

estimates of the amount of water filtered during each tow.

Both midwater trawl and meter net tows were made to 200 m, depth permitting, between dusk and dawn. Sampling after darkness presumably minimized variations that may be due to diel vertical migrations or net avoidance of animals.

Meter net sampling in conjunction with the midwater trawling was begun May 1963. At first, the meter net was attached above the midwater trawl and both were towed simultaneously. These oblique tows were abandoned in favor of separate vertical tows in December 1963.

Midwater trawl collections contained most of the salps used in this thesis. Meter net collections apparently did not filter enough water to effectively sample the generally sparse salp populations. Frequently salps were not present at all in meter net collections though they were numerous in midwater trawl collections at the same station.

Two collection methods provided information on depth distribution of the Salpidae. A total of 116 samples from multiple opening-closing meter nets, operated by piston cutters (Yentsch et al., 1962), and 103 midwater trawl samples, taken with a Multiple Plankton Sampler attached to the cod-end of the trawl (Pearcy and Hubbard, 1964; Pearcy and Laurs, 1966), were examined for salps.

In all, 317 midwater trawls and 86 meter net samples were

examined for salps. Samples were preserved with formalin at sea and sorted ashore. When there were fewer than 100-200 individual salps per sample the entire sample was sorted for salps. If the sample contained more than 100-200 salps a Folsom plankton splitter (McEwen et al., 1954) was utilized to produce a subsample of at least 100 salps.

Thompson's (1948) and Yount's (1954) papers on the salps were used as primarily sources for taxonomy. In addition selected samples of each species were sent to Yount for verification.

RESULTS

Species Composition

Six species of salps were collected during the study. The species, along with their frequency of occurrence (based on the number of tows in which species occurred divided by total number tows), is given below:

Table 1. Frequency of salp occurrence off Oregon

Species	Frequency
<u>Salpa fusiformis</u>	0.188
<u>Iasis zonaria</u>	0.119
<u>Pegea confoederata</u>	0.022
<u>Thetys vagina</u>	0.016
<u>Thalia democratica</u>	0.019
<u>Helicosalpa virgula</u>	0.003

The distribution and occurrence of these species is discussed below, beginning with S. fusiformis and I. zonaria which were the only species that were frequently caught.

Salpa fusiformis Cuvier 1804

According to Thompson (1948) this is a cosmopolitan species occurring in all oceans except the Arctic, and when transported to high latitudes by currents it is usually the most abundant salp, while in other regions it is second to Thalia democratica in numbers.

The systematic position of the echinate form of this species, S. aspera Chamisso 1819, has been in question by many investigators.

Foxton (1961), described several distinct species from the fusiform species. However Yount (personal communication) and Thompson (1948) believe that careful study of many more specimens is needed before the problem can be resolved, hence I have made no attempt to separate these forms.

Salpa fusiformis was the most abundant species of salp collected off Oregon during the three years of this study. Geographical variations in the distribution of S. fusiformis are shown in Table 2. Both frequency of occurrence and the average number per tow was lowest along the northern stations.

The inshore-offshore distribution of S. fusiformis showed a varied pattern. However the highest catches often appeared at stations 45 and 65 offshore on all lines, and it was infrequently collected at either the offshore or near shore stations (Table 2). S. fusiformis was not caught inshore of 35 miles off Brookings, but was recorded at all stations beyond 35 to 165. This was the only station line where it was collected at all offshore stations. It was found 15-25 miles off Newport and Coos Bay and occurred irregularly at stations beyond 85 miles offshore.

Salpa fusiformis occurred each month of the year at some time during the study, except October. Thus its occurrence was not limited to any one season. There was a definite seasonal "bloom" from May through September 1962 when catches were high and it was numerically the dominant species. It was not particularly common during the summers of 1961 and 1963 however, but was found

Table 2. Geographic distribution of Salpa fusiformis July 1961 to June 1964.

Station	5	15	25	35	45	65	85	105	125	145	165	Ave.
AH												
No. tows	2	13	13	1	13	9	0	2	3	0	0	5.09
No. tows occurred	0	0	1	0	3	1	0	0	0	0	0	9%
Ave. no. /tow	0	0	2.38	0	48.85	0.33	0	0	0	0	0	11.95
NH												
No. tows	1	25	28	-	28	27	2	1	9	1	1	11.18
No. tows occurred	0	1	3	0	5	8	0	0	1	0	1	15%
Ave. no. /tow	0	0.12	0.57	0	2.89	103.22	0	0	192.00	0	880.00	36.72
CH												
No. tows	0	13	13	1	13	5	2	2	2	1	0	4.73
No. tows occurred	0	5	4	0	5	2	0	0	1	0	0	33%
Ave. no. /tow	0	48.08	65.38	0	65.38	115.60	0	0	52.00	0	0	58.44
BH												
No. tows	7	5	8	8	8	8	8	8	7	6	6	7.18
No. tows occurred	0	0	0	2	4	4	1	1	1	2	2	22%
Ave. no. /tow	0	0	0	4.75	30.00	133.75	3.75	0.88	1.28	3.00	50.83	21.73

sporadically throughout these years (Figure 2).

The irregular occurrence of salps off Oregon is dramatically illustrated in Table 3 which shows the catches of S. fusiformis off Newport. This species was absent from most of the collections. Moreover, high variability in occurrence is emphasized by the fact that when catches were made at one station during a month, it was often absent at adjoining stations for that month, or from the same station for preceding or succeeding months. This variability typified the occurrence of salps off Oregon.

Iasis zonaria (Pallas) 1774

This species is found in all oceans except the Arctic and as far north in the Pacific as 56°N. It is one of the most common species in temperate waters (Thompson, 1948).

Iasis zonaria, because of its gut morphology, reduced body and oral musculature, and distorted "eye" form, is distinct from all the other salp genera and has been termed an aberrant form by Metcalf (1918).

Off Oregon I. zonaria was second only to S. fusiformis in its occurrence and abundance. I. zonaria showed a very definite pattern in its latitudinal distribution. Its frequency of occurrence and catch per cubic meter decreased from south to north (Table 4). It appeared most commonly off Brookings and not at all off Astoria. Iasis zonaria was found in 33% of the collections off Brookings, 11% off Coos Bay, and 4% off Newport. This trend indicates a southerly center of

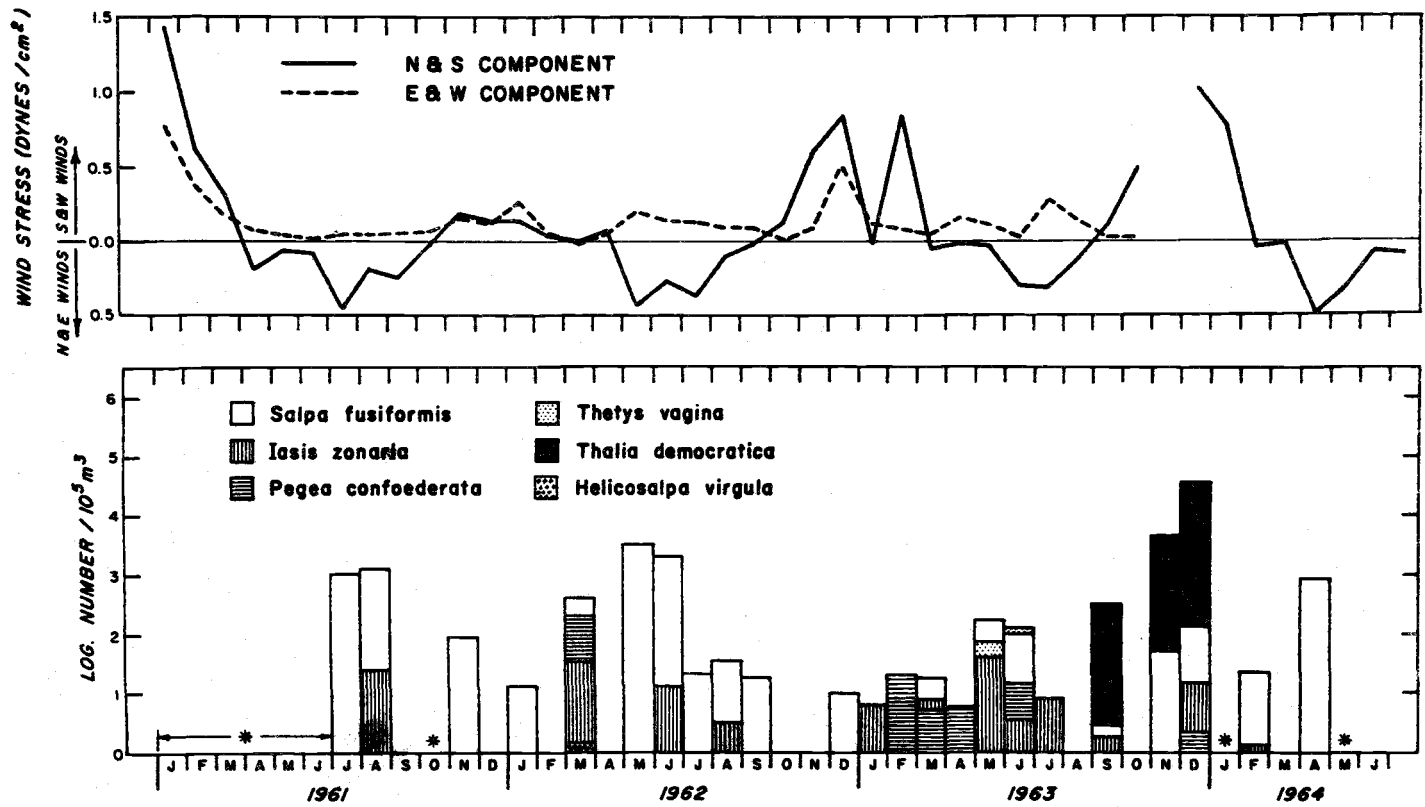


Figure 2. Wind stresses and salp catches off the Oregon coast for the period July 1961 to June 1964. Asterisks denote months when no tows were made. The logarithm of the catch of each species is plotted from the abscissa. When tows were made but no salps collected months are blank (i. e., no asterisks or histograms). Wind data from Smith, 1964

Table 3. Midwater trawl catches of *Salpa fusiformis* off Newport August 1961 to May 1964

Months	Stations				
	Nautical miles offshore				
	15	25	45	65	65+
1961					
Aug.	0 ^a	0	0	- ^b	-
Nov.	0	0	0	1.51 (24) ^c	-
Dec.	0	0	0	0	0
1962					
Jan.	0	0	0	0	0
Feb.	0	0	0	0	0
April	-	0	-	-	0
May	0	0	0	0	135.64 (1728)
June	-	-	1.01 (16)	518.36 (2592)	77.33 (880)
July	0	0.42 (6)	0	2.09 (32)	-
Aug.	0.22 (3)	0.44 (7)	0.29 (5)	2.07 (33)	-
Sept.	0	0	0	1.82 (25)	0
Oct.	0	0	-	-	-
Nov.	0	0	0	0	-
Dec.	0	0	0	1.26 (24)	0
1963					
Jan.	0	0	0	0	-
Feb.	0	0	0	0	0
May	-	0	0.24 (2)	0	0
June	-	0	0	4.50 (59)	-
July	-	-	0	0	0
Aug.	-	0	0	0	-
Sept.	0	-	-	-	0
Oct.	0	0	0	-	-
Nov.	0	0	4.47 (57)	0	-
Dec.	0	0.08 (1)	0	0	-
1964					
Feb.	0	0	0.05 (1)	1.63 (21)	0
Mar.	0	0	0	0	-
April	0	0	0	1.10 (13)	-
May	-	0	0	0	-

^a 0 = no. salps caught^b - = no. tows^c 1.51 = no. /tow (24) = total catch for month

Table 4. Geographic distribution of Iasis zonaria July 1961 to June 1964.

Stations	5	15	25	35	45	65	85	105	125	145	165	Ave.
AH												
No. tows	2	13	13	1	13	9	0	2	3	0	0	5.09
No. tows occurred	0	0	0	0	0	0	0	0	0	0	0	0%
Ave. no. /tow	0	0	0	0	0	0	0	0	0	0	0	0.00
NH												
No. tows	1	25	28	0	28	27	2	1	9	1	1	11.18
No. tows occurred	0	1	1	0	1	1	0	0	1	0	0	4%
Ave. no. /tow	0	0.56	1.14	0	0.25	0.07	0	0	0.22	0	0	0.36
CH												
No. tows	0	13	13	1	13	5	2	2	2	1	0	4.73
No. tows occurred	0	2	1	1	1	1	0	0	0	0	0	11%
Ave. no. /tow	0	0.23	1.46	4.00	0.08	9.60	0	0	0	0	0	1.42
BH												
No. tows	7	5	8	8	8	8	8	8	7	6	6	7.18
No. tows occurred	0	1	1	3	4	5	3	2	2	2	3	33%
Ave. no. /tow	0	0.20	0.12	0.88	7.50	2.00	3.12	1.00	1.14	1.83	1.50	1.86

abundance. Such a conclusion was further substantiated by large catches of this species on a cruise to the south of Oregon SICS-PAC Cruise of the M/V Yaquina, February-March 1965).

Table 4 also provides data on the inshore-offshore distribution of I. zonaria. It occurred at every Brookings station except the one 5 miles offshore. On the Coos Bay and Newport lines it was limited to between 15 and 65 miles offshore, appearing only once beyond 65 miles offshore. It was not collected at the 5 mile station.

Seasonally, I. zonaria occurred mainly from March through October with rare appearances in January and December (Fig. 2) Highest catches of this species were in the spring and summer. The seasonal pattern of occurrence is similar to that found off Australia where I. zonaria was caught during all seasons of the year with peaks in the spring from August through December (Thompson, 1948).

Pegea confoederata (Forsk.) 1775

This is a truly warm water species and is abundant in all warm and temperate oceans as far north as Southern California in the eastern Pacific (Thompson, 1948). Its occurrence off Oregon represents a significant extension of its range.

Another feature of this species is the apparent rarity of the solitary, asexual phase. This is perhaps due to its deep-water distribution (Metcalf, 1918), although Thompson (1948) found that the asexual zoid was not unusually scarce in collections in the upper 100 m off Australia. One specimen of the solitary zoid was caught

off Oregon in the upper 200 m at Newport 45 in December 1963. The bicaudate form, P. confoederata bicaudata Metcalf 1918 (considered invalid by Yount, 1954), was not noted off Oregon.

Pegea confoederata occurred in only 2% of the collections during the study (Table 1). It was captured at least once on every station line: twice in the Brookings and Newport collections, and once off Newport. An interesting latitudinal change in its location offshore is apparent in Table 5. The farther north this species was found in our collections, the closer to shore it occurred.

Pegea confoederata appeared irregularly throughout the winter and spring (December-June) but only once in the summer (June 3) off Oregon (Fig. 2). In 1962 it appeared off Coos Bay in March, then off Newport in June. In 1963 it was caught off Newport in February and off Astoria in April. These observations suggest a northward transport of the species during these times.

Thetys vagina Tilesius 1802

Thetys vagina has been recorded in most of the oceans of the world and in the eastern Pacific from California to the Bering Sea (Thompson, 1948). Thompson also stated that it appears to tolerate colder water than most salps since it was caught off southern Tasmania. It was taken off Australia in June with the exception of a single specimen caught in February (Thompson, 1948); so it appears to occur there only in the winter. This is the largest of all the Salpidae (Thompson, 1948). One Oregon specimen measured over 300 mm.

Table 5. Geographic distribution of Pegea confoederata July 1961 to June 1964.

Stations	5	15	25	35	45	65	86	105	125	145	165	Ave.
AH												
No. tows	2	13	13	1	13	9	0	2	3	0	0	5.09
No. tows occurred	0	1	0	0	0	0	0	0	0	0	0	2%
Ave. no. /tow	0	0.23	0	0	0	0	0	0	0	0	0	0.02
NH												
No. tows	1	25	28	0	28	27	2	1	9	1	1	11.18
No. tows occurred	0	1	0	0	1	1	0	0	0	0	0	2%
Ave. no. /tow	0	1.24	0	0	0.36	- 0.30	0	0	0	0	0	0.32
CH												
No. tows	0	13	13	1	13	5	2	2	2	1	0	4.73
No. tows occurred	0	0	0	0	0	1	0	0	0	0	0	2%
Ave. no. /tow	0	0	0	0	0	56.00	0	0	0	0	0	5.28
BH												
No. tows	7	5	8	8	8	8	8	8	7	6	6	7.18
No. tows occurred	0	0	0	0	0	0	0	1	0	1	0	2%
Ave. no. /tow	0	0	0	0	0	0	0	1.38	9	1.67	0	0.15

As seen in Table 6, T. vagina was captured only five times, too infrequently to demonstrate any distributional pattern off Oregon. It was collected on every station line except Astoria between 25 and 65 miles offshore, usually during the spring and summer.

Thetys vagina was found off Newport in May and June of 1962 and off Coos Bay and Brookings in May 1963 (Fig. 2).

I found many specimens of this species while diving off La Jolla, California in July 1963.

Thalia democratica (Forsk.) 1775)

According to Thompson (1948) this abundant species of salp has a wide distribution in tropical and temperate seas. He stated that its abundance off the west coast of North America is not as great as that of S. fusiformis, perhaps due to the influence of cooler water. Thalia democratica has not been found north of 30°N in the Pacific Ocean (Thompson, 1948), therefore the occurrence of this form off Oregon represents a northern extension of range in the eastern Pacific.

Several species of this form have been recorded: T. longicauda, Quoy and Gaimard 1824 and T. orientalis Tokioka 1937. Even though it is the most abundant salp of the warm waters, more systematic study of the genus is needed (Yount, 1954). The species T. longicauda, found by Thompson (1948) from Australian waters, for instance, has not been positively recorded since 1906 leaving some doubt in mind as to its validity as a species.

Table 6. Geographic distribution of Thetys vagina July 1961 to June 1964.

Station	5	15	25	35	45	65	85	105	125	145	165	Ave.
AH												
No. tows	2	13	13	1	13	9	0	2	3	0	0	5.09
No. tows occurred	0	0	0	0	0	0	0	0	0	0	0	0%
Ave. no. /tow	0	0	0	0	0	0	0	0	0	0	0	0.00
NH												
No. tows	1	25	28	0	28	27	2	1	9	1	1	11.18
No. tows occurred	0	0	0	0	0	2	0	0	0	0	0	2%
Ave. no. /tow	0	0	0	0	0	2.67	0	0	0	0	0	0.58
CH												
No. tows	0	13	13	1	13	5	2	2	2	1	0	4.73
No. tows occurred	0	0	1	1	0	0	0	0	0	0	0	4%
Ave. no. /tow	0	0	0.69	89.00	0	0	0	0	0	0	0	1.85
BH												
No. tows	7	5	8	8	8	8	8	8	7	6	6	7.18
No. tows occurred	0	0	0	0	1	0	0	0	0	0	0	1%
Ave. no. /tow	0	0	0	0	6.25	0	0	0	0	0	0	0.63

Thalia democratica was the smallest species of salp caught off Oregon, ranging in size from 3-10 mm. It rarely was collected, but when present, it was very numerous. Thalia democratica was caught off Brookings, Newport and Siuslaw stations. It occurred in only six trawls. Five of these were made during a three month period (September, November, December 1963) when large numbers of this species were found in both midwater trawl and meter net collections off Siuslaw (November 1963) and Newport (November-December 1963)(Fig. 2). The only other appearance during the study was also in the fall of 1963, off Brookings in September.

This species was captured from 15 to 125 miles off Newport and 65 miles off Brookings (Table 7). On the Siuslaw line, stations 15, 25, 45, 65 and 125 miles offshore were sampled with all collections, except that at 125, containing T. democratica. Because of its infrequent occurrence no seasonal or geographic distributional pattern could be established.

Helicosalpa virgula (Vogt) 1954)

This species has been collected from the Mediterranean Sea, the Atlantic, Pacific and Indian Oceans (Thompson, 1948). The only record of its appearance in the central Pacific Ocean is by Yount (1954). Apparently H. virgula has never been reported from north-eastern Pacific before.

Table 7. Geographic distribution of Thalia democratica July 1961 to June 1964.

Station	5	15	25	35	45	65	85	105	125	145	165	Ave.
AH												
No. tows	2	13	13	1	13	9	0	2	3	0	0	5.09
No. tows occurred	0	0	0	0	0	0	0	0	0	0	0	0%
Ave. no./tow	0	0	0	0	0	0	0	0	0	0	0	0.00
NH												
No. tows	1	25	28	0	28	27	2	1	9	1	1	11.18
No. tows occurred	0	2	1	0	1	0	0	0	1	0	0	4%
Ave. no./tow	0	2,854.72	501.54	0	196.64	0	0	0	6,428.44	0	0	1,189.05
CH												
No. tows	0	13	13	1	13	5	2	2	2	1	0	4.73
No. tows occurred	0	0	0	0	0	0	0	0	0	0	0	0%
Ave. no./tow	0	0	0	0	0	0	0	0	0	0	0	0.00
BH												
No. tows	7	5	9	9	9	9	9	9	7	6	6	7.18
No. tows occurred	0	0	0	0	0	1	0	0	0	0	0	1%
Ave. no./tow	0	0	0	0	0	5.62	0	0	0	0	0	0.57

This salp is different from the other five genera in two distinct ways: first, it possesses patches of bioluminescent tissue along each side between muscle I and muscle VI, and secondly it has a straight gut while in most other salps the gut is coiled. This last characteristic separates it from the subfamily Salpinae and places it into the subfamily Cyclosalpinae (Yount, 1954).

Helicosalpa virgula was caught 45 miles off Coos Bay in March 1963. Thompson (1948) collected it once, off southeastern Australia in October 1939.

Depth Distribution

Over 200 samples made with opening-closing nets in the upper 1000 m were examined for salps. No salps were collected below 150 m. This indicates that salps off Oregon are exclusively epipelagic in their vertical distribution.

DISCUSSION

Salps are thought to have a zoogeographical range that is mainly tropical and temperate (Ekman, 1953 and Thompson, 1948). Yount's (1958) study indicated the subtropical distribution of the salps. From the Central Pacific he recorded 19 of 22 world recognized species of salps and all six species of salps caught in my study (Salpa fusiformis, Iasis zonaria, Pegea confoederata, Thetys vagina, Thalia democratica, and Helicosalpa virgula).

Since the waters off Oregon are largely Subarctic in origin (Sverdrup et al. , 1942; Rosenberg, 1962; and Pattullo, unpublished) this region might be considered as the northern periphery of their range, where the occurrence of salps is related to the intrusion of warmer waters that originated in the south or southwest.

This contention that salps caught off Oregon have their center or origin to the south and west is substantiated by the trends in geographic distribution. The frequency of occurrence and abundance of all species was lowest at the northernmost stations and increased to the south (Tables 2 to 7). These trends suggest that salps are transported into the ocean off Oregon by advection from the south and can be used to indicate influxes of water.

Even though salps are reported as deep as 1000 m (Thompson, 1948) they were found to be epipelagic off Oregon. The circulation

of these upper waters is mainly induced by wind stress. Therefore shallow, wind-driven currents are undoubtedly an important factor in affecting the distribution of salps.

Generally the winds off Oregon blow from the west-southwest from October through March and from the north and northwest during April through September (Smith, 1964 and Fig. 2). The northerly components which cause offshore transport of surface waters are strongest during the summer. This is the period of upwelling off Oregon (Maughan, 1963). During the winter inshore surface flow has been measured with current meters (Collins, personal communication), with drogues (Stevenson, 1966), and with drift bottles (Burt and Wyatt, 1964).

The wind stress and the salp catches off Oregon are shown for the years 1961-1964 in Fig. 2 (The logarithm of the number of each species caught per 10^5 m^3 is plotted from the abscissa). As can be seen in Fig. 2, the occurrence of some species is correlated with periods of southerly winds, indicating that they are probably transported into the region off Oregon with an influx of warmer waters. The very large catches of Thalia democratica in the fall of 1963 coincide with a period of southerly wind stress. Also Pegea confoederata usually occurred during the winter just after periods of southerly winds.

On the other hand, large catches of salps were also made

during the summers when northerly winds prevailed. These peaks were usually composed of two species, Salpa fusiformis and Iasis zonaria, species which occurred erratically throughout all seasons of the year. Thus, factors other than advection from the south appear to be important in the distribution of these two species.

Salpa fusiformis and Iasis zonaria have the widest latitudinal range and are perhaps the most likely to have endemic populations off Oregon. To show the temperature and salinity values where S. fusiformis was collected during my study, I have constructed a temperature-salinity-plankton diagram (Fig. 3). Surface temperatures ranged from 8° to 14° C and surface salinities from 30.5 to 33.5‰. Although temperature is thought to be a primary limiting factor in distribution of salps (Yount, 1958) the wide range of variation indicated in Fig. 3 shows that at least some species are quite eurythermal.

Assuming that S. fusiformis and I. zonaria are found in Oregon waters the year around, increased numbers are most likely caused by in situ changes in population number related to reproduction. The variety of sizes, the occurrence of sexual as well as asexual stages, and apparent stolon proliferation are all evidence for reproduction of S. fusiformis off Oregon. Salps are herbivores and synchronization of reproduction with upwelling and phytoplankton blooms would have adaptive value. Upwelling causes nutrient rich

water to be brought into the euphotic zone, resulting in high phytoplankton production during the summer. This is the period of the year when the highest number of S. fusiformis and I. zonaria are found, suggesting that reproduction of these species may be related to seasonal variations in the production of their food.

In summary, salp populations off Oregon are affected by immigration and emigration as well as changes in reproduction and mortality rates. Some species appear to be transported into Oregon waters with intrusions of water from the south. Other species maintain breeding populations off Oregon, are more endemic, and are found in largest numbers during periods of upwelling.

CONCLUSIONS

1) The following species of the Salpidae were caught off Oregon during a three year period from July 1961 to June 1964: Salpa fusiformis, Iasis zonaria, Thetys vagina, Thalia democratica, Pegea confoederata, and Helicosalpa virgula.

2) The distribution of these species was patchy in time and space.

3) Most species were more abundant in southern Oregon waters than in northern waters.

4) The vertical distribution of salps off Oregon was limited to the upper 200 m of the water column.

5) There was some evidence that wind induced surface currents may transport warm water salps into Oregon waters from the south and west during the winter.

6) Salpa fusiformis, the most common salp off Oregon, occurred over a broad range of temperature and salinity and was found during all seasons of the year. Highest numbers often occurred during the season of upwelling, perhaps because of increased reproductive rates.

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