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Plankton Sampling System with a New Submersible Vortex Pump and Its Use to Estimate Small-scale Vertical Distribution of Eggs and Larvae of *Sergia lucens*[1),2)]

MAKOTO OMORI[3)] and SOO-GUN JO[3)]

Tokyo University of Fisheries,
4-5-7 Konan, Minato-ku, Tokyo 108

Abstract

Following the previous development of a vortex pump system that made possible the shallow collection of zooplankton in good condition, a new submersible vortex plankton pump capable of sampling at 100 m depth was designed for examining small-scale distribution of planktonic organisms. The pumping system consists of a pump, vinyl hose, depth sensor, and a deck-mounted collecting unit. Specifications of the pump are, height 111 cm, width 19 cm, and weight 70 kg without cable. A built-in motor (0.4 kw) operating at AC 200V, 50/60 Hz rotates an impeller to produce a vortex.

The pumping system was used successfully to study small-scale distribution of eggs and larvae of the sergestid shrimp, *Sergia lucens*, in Suruga Bay in August 1987. The pump collected more specimens than did standard NORPAC net vertical hauls. Merits and demerits of the pumping system are considered. Vertically, eggs and nauplii of *S. lucens* mostly occurred at 20 m and at 35-45 m depths. Their distribution was related to the discontinuity layer. Spawning appeared to take place mainly at 50 m or above, in the lower part of the thermocline where the temperature varied from 24 to 20 ℃.

In a previous paper (OMORI 1985), one of the authors briefly described a submersible vortex pump SV-1 (Ebara 50 DVS A6.4) for sampling plankton in the water column between the surface and about 20 m depth. The pump generates a vortex which produces the flow for pumping water. The delivery rate does not decrease with increased sampling depth. Most plankton do not pass through the impeller, so that firm-bodied organisms are collected without much physical damage. Taking these advantages into consideration, another submersible vortex plankton pump that can be operated at 100 m depth was devised in order to investigate small-scale distribution of zooplankton. The present paper deals with the new pumping system. Together with description of the system, the vertical distribution of the eggs and larvae of the sergestid shrimp, *Sergia lucens* (HANSEN), collected by the pump in a test of its performance, is considered.

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2) プランクトン採集のための新型渦巻きポンプとそのサクラエビ卵及び幼生の微細鉛直分布調査への応用
3) 大森　信・趙　守根，東京水産大学資源育成学科

Design of Pumping System

a) The pump

Specifications of the new pump (Ebara 50BVS 5. 4), hereafter referred to as SV-2 are, height 111 cm, width 19 cm (max. 28. 3 cm), and weight 70 kg without a 120 m standard electric cable (Fig. 1). The impeller in the head part of the pump is rotated by a built-in electric motor (0. 4 kw) operating on AC 200 V, 50 Hz (convertible to 60 Hz by changing the impeller). The power is

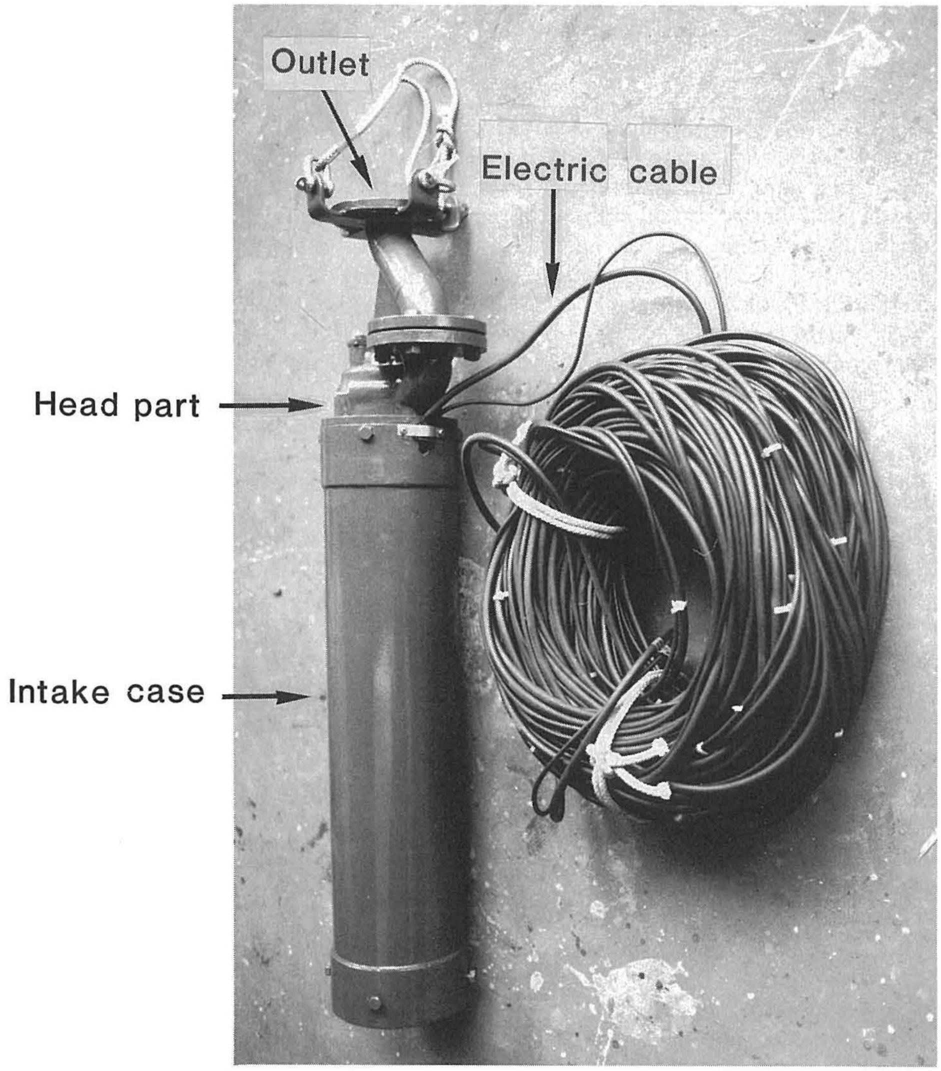

Fig. 1. Submersible vortex pump (Ebara 50BVS 5. 4) for deep sampling (SV-2). Capacity 135 liter · min^{-1}.

supplied from the ship's generator through the electric cable attached to the pump. The shaft connecting the motor to the impeller passes through sealed bearings with a chamber between. In normal applications the housing of the motor and shaft seal space inside of the intake case are filled with distilled water. In operation, seawater taken from lower end of the intake case is delivered to the pump's outlet by vortex produced by the impeller. The outlet is 50 mm in inside diameter (ID) and is connected to 100 m of 50 mm ID vinyl hose. The performance charts for the SV-2 provided by the manufacturer are shown in Fig. 2. The *total head** of the pump is 6.8 m when water is taken from depths down to 80 m through a straight hose and released 2 m above the water line (additional hose on deck will be 6 m with one elbow.): speed 2760 rpm, capacity 135 liter·min^{-1}.

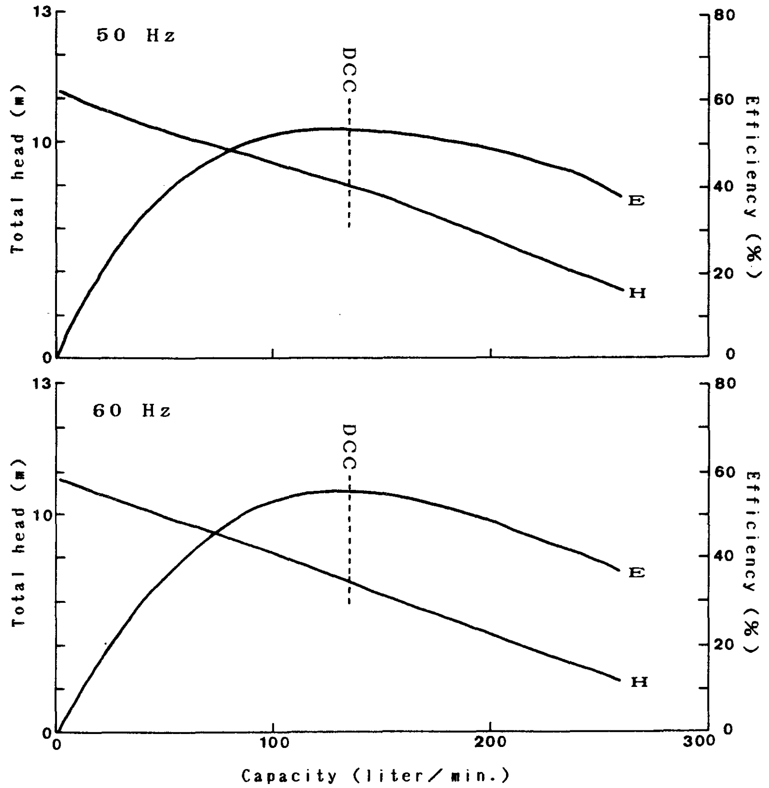

Fig. 2. Relationships between total head (H), efficiency (E), and capacity of the SV-2. Upper: the case of 50 Hz. Lower: 60 Hz. Efficiency is the relation between pump output power and required driver power. DCC means design criterion capacity.

* Power required for operation of a pump at any particular capacity depends upon sum of the suction lift and output head, which is termed the total head or the dynamic head.

b) Sampling procedures

Figure 3 is schematic drawing of the layout of the pumping system. The pump is hoisted overboard by a hydrographic winch, with the cable attached to a bail, which is part of a bridle rope attached to the pump. The hose is loosely bound to the cable at every 10 m. Samples are taken at specified depths as the pump is lowered in order to sample undisturbed water. Exact sampling depths are determined from a pressure-depth sensor, which is attached to the pump and is monitored on deck. The water sample is pumped into the collecting unit which has a flowmeter, two filtering nets and a clear plastic cylindrical tank, 25 cm ID and 60 cm height for outflow water. The two conical nets, of different mesh size and length, are layered in the tank so that the fine mesh net is backed by the outer layer of coarse mesh. To sample *S. lucens* eggs and larvae we used 100 and 330 μm mesh nets for filtration. A plastic hat (15 cm in height) is placed on top of the tank with mouth rings of the nets between. There are two drain holes at different heights in the tank; by choking the outflow at the holes, the rate of outflow is controlled so that the water line is kept a little below the mouth of the nets, ensuring that the collecting nets are submerged in water to minimize physical damage

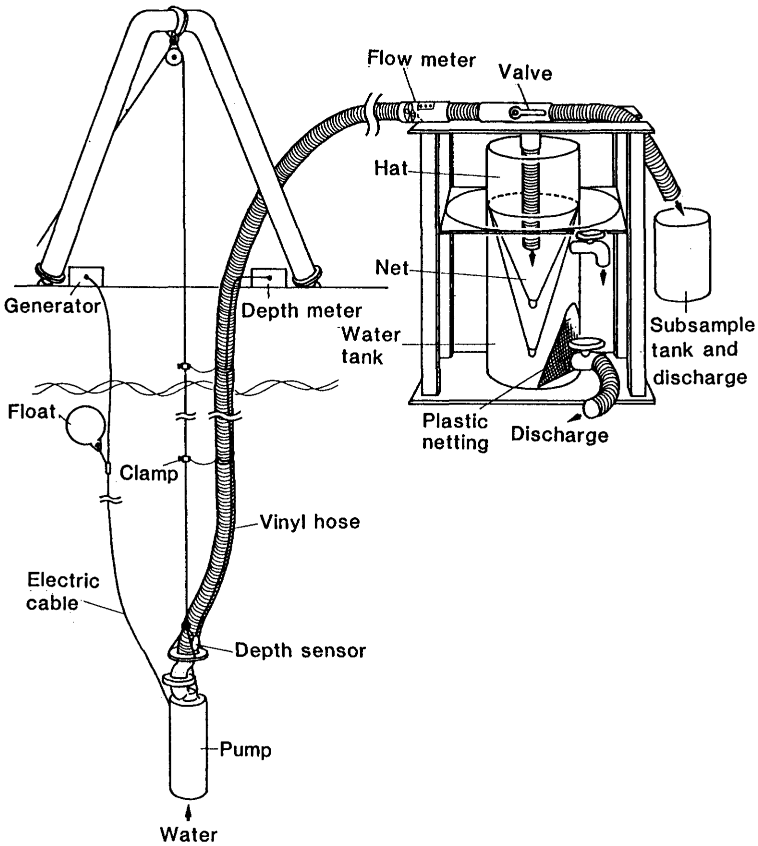

Fig. 3. Schematic drawing of the layout of the pumping system.

of the samples during filtration. The lower side of the fine mesh net is restrained by hard plastic netting to prevent clogging of the drain holes by the nets. Water samples for chlorophyll *a* and nutrient measurements are subsampled from a subsample tank through a hose branches from the main sampling stream: in vivo chlorophyll concentration may be determined by a flow-through fluorometer.

c) Test of the performance

Sampling tests were carried out on board the T/S Shinyo Maru in Suruga Bay on Aug. 6, 1987. We selected two sampling stations in the spawning ground of *S. lucens*. One (Sta. A: Loc. 35°05.9′N, 138°34.7′E) was located off Yui and the other (Sta. T: Loc. 35°06.4′N, 138°38.6′E) was off the mouth of the Fuji River. Water samples were taken at each 5 m down to 100 m at Sta. A between 1600–1840 h, and at each 2.5 m down to 60 m depth at Sta. T between 1200–1450 h. Insulation resisting value, amperage and water delivery rate of the pump were measured at every 10 m. For estimates of abundances of the eggs and larvae, 540 liters (4 min discharge) of seawater from each depth were filtered. The concentrated samples were fixed in 5% neutral formalin and brought back to the laboratory for counting all individuals. Temperature and salinity were measured by CTD casts. At each station, immediately before the sampling, a vertical haul was made with the paired NORPAC nets (100 μm mesh) from 50 m to the surface at a rate of 1 m·sec^{-1}. The pump samples taken stepwise at the specified depths were integrated for comparison with the vertical hauls.

Results

With development of the present pumping system, it became possible to obtain a plankton sample in good condition either from a point source or a sample integrated a defined layer/distance between the surface and 100 m depth, with a reliable measurement of the volume of the water filtered.

At 60 Hz, amperage of the SV-2 ranged between 3.8 and 4.3A throughout the water column. Average flow rate was 1.11 m·sec^{-1} (ca. 135 liter·min^{-1}) at 100 m depth. The time for passage through 100 m of the hose was 90 sec. A complete sequential sampling with 540 liters from each depth took about 2.5 h at each stations. The eggs and larvae were in excellent condition when concentrated.

At Sta. A, the eggs and nauplii occurred from 10 to 100 m depth, but the majority (95%) were distributed above 50 m. About 60% of all eggs were collected between 35 and 45 m, at the upper edge of the seasonal thermocline; numerous eggs (20% of all) were also found at 20 m (Fig. 4). Vertical distribution of the protozoea tended to shift upward; they were most abundant around the 20 m. The eggs and larvae at Sta. T showed distribution patterns similar to those at Sta. A, although the number of individuals was comparatively small and the trend was less prominent. At both stations, the water density (sigma-t) of the layers where a majority of eggs occurred ranged between 22.3 and 23.8; with a salinity of 33.80–34.40‰ and temperature of 22.2–25.5 ℃.

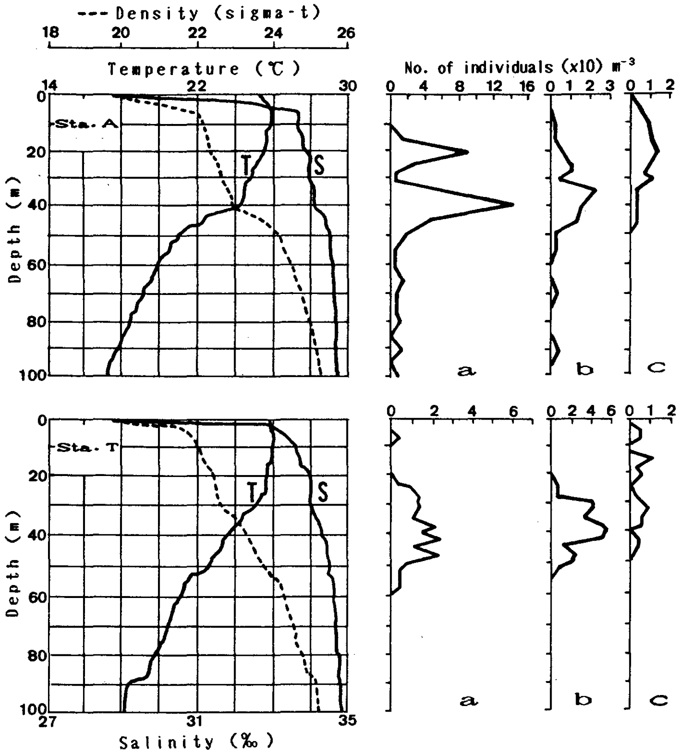

Fig. 4. Vertical distribution of eggs and larvae of *Sergia lucens* at two stations in Suruga Bay, in relation to the vertical profiles of temperature, salinity and sigma-t. a, Egg; b, Nauplius; c, Protozoea.

TABLE 1. COMPARISON OF ESTIMATES OF ABUNDANCES OF THE EGG AND LARVAL STAGES OF *Sergia lucens* TAKEN WITH A SUBMERSIBLE VORTEX PUMP (SV-2) AND WITH VERTICAL NET HAULS WITH A PAIRED NORPAC NET.

	Number of individuals·m^{-2} in 0–50 m water column		
	Egg	Nauplius	Protozoea
Station A			
a. Pump	1619	367	306
b. NORPAC-1	581	67	118
c. NORPAC-2	1533	312	84
$(\overline{b+c})/a$ (%)	65.3	51.7	33.1
Station T			
a. Pump	354	397	113
b. NORPAC-1	194	202	34
c. NORPAC-2	312	320	25
$(\overline{b+c})/a$ (%)	71.4	65.7	26.0

Table 1 compares the results of vertical net haul and the pump sample in a 0–50 m profile. The pump caught more organisms in all of 6 comparisons at different developmental stages. On average, the net estimate of the egg density was 68% of the pump estimate; the difference became even greater in a comparison of the protozoeae.

Discussion

Generally, advantages of pump sampling may be: 1. reliable measurement of the volume filtered and avoidance of problems of clogging of towed nets; 2. reliable control of filtration, with the potential for sequential use of several mesh sizes; 3. reliable depth control of vertically stratified samples; 4. capability for sampling a wide size range of plankton, including all of the lower trophic levels, and physico-chemical parameters in exactly the same water at exactly the same time; and 5. capability to take sets of sequential samples for analysis of small-scale distribution (MILLER and JUDKINS 1981). The present pumping system took all of these merits. However, there are a number of disadvantages that is common in pump samplings. They are: 1. comparatively heavy sampling system that requires 2–3 people for handling; 2. longer time needed for vertically stratified sampling in comparison with simultaneous, multiple layer samplers such as the MTD net (MOTODA 1971); and 3. inadequate study of possible avoidance by plankton. The SV-2 does not necessarily respond to these demerits, but test of the performance showed development of manufacture with considerable capacity, easy handling, and capability of sampling zooplankton in good condition at 100 m depth. Majority of the previous pump samplers could collect plankton samples only in shallow layer.

With regard to sampling efficiency, WIBORG (1948) and MULLIN & BROOKS (1976) indicated that their zooplankton pumping systems with capacities lower than 200 liter $\cdot$ min^{-1} did not show a large difference from towed nets. In the present sampling, the pump caught more eggs and larvae than did the NORPAC net hauls. As mentioned above, however, vertically stratified sampling with the SV-2 took about 2.5 h at each station, as zooplankton densities were not adequate enough for counting individuals in smaller amount of water. Thus, the pump may collect plankton from different water masses while the ship drifts at the sampling station. This is significant problem at locations where the horizontal distribution of plankton is broad, but patchy. The problem of avoidance deserves further study. HARRIS et al. (1986), using a large volume pumping system ($2.8\ m^3 \cdot min^{-1}$), reported visual avoidance by fish larvae in daytime. OMORI (1985) visually observed avoidance of the SV-1 in daytime by *Acartia* and *Centropages* copepods at a distance of 30–40 cm from the intake: also, young sea smelt *Hypomesus pretiosus* kept away from the pump, avoiding the flow. Many organisms use senses other than vision to avoid water flow in the acceleration field that is formed around the intake of any pump sampler. Although orifice velocity becomes important once they are entrapped in this field, the velocity per se is not likely to determine escape rate (MILLER & JUDKINS 1981). If an organism is sensitive to the flow in the acceleration field, it will avoid the pump. Therefore, for future development of the pumping system, an intake design that creates a sharp transition from still water to a velocity greater than the organism's escape velocity is desired.

Average time elapsing between spawning of the egg and hatching of the nauplius of *S. lucens* is 20–33 h at 20–26℃ (KONDO et al. 1988). Therefore, all eggs counted should have been released during the previous night. According to OMORI (1974), the eggs float upward at about 22 cm・h^{-1} in seawater of 32‰ salinity at a temperature of 22℃. Supposing that the spawning occurs around 2000 h (KONDO et al. 1988), this buoyancy rate could cause the eggs at 44 m depth to float to 40 m depth by 1800 h of the next day. The buoyancy naturally increases in waters of the same temperature but of higher salinity, but the occurrence of the eggs around the 20 m depth apparently indicates that some eggs were spawned at depths shallower than 30 m. The peak occurrence of the eggs at the 35–45m layer agrees with the well-known phenomenon of accumulation of plankton around the marked discontinuity layers (e. g. BANSE 1964), and indicates that *S. lucens* spawns mainly at the lower part of the thermocline where the temperature varies between 20 and 24℃.

Acknowledgements

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