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by

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During the summer of 1930 experimental work was begun for the purpose of designing a suitable, efficient net to be adopted as a standard type for quantitative plankton work carried on by the Pacific Biological Station.

For a beginning a large net was made of #20 bolting silk. This material is used more or less generally at present for fine plankton work as, under ordinary conditions of use, it is fine enough to retain all but the very finest plankton organisms.

The net was of the ordinary inverted cone type. The ring at the open end was of 3/8 in. galvanized iron, and had an inside diameter of 24 in. The length of the net along the side was 60 in. At the lower end an opening 3 in. in diameter permitted the insertion of a brass collar for the attachment of a plankton bucket by means of a simple bayonet catch. The silk was in four sections. In order to reduce the filtering area of the net as little as possible, the seams were made as narrow as was consistent with giving them sufficient strength. They were reinforced by having a narrow strip of cotton tape sewed between the layers of silk. Inclusion of the softer cotton also produces a closer fitting seam, particularly by filling the holes made by the needle, and it reduces the possibility of the silk's ripping along the line of stitching. Attachment to the ring was made by folding a narrow band of heavy unbleached factory cotton over the ring and stitching the silk firmly between its inturned edges. To the lower end a short cylinder of factory cotton about 2 in. long was sewed. A brass clamp around this held the collar of the plankton bucket firmly attached to the net and prevented the metal from damaging the more delicate silk.

The plankton bucket used was about 2 3/4 in. in diameter and similar to that

described by Juday (Trans. Wisconsin Acad. Science, Arts and Letters, Vol. XVIII, Part II, 1916). Its windows, three in number, were made as large as possible in order to drain off the excess water quickly before emptying the bucket of plankton.

A series of six interchangeable cones, to be attached in front of the net so that it could be used as a closing net, was also constructed. Each cone was made with a different size of opening in its smaller end, the sizes ranging from 6 in. to 12 in. in inside diameter. Rings of 3/8 in. galvanized iron were firmly stitched around these openings. The cones were made of heavy factory cotton with 24 in. galvanized rings sewed in their lower ends.

The cones were quickly and easily interchangeable, being attached to the net by a series of six small brass clamps placed at intervals around the circumference of the 24 in. rings. The clamps were specially made to grip both rings and hold them tightly together. A cotton flap about four inches wide handing from the inside of the base of the cone and covering the point between cone and net, served further to prevent any possible leakage here.

The rings sewed in the upper ends of the six cones, were 6, 7, 8, 9, 10 and 12 in. in inside diameter. The length of the cones was 28 in. along the side, so that when they were dropped to close the net, they extended 4 in. beyond the lower edge of the ringof the net.

The usual bridles for attaching sinkers and for hauling were added along with the tripping device to be used when it was desired to close the net before reaching the surface.

With this equipment it was possible to use the net open (24 in. opening), or to add any one of the six cones, and thus compare the effects of reducing the opening to 6, 7, 8, 9, 10 or 12 inches in diameter. The changes could be made

easily and quickly. It was, therefore, possible to make a number of hauls in a short period of time, and consequently under conditions as nearly uniform as it is possible to obtain them in the sea.

This apparatus was somewhat large and cumbersome to handle with the facilities available. It was felt, however, that for experimental purposes large nets should be used so that the quantities of plankton collected would be greater, and consequently the variations in the amounts taken under varying conditions and with openings of different sizes would be more marked. With knowledge of the most satisfactory shape and proportions, smaller nets, constructed according to the same plan, could be made and standardized, if so desired.

Quantitative comparisons only were made of the plankton collected. Material from each haul, diluted with a considerable amount of sea water, was preserved by addition of formalin to about 5% strength. This dilute suspension was then allowed to settle in graduated cylinders for 24 hours. Throughout this report, the figures given for amounts of plankton refer to the number of cubic centimeters of preserved plankton which settled in 24 hours under the conditions first described. In a number of cases, in which the amount of plankton taken in a haul was small, a number of similar hauls were made, and the resultant plankton combined. In these cases the figures given are the averages of the combined hauls.

No simple conical net will filter all the water in the column cut out during the period of haul by the ring in its open end. There are two main reasons for this. The first is the resistance offered by the material of the net itself. The second is the fact that the organisms gathered tend to clog the openings of the net and thus lower its filtering capacity. This is par-

ticularly true of fine nets used to collect the more minute plankton organisms.

The amount of water admitted to a net can easily be controlled by reducing the size of the opening through which the water enters. For this purpose the cones with upper rings of various sizes were constructed.

The first problem seemed to be to find what size of opening would admit just the amount of water that the net would completely filter under the most adverse conditions, viz., when fine plankton (diatoms) was particularly plentiful and the clogging effect would be greatest.

It follows that with any opening smaller than this, the net would filter all the water admitted, but it would not be functioning at its full capacity.

For any net, the largest opening that would admit only the amount of water that the net could completely filter under the most adverse conditions, I would term the optimum opening.

It follows, then, that a net with an "optimum opening", or smaller, should be suitable for quantitative plankton work.

Variations in the rate of hauling would also materially affect the result. In the experiments to date all hauls were made at the uniform rate of 165 ft. per minute or 2.75 ft. per second.

All hauls made to the time of this report were taken vertically. The distance through which the net was hauled was measured by a meter. From this figure and the inside diameter of the front ring of the cone, the volume of the cylinder of water cut out by the opening to the net during its haul is easily determined. Comparison of results is made by calculating the number of cubic centimeters of settled plankton per gallon of water in the column cut out by the opening of the net.

Successive hauls were made under identical conditions (i.e., as nearly identical as can be obtained in the sea) with a gradual reduction in the size of the opening of the net gave gradually increasing amounts of plankton per gallon of water in the column until a maximum was reached. This maximum indicated that the net was giving complete filtration of the water in the column. Further reduction of the size of the opening gave the same amount of plankton per gallon of water in the smaller column. The total amount of plankton was, of course, reduced.

In designing a net to meet all conditions, particularly great concentrations of the finer plankton organisms, it would be advisable to make the opening a little smaller than the optimum size in order to give an additional factor of safety.

For further reference, the volume per yard in length of cylinders of various diameters follows:

Diameter		Volume per yard of Length
24 in.	-	48.70 gal.*
12 "	-	14.675 "
10 "	-	10.19 "
9 "	-	8.66 "
8 "	-	6.52 "
7 "	-	4.99 "
6 "	-	3.67 "

* Volume is Imperial gallons.

All hauls of each series were made in one location, and under conditions as nearly uniform as they will remain at any one place during the period of the hauls.

The fact that uniform conditions are practically impossible to obtain is amply illustrated by the results of the hauls made on August 23rd. All the hauls of this series were taken while at anchor in the deepest portion of Departure Bay, and all were from 30 yds. to the surface. The results are as follows:

No. of Haul	Opening of Net	Time of Haul	Amount of Plankton
27	24 in.	9:59 A.M.	270 c.c.
28	"	10:05 "	200 "
29	"	10:10 "	285 "
40	"	11:46 "	288 "
41	"	11:50 "	284 "
30	12"in.	10:31 A.M.	265 c.c.
31	"	10:36 "	292 "
32	"	10:41 "	200 "
33	"	10:50 "	246 "
34	"	10:55 "	274 "
35	8 "in.	11:15 "	146 "
36	"	11:20 "	172 "
37	"	11:25 "	116 "
38	"	11:29 "	144 "
39	"	11:34 "	170 "

On account of such variations as just indicated all final conclusions regarding efficiency of any net should be acceptable only when based on the results of a very great number of hauls.

Results of the hauls made during the past summer follow:

Table I.

Station I, August 19th.

Distance of Haul	Diameter of Opening	Total Plankton	Plankton per gal.
400 - 0 yds.	24 in.	420 c.c.	.0179 c.c.
do.	12 "	300 "	.0511 "
do.	8 "	140 "	.0534 "
400 - 25 yds.	12 in.	25 c.c.	.00454 c.c.
do.	8 "	20 "	.00818 "
25 - 0 yds.	12 in.	68 c.c.	.1854 c.c.
do.	8 "	34 "	.2086 "

Table II.

Station I, August 21st.

Distance of Haul	Diameter of Opening	Total Plankton	Plankton per gal.
400 - 0 yds.	24 in.	297.5 c.c.	.0126 c.c.
do.	12 "	499 "	.0850 "
do.	8 "	229 "	.0878 "
25 - 0 yds.	24 in.	390 c.c.	.2658 c.c.
do.	12 "	470 "	1.2817 "
do.	8 "	215 "	1.3190 "
400 - 25 yds.	12 in.	29 c.c.	.0052 c.c.
do.	8 "	14 "	.0057 "

Table III.

Departure Bay, August 23rd.

All hauls 30 yds. to surface. All figures in columns 2 and 3 are averages of five hauls.

Diameter of Opening	Total Plankton	Plankton per gal.
24 in.	265 c.c.	.1507 c.c.
12 "	255 "	.5803 "
8 "	150 "	.7670 "

Table IV.

Departure Bay, September 10th.

All hauls 40 yards to surface. Figures given for total plankton are for five combined hauls. Figures in right-hand column are averages of the five hauls.

Diameter of Opening	Total Plankton	Plankton per gal.
24 in.	32 c.c.	.0027 c.c.
12 "	40 "	.0136 "
10 "	36 "	.0177 "
9 "	27 "	.0161 "
8 "	26 "	.0199 "
7 "	22 "	.0220 "
6 "	16 "	.0218 "

The hauls taken September 10th show a very small quantity of plankton on account of the fact that the summer maximum of diatoms, which constituted a great proportion of the previous hauls, was past.

Diatoms practically all occur near the surface, certainly few occurring below 25 yards at most. Below the diatom layer, the plankton organisms are fewer and larger. It follows that below the level of the diatoms a net will efficiently handle a much greater volume of water than when diatoms are present to cause clogging. It would work efficiently with a much larger opening, but if one net is to be capable of meeting all the conditions encountered, it must be designed to meet the extreme conditions imposed by the greatest concentration of diatoms that may be encountered.

To give greater amounts of plankton in return for the labor expended in making the hauls, it would seem advisable to use two standardized nets,- one for use near the surface and one for use below the level of the diatoms, say below 25 yards.

In Tables I, II, and III, when 24 in., 12 in., and 8 in. openings were used, the figures in the last column all indicated that the 8 in. opening gave a much greater quantity of plankton per gallon of water in the column cut by the front ring than did either the 12 in. or the 24 in. (net without a cone) opening. It followed, then, that for this net, the amount of water that it could completely filter was probably in the vicinity of the amount admitted by an 8 in. opening.

For the hauls made September 10th, a greater variety of cones was available. Although, as previously stated, the summer maximum of diatoms was past and the quantity of plankton was small, figures in the right-hand column of Table IV indicate that the optimum opening for the net was in the vicinity of 6 in. or 7 in. in diameter.

To further check this, a great number of hauls should be made with cones having openings of say 5 in., 6 in., 7 in., and 8 in. inside diameter, and at

a time when diatoms are present in great abundance.

In addition to the foregoing work with nets, a deep sea water and plankton bottle was designed. This device is so planned that it can be lowered to any desired depth, and when the closing device is released, a cylinder 12 in. in diameter and 25 in. long drops rapidly, cutting out a ten gallon sample of water with its contained plankton in a fraction of a second. The cover follows immediately, and a completely sealed sample may be brought to the surface.

There has been no opportunity to thoroughly test this apparatus as yet. It is hoped and believed that it will prove satisfactory, and that it will give very accurate quantitative samples of plankton, so that it may be used as a standard by which to calibrate plankton nets.