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Evaluation of a Pump and Reeled Hose System for Studying the Vertical Distribution of Small Plankton

By Roderick Leong

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ABSTRACT

The system consists of a submerged pump that delivers water from sampling depth to inboard filters through a long hose. It features a special winch that can store more than 120 m. of collapsible, large-diameter hose. Sources of error due to fragmentation and dispersion of organisms during passage through the system, and escapement through the strainers, were examined. Fragmentation may be excessive if animals are fragile or longer than 5 mm. Organisms that enter the system simultaneously may become widely dispersed but most remain together. Strainers of 100μ mesh (bar measure) retain organisms as narrow as 100μ.

The capabilities of the pump were illustrated by its use in obtaining vertical profiles of abundance of eggs and larvae of sardines (Sardinops caerulea) and of chaetognaths and doliolids at one station. The eggs and larvae were clearly restricted to the upper mixed layer and upper part of the thermocline. Numbers of chaetognaths increased and numbers of doliolids decreased with increasing depth. The advantages and limitations of the pump for studying vertical distribution are discussed.

INTRODUCTION

O'Connell and Leong (1963) described a towed plankton pump system that could collect horizontal samples of small plankton at speeds up to 9 knots and at depths to 5 m. The purposes of this report are to evaluate the system as a vertical sampler and to describe modifications which increase its vertical range to more than 100 m. General design, field performance, and sources of sampling error are discussed. The capabilities of the system are evaluated by its effectiveness in obtaining vertical profiles of sardine eggs and larvae, chaetognaths, and doliolids at one station.

GENERAL DESIGN AND PERFORMANCE

The system consists of a submerged pump that forces water through a long hose to one of two strainers in the laboratory (fig. 1). A submersible electric pump (1.27-cm. intake, 0.5 hp., 3,450 r.p.m.) at the bottom of the system draws in water and forces it through a short connector hose and then through a firehose 120 m. long and 5 cm. in diameter. A stainless steel support cable (0.64-cm. diameter) and an electric cable (1.27-cm. diameter) that powers the pump run through the length of the hose. The hose is supported by a large net roller (20-cm. diameter and 1 m. long) on the stern and is connected to a special winch on the deck. Water is piped from the winch to the ship's laboratory, where it passes through a watermeter and is directed to one of two strainers by a switch valve. One strainer is used while the other is being serviced. O'Connell and Leong (1963) give further details of construction and operation.

The winch had to be extensively modified to store the great length of large-diameter hose needed for deep vertical sampling. The present winch (fig. 2a) is capable of storing three layers of collapsible hose without compressing the inner layers. It has a three-level reel which consists of a central rotating drum (1-m. diameter and 1.5 m. long) and two concentric outer shells with interspaces of 10 cm. These shells bear the weight of the hose and keep the layers separated. A slot on the edge of the shell (fig. 2c) allows the hose to pass from one level to the next. To permit spooling on all levels, the shells are built in detachable quarter sections that weigh about 20 kg. each. Each section is supported by a series of alternating rods and plates which project from the level beneath (fig. 2b). Each section is bolted to the plates that support it.

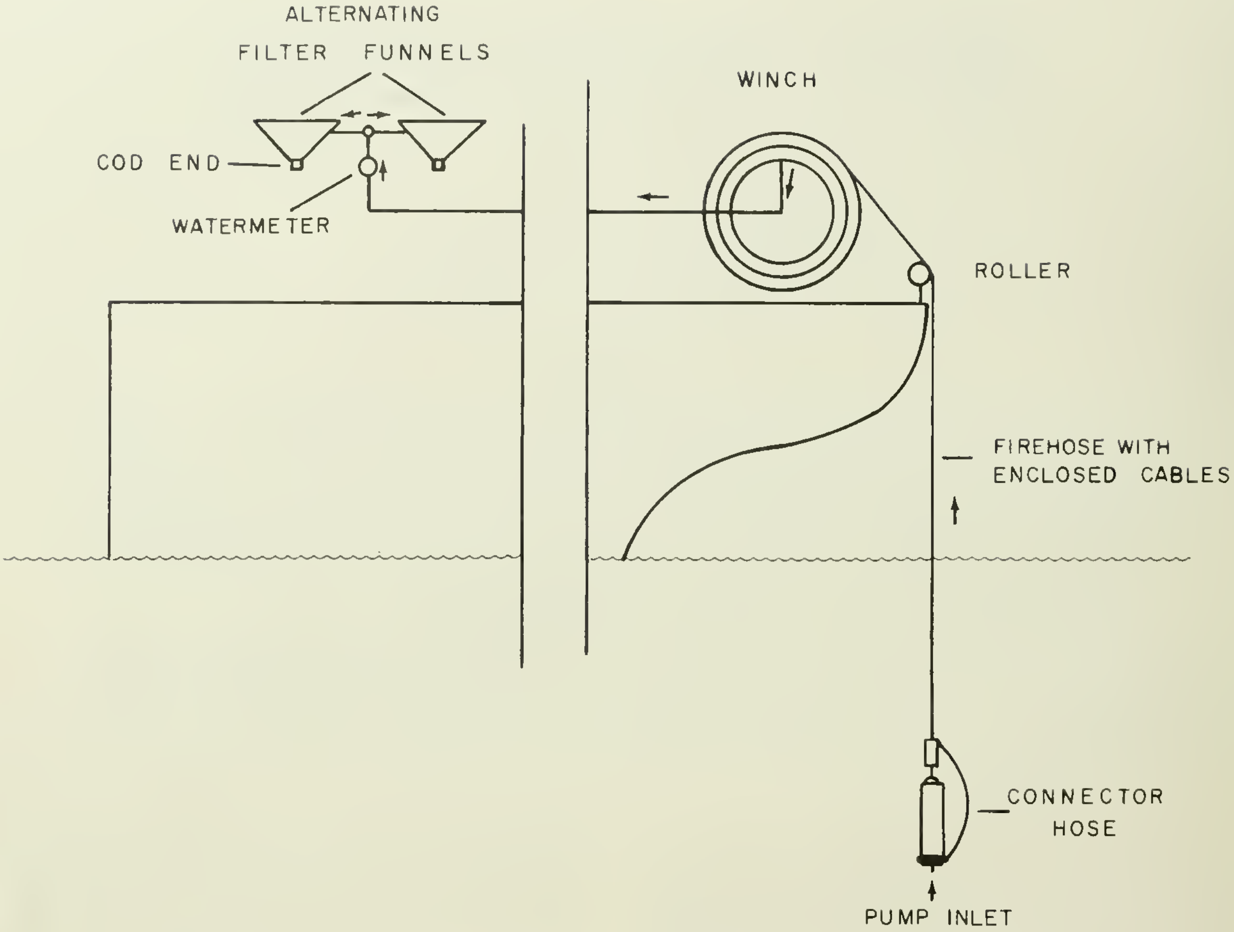

Figure 1.--Schematic drawing of the plankton pump system. The drawing is not to scale.

Three rings of rods and plates support each shell--one at each end and one in the center of the shell. When the first layer of hose has been unwound, the quarter sections of the outer shell are unbolted in sequence to expose the layer beneath. The second shell is similarly removed after the second layer is unwound. The winch is chain-driven at 2 r.p.m. by a 0.75-hp. motor with built-in brake (fig. 2d). The disc brake at the end of the axle was added as a safety measure.

Launching the pump is relatively simple. The pump, which weighs slightly less than 20 kg., is placed over the open roller at the stern and lowered by its own weight as the hose is unreeled. The hose has paint marks at 5-m. intervals. Three men required about 45 minutes to unwind and retrieve 105 m. of hose, including time for removal and replacement of shells, but excluding sampling time.

Four trials yielded some information on the relation between length of hose out and depth attained. The first trial was made while the ship was drifting in a calm sea. A bathykymograph, which records depth against time, was attached to the pump and 105 m. of hose was unreeled. During descent, the winch was stopped at 15-m. intervals to obtain depth readings. The tracing showed that when 60 m. of hose was submerged, the pump was at a depth of 60 m.; therefore the hose was vertical. The bathykymograph malfunctioned beyond this depth.

In the second and third trials the seas were moderate. The ship headed into the swell as hose was unreeled but was then allowed to drift. In these trials, a BT (bathythermograph), which records temperature against depth, was attached to the pump. The winch was stopped, and the temperature of the stream of water delivered by the pump was measured after each 15-m. length of hose was unreeled. By later comparing these temperatures with the temperature-depth profile on a BT trace, we could estimate the depth of the pump at each 15-m. interval. With 105 m. of hose unreeled, the pump was at depths of 55 and 60 m. at a vessel speed of 1 knot and 100 m. when the vessel was adrift.

In the fourth trial, 35 m. of hose was submerged while the vessel was anchored in 45 m.

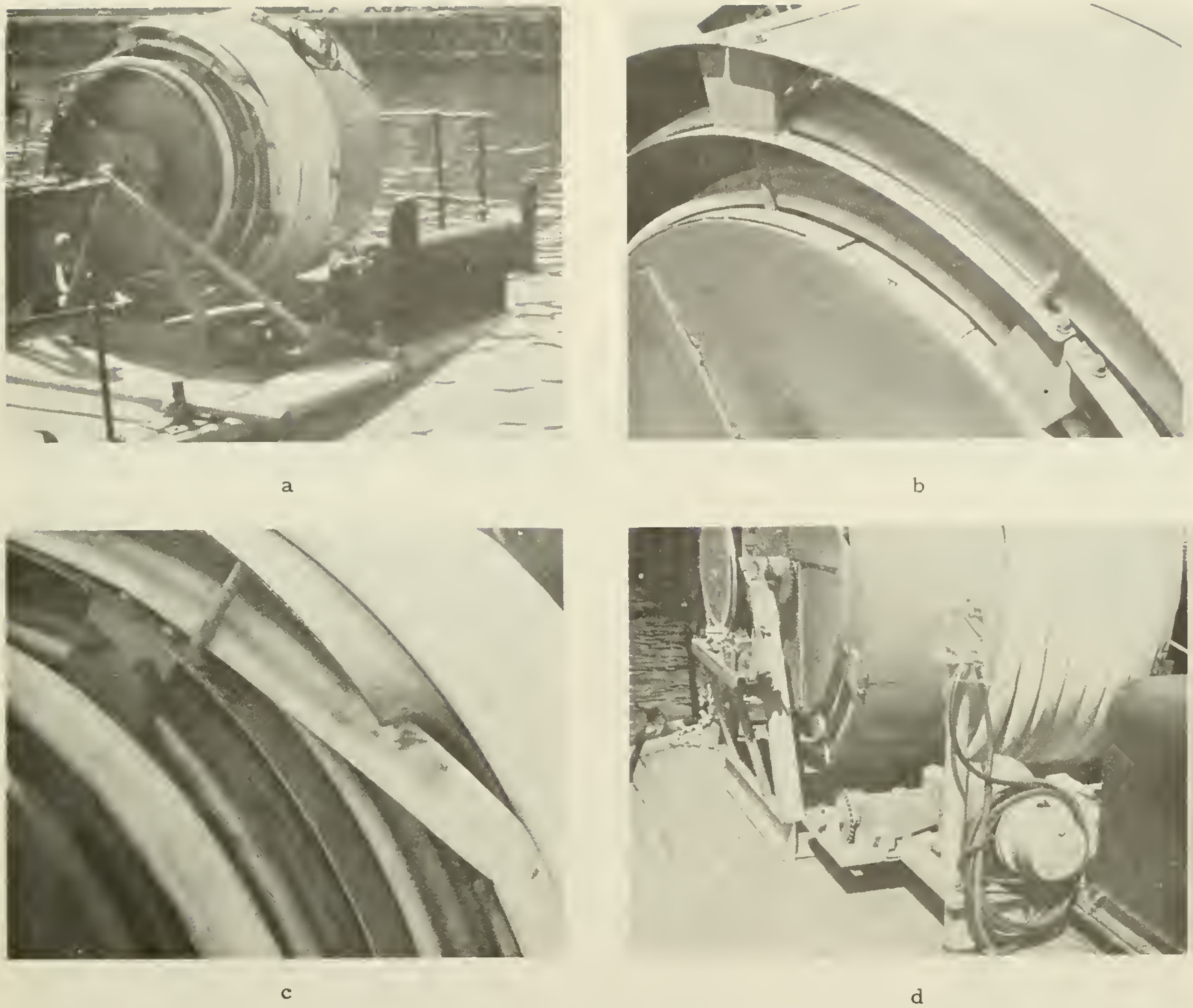

Figure 2.--Photographs showing the general construction of the winch: (a) general view of the winch and stern roller; (b) details of support for the shells; (c) passage of hose from second to third level; (d) the winch motor (chain removed) and hand brake.

of water. The winch was stopped at 5-m. intervals to obtain temperature readings from the incoming stream. Comparison of these temperatures to a BT trace, made immediately after the pump was retrieved, indicated that the hose was nearly vertical. Only at the 35-m. level, where the temperature of the incoming stream was 15.1° C. and the BT temperature was 14.4°C., was there any noticeable discrepancy. The period of flushing, which is necessary to remove temperature effects from previous depths, was probably too short at that level. The BT profile and temperature measurements are discussed further in the section on egg distribution.

The watermeter indicated that the rate of flow varied little within each of the above trials but differed between them. In the least variable trial, the rate ranged from 79 to 81 liters per minute and in the most variable trial the range was 71 to 77 liters per minute. The rate of flow tended to be slightly higher when the pump was at greater depths, possibly because friction is less in a straight hose than in a coiled hose.

SOURCES OF ERROR

Errors in sampling marine organisms generally fall into two categories. First, a sampler may be unable to collect effectively owing to the behavior of the organisms: avoidance for example. Second, the organisms can be collected but the sampler may introduce error: inaccurate measurements of water volume for example.

No attempt was made to analyze the effect of organism behavior on pump samples but some attention was given to possible sources of error in the pump system. Water volume is measured accurately but errors may arise from fragmentation of organisms by the pump impeller, uneven transport of organisms through the hose, and escapement of organisms through the strainers. Each of these will be considered in turn.

Fragmentation of organisms

When organisms have to pass through a 1.27-cm. pump whose impeller turns at 3,450 r.p.m. and then through a 120-m. hose with internal cables, fragmentation is possible. Estimates of abundance will be low if a large portion of the animals are so severely damaged that they become unrecognizable or are torn into parts which may then pass through the mesh of the strainer. The percentage of fragmented organisms, as indicated by the number of damaged specimens among the first 100 of four kinds counted, were as follows:

Organisms	Size	Percentage fragmented
Copepods (various species & stages)	<0.3 mm. long	2
Sardine eggs (Sardinops caerulea)	1.7 mm. diameter	3
Sardine larvae (Sardinops caerulea)	5 mm. long	92
Brine shrimp (Artemia)	10 mm. long, used for testing	49

Only a small percentage of the small copepods and stage VI and VII sardine eggs (Ahlstrom, 1943) were damaged. Damaged copepods were slightly crushed but easily recognized. The perivitelline membranes of some eggs were ruptured, but the embryos remained intact.

Sardine larvae and brine shrimp suffered a high percentage of fragmentation. Nearly all of the sardine larvae were headless but the bodies were not injured. They are probably too fragile to pass the impeller uninjured. Fragmented brine shrimp were headless, and the bodies often mutilated. Brine shrimp also are probably too large and fragile to pass the pump undamaged.

General inspection (no counts made) showed that chaetognaths, 6 mm. long, and doliolids, 1 mm. long, remained in good condition, but many euphausiids, ostracods, and fish larvae were damaged. The pump described here should not be used for sampling fragile organisms or organisms longer than 5 mm. Diaphragm, air lift, or centrifugal pumps with larger chambers offer possibilities for sampling larger organisms.

Uneven Transport of Organisms Through the Hose

Because friction and turbulence prevent water from flowing evenly through the hose, the transport of organisms is not uniform. This uneven transport can cause contamination of samples by mixing organisms that were collected from different strata in a vertical series. Two trials indicated the differences in the transport of organisms through the hose. In each test the pump was placed in a large container so that it recirculated water through the system and back into the container. Known numbers of dead adult brine shrimp, 1 cm. long, were introduced simultaneously at the pump intake and retrieved in a series of samples after passage through the hose. Ten consecutive 100-liter samples and a final 500-liter sample were collected in small nets with mesh aperture of 0.75 mm. Sampling started immediately after introduction of the shrimp. One hundred shrimp were used in one trial, and 50 in the other.

Table 1 presents the frequency distribution, percentage frequency, and cumulative percentage of shrimp for the series. The number of shrimp retrieved rather than the number introduced forms the base of these percentages. Only 129 of the 150 shrimp used in the two trials were recovered. A few were probably lost in handling but the major loss was due to fragmentation, a factor which was not anticipated. Only heads were counted but some may have become unrecognizable or may have passed through the mesh. It was presumed that few if any shrimp remained in the hose after the passage of 1,500 liters of water.

The frequency distribution shows that most of the shrimp remained together but some were separated by more than 800 liters of water pumped (table 1, column 4). The small number of shrimp that appeared in the second sample of each trial must have been carried by the swifter central core of water. They reached the outlet even before the calculated volume of the hose, 250 liters, was replaced once after introduction of the shrimp. The majority of the shrimp appeared in the third sample; all the shrimp would have appeared in this sample if transport of organisms had been uniform. The remainder, 24.1 percent, were detained for varying periods, probably by eddies.

Table 1.--The number and percentage of simultaneously introduced brine shrimp recovered in 10 consecutive 100-liter samples and a final 500-liter sample, after passage through the pump and hose

Consecutive 100-liter samples	Trial 1 100 shrimp	Trial 2 50 shrimp	Trials 1 and 2 combined[1]		
			Frequency distribution		Cumulative total
	Number	Number	Number	Percent	Percent
1	0		0	0.0	0.0
2	9	2	11	8.5	8.5
3	53	34	87	67.4	76.0
4	4	1	5	3.9	79.8
5	2	1	3	2.3	82.1
6	6	2	8	6.2	88.3
7	2	2	4	3.1	91.4
8	1	2	3	2.3	93.7
9	1	0	1	0.8	94.5
10	3	0	3	2.3	96.8
11-15	2	2	4	3.1	100.0
Total number	83	46	129		

[1] The percentages are based on the 129 shrimp retrieved.

In the field, contamination is most likely to occur between consecutive samples that are taken without interruption. In a discrete vertical series, where samples are taken from depths that are distinctly separated, contamination between depths can be reduced by flushing the system with water from each new depth before collecting. The cumulative percentages (table 1, column 6) offer a guide for judging the presample flushing volume that is needed in the field. They indicate the probability of passing a shrimp through the system in relation to the volume of water pumped after its introduction. If we assume that planktonic organisms become dispersed as the brine shrimp were, the cumulative percentages offer conservative estimates of the portion of contaminating organisms that would be cleared from the hose with different flushing volumes. For example, a flushing volume of 700 liters in the field should remove at least 91 percent of the organisms that remain in the hose from the previous sampling depth.

Escapement Through Straining Apparatus

After the organisms pass through the watermeter, they enter a plastic funnel which has screened windows and a cylindrical cod end at the bottom (fig. 3). The screening is stainless

Figure 3.--A filter funnel showing the screened windows, cod end, and rubber cap.

steel with square mesh openings of 100μ along a side (diagonal of 140μ). A rubber cap fits under the screened bottom of the cod end to keep it from clogging during a period of straining. Removal of the cap after a period of straining allows residual water in the funnel, about 1.5 liters, to drain through the cod end.

Estimates of the sizes of organisms that are retained by the screening were obtained in two trials. In each trial three types of samples were collected after a short period of straining: (a) organisms that passed through the cod end after the cap was removed; (b) organisms that were retained in the cod end; and (c) organisms that were washed off the screening of the funnels with a spray gun. All organisms passing through the cod end (sample type (a)) were counted and measured for maximum width excluding appendages. Numbers in the other types of samples were estimated from one-fourth aliquots. The two trials gave such similar results that they were pooled. They are summarized in three histograms of width composition (fig. 4.).

Comparison of the histograms for organisms that passed through the cod end (type a) and those that were retained (type b) reveals that only organisms wider than 100μ are effectively retained by the 100μ mesh. The number of organisms passing through the cod end declines abruptly above the 80 to 100μ category but the number of organisms retained on the screening of the cod end does not show this change.

Comparison of the histograms of organisms that were retained by the cod end (type b) and those that were washed off the screen with a spray gun (type c) shows that the width compositions of

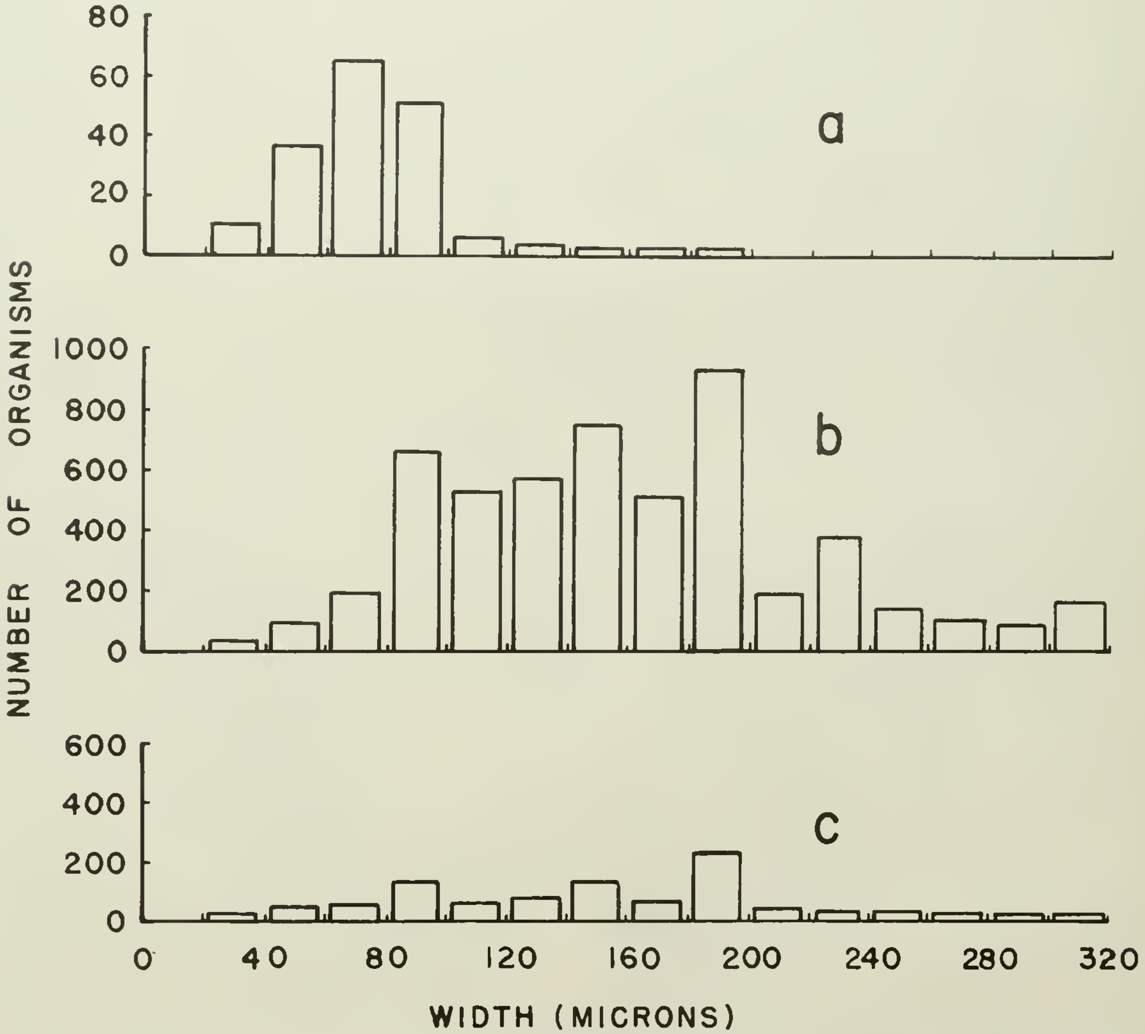

Figure 4.--Width composition of animals that: (a) pass through the screening of the cod end, (b) are retained on the screening of the cod end, and (c) adhere to the screening of the funnel. All screening had 100μ mesh openings. Histogram (a) was constructed from total counts and (b) and (c) were estimated from one-fourth aliquots.

the two groups of animals are not qualitatively different. The number of organisms adhering to the screening of the funnel was about 20 percent of that in the cod end, which means that the funnels must be washed after every sampling period and all residue must be included with the sample.

VERTICAL DISTRIBUTION OF SARDINE EGGS AND LARVAE AND OTHER ZOOPLANKTON

After the initial testing of the pump we found an exceptionally high concentration of sardine (Sardinops caerulea) eggs and larvae in Sebastian Vizcaino Bay, Baja California. This provided an excellent opportunity to test the gear, because eggs float passively in the water and eggs and larvae were so abundant that only relatively small amounts of water had to be strained to detect changes in vertical distribution.

A vertical series was taken at lat. 28° 01.7 N., long. 114° 25.4 W. on August 26, 1964, between 1925 and 2237 hours P.s.t. while the vessel Black Douglas was anchored in 45 m. of water. Two 500-liter samples were taken at each 5-m. level from the surface to 35 m. The system was flushed with 500 liters of water at each depth before sampling was started but was not flushed between samples from the same depth. According to table 1, a flushing volume of 500 liters removes at least 82 percent of the organisms that remain in the hose from a previous depth.

Salinity and temperature of the water from each level were measured. Comparison of the temperatures with a BT tracing made after sampling indicated that the hose was nearly vertical.

The sardine eggs and larvae were identified and counted, and stages of development of the eggs were determined according to the criteria of Ahlstrom (1943). All eggs except one were either stage VI or VII; as the water temperature was 20.7° C., they must have been spawned the previous night (Ahlstrom, 1943). Many of the larvae were headless, but enough characters remained for reliable identification. Most were between 4 and 5 mm. long.

The numbers of sardine eggs and larvae and of chaetognaths and doliolids in each sample are given in table 2 with temperatures and salinities. Temperature and salinity profiles and mean numbers per cubic meter for each level appear in figure 5. The BT tracing obtained immediately after sampling is shown in figure 6. The eggs were abundant and uniformly distributed, 42 to 46 per m.^{3}, in the upper levels where temperature and salinity were uniform. The water temperature, 20.7° C., is near the upper limit of the spawning temperature range, but according to Ahlstrom (1954) it is typical of off-season spawning temperature in Vizcaino Bay. Egg abundance dropped significantly to 11/m.^{3} at the 15-m. level. The BT tracing (fig. 6) indicates that this depth was near the upper boundary of the thermocline. Water samples from this level showed a 0.1° C. drop in temperature and a 0.02 p.p.t. rise in salinity. At the 20-m. level, the egg concentration was only 2/m.^{3}, and at greater depths none were found.

The larvae were uniformly distributed, 32 to 35/m.^{3} in the upper 10 m., but at the 15-m.

Table 2.--Temperature, salinity, and numbers of sardine eggs, sardine larvae, chaetognaths, and doliolids for pairs of 500-liter samples in the vertical series

[Temperature and salinity were taken only in the first sample of each pair; all counts are total except for doliolids which were estimated from one-fourth aliquots]

Depth	Temperature	Salinity	Sardine eggs	Sardine larvae	Chaetognaths	Doliolids
M.	°C.	P.p.t.	Number	Number	Number	Number
0	20.7	33.74	18 24	23 10	9 5	888 756
5	20.7	33.74	26 20	18 17	3 3	796 892
10	20.7	33.74	23 19	24 8	5 1	900 540
15	20.6	33.76	7 4	19 22	14 16	772 692
20	18.8	33.77	1 1	9 12	42 29	300 296
25	17.0	33.69	0 0	0 0	83 203	380 208
30	15.3	33.68	0 0	0 0	82 80	7 23
35	15.1	33.67	0 0	0 0	86 96	3 2

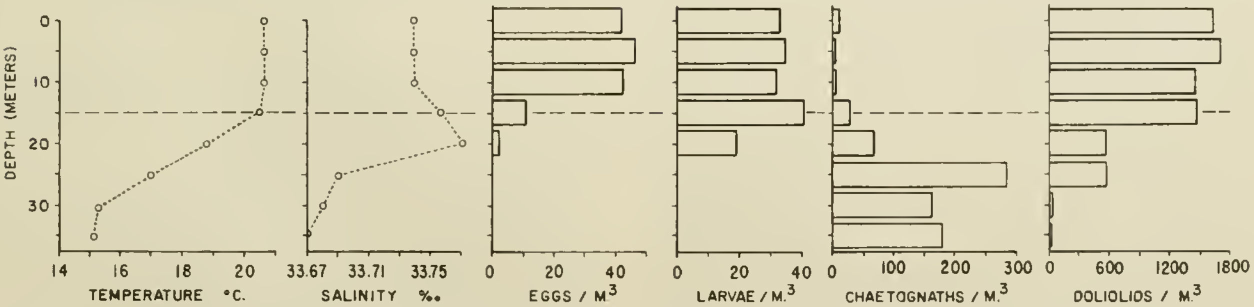

Figure 5.--Vertical distribution of temperature, salinity, and the numbers of sardine eggs, sardine larvae, chaetognaths, and doliolids per cubic meter. The horizontal line represents the beginning of the thermocline.

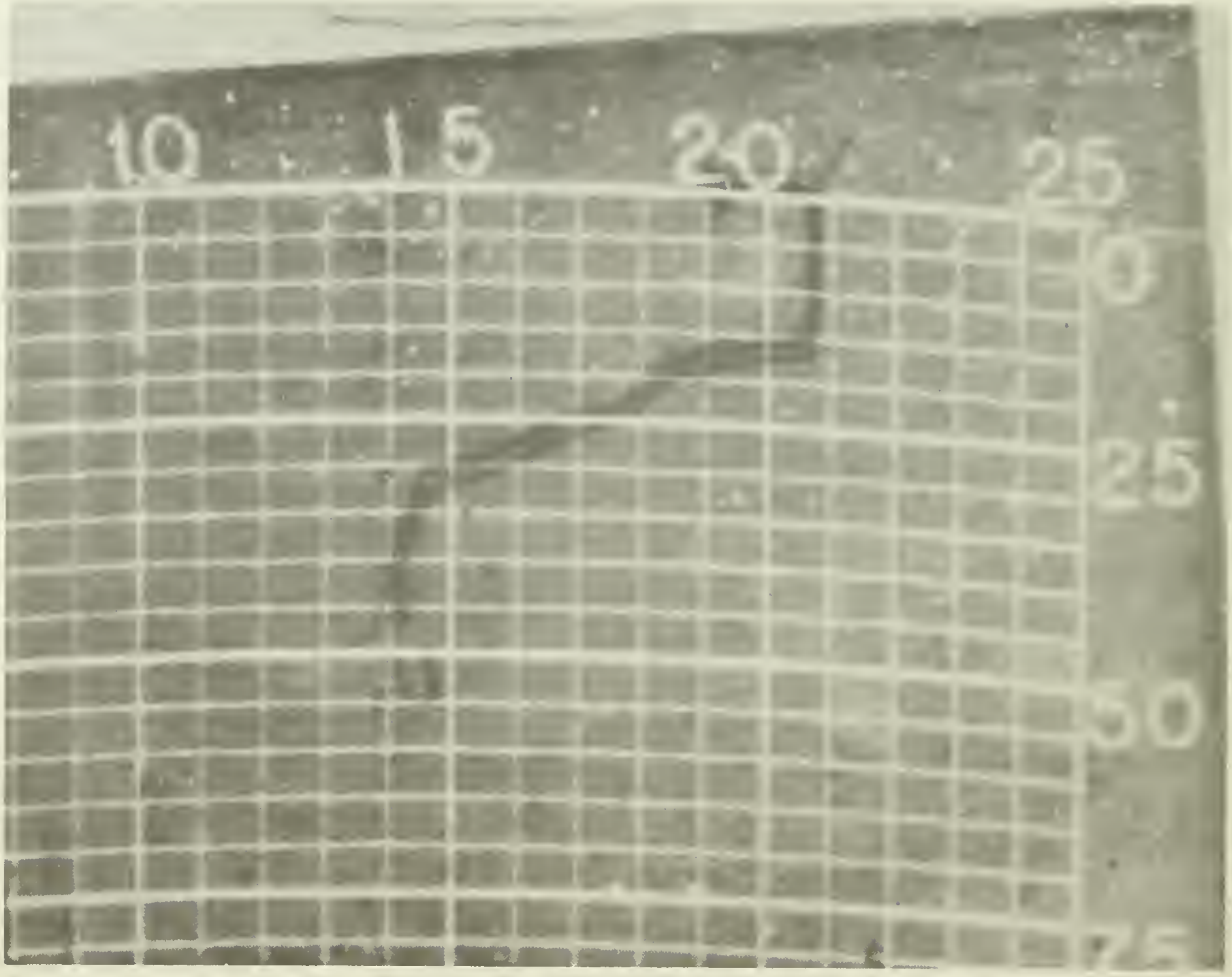

Figure 6.--BT tracing made after sampling.

level, where the thermocline started and where the eggs decreased significantly, larvae increased to 41/m.[3]. They were moderately abundant at 20-m. but were absent at greater depths. These results are consistent with the conclusion, based on a large number of net hauls, that sardine eggs and larvae are restricted to the upper mixed layer and upper part of the thermocline (Ahlstrom, 1959). In the present series the eggs were clearly confined to the upper mixed layer, while the larvae were found in moderate numbers in the upper part of the thermocline as well as in the upper mixed layer.

Chaetognaths and doliolids occurred at all sampling levels, but their vertical distributions were very different (fig. 5). The chaetognaths, mostly 3 to 6 mm. juveniles of Sagitta euneritica, were sparse in the upper mixed layer, increased at the thermocline, and were abundant at the lower depths. The numbers of doliolids (unidentified), about 1 mm. long, were high in the upper levels, declined in the thermocline, and were low at the lower levels. Changes in the abundance of other organisms (not counted) were similarly striking. For example, ostracods decreased in numbers and pteropods increased, with increasing water depth.

ADVANTAGES AND LIMITATIONS OF A PUMP AND REELED HOSE SYSTEM

The use of a pump and a reeled hose to study vertical distribution is not new. Aron (1958), in a historical review, listed several workers who have used pumps to sample plankton from various depths.

A pump and reeled hose system has several advantages over the closing nets used by Leavitt (1935 and 1938), which are opened and closed while being towed slowly at depth. The basic advantage is that the stream of water is delivered on board where it can be manipulated and closely monitored. Salinometers, thermometers, and other apparatus may be used to measure water properties directly, or water samples may easily be collected for analysis on shore. Hydrographic and BT casts taken in conjunction with a net series can provide this information, but they are separated temporally and spatially from the organisms in the sample. The pump and reeled hose make it possible to observe changes in water properties as they occur. The temperature readings on deck show when the thermocline is penetrated, and inspection of the plankton samples indicates when the vertical range of an organism has been exceeded. Strainers of variable mesh sizes may be used because clogging can be observed and controlled even when the mesh openings are small.

The pump and reeled hose system has some severe limitations in comparison with plankton nets. The vertical series described in this paper was taken in an unusually high concentration of eggs and larvae. Standardization of the numbers by Ahlstrom's method (1948) for oblique net tows indicates an abundance of about 6,100 eggs and 7,200 larvae under 10 $m.^2$ of sea surface. Net tow data show that patches of sardine eggs generally occur in much lower concentrations. In such lower concentrations the pump would not be very effective because the volume of water strained in a reasonable length of time would produce insufficient numbers of eggs and larvae for meaningful analysis. Also, the large mouth opening of nets decreases the opportunity for escapement of the larger, more motile organisms. The intake of the pump is small, and even if a large organism is captured, it may be mutilated beyond recognition. Thus, nets and pumps complement each other; each has advantages for sampling particular segments of the biomass.

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