RESTRICTED

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

Serial No.1910
(D.c.12)

ICNAF Res.Doc.67/110

ANNUAL MEETING - JUNE 1967

Tests of Zooplankton Samplers

by

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The original proposal for the ICNAF-Georges Bank Surveys (Res. Doc. 66-50) did not specify the type of gear to be used to collect quantitative samples of fish eggs and larvae, forage organisms, and juvenile fish still in mid-water. At the time that this document was written, the ICES/SCOR/UNESCO Working Group on the standardization of zooplankton methods at sea was reviewing these problems and preparing reports which we hoped would recommend the most efficient samplers for each of these groups of animals.

The final report of the Working Group has not yet, to our knowledge, been published but Fraser (1966) has published a summary of the reports of each of the four working parties which had been set up to consider different aspects of the problem. The terms of reference and the recommendations of three of the working parties are given briefly below.

Working Party 2 - To give an assessment of the biomass of the plankton from 200μ upwards to about 10 mm.

A ring 57 cm in diameter (.25 m^2) supporting a net of 200μ nylon mesh with a cylindrical section 95 cm long followed by a conical section with a side length of 166 cm. This amounts to a 6 : 1 filtration ratio. To be towed by three bridles each 57 cm long attached to a swivel and a nylon rope lead. To be hauled vertically using a 25 or 40 kg weight; lowered at 60 m/min and hauled at 45 m/min.

Working Party 3 - To sample those components of the plankton often sampled by stramin or other coarse meshed nets.

A ring 113 cm in diameter (1 m^2) supporting a net of 1 mm nylon mesh with a cylindrical section 57 cm long followed by a conical section 200 cm in length. This amounts to a 3.5 : 1 filtration ratio. To be towed by three bridles each 113 cm long at 2-3 knots(62-93 m/min) using a 40 kg weight.

Working Party 4 - To sample organisms in the 2-20 cm range.

A 6 or 10-foot Isaacs-Kidd Midwater Trawl with a net of 12.5 mm stretched mesh nylon supported within an outer net of about 6.5 cm knot to knot. To be towed at a ship's speed of 3 knots (93 m/min) with the wire paid out at 40 m/min and hauled at 60 m/min for oblique tows and 60 m/min for horizontal tows.

Tests with the Working Party 3 Net.

With the aid of a set of drawings and specifications kindly provided by Dr. Fraser, we had two Working Party 3 (WP-3) samplers built (Fig. 1). Both of these were lost early in the cruise made to evaluate them so there is less data than is desirable but the results are striking.

As a comparison, we used a Brown-McGowan (McGowan and Brown, 1966) sampler (Fig. 1). This is a frame, free to rotate in both the horizontal and vertical planes, which holds two nets, one on each side of the towing wire. The special characteristic of this sampler is that, used with an efficient depressor so that the towing wire is nearly vertical, the mouths of the nets enter undisturbed water. Each net has a .39 m^2 mouth area; ours were made of 333μ mesh nylon with about a 10 : 1 filtration ratio.

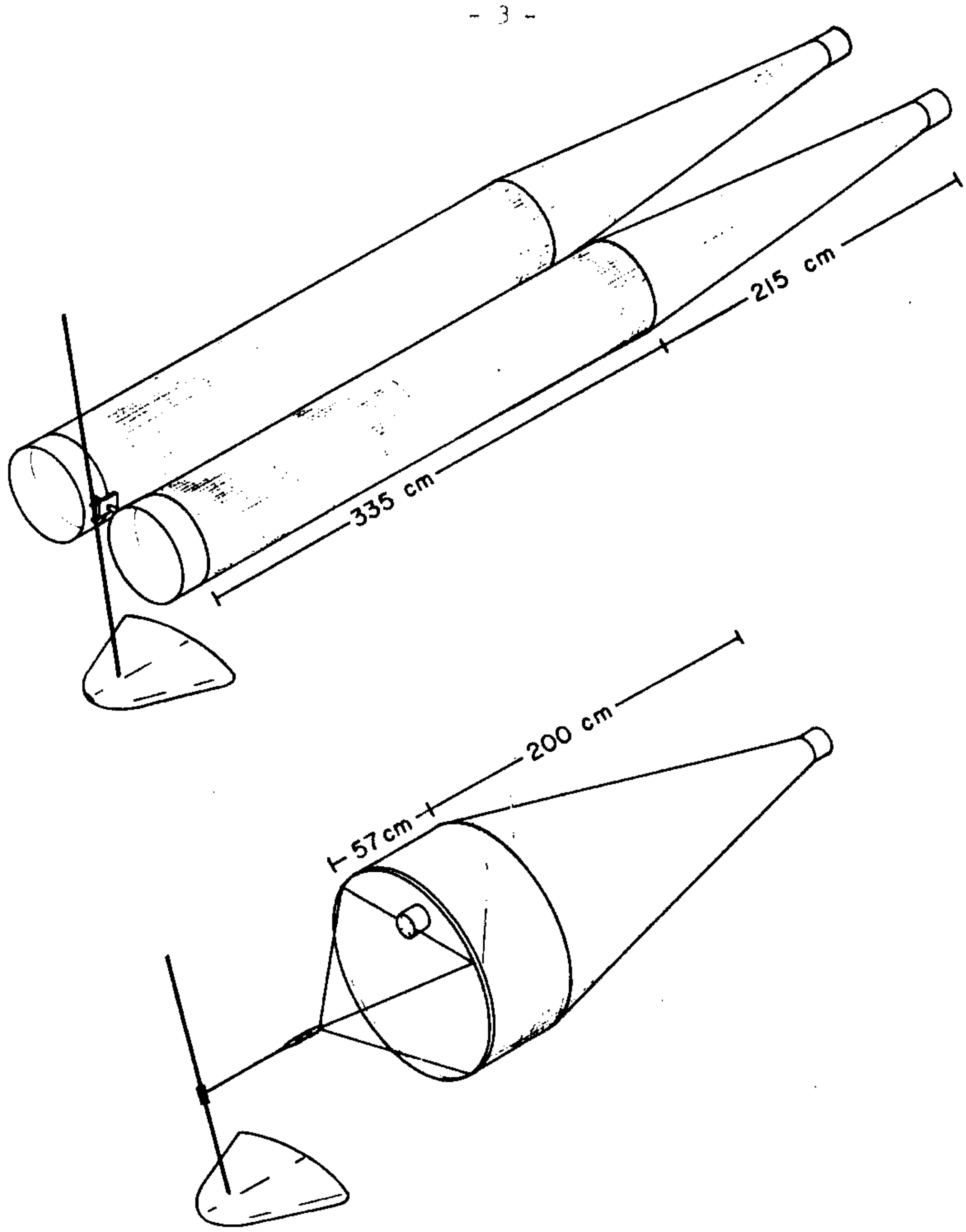

Figure 1. The Brown-McGowan sampler and the Working Party 3 net.

We completed six stations at each of which we first made a 14-minute step oblique haul at 3 knots (93 m/min) with the BM sampler and then repeated the haul as exactly as possible with the WP-3 sampler. We used a Braincon V-Fin as a depressor. The fish larvae were picked out of the samples; divided into 3 types, "herringlike," "croakerlike," and "flounderlike"; and then counted and measured to the nearest 0.5 mm. The results, summing the catches of the two nets on the BM sampler, are shown in Table 1. It is obvious that the BM sampler consistently took a great many more of all three types of larvae than the WP-3 sampler. In all, without adjusting for the difference in mouth areas, the BM sampler took 4 times as many fish larvae as the WP-3 sampler.

Table 1. Numbers of 3 types of fish larvae taken by alternate duplicate hauls of a Brown-McGowan (BM) net and a Working Party-3 (WP) net at 6 stations.

	Type	"Croaker"		"Flounder"		"Herring"	
	Net	BM	WP	BM	WP	BM	WP
Station		Nos.	Nos.	Nos.	Nos.	Nos.	Nos.
2		291	120	70	30	324	72
3		71	24	142	42	175	13
4		19	9	22	6	30	3
5		40	11	1	2	24	24
6		362	67	1	0	172	26
8		10	3	1	1	0	1
Total		793	234	237	81	725	119

The poor catches of the WP-3 sampler were not caused by the net clogging. The average distance traveled during the six hauls, as measured by a flowmeter in the net, was 1289 m with a standard deviation of 144 m. The duration of tow was timed with a stop watch; and if it had been possible to hold the ship's speed to exactly 3 knots, the net would have traveled about 1300 m.

Table 2 shows that the greater catch of the BM sampler, all stations pooled, was not caused by the 333μ mesh retaining smaller larvae which escaped through the larger 1 mm meshes of the WP-3. In this table the BM catch has been adjusted to a mouth area of 1 m^2 to give a better comparison. Except in the very smallest size category, 2-4 mm for "croakers" and "flounders" and 8-10 mm for "herring," there is no evidence of escapement through the meshes. On the other hand, the WP-3 sampler was particularly inefficient in capturing the larger larvae. The second mode shown in the "herring" catch of the BM sampler is entirely lacking in the WP-3 catch.

Table 2. Length-frequency distribution of three larval fish types taken in alternate hauls of a Brown-McGowan (BM) net and a Working Party-3 (WP) net.

Type	"Croaker"			"Flounder"			"Herring"		
Length mm	BM nos.	WP nos.	WP/BM	BM nos.	WP nos.	WP/BM	BM nos.	WP nos.	WP/BM
0-2									
2-4	3.1	0.0	-	1.5	0	-			
4-6	123.1	39.8	.32	54.4	19.0	.35			
6-8	185.1	36.5	.20	95.1	23.0	.24			
8-10	134.2	44.7	.33	96.9	24.0	.25	2.6	0.0	--
10-12	239.0	66.9	.28	37.4	13.0	.35	36.8	7.4	.20
12-14	278.7	46.1	.17	17.0	2.0	-	131.3	9.8	.07
14-16	50.9	0.0	-	1.5	0	-	246.8	46.6	.19
16-18	3.1	0.0	-				147.0	29.4	.20
18-20							47.2	7.4	.16
20-22							91.9	8.6	.09
22-24							89.3	8.6	.10
24-26							107.6	1.2	.01
26-28							18.4	0.0	-
28-30							10.5	0.0	-
Total	1016.6	234.0	.23	303.8	81.0	.27	929.4	119.0	.13

Tests with other samplers.

The tests reported above led us to rule out conventional bridled ring net samplers, but we still did not have a sampler that we could recommend for the purposes of the larval fish survey. The BM sampler, in its commercially available version, leaves much to be desired in spite of its demonstrated efficiency. It is large, clumsy, and expensive. We found it difficult, it not dangerous, to handle in all but the best weather.

The unique characteristics of the BM sampler, no bridles in front of the net to create turbulence and give a signal of its approach and a double net offering the possibility of either true replicate tows or nets with different meshes, are inherently attractive and some modification of it would make a useful sampler for routine surveys. It is, however, necessary to decide on the required mouth area, the speed of tow and the length of tow. To test the effect of these factors, we constructed two other samplers on the BM principles (Fig. 2). One had a mouth area of .008 m^2 on each side, the other .1 m^2.

.008 m^2 Sampler - This was made up of the reinforced plastic (RFP) tubes from two Miller Samplers (Miller, 1961) connected by a vane constructed and fastened to the towing wire in such a manner that the samplers were free to rotate in both the vertical and horizontal planes (Fig. 2). The tubes are 61 cm long and 14 cm in diameter with a nose cone reducing the mouth to 10. 2 cm. The nets are conical, 90 cm long, and have a filtration ratio of about 18 : 1.

.1 m^2 Sampler - This is made up of two RFP tubes, 35. 7 cm in diameter at the mouth, 38. 0 cm at the rear and 35 cm long. The two tubes are connected by a rigid vane with a towing eye 10 cm behind the mouths of the sampler (Fig. 2). A swivel and snap hook to the towing wire permits the sampler to orient itself normal to the direction of tow. A similar sampler with the same mouth area but square rather than round was also built. The nets are cylinder (140 cm)-cones (110 cm) and have a filtration ratio of 10 : 1.

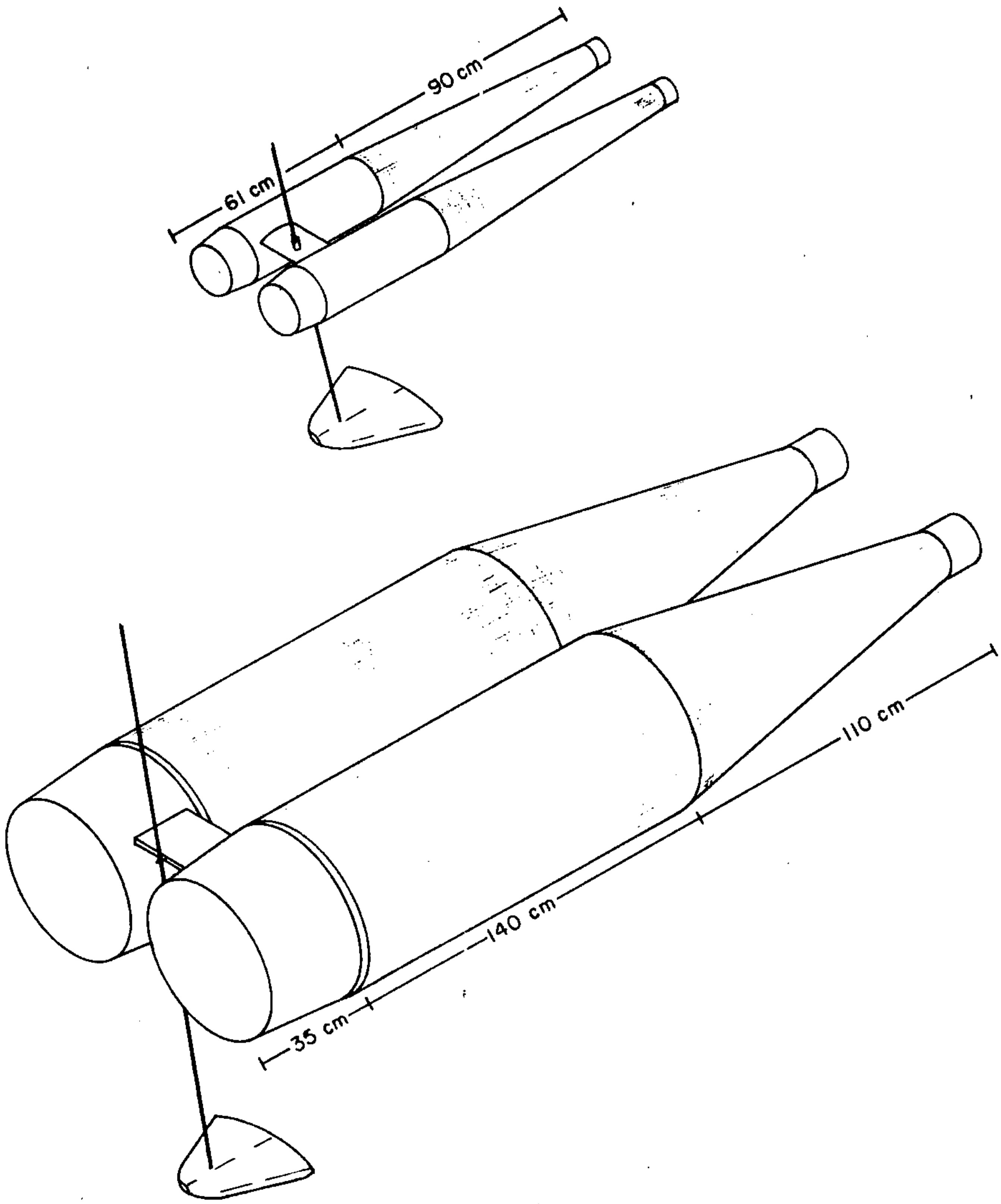

Figure 2. The .008 m^2 sampler and the .1 m^2 sampler.

A randomized 3^3 sampling design was set up to test the 3 samplers, each to be towed at 2, 4, and 6 knots (62, 124, and 185 m/min), for 10, 20, and 30 minutes. Three replicates of the 27 block sampling design were planned but a combination of bad weather, equipment malfunction and loss of gear forced a curtailment of the cruise.

Only 12 tows, all made at night between 2045 and 0320, are worth examination (Table 3). All of these tows were made horizontally about 2 meters below the surface and the catches fell off drastically as the sun rose. Figures 4 and 5 show a plot of the catches of herring larvae and arrow worms (Sagitta elegans) as a function of the speed, distance, and volume filtered for each tow.

Table 3. Catch of herring larvae and Sagitta elegans by 3 different samplers towed for different distances at different speeds.

Tow No.	Time	Mouth area	Speed	Distance	Volume	Larvae	Sagitta
		m^2	m/min	m	m^3	nos/m^3	nos/m^3
1	2045	.008	97	2910	23	0.47	3.5
2	2117	.1	79	1580	158	0.16	11.2
3	2140	.008	130	2600	21	0.28	16.0
4	2210	.008	177	5300	42	0.27	12.7
5	2248	.39	57	1710	667	0.34	46.1
6	2345	.008	74	740	6	0.25	44.4
7	0010	.1	85	2560	255	0.92	45.4
8	0050	.1	161	1610	161	0.87	48.5
9	0112	.39	80	1600	624	1.15	57.2
10	0145	.1	182	5450	546	1.34	35.0
11	0306	.1	83	830	83	1.25	72.2
12	0320	.008	137	4110	33	1.03	19.0

For both organisms, neither mouth area, speed, nor distance seems to have affected the catch per m^3. The patterns look random. It is far from conclusive but the plots of catch vs. volume suggest that, on the average, the smallest sampler with the smallest volumes was less efficient than the medium sampler with the medium volumes, which in turn was less efficient than the largest sampler with the largest volumes.

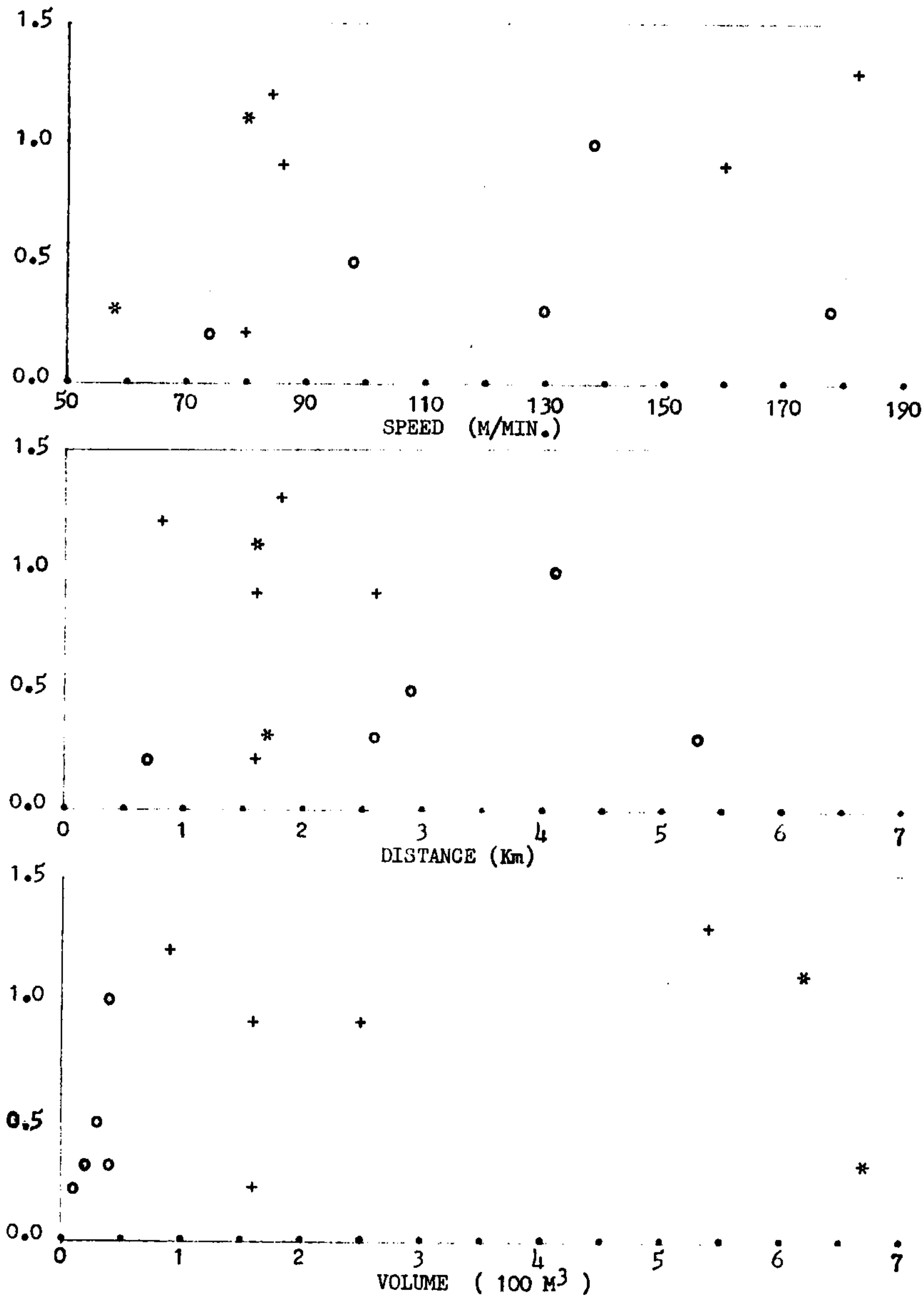

Figure 4. Catches of herring larvae at different speeds of tow, distance of tow, and volume of water filtered for three different samplers (o = .008 m^2, + = .1 m^2, * = .39 m^2).

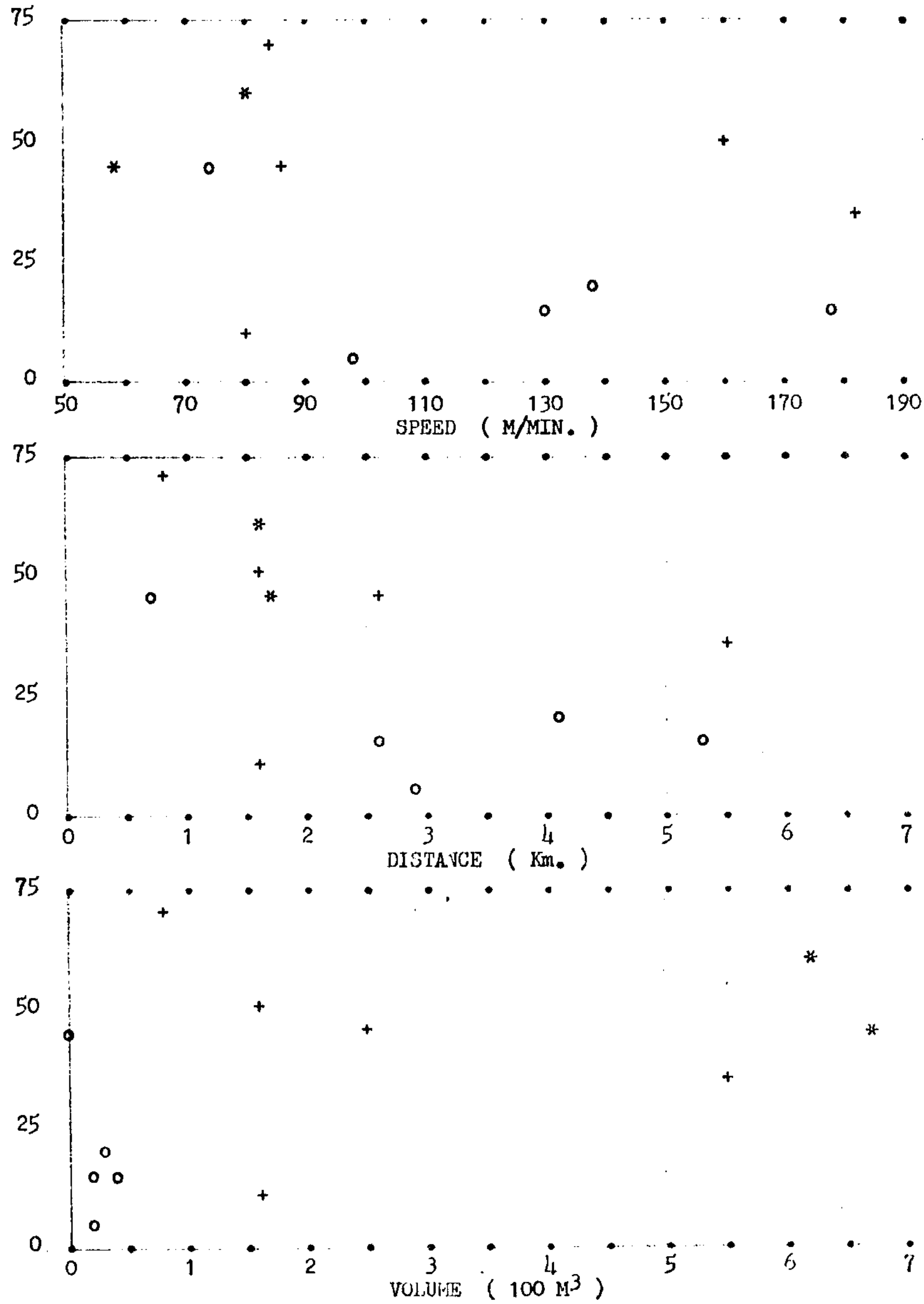

Figure 5. Catches of Sagitta elegans at different speeds of tow, distance of tow, and volume of water filtered for three different samplers (o = .008 m^2, + = .1 m^2, * = .39 m^2).

Effect of mouth area.

To see what effect the size of the net mouth had on samplers which were not preceded by a towing wire and bridles, we built a frame similar to that described by Graham and Vaughan (1966) to use as a test bed. This has its own depressor and is rigged so that the towing warps are outboard and above the samplers. We hung five .008 m^2 samplers (MS), three .1 m^2 samplers (RB, SB), and one .39 m^2 sampler (BM) in the frame (Fig. 5). All nets were 333 μ nylon mesh of the proportions described earlier.

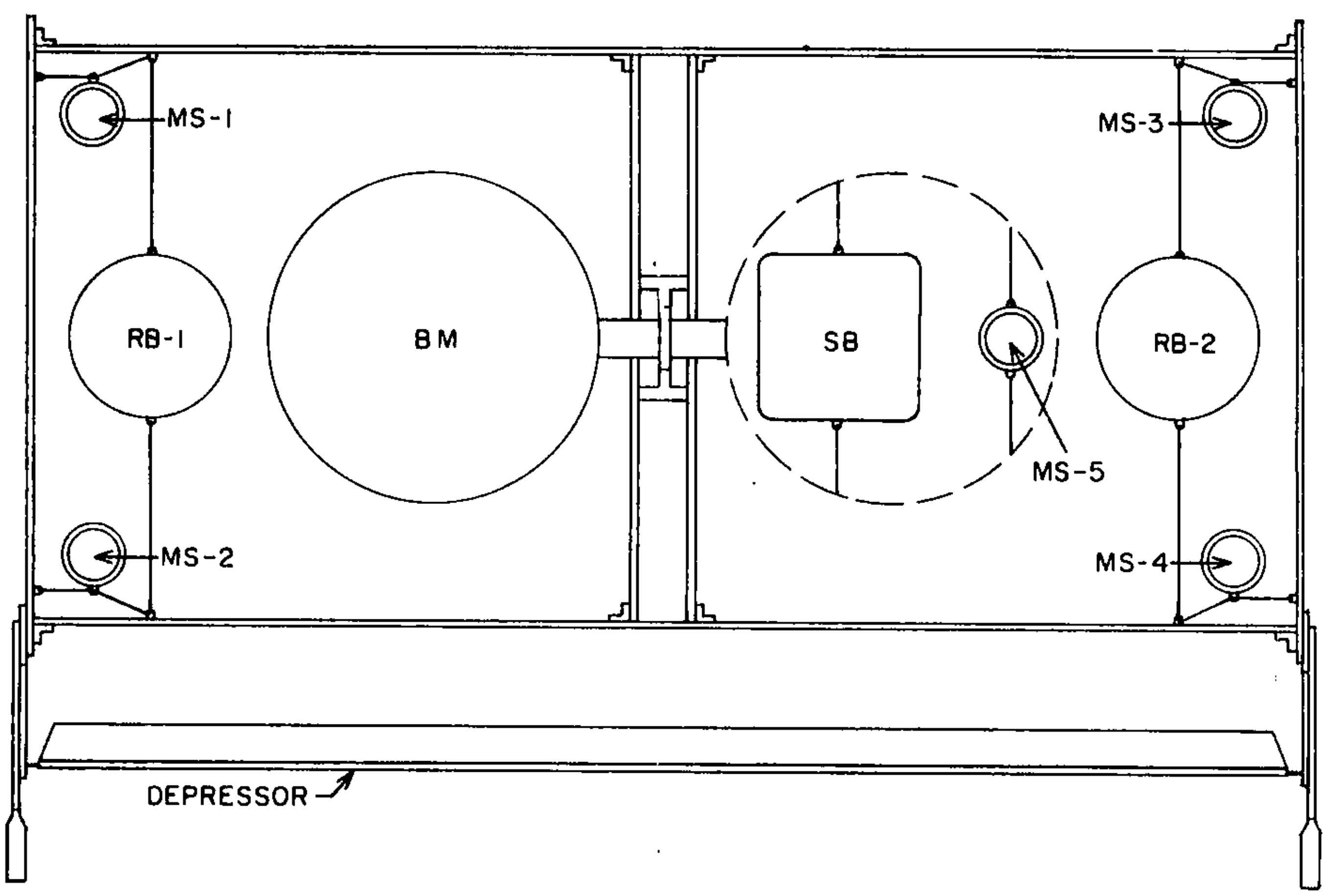

Figure 5. The towing frame used to tow the 9 samplers simultaneously. The broken circle on the right is the other half of the BM sampler; no net was on it.

Each tow with this arrangement is a true replicate. All samplers are hauled simultaneously through the same body of water. Our tows were made horizontally at 3 knots (93 m/min) for 15 minutes (No. 2 was 30 minutes) around a floating buoy on a parachute drogue. The distance the gear was hauled through the water was measured by electromagnetic log. The attitude of the frame was measured to always be within 5 degrees of vertical.

The samples were broken down by first picking out all the fish larvae and the few occasional large pandalids and then splitting the catches of the RB, SB, and BM samplers in a Folsom Splitter. The fish eggs, grass shrimp, and gammarid amphipods were then picked out. These four groups were then counted and measured. The rest of the sample was then drained and its displacement volume measured. The Sagitta elegans were later picked out of this mixed group and counted and measured to give us another series of catch comparisons.

These counts were then multiplied by the required factor for those samples which had been split and converted to numbers per cubic meter assuming that all the water presented to the samplers had passed through the nets. This seems reasonable in view of the large ratio of filtration area to mouth area and the short tows.

Table 4 shows the results of pooling the catches of all 10 tows. The MS samplers (.008 m^2) show the greatest variation in all categories but no one of them is always high or always low so there does not seem to be any effect of position within the towing frame. The best explanation seems to be that they are giving a measure of microdistribution. The RB 1 and 2 samplers (.1 m^2) show very little difference between them and give practically the same measure as the BM sampler (.39 m^2).

Table 4. Summary of the catches made by the 9 samplers hauled simultaneously; averages of 10 tows. MS are .008 m^2, RB and SB are .1 m^2, BM is .39 m^2.

Item	Fish Larvae	Fish Eggs	Grass Shrimp (1)	Gamm. Amphi. (2)	Other	Sagitta
Gear	N/m^3	N/m^3	N/m^3	N/m^3	ML/m^3	N/m^3
MS-1	0.16	1.64	0.69	0.24	0.16	2.57
MS-2	0.08	2.15	0.71	0.27	0.18	2.95
MS-3	0.12	1.97	0.47	0.26	0.17	2.76
MS-4	0.07	1.84	0.51	0.42	0.16	1.63
MS-5	0.02	1.62	0.47	0.25	0.15	2.83
RB-1	0.07	2.23	0.77	0.36	0.16	2.43
RB-2	0.06	2.14	0.63	0.38	0.14	2.40
SB	0.08	2.45	0.95	0.57	0.16	2.80
BM	0.07	2.06	0.66	0.35	0.14	2.71

(1) Tow 3-8 only. (2) Tow 4-8 only.

The fact that the SB sampler always caught more than the RB and the BM samplers is puzzling. It differs from the RB samplers only in that it is square rather than round. No explanation can be offered now but we intend to attempt a more refined analysis of the data and some more experiments.

Net Form and Area

Smith, Counts and Clutter (in press) have conducted a series of experiments to determine the degree to which various net characteristics affect the volume of water which can be filtered without clogging. They mounted two different nets, each 1 m diameter, in a frame with deck read-out flowmeters both inside and outside the mouths of the nets and towed them at 2 knots in both turbid littoral water and clear neritic water. Their criterion for clogging was that point in the tow when the flowmeter in the net mouth showed that it was passing less than 85 percent of the water presented to it as measured by the flowmeter outside the net mouth. Using this technique, they have investigated the effects of mesh size and mesh amount in cone, cylinder, and cylinder-cone nets. The cylinder-cone proved to be the most efficient (Table 5).

Table 5. Elapsed time and volume filtered before meter nets started to pass less than 85% of water presented.

Net type	R	Speed knots	Littoral vol. m^3	Littoral time min.	Neritic vol. m^3	Neritic time min.
Cone	3.2	2	39	1	112	2
Cyl-cone	3.2	2	49	1	390	8
Cone	4.8	2	89	2	542	11
Cyl-cone	4.8	2	123	3	1172	24
Cyl-cone	6.4	2	300	6	2564	53

Observations made in a towing tank showed that a sort of peristaltic motion, probably caused by turbulence from the mounting ring, is set up in the cylindrical section. This causes nets of this type to be somewhat self-cleaning so that, even if the cone section is clogged, there remains, if the cylinder is long enough, a reserve filtration area which allows the water to pass out through the net without restricting the flow through the mouth.

From their field data they have derived an empiric formula for calculating the amount of cloth of a given mesh size required for a net of a given mouth area that is to be towed a given distance.

$$\text{Log } R = 0.38 (\text{Log } D) - k$$

where:

R = open area in the net/mouth area

D = distance in meters

k = a factor depending on the abundance of organisms in the water that will be retained in the net. In their experiments, using 333μ nylon mesh, k averaged 0.17 in littoral waters and 0.49 in neritic waters.

To give an example: suppose that you wish to tow a 0.5 m^2 net of 333μ nylon mesh 3 km and so filter 1500 m^3 of neritic water. Then log R = 0.38 (3.477) - 0.49 and R = 6.8. Since the mouth area is 0.5 m^2 and 333 nitex is 0.46 open area, you will need 0.5 x 6.8/.46 = 7.4 m^2 of cloth in the net. They recommend that 3 mouth areas, 3.3 m^2 of cloth, be put in the conical section and the rest, 4.1 m^2, be put in the cylinder. If you were then to use this same net in turbid littoral water (k = 0.17) you could safely tow it only 440 meters before it began to clog.

Summary

1. A quantitative zooplankton sampler must not be preceded by the towing warp or other obstructions to cause turbulence and signal its approach.

2. Mouth area of the sampler does not of itself have much effect on volumetric efficiency except that the smaller samplers will increase the variance between samples.

3. Nets should be cylinder-cones with a ratio of filtration area to mouth area large enough to suit the expected conditions.

Acknowledgements

Many people have contributed their time and efforts to this investigation. We are particularly indebted to Paul E. Smith, BCF, La Jolla, Calif; Daniel Brown of Scripps Institute of Oceanography; John Gehringer, BCF, Brunswick, Ga.; and Joseph Graham and Kenneth Sherman, BCF, Boothbay Harbor, Me. for advice, criticism, and access to unpublished data. John Reintjes and James Guthrie, BCF, Morehead City, N. C. helped with the field work and the sample sorting on the WP-3 trials. George Kelly, James McGuire, Henry Jensen, and Robert Hersey of our own laboratory helped with the field work and sorted the samples in the mouth area trials.

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