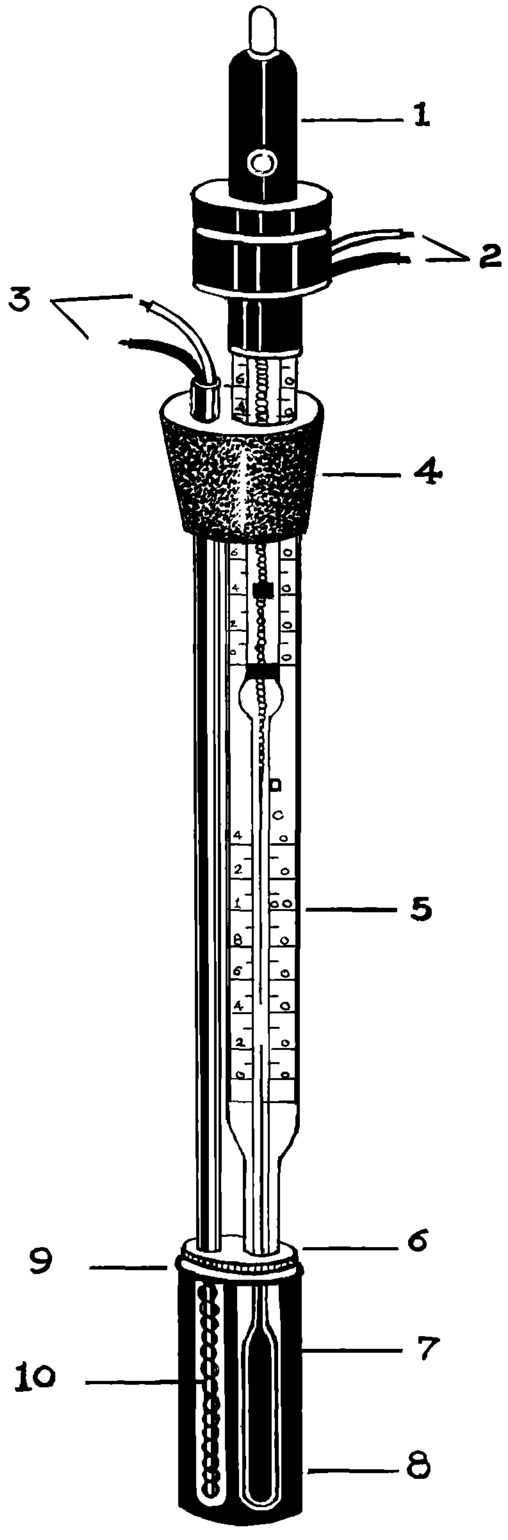


increase is the measure of the activity of the fish.

The advantages of the meter described here over that described by Beamish and Mookherjii (1964) are that it does not require any special glassblowing and that the magnetic head provides a convenient and accurately reproducible setting (Figure 1).

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## Quantitative Sampling with Three Benthic Dredges

The sampling characteristics of the 9 inch × 9 inch Ekman, the Ponar and a Number 1 orange-peel (Figure 1) were tested in the laboratory and in the field. The assumed sampling area of the three dredges is near 520 $cm^2$. Sampling area and volume of bottom material collected were measured in the laboratory. Efficiency of the samplers with different bottom types and organisms was evaluated in the field.

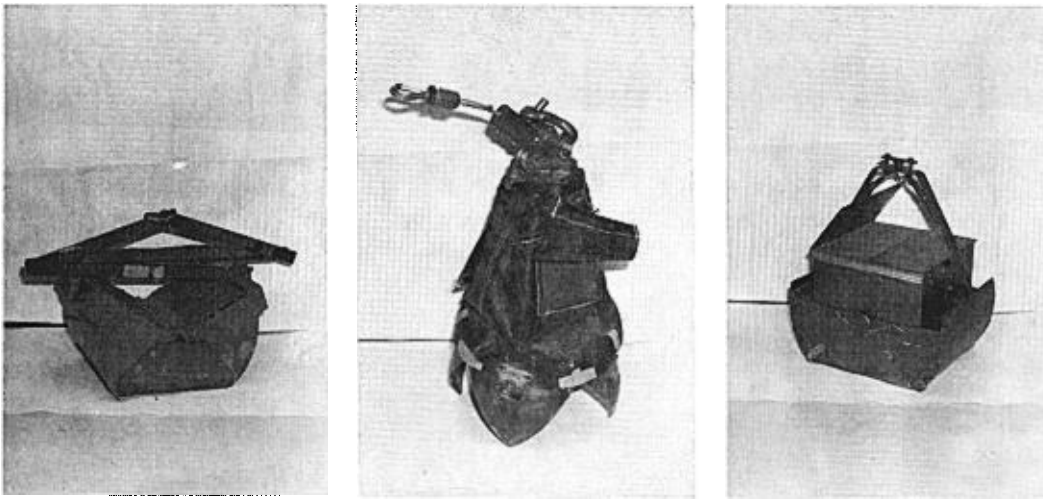

FIGURE 1.—The three benthic dredges, (left) Ponar, (center) Number 1 orange-peel, (right) 9 inch × 9 inch Ekman.

The laboratory studies used the sand and dry bean technique described by Merna (1962). Two methods were used to collect samples. In Method 1 the depth of the sand was increased by 2.5 cm intervals and the sampler forced to penetrate to the bottom of the container for each measurement. In closing, the dredge was held in place so that the blades moved against the bottom of the container. The second method used a sufficient depth of sand so that the blades of the dredge never touched the bottom of the container. The dredge was forced to a given depth and then closed, allowing the weight and mechanical action of the dredge to penetrate further into the sand. An oceanographic hand winch simulated field use. Sampling was replicated at least three times at each depth interval.

Field samples taken from various known substrates were sieved through a 0.234 mm screen and preserved in 10% formalin. Bottom organisms were separated from mud and detritus in a sugar solution (Anderson, 1959).

The Number 1 orange-peel dredge has a bowl capacity of 1,600 cc and a height and diameter of 50.8 cm and 29.2 cm, respectively (Figure 1). Our dredge is covered with a neoprene shroud and has two 10.2 cm × 12.7 cm plastic screen windows with flaps. The dredge weighs 20.4 kg and has been used extensively in our reservoir research. The assumed sampling area of the Number 1 orange-peel as given by Henson (1954) is 669 $cm^2$ if you accept the company's (Hayward Company, New York, New York[1]) stated diameter of the dredge when open as 29.2 cm. Our dredge has maximum inside diameter of 26.0 cm at 8.9 cm from the tip of the blades, resulting in a maximum circular sampling area of 531 $cm^2$. The value of 531 $cm^2$ is near the maximum surface area covered of 550 $cm^2$ as determined by Method 1 in the laboratory and could be used as the standard conversion unit. The surface area sampled exceeded 531 $cm^2$ when penetration depth increased beyond 10.2 cm but then leveled off. The surface area is only 80% the value normally given for the Number 1 orange-peel dredge and agrees closely with Merna's (1962) work.

The Ponar (Wildlife Supply, Saginaw, Michigan) is constructed similar to a Petersen dredge. The top of this samplers' jaws are covered with 0.516 mm mesh screen. This sampler weighs 20.4 kg and has a sampling area of 520 $cm^2$. The samples cover the same area at all depths in contrast to bowl-shaped sample of the orange-peel dredge.

The Ekman dredge used covered a surface area of 520 $cm^2$ and weighed 5.4 kg. It was

[1] Mention of the company name does not imply endorsement of the product.

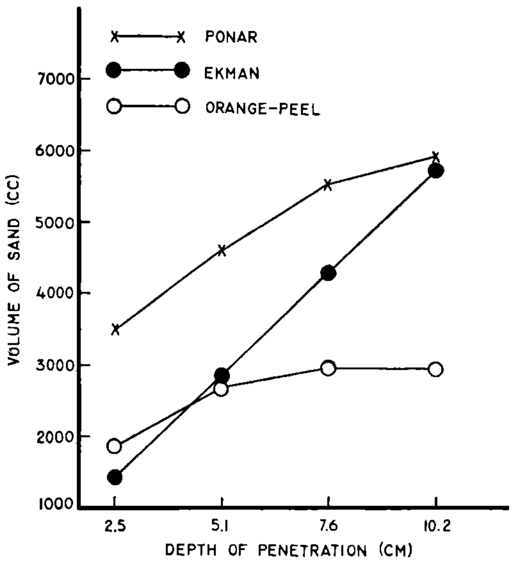


FIGURE 2.—Volume of sand collected at various depths of penetration by a Number 1 orange-peel dredge, Ponar dredge, and Ekman dredge. Sampler initially set to given depth and while closing allowed to settle further.

modified by placing a 0.516 mm mesh screen over the top and the flaps were retained. Because of the Ekman's light weight and uniform shape no laboratory testing was done.

### LABORATORY EXPERIMENTS

The Ekman and Ponar dredges using Method 1 sampled the same area to their maximum penetration. In contrast the orange-peel dredge sampled a decreasing area from the surface to maximum penetration of the jaws. For example, at 10.2 cm of penetration the tip area of the blades sample an area of 293 $cm^2$ while the dredge covers 541 $cm^2$ at the surface. The surface area ($cm^2$) covered by the orange-peel at 2.54 cm intervals was: 293, 426, 503, 541, 550, and 550.

When the dredges were allowed to sample according to Method 2 a different set of results was obtained (Figure 2). The values for the Ekman are calculated figures and are included as a reference since its light weight and closing action of the jaws would not result in further penetration.

The weight and closing action of both the Ponar and orange-peel dredges resulted in further penetration after the samplers were set at a given depth. With the orange-peel dredge this closing action resulted in a greater area and volume of material sampled up to 5.1 cm of penetration (Figure 2). However, at 7.6 cm the hinging of the blades to the main body of the sampler prevented any further penetration in the sand substrate. The Ponar makes an exceptionally good penetration up to 10.2 cm at which depth the top of the sampler binds on the bottom material and prevents further penetration.

### FIELD EXPERIMENTS

Field studies were conducted to determine if the sampling characteristics of the three dredges would affect their efficiency in collecting various organisms inhabiting different bottom types. All samples were collected from Lewis and Clark Lake, a main stem Missouri River reservoir. The substrate sampled was field soil covered by variable levels of silt depending on location and depth. The dominant organisms were burrowing mayflies of the genus *Hexagenia* and chironomids in which members of the subfamily Tanypodinae domi-

TABLE 1.—*Comparison of the means of the main groups of benthic organisms sampled by the Ponar dredge, orange-peel dredge, and Ekman dredge from a number of bottom types*

| Organism | Bottom type | Average number of organisms per $m^2$ | | | Number of paired samples | Level of significance |
|---|---|---|---|---|---|---|
| | | Ponar | Orange-peel | Ekman | | |
| *Hexagenia* | Variable | | 368.2 | 245.1 | 8 | 0.05 |
| *Hexagenia* | 4–5 inches of silt over field soil | 100.0 | 69.8 | | 10 | 0.10 |
| Chironomids | Variable | | 668.4 | 805.3 | 10 | n.s. |
| Chironomids | 4–5 inches of silt over field soil | 713.0 | 587.2 | | 10 | n.s. |
| Tanypodinae | | 644.0 | 519.2 | | 10 | n.s. |
| Others | | 69.2 | 68.0 | | 10 | n.s. |
| Chironomids | Hard field soil | 9,613.2 | 5,336.8 | | 6 | 0.10 |

nated. Number and weight of organisms per grab were converted to number per square meter, transformed using $\sqrt{x + 0.5}$, and tested using a paired t-test to determine whether differences in the means were significant. Results of the field tests are summarized in Table 1.

Ten paired samples were taken with the orange-peel and Ekman dredges from a variety of substances. The orange-peel collected more *Hexagenia* at the 0.05 level of significance but differences in chironomids were not significant. *Hexagenia* commonly burrow deeper than 5.1 cm (Hunt, 1953; Eriksen, 1968). Bottom types contained abundant organic matter but allowed only limited penetration by the Ekman. The orange-peel will normally penetrate 8.9 cm or more under these conditions but its average area sampled is still less than the Ekman. The area difference is negligible but the lack of penetration by the Ekman is significant.

Ten paired samples were taken with the orange-peel and Ponar dredges in an area of uniform bottom composed of 7.6 to 10.2 cm of recently deposited silt over field soil. Although there was no significant difference between the dredges in total chironomids the Ponar dredge collected more Tanypodinae. The Tanypodinae are free living and do not construct silken cases or tubes. They would be susceptible to shock wave produced by the descending dredge and would be washed aside. A stronger shock wave should be produced by the orange-peel dredge whose windows are on the side. The subfamilies which are typically burrowers or case builders and not susceptible to shock wave were sampled equally. This reasoning could also be applied to the differences in chironomids collected between the Ekman and orange-peel although these data were not broken down to subfamilies.

The Ponar dredge collected more *Hexagenia* than the orange-peel dredge at the 0.10 level. This could be attributed to the reduced area and volume of material sampled by the orange-peel dredge (Figure 2).

Six paired samples were taken with an orange-peel and Ponar dredge over a bottom type composed of field soil. Wave action in this shallow shore area kept the bottom fairly devoid of silt. Penetration of the orange-peel averaged 8.9 cm. The fauna was almost 100% chironomids of the genera *Pseudochironomus* and *Tanytarsus*. The Ponar dredge caught more chironomids (0.1 level). Although not significant, the average weight per Ponar dredge sample was higher. The apparent discrepancy between the estimates based on numbers and weight was attributable to the composition of the fauna. The majority of the organisms were small *Tanytarsus* (2 mm) which occur on the surface of the mud (Darby, 1962) and in some species they build felted tubes loosely attached to dead leaves and other partly submerged debris (Hauber, 1944). These would have been more vulnerable to the shock wave produced by the orange-peel dredge. The larger *Pseudochironomus* (8 mm) live in tubes but are found beneath the mud (Darby, 1962) and are not as susceptible to shock wave as *Tanytarsus*. The Ponar dredge made a more uniform penetration, and the reduced shock wave resulted in a better grab.

Both the orange-peel dredge and Ponar dredge are limited in deep deposits of silt. Their weight drives them into the silt which fills the sampler and passes the silt through the screened windows. This is especially true in the Ponar dredge where there are no flaps to partially prevent this and most of the extruded silt is washed away upon retrieval. The orange-peel dredge with side screens and flaps is less affected. This would be serious if the screen mesh size is larger than that of the sieving device. This problem was not studied quantitatively.

## CONCLUSIONS

The Ekman dredge is restricted in use to soft and finely divided littoral bottoms of lakes free from vegetation and intermixtures of sand and other coarse debris and this severely limits its application. Even in silty deposits Hilsenhoff (1967) noted that it may not effectively sample the deeper burrowing *Chironomus plumosus*. The Ekman dredge is useful with SCUBA because of its light weight; the sampler can be forced into the bottom and the jaws forceably closed to assure a good grab.

The requirements of bottom sampling are

so diverse that no one sampler has been devised to serve all purposes. Of the three samplers tested, the Ponar dredge is the most versatile and is only limited in deposits of silt over 12.7 cm. The orange-peel dredge, with its variable sampling characteristics and production of a shock wave, is of questionable value.

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## Plastic Enclosure Versus Open Lake Productivity Measurements

INTRODUCTION

Studies to determine the effects of nutrient enrichment on primary productivity in lakes have been conducted using: (1) whole lake fertilization (Ball and Tanner, 1951); (2) addition of nutrients to glass bottles or polyethylene tubes suspended in the lake (Wetzel, 1966 and Goldman, 1962); and (3) batch and continuous laboratory bioassays of the lake water of interest (Oswald, 1960 and Pearson *et al.*, 1969). Recently in the *Transactions*, Kemmerer (1968) indicated that the polyethylene enclosures give more valid approximations of the fertilization effects than do the laboratory methods. Other authors, including McAllister *et al.* (1961) have implied that these enclosures are superior to bottle tests for phytoplankton studies. Following Kemmerer's report, Verduin (1969) commented on these results, questioning the usefulness of the column technique. Our experiments were conducted to establish the comparability of productivity measurements made in these columns to those made in the open lake, in anticipation of incorporating the column method into our own enrichment studies.

The productivity comparisons were made in Third Sister Lake, a protected 10-acre lake located in the Saginaw Forest preserve near Ann Arbor, Michigan. The columns used in the study were constructed of polyethylene film 0.006 inches in thickness. The tubes were held open with polyethylene hoops placed at one meter intervals, and when completed formed cylinders of the following dimensions: 0.5 × 10 meters. These columns were suspended in the lake from a wooden frame, and samples were collected three times during each experiment, at one meter intervals from the surface to nine meters. In the first experiment, a Van Dorn sampler was used, but in the second experiment a specially constructed sampler, designed to minimize the turbulence produced in the column, was substituted.

Lake samples were collected at the same depths at 2 stations within 3 meters of the position of the columns. The samples from the columns and from the lake stations were placed in 300-ml BOD bottles, 2 light and 2 dark, for each depth. Following the removal of 1 ml of lake water from each sample, 1 ml to a solution containing 0.5 $\mu$C/ml of C-14 as sodium bicarbonate was added. The samples were then incubated at their respective depths for 24 hours, sunrise to sunrise, a period necessitated by our research and teaching schedules. After incubation the samples were filtered through 0.45$\mu$ membrane filters, air dried, glued to planchets, and their Beta activity counted for 10 minutes in a gas flow proportional counter (Beckman-Sharpe Laboratories Low Beta II).