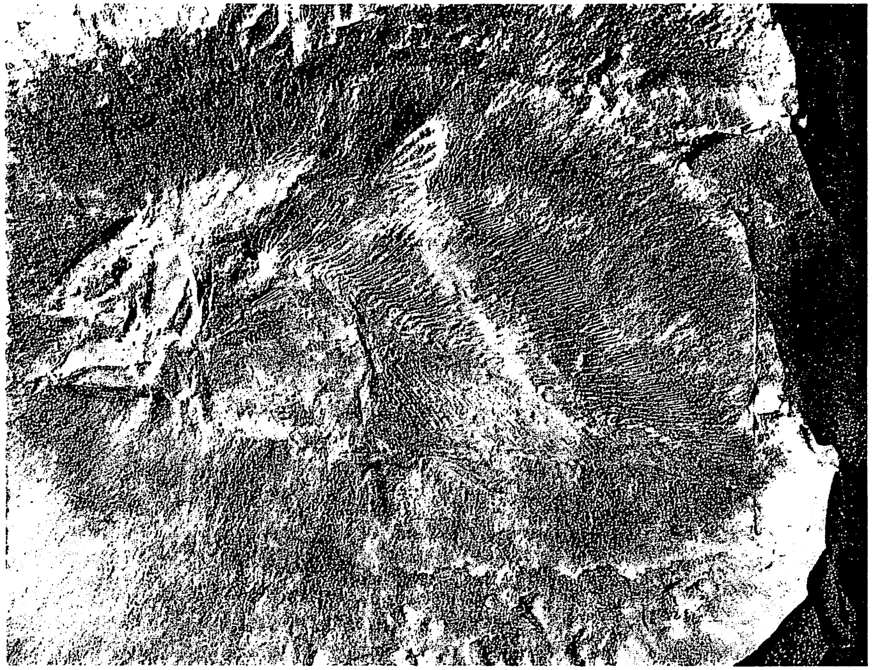

PLATE I. Photograph of *Allenypterus:* a right side.

PLATE II. Photograph of *Allenypterus:* left side.

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Trophic Relationships of Hydromedusae in Yaquina Bay, Oregon[2]

Hydromedusae are quite varied in their size and appearance. Generally they are bell-shaped, with a hollow tube (manubrium) hanging down from the interior roof of the bell. The manubrium contains the stomach and opens downward by means of a mouth. The interior of the manubrium is continuous with (usually) four radial canals which lead from the top of the manubrium outward and downward to meet a ring canal which encircles the bell near the rim. Tentacles are found around the rim and bear stinging cells (nematocysts).

According to Hyman (1940), the phylum Cnidaria is strictly carnivorous. Animals coming in contact with the tentacles are "held and paralyzed by the nematocysts aided by adhesive secretions." The food is moved toward the mouth by the tentacles, and sometimes the mouth moves toward the food also. The food is grasped by the mouth rim and engulfed by ciliary and/or muscular action, "aided by mucous secretion from the pharynx or from the gastrodermis of the manubrium." Their bodies are quite distensible and relatively large objects can be swallowed. Coelenterates exhibit some selectivity in their choice of food and will generally reject non-nutritive objects unless soaked in flesh juices. "When satiated with food, coelenterates generally fail to react to additional food or drop it after capture and often remain in a contracted state until digestion is completed" (Hyman, 1940, pp. 392-393).

The digestion is both extracellular and intracellular.

> . . . the fleshy parts of prey may be broken down in a few hours and the resulting broth completely engulfed by the gastrodermis in 8 to 12 hours. Undigested parts are then ejected through the mouth (Hyman, 1940, p. 393).

Intracellular digestion usually takes a few days. "Excess food is stored in the gastrodermis chiefly as fat; glycogen may be stored without change" (Hyman, 1940, p. 393).

Notes on the feeding of medusae have been made by Lebour (1922, 1923), Hyman (1940), Mikhailov (1962), and Roosen-Runge (1967).

Marshall and Orr (1955) mentioned that the copepod *Calanus* is sometimes eaten by medusae.

Lebour (1922, 1923) reported that in the laboratory *Aurelia* ate fish, amphipods, crab zoeae, other crustacea, and the hydromedusa *Sarsia tubulosa*. *Phialidium* was seen to eat a variety of fishes, including very young herring and sprat eggs. One *Sarsia tubulosa* ate copepods (*Pseudocalanus elongatus, Acartia clausii, Calanus fin-*

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[2] This report includes part of the author's Ph.D. thesis presented at Oregon State University.

marchicus, and *Temora longicornis*). It ate at least 15 copepods in 11 days (an accurate count was not kept). She also examined the stomachs of some hydromedusae taken from net samples; the main constituent of the food was copepods. *Obelia* contained copepods, cladocera, crab zoeae, *Oikopleura, Tomopteris, Sagitta,* and fish. Lebour's sampling was apparently somewhat irregular, but it gives an idea of the great variety of food eaten by medusae.

Mikhailov (1926) reported diatoms, dinoflagellates, silicoflagellates, coccolithophores, copepods, barnacle cypris, decapod zoeae and larvae of pelecypods and gastropods from the stomachs of the scyphomedusa, *Aurelia aurita.*

Materials and Methods

Yaquina Bay is an estuary opening into the Pacific Ocean near 44° 37′N on the Oregon coast. This study was confined to the part of the bay from the Newport Bridge (station "Bridge") to Buoy 45 ("B-45"), a channel distance of about 8.7 nautical miles upstream (16.5 kilometers) (see Fig. 1).

In the lower bay the channel is dredged annually to a depth of about eight meters as far upstream as McLean Point (see Fig. 1); above this the channel is maintained at a minimum of three to four meters as far as Toledo (Manske, 1968). Above McLean Point there are shallow tidal flats bordering the channel for about 1.2 nautical miles (2.0 kilometers). The bay is considerably narrower above this area.

Quantitative samples of plankton have been taken with a No. 6 mesh (0.239 millimeter aperture) nylon net and a Clarke-Bumpus plankton sampler (Clarke and Bumpus, 1950) at each of four stations in Yaquina Bay (Fig. 1) at approximately weekly intervals from April 1966 to November 1967. Two 24-hour studies (at Buoy 21), two six-station spatial surveys (from the Newport Bridge to Buoy 45), and two daily studies were made in September 1966 and March 1967.

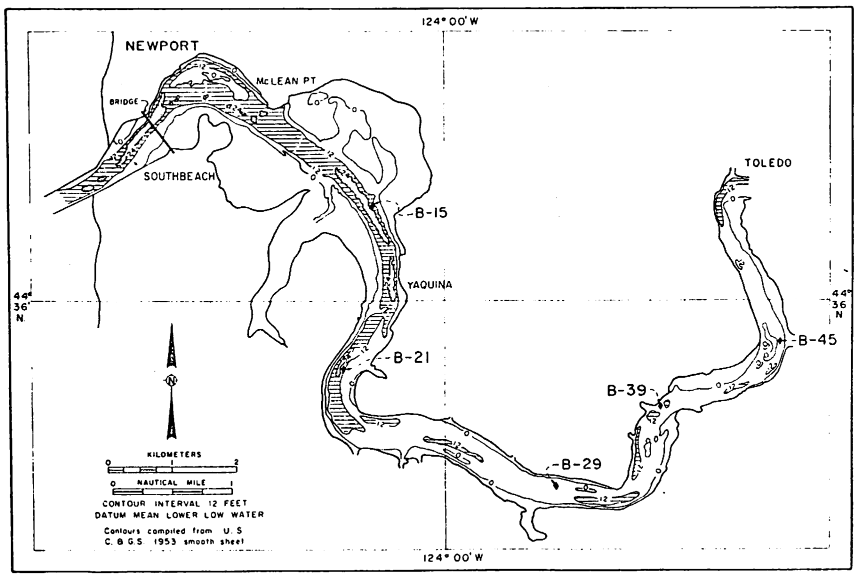

Figure 1. Map of Yaquina Bay, Oregon, indicating sampling stations (diamonds). (Frolander, 1964)

Samples were taken by an oblique step-tow at one meter above the bottom, at mid-depth (except in water less than three meters), and just under the surface of the water. Plankton samples were immediately preserved in 10 per cent formalin in sea water. After collection, the samples were analyzed in the laboratory for composition of zooplankton. Stomach contents of the hydromedusae were examined by dissection or direct observation through the stomach wall. Since the very small medusae, such as *Sarsia eximia,* tend to be quite transparent, it can be determined without dissection whether or not the gut contains food. The small medusae that may be thus treated are *Dipurena ophiogaster, Sarsia eximia, Sarsia prolifera,* and *Rathkea octopunctata.* All cases are noted where food was found. Temperature and salinity data were determined from samples taken in conjunction with all plankton tows and compared with the hydromedusa data (McCormick, 1969).

Results and Discussion

The hydromedusa population during the period from April 1966 to November 1967 consisted of 11 species. In order of decreasing frequency of occurrence in weekly samples, these species were *Phialidium gregarium* (L. Agassiz, 1862), *Sarsia eximia* (Allman, 1859), *Obelia* sp., *Polyorchis pencillatus* (Eschscholtz, 1829), *Dipurena ophiogaster* (Haeckel, 1879), *Rathkea octopunctata* (M. Sars, 1835), *Sarsia prolifera* (Forbes, 1848), *Proboscidactyla* sp., an unidentified moerisiid and *Aglantha digitale* (O. F. Muller, 1776). *Aequorea aequorea* (Forskål, 1775) was found once during the 24-hour study of September 1966. Abundance of hydromedusae reached a maximum of over 300 per cubic meter (m^3) near the oceanic, more saline end of the bay. Numbers of medusae generally were lower in samples taken up the bay in fresher water.

The abundance of all of the medusae appeared to be related to the intrusion of salty, cool marine water into the bay (McCormick, 1969).

The following is a discussion of the stomach content studies. Table 1 lists the feeding ratio data; that is, the fraction of the medusae examined for food that actually had some food in the stomach. This includes unrecognizable material. The "no food" (n) column can be regarded as the total number of that species of medusa examined where no food was found. The number of medusae with some food (s) divided by the total number examined (n + s) gives the feeding ratio (r).

TABLE 1. Feeding ratios of medusae examined for stomach contents.

	Number of Analyzed Medusae Containing			Ratio of Medusae with Food
Species of Medusa	No Food (n)	Some Food (s)	Identified Food (i)	$\frac{n+s}{s} = (r)$
Dipurena ophiogaster	(19) + 7	3	1	3/29
Sarsia eximia	(448) + 16	53	37	53/517
Sarsia prolifera	(16) + 0	3	0	3/19
Rathkea octopunctata	(35) + 2	1	1	1/38
Polyorchis pencillatus	2	11	11	11/13
Obelia sp.	12	0	0	0/12
Phialidium gregarium	114	66	60	66/180
Moerisiid	0	1	1	1/1
Proboscidactyla sp.	5	8	3	8/13
Aglantha digitale	1	0	0	0/1

( ) number of empty stomachs examined through manubrium wall.
r = ratio with food.

The *Obelia* sp. found during this study were very small and the successful holding of the prey may depend on the medusae being alive. Thus, low feeding ratios for the small medusae may indicate that the food was lost on capture of the medusa. *Rathkea octopunctata* often everts its bell while feeding (Lebour, 1922, 1923) and holds onto the prey with its mouth lips. One copepod fills the manubrium and stomach of *Sarsia eximia* and *Rathkea octopunctata*. The animals found in *Sarsia eximia* were always held fast; frequently when the copepod was removed, an impression of the copepod was left in the wall of the manubrium or bell.

If, as Hyman (1940) suggests, a medusa digests its food in about 10 hours, it should be possible to estimate the feeding rate of a medusa such as *Phialidium gregarium*, which has been found here to have a feeding ratio of $r = 0.37$. If we assume that it takes the medusa about ten hours to get rid of the food that it has caught, starting with the first animal caught, and that it spends some time (x) with an empty stomach and manubrium, one should expect to find food in the gut during the 10 hours and nothing during x hours. Thus the feeding ratio,

$$r = \frac{10 \text{ hours}}{10 \text{ hours} + x \text{ hours}}$$

or the total time for one feeding and "resting" session,

$$t = \frac{10 \text{ hours}}{(r)}$$

For *Phialidium gregarium*, $t = 27.2$ hours. *Phialidium gregarium* might be expected to consume very roughly q animals/27.2 hours (where q = average number of animals/gut. *Polyorchis pencillatus* ($t = 10.7$ hours) must be almost constantly eating. For *Sarsia eximia*, $t = 97.6$ hours; that is, *Sarsia eximia* eats about one animal per four days. However, a similar medusa, *Sarsia tubulosa*, was observed by Lebour (1922) to capture approximately 1.5 copepods per day (in a tank). Of course, the medusae may capture more than they need and expel undigested food. Medusae may capture varying numbers (q) of animals over a period of days, and the average value ($\bar{q}$) may be an average number eaten. Figure 2 presents the frequencies of occurrence of *Phialidium gregarium* with varying numbers of food organisms in the stomachs. It appears that *P. gregarium* eats varying numbers of animals (average number eaten = 4.2 animals/27.2 hours). Most *P. gregarium* with food were adults of approximately the same size (about 15 mm; see Table 3 for species involved).

There was a considerable variation in the size of food organisms found in the medusa guts examined (Table 2). The means were found to be not significantly different at the 90 per cent confidence level by the t-test (Hoel, 1960).

Selection of food by hydromedusae is apparently made on a size basis, the medusae taking animals in approximately the size range captured by the No. 6 mesh net, mostly between 0.1 and 1.0 mm in length. The size of prey eaten is probably determined by the nature of the food-catching apparatus (stinging cells, tentacles, etc.) and the size and shape of the manubrium.

There is apparently no definite selection by the medusae, of food different from the composition of net plankton (Tables 3 and 4). When *Acartia tonsa*, a copepod quite similar in size and appearance to *Acartia clausi*, was present along with hydro-

TABLE 2. Data on measurements of food of hydromedusae.

Medusae	Number of Food Specimens Measured	Mean Length (mm)	Range Length (mm)
Dipurena ophiogaster	1	.67	.67
Sarsia eximia	32	.73	.33-1.01
Polyorchis pencillatus	50*	.79	.10-2.20
Phialidium gregarium	115*	.70	.10-1.10
Moerisiid	3	.98	.82-1.08
Proboscidactyla sp.	6	.48	.10- .84

* Does not include eggs (minimum length = 0.07, maximum = 0.20).

medusae, it was usually captured without apparent discrimination. *Acartia tonsa* is a more brackish-water species than *Acartia clausi* and the hydromedusae; thus, they usually did not occur together, resulting in generally low correlation between hydromedusae and *Acartia tonsa*. Variations from the composition of net plankton can be explained easily by statistical variation and by medusae feeding in water different from that in which they were caught.

Organisms other than those listed in Table 4 were found in the net plankton, but not in large enough numbers to affect the conclusions. These included fish larvae, chaetognaths, *Centropages mcmurrichi, Clausocalanus arcuicornis, Tortanus discaudatus, Rhincalanus* sp., *Corycaeus affinis*, Isopoda, Amphipoda, Euphausiacea, and Mysidacea.

Two of the medusae possibly get a small part of their food from the benthos; *Polyorchis pencillatus* ate a number (seven) of Harpacticoida, and *Proboscidactyla* sp. ate two harpacticoids and two pelecypod larvae out of a total of seven food animals. These numbers are too small to make many conclusive statements about their feeding. The role of benthic animals in the food of *Polyorchis pencillatus*, at least, appears to be quite small. The other medusae apparently are strictly plankton feeders.

Special attention has been paid to the problem of contamination. Animals found stuck to the margin of the bell, contained loosely in the manubrium or otherwise likely to have been "captured" in the net, were not counted. Food in all states of digestion was found. In the fairly long (about 10 mm) manubrium of *Polyorchis pencillatus*, it was sometimes found that the food near the mouth was fresh and the food in the stomach was an unrecognizable mass of broken exoskeletons and miscellaneous material, with all intermediate stages of digestion.

Summary

The hydromedusa population during the period of this study consisted of primarily 10 species. In order of decreasing frequency of occurrence in weekly samples, these species were *Phialidium gregarium, Sarsia eximia, Obelia* sp., *Polyorchis pencillatus, Dipurena ophiogaster, Rathkea octopunctata, Sarsia prolifera, Proboscidactyla* sp., an unidentified moerisiid, and *Aglantha digitale*.

It appears to be possible to estimate feeding rates from field data and digestion rates. However, more information is needed on digestion rates for different species of medusae.

The food of most hydromedusae consisted largely of the copepods, especially *Acartia clausi*, that were most abundant in the No. 6 mesh Clarke-Bumpus plankton sampler tows.

Selection of food apparently was made mainly on a size basis, medusae taking small zooplankters between 0.1 and 1.0 mm in length; this probably depends on the nature of the food-capturing and eating apparatus.

TABLE 3. Total abundance of food organisms in the stomachs of the medusae examined, listed in order of decreasing frequency for each medusa species (medusae taken from July 1966 through October 1967).

Food	Number
Phialidium gregarium (61 observed with identifiable food)	
Acartia clausi	55
Unidentified copepods	25
Unidentified *Acartia* sp.	23
Unidentified Calanoida	22
Eggs	14
Oikopleura sp.	13
Acartia tonsa	12
Unidentified Crustacea	9
Pseudocalanus sp.	7
Podon sp.	6
Oithona similis	6
Acartia longiremis	6
Barnacle nauplius	3
Copepod nauplius	1
Gastropod veliger	1
Decapod larva	1
Calanus sp. ?	1
Sarsia eximia (37 observed with identifiable food)	
Acartia clausi	25
Unidentified copepods	5
Unidentified *Acartia* sp.	4
Copepod nauplii	3
Evadne sp.	1
Unidentified Calanoida	1
Polyorchis pencillatus (11 observed with identifiable food)	
Eggs	119 (all in one medusa)
Acartia clausi	112
Unidentified copepods	19
Unidentified *Acartia* sp.	16
Unidentified Calanoida	7
Harpacticoida	7
Copepod nauplii	5
Unidentified Crustacea	5
Decapod larvae	4
Polychaete larvae	2
Podon sp.	2
Acartia tonsa	1
Pseudocalanus sp.	1
Paracalanus sp.	1
Oithona similis	1
Barnacle cypris	1
Proboscidactyla sp. (3 observed with identifiable food)	
Harpacticoida	2
Pelecypod larvae	2
Acartia clausi	2
Decapod larva	1
Dipurena ophiogaster (1 observed with identifiable food)	
Acartia clausi	1
Moerisiid (1 observed with identifiable food)	
Acartia clausi	3
Sarsia prolifera (none observed with identifiable food)	
Rathkea octopunctata (none observed with identifiable food)	
Aglantha digitale (none observed with identifiable food)	

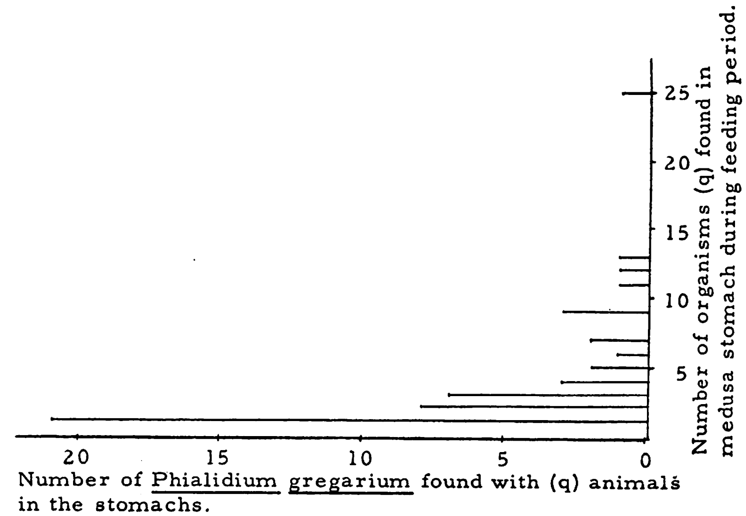

Figure 2. Frequencies of occurrence of *Phialidium gregarium* with various numbers of organisms in the stomachs.

TABLE 4. Non-medusa zooplankton, listed in order of decreasing frequency. (Frequency of occurrence given in parentheses.)

1. *Acartia clausi* (158)
2. *Eurytemora* sp. (108)
3. *Pseudocalanus* sp. (98)
4. Barnacle nauplius (92)
5. *Paracalanus* sp. (88)
6. Decapod larva (87)
7. *Acartia longiremis* (80)
8. *Oithona similis* (79)
9. *Podon* sp. (72)
10. *Acartia tonsa* (70)
11. Copepod nauplius (67)
12. Harpacticoida (66)
13. Pelecypod larva (65)
14. Barnacle cypris (49)
15. Gastropod larva (36)
16. *Calanus* sp. (36)
17. *Oikopleura* sp. (35)
18. *Evadne* sp. (23)

Acknowledgements

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Association News

Annual Meeting

The 43rd annual meeting will be held at Oregon State University in Corvallis, Oregon, on March 27 and 28, 1970. Current and recent members of the Association, as well as most of the relevant institutions and organizations in the region, should have now received forms for submitting information on papers proposed for presentation at the meeting. If a form is not readily available, individuals may simply send the following information to the appropriate Section Chairman (listed below): title of paper, brief summary, requested time for presentation, visual aid equipment needs, author's name and mailing address, organizational affiliation, and whether or not he is a student. *This must be sent to the Section Chairman by December 12, 1969.*

Botany-Zoology	J. H. Ferguson, Zoology Dept., Univ. of Idaho, Moscow, Idaho 83843
Chem.-Physics	Bert Christensen, Chemistry Dept., Oregon State Univ., Corvallis, Ore. 97331
Forestry	J. W. Edgren, PNW Forest and Range Exp. Sta., P.O. Box 3141, Portland, Ore. 97208
Geol.-Geogr.	W. H. Taubeneck, Geology Dept., Oregon State Univ., Corvallis, Ore. 97331
Mathematics	H. D. Sullivan, Math. Dept., EWSC. Cheney, Wash. 99004
Sci. Educ.	G. F. Craven, Sci. Educ. Dept., Oregon State Univ., Corvallis, Ore. 97331
Social Sci.	B. L. Crowe, Pol. Sci. Dept., Oregon State Univ., Corvallis, Ore. 97331
Soil & Water	P. R. Cochran, PNW Forest and Range Exp. Sta., P.O. Box 1208, Bend, Ore. 97701

Attention is again called to the incentives to students to present papers: The Association grants free registration, a free banquet ticket, and a year's membership (including a subscription to *Northwest Science*) to those students whose papers are accepted for presentation.

Those giving papers are encouraged to submit an abstract (not more than 100 words, preferably) for publication in the February issue of *Northwest Science.* Send to the Editor, Joseph W. Mills, Geology Dept., Washington State University, Pullman, Wash. 99163. *December 20, 1969, is the deadline date for this.*

Research Grants

Applications are being accepted for research grants by the Association, generally to cover such items as laboratory supplies and services, computer time, and field costs. Send requests for guidelines for submitting applications to the chairman of the Research Grants Committee, Harry H. Caldwell, Dept. of Geology and Geography, University of Idaho, Moscow, Idaho 83843. The grants will be awarded in March, 1970.