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The MARMAP Bongo Zooplankton Samplers

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Abstract

Two bongo zooplankton samplers are described and the methods of construction given. Each sampler consists of a pair of nets mounted so that the mouth openings of the rigid body sections are on either side and in front of the towing wire. The results of tests comparing the bongo samplers with a 1-m ring net and the Gulf III encased sampler indicate that the bongo samplers give a more representative sample of the ichthyoplankton community than either of the other two types. The results of testing the bongo samplers for filtration efficiency and the effects of different mouth areas, towing distances and towing speeds show that none of these factors had a significant effect upon the catch per volume of water filtered.

Introduction

The zooplankton samplers described in this paper were developed primarily to collect pelagic eggs and larvae of fishes and their forage organisms inhabiting the upper 200 m of water over the continental shelf of the Northwest Atlantic. The fisheries of this area exhibit great variation in the annual recruitment of many species, seemingly caused by variation in mortality during the very early life stages of the fishes. In order to study these variations in mortality rates and their causes, a better sampler than those customarily used in this type of work was needed. It was obvious that such a study would require the use of many ships, probably from several nations, over several years. Sampling would have to be done year-round in all kinds of weather. A standard quantitative sampler was needed that was simple, sturdy, reliable, efficient, and preferably inexpensive, and that could be deployed from small vessels used in coastal waters as well as from large offshore research vessels.

The samplers described here were inspired by one developed by McGowan and Brown (MS 1966). Departure from their design has been considerable but the basic principle of a pair of nets with mouth openings on either side of and in front of the towing wire remains the same. They called their sampler the "bongo net" and that name has been retained for those described here.

MARMAP is an acronym for Marine Resources Monitoring, Assessment, and Prediction program of the USA National Marine Fisheries Service. The MARMAP program and its international cooperators have adopted our versions of the bongo net (Fig. 1) as their standard zooplankton samplers. Smith and Richardson (1977) in a recent FAO publication recommended the bongo configuration as the best type of gear for ichthyoplankton surveys.

Description of the Samplers

The tests and trials described below were convincing enough to indicate that the bongo design was better than either the traditional ring-net or the more modern high-speed encased net. It was also considered that two sizes would be useful: a rather large sampler with fairly coarse mesh to filter a large volume of water without using excessive ship time to collect fish larvae which may be scarce at certain times in certain places, and a smaller sampler of fairly fine mesh to collect forage organisms. The sizes adopted for use, 20 cm and 61 cm inside diameters, gave roughly a 9:1 ratio to test the effects of mouth area on catches, and construction materials for these sizes happened to be conveniently available.

The 20-cm MARMAP bongo

The bodies of this sampler (Fig. 2) were made of commercially available polyvinyl chloride (PVC) pipe, nominally 8 inches (20 cm) in diameter with wall thickness of 5/16 inches (8 mm). The pipe was cut into 30-cm lengths which were turned in a lathe to square the ends, round the leading and trailing edges, and make a groove 32 mm wide and 3 mm deep near the trailing edge. This groove is used to fasten the collar of the net to the sampler body with a stainless steel hose clamp. Actual measurement of 10 sampler bodies, after construction, gave an average mouth area of 0.0314 m^2.

The towing yoke (Fig. 2), used to fasten the sampler to the towing wire and support the two bodies, is made of Type 304L stainless steel flatbar bent and welded to shape. The cylindrical wire fastener is a modified swivel-top messenger. The slot in the fastener is a loose fit on 1/4-inch (6mm) wire, permitting the sampler to rotate in the horizontal plane. The trunnion pins permit rotation in the vertical plane

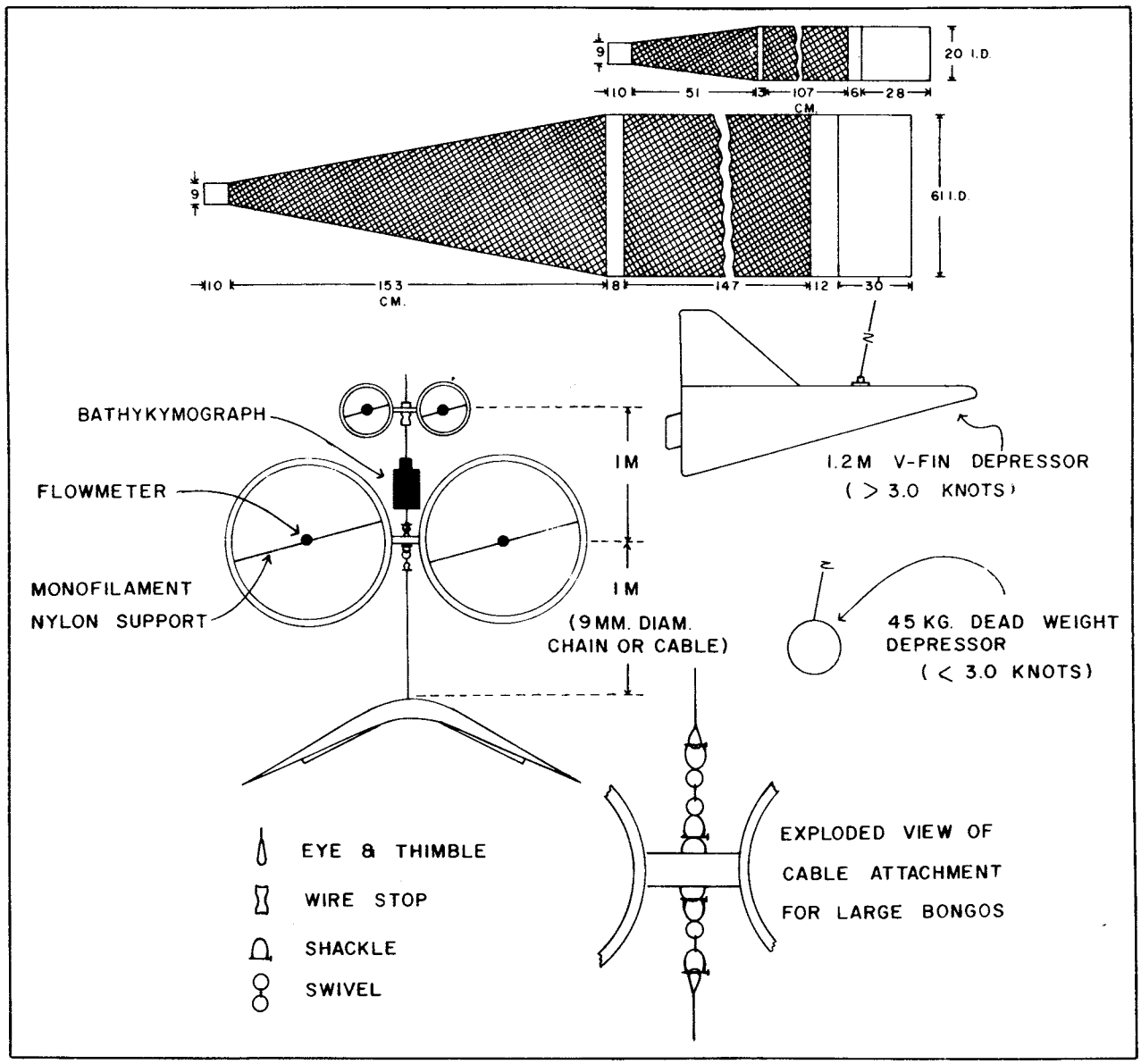

Fig. 1. The MARMAP bongo sampler array.

so that the sampler always faces straight ahead when being towed. A wire-stop is used below the sampler to support it on the towing wire. Stops at various positions along the towing wire allow a series of samplers to be used for simultaneous collections at different depths.

The 61-cm MARMAP bongo

The cylindrical bodies of this sampler (Fig. 3) were constructed of fiberglass reinforced polyester resin (FRP), 30 cm long with wall thickness of 12 mm. The inner diameter is 24 inches (61 cm), giving a mouth area of 0.2923 m^2. The leading edge is rounded and the trailing edge has a 1/4-inch (6 mm) raised bead, just forward of which the net is fastened by a stainless steel hose clamp.

The yoke (Fig. 4), also made of Type 304L stainless steel, is an axle between two cheek plates riding in a split sleeve with a nylon or teflon bushing, allowing orientation in the vertical plane. The two pad-eyes welded to the lugs of the split sleeve are shackled to the towing wire with good quality swivels to allow orientation in the horizontal plane. The two sampler bodies are bolted to the cheek plates of the yolk with reinforcing plates inside the bodies to better distribute the towing load. The round bar at the rear of the yoke is intended to reduce the bending load on the axle when the samplers are towed at high speed.

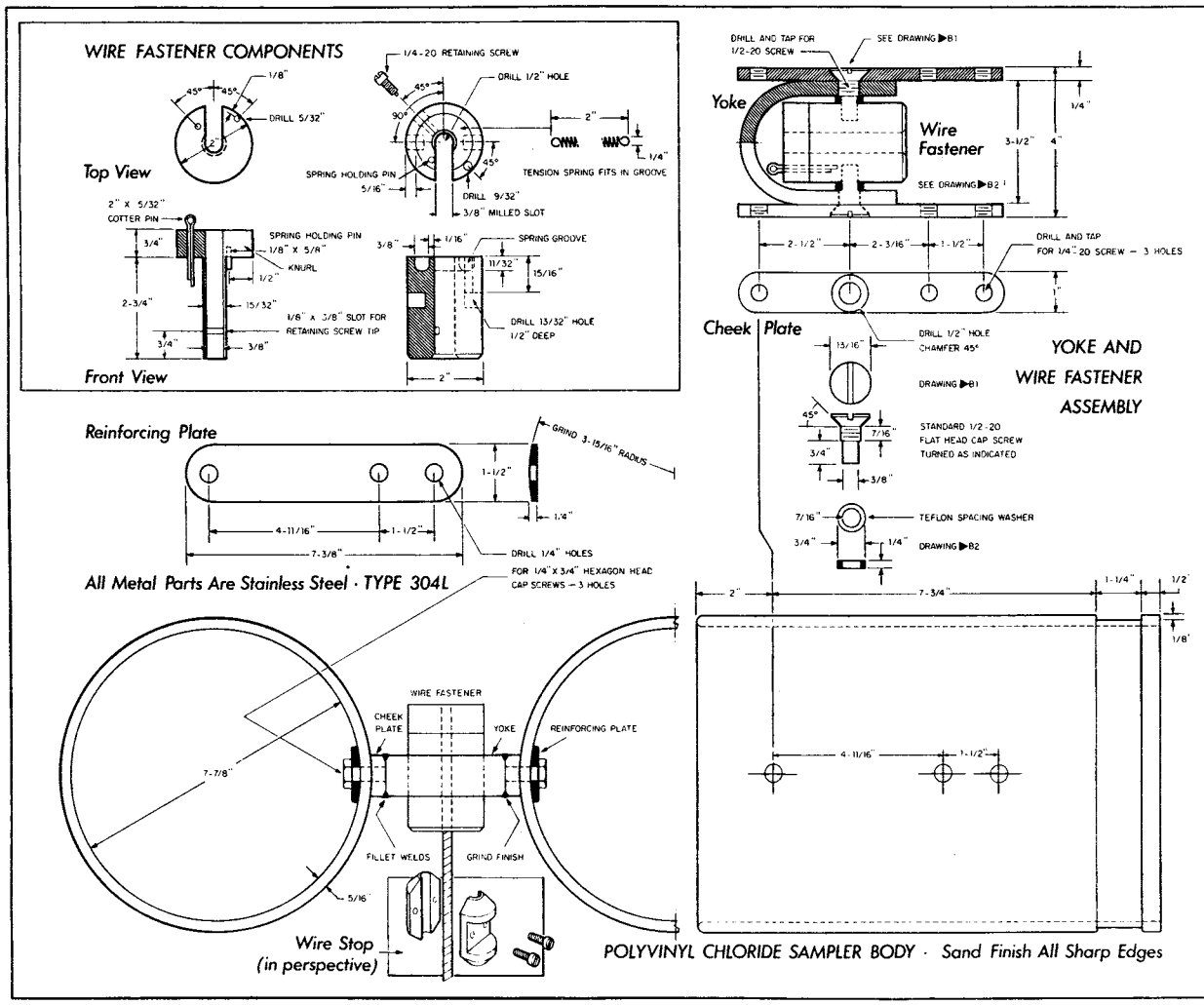

Fig. 2. Construction details of the 20-cm MARMAP bongo sampler.

Nets and Accessories

The nets used on the bongo samplers are cylinder-cones (Fig. 1), this construction having been shown (Smith *et al.*, 1968) to be highly resistant to clogging. The practice has been to make the open area in the gauze of the conical section equal to three times the mouth area and to put enough gauze in the cylindrical section so that the ratio of the total open gauze area to the mouth area is 8–15:1 depending on the mesh size. The finer the mesh size used, the larger the net. Mesh sizes from 0.1 to 0.5 mm have been used for sampling in neritic and littoral waters with very few cases of clogging, most of which were caused by blooms of filamentous algae or dense concentrations of salps or ctenophores.

The two nets on a sampler need not have exactly the same mesh size, but the difference cannot be too great especially on the 20-cm sampler, as the more rapid accumulation of catch in the net with the smaller mesh will throw the sampler out of balance to the extent that it ultimately stops sampling. The difference in mesh size should not be much more than 0.15 mm.

Codend cups of various types (metal, plastic, glass, canvas, gauze) have been tried at one time or another, and all have been more or less unsatisfactory. The weight of most types of cups causes the rear end of the net to sink at slow speed, and they whip around dangerously during retrieval in strong winds. Instead of using codend cups, the best method was to securely tie the end of the net with twine. The nets are gently hosed down before being brought on board, washing most of the catches into the conic part of the codends. Further hosing on board cleans the forward part of the nets, and the rear part of the nets are carefully washed after the codends are placed in buckets and untied. The catch from each net is bottled and preserved after

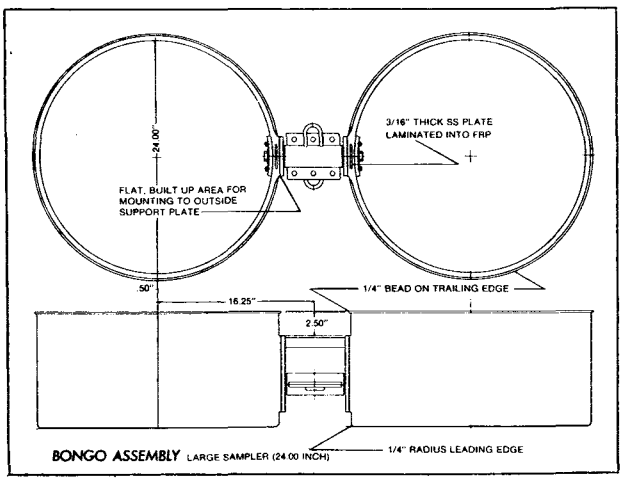

Fig. 3. Assembly details of the 61-cm MARMAP bongo sampler.

straining through a fine-mesh sieve.

Flowmeters of various types to measure the volume of water filtered have been used both inside and outside the sampler bodies. A satisfactory type of flowmeter used consists of a 6-digit counter encased in a 3.5-cm transparent acrylic sleeve with a brass bullet-shaped nose piece. The 7.6-mm diameter rotor is precision-molded in plastic with helical vanes fastened directly to the shaft of the counter. The design of the rotor vanes is such that they offer minimum resistance to water flow and shed seaweed strands or other debris which tend to clog the traditional ducted fan-type flowmeters. All moving parts are stainless steel or plastic. Although the flowmeters are calibrated by the manufacturer, further recalibration is carried out in a tank on shore and checked against the ship's electromagnetic log at sea.

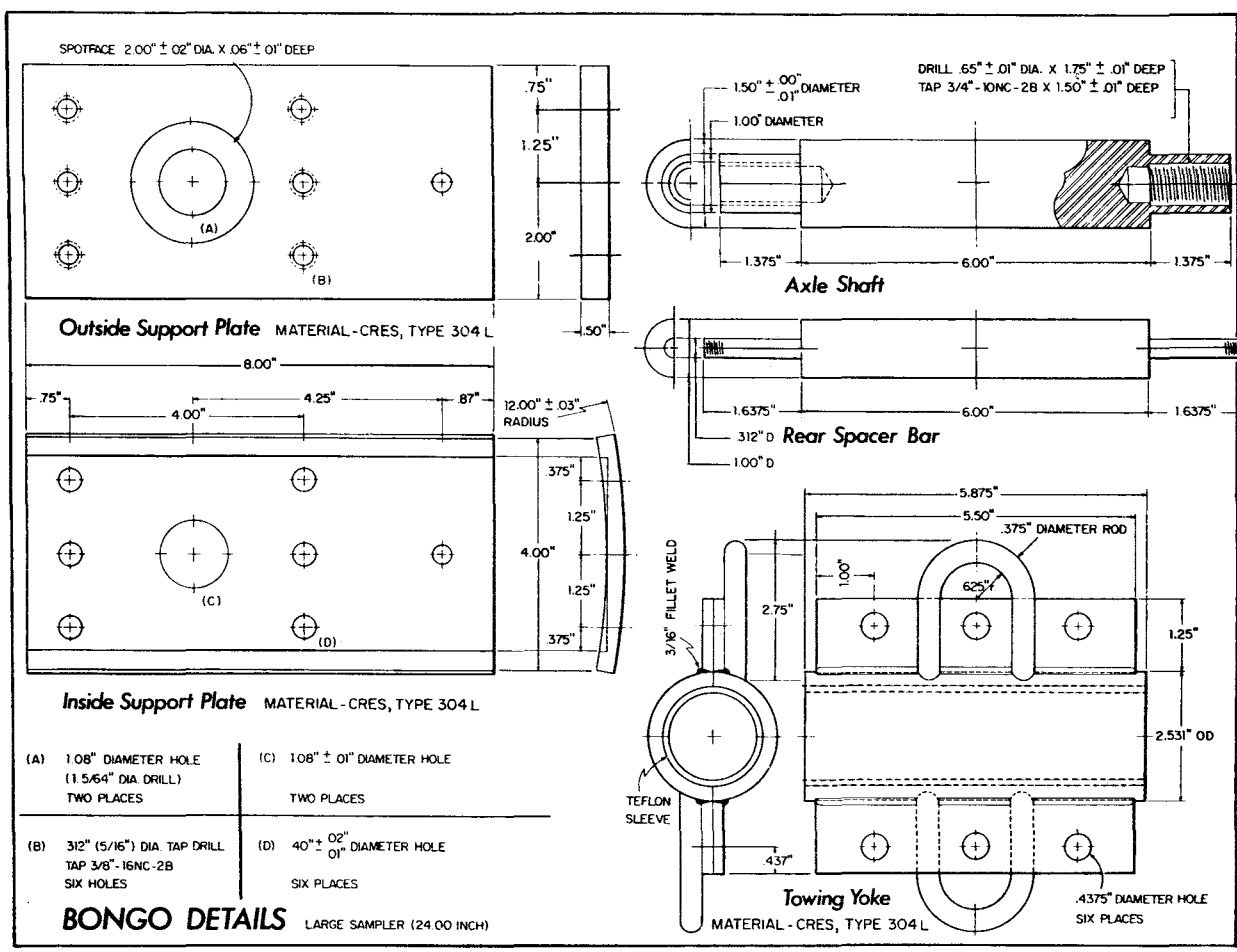

Fig. 4. Construction details of the yoke of the 61-cm MARMAP bongo sampler.

A time-depth recorder has been used on most of the tows, giving a strip-chart recording of the amount of time sampling as a function of depth.

A depressor of some type is required to overcome the drag of the samplers and to maintain them at the desired depths. A simple weight of about 45 kg was found to be sufficient at low speeds, below 3 knots. A 4-ft (1.22-m) V-fin depressor was used at higher speeds. With both samplers at the end of 270 m of towing wire (6 mm), the V-fin took the gear down to 160 m at 3 knots, 115 m at 5 knots, and 100 m at 7 knots. Tank tests have shown the drag of the samplers at the above speeds to be 100, 350 and 650 kg respectively.

Remarks on Construction

The MARMAP program has adopted the designs of the bongo samplers described above, but the details of dimensions and materials are not unique. Anyone desiring to modify the designs should be careful of a few points. The sampler bodies must be long enough so that the mouths will always be forward of the towing wire. The two mouth openings must be in the same plane and the towing point must be exactly centered or the sampler will not face precisely in the direction that it is being towed. The pivot point of the yoke should be about 25 mm forward of the balance point of the bodies. The samplers will not enter the water smoothly and tow truly unless they are tail heavy.

The dimensions given in Fig. 2, 3 and 4 were taken from the construction drawings used by the MARMAP Program Office to purchase more than 100 units which have been distributed to many investigators in the United States and several other countries. As a result, components are interchangeable and a damaged sampler can be used as a source of spare parts. There are no exact metric equivalents of the nuts, bolts, rods and bars that were used to fabricate the samplers, and a simple mathematic conversion from inches to metric equivalents would not be useful. A completely new "metric model" of the sampler could be designed, if there were a need, but similar metric components can be substituted if necessary without changing the fundamental design.

PVC and FRP materials were used for the sampler bodies because these products were readily available, relatively inexpensive, and strong enough to withstand the rough handling at sea, but other materials might be equally satisfactory. Even the shape need not be fixed, as square-shaped bodies were tested in some early trials and found to work as well as cylindrical bodies. Some investigators have constructed similar samplers using aluminum tubing for the leading and trailing edges with fore and aft spacers and a canvas sleeve fastened around the frame. This type of construction may provide a lighter, more manageable, and cheaper sampler, but filtration efficiency may be reduced by turbulence inside and outside the sampler. The yoke can be made of other metals such as steel or bronze, but care should be taken to avoid using dissimilar metals so that welds do not become sites of electrolytic corrosion.

Tranter and Heron (1967) have reported some interesting tests using sampler bodies shaped like truncated cones. Their design giving the greatest filtration efficiency had a cylindrical forward section, 25 cm long and 12.7 cm inner diameter, to which was attached a conical section 10 cm long which expanded to an inner diameter of 18 cm. With the net attached to the rear end of the cone, they reported filtration efficiency of 1.145 for the net mouth opening. This amounts to 2.3 times the mouth opening of the sampler.

Filtration Efficiency of the 61-cm Sampler

The filtration efficiency, that is, the volume of water accepted by the sampler divided by the volume of water presented to it, of the 61-cm sampler has been measured at the USA Naval Ship Research and Development Center (Smith, MS 1972). The tests were made in the high-speed towing basin with the sampler (one side only) and the net mounted on a strut attached to the towing carriage. A pitot-static pressure probe was mounted on another strut which passed through a slit in the net, placing the probe approximately 6 mm ahead of the trailing edge of the sampler body. Pressure data were taken at velocities from 0.5 to 6.5 knots (25–335 cm/sec) in 0.5 knot increments. The pressure probe was calibrated by running it in the free stream with the sampler removed.

The pressure probe was first placed at the center of the mouth opening and a complete series of data on carriage velocity and the corresponding pressure inside the sampler obtained. The probe was then lowered 15.2 cm below the center point of the mouth opening and the series of speed runs repeated. Successive runs were then made with the probe located 22.9, 26.7, 28.6, 29.2 and 30.0 cm from the center.

Table 1 gives the results of the measurements expressed as relative velocity, that is, the observed pressure inside the sampler divided by the free stream pressure clear of the sampler, for speeds of 2.5–5.0 knots. The instruments were difficult to read accurately at speeds less than 2.5 knots, and vibration interfered with the readings at speeds greater than 5.0 knots. All of the values, except those taken close to the wall of the sampler, are equal to or greater than 1.0 (Table 1), indicating that the sampler actually takes in and filters about 6–7% more water than would be predicted from the product of mouth area times

TABLE 1. Relative velocities of water passing through the sampler compared to the speed of the sampler through the water at seven radial distances from the center of the mouth opening, with mean and standard deviation for each location over a range of speeds from 2.5 to 5.0 knots.

Sampler speed	Relative velocities for 7 radial distances (cm) from center of sampler mouth opening						
(knots)	0.00	15.2	22.9	26.7	28.6	29.2	30.0
2.5	1.083	1.083	1.000	1.083	1.083	1.083	1.000
3.0	1.056	1.111	1.056	1.000	1.056	1.111	1.000
3.5	1.125	1.083	1.083	1.083	1.083	1.083	0.958
4.0	1.063	1.063	1.094	1.125	1.063	1.094	1.000
4.5	1.045	1.000	1.023	1.091	1.023	1.000	0.955
5.0	1.080	1.100	1.080	1.080	1.060	1.040	1.040
Mean	1.075	1.073	1.056	1.077	1.061	1.069	0.992
S.D.	0.028	0.040	0.037	0.041	0.022	0.041	0.032

distance towed. It should also be noted that the flow of water through the sampler is quite uniform. The flowmeter, therefore, can be located anywhere it can be conveniently mounted provided that the rotor is kept about 50 mm away from the wall of the sampler.

Results of Field Tests

The two sizes of the MARMAP bongo samplers have been tested to measure the differences, if any, in catches of port and starboard nets, different mouth areas, different towing speeds, different towing distances, and any day-night effects. Towing speeds were 3 and 6 knots (93 and 186 m/min), and distances were 1 and 2 nautical miles (1,852 and 3,704 m). All nets were 0.505 mm nylon mesh cylinder-cones with filtering ratios of about 8:1 in the 61-cm sampler and 15:1 in the 20-cm sampler. An 8.5-cm ducted-fan flowmeter (TSK) was mounted in each of the samplers and another on the outside of the 61-cm sampler. The flowmeters and the ship's electromagnetic log were calibrated on the Provincetown, MA, measured mile. The bongo sampler array is shown in Fig. 1.

The sampling area was a 10-mile (18 km) square in the Gulf of Maine with average water depth of about 100 m. Four sets of eight stations each and the sequence in which the four combinations of speed and distance were made were randomly selected, two of each combination in each eight-station replicate. Two replicates were done at night and two during the day. All tows were made horizontally at about 20 m, using the same length of wire for each tow.

In additon to the expected plankton organisms, a goosefish (88 cm), a silver hake (32 cm) and three dogfish (78, 62 and 57 cm) were caught, all being taken at night in the 61-cm sampler at 6 knots; two of the dogfish were taken in the same tow, one in each net. Plankton samples were preserved at sea and subsequently sorted on shore. Seven species of fish larvae from 2 to 20 mm long were identified and

TABLE 2. Catches of fish larvae (numbers per 100 m^2) in the four-net MARMAP bongo array for the different combinations of speed (S) in knots and distance (D) in nautical miles. (The symbol ... indicates that the catch was not sorted.)

Night					Day				
	20-cm		61-cm			20-cm		61-cm	
S-D	Port	Stbd	Port	Stbd	S-D	Port	Stbd	Port	Stbd
6-2	45	38	...	33	6-2	16	13	...	9
3-2	34	23	17	...	3-2	76	71	65	...
3-1	53	...	80	73	6-2	29	...	43	28
6-2	28	...	57	59	6-1	110	137	...	97
6-1	...	25	16	20	3-1	...	60	56	90
3-2	712	...	912	1016	6-1	...	435	435	lost
3-1	142	192	212	...	3-2	...	95	79	33
6-1	318	285	225	...	3-1	154	199	...	123
3-2	99	101	76	...	3-1	35	...	32	47
6-1	...	27	25	25	6-2	39	...	32	33
3-2	...	25	19	21	6-1	35	50	43	...
6-2	45	76	...	47	3-1	lost	40	43	...
3-1	...	48	54	65	3-2	25	30	32	...
6-1	10	18	10	...	6-1	...	110	125	120
6-2	...	52	65	62	6-2	58	55	...	48
3-1	434	504	...	336	3-2	...	42	38	42

counted (yellowtail flounder, Atlantic cod, four-bearded rockling, silver hake, Atlantic redfish, cunner and shanny). The catch of one net randomly selected from each tow was not sorted, as indicated in Table 2.

Catch per tow was converted to catch per 100 m^3, using the sampler mouth area and the observed revolutions of the flowmeters inside the nets as a measure of the distance towed. Comparison of these readings with the flowmeter attached outside the sampler and with the ship's electromagnetic log showed no evidence of clogging. The 20-cm sampler filtered about 60 m^3 of water through each net during the 1-mile tows and about 120 m^3 during the 2-mile tows, whereas the 61-cm sampler filtered about 550 m^3 and 1100 m^3 respectively over the same distances. The numbers of fish larvae caught per 100 m^3 of water filtered by the nets are given in Table 2.

Statistical analyses

The traditional parametric tests were not considered appropriate for data of the type presented here, as the number of samples is small, their distributions are not normal, and the variances are not independent of the means. Logarithmic transformations on other data, not reported here, did not materially improve the situation. Consequently, the following analyses are based on non-parametric (sometimes called distribution-free) statistical tests. These tests are not particularly new (Bradley, 1968) but they seem to have been neglected by all but a few investigators of marine populations. Specifically, the Wilcoxon matched-pairs signed-rank test was used to compare two sets of related samples, and the Kruskal-Wallis test was used to compare two or more sets of independent samples (Siegel, 1956; Conover, 1971). All analyses were made using the catch per unit volume filtered.

Port and starboard nets

Application of the Wilcoxon test for differences in catches of fish larvae by the port and starboard nets of both samplers indicated no significant difference for both the 20-cm sampler ($P = 0.16$) and the 61-cm sampler ($P = 0.54$).

The 20-cm and 61-cm samplers

The availability of more samples for these comparisons enabled the testing of the day and night samples separately as well as combined. All tests were made on a diagonal of the sampler array, comparing the catch of the port net of one sampler with the starboard net of the other sampler. There was no significant difference between the catch per unit volume of the larger net and that of the smaller net either during the day ($P = 0.08$) or at night ($P = 0.86$) or for day and night catches combined ($P = 0.25$).

Day and night effects

Having confirmed that there was no significant difference between the port and starboard nets, the catch rates of fish larvae by the 20-cm starboard net and the 61-cm port net was taken as being representative of each tow. In cases where the catch of the selected net was not sorted, the catch of the other net of the pair was used. Using the Kruskal-Wallis test, the four replicate blocks were tested to see if the population in the area sampled had changed during the 2 days spent sampling (Table 3). Catch rates declined somewhat on the second day but the

TABLE 3. Results of the Kruskal-Wallis test comparing catches of fish larvae (number per 100 m^3) under various factors investigated using the two sizes of bongo sampler. (N = number of tows, ΣR = sum of ranks, H = test statistic, and P = probability that differences caused by chance.)

		20-cm sampler			61-cm sampler		
Factor	N	ΣR	H	P	ΣR	H	P
Block 1	8	132			149		
Block 2	8	157			158		
Block 3	8	121			116		
Block 4	8	118	1.34	0.72	105	2.77	0.42
Night	16	253			265		
Day	16	275	0.17	0.69	263	0.002	0.96
3 kt/1 mi	8	160			159		
3 kt/2 mi	8	131			127		
6 kt/1 mi	8	138			136		
6 kt/2 mi	8	99	2.71	0.45	106	2.05	0.57
3 knots	16	291			286		
6 knots	16	237	1.04	0.31	242	0.69	0.42
1 mile	16	298			295		
2 miles	16	230	1.64	0.20	233	1.37	0.25

difference was not significant for either net. Both nets showed no significant day-night differences.

Speed and distance effects

Application of the Kruskal-Wallis test to examine speed and distance effects showed no significant difference between the catch rates for the four speed-distance combinations, although both nets took the fewest larvae during the 6 knot-2 mile tows (Table 3). Looking at speed of tow only, catch rates were higher at 3 knots than at 6 knots, but the difference was not significant for either sampler. The 1-mile tows took more fish larvae per unit volume than the 2-mile tows, but again the differences were not significant.

Comparison of Bongo Nets with Other Samplers

Gehringer's bongo and the Working Party-3 net

Jack W. Gehringer (pers. comm., National Marine Fisheries Service, Washington, D. C.) compared the performance of the Working Party-3 net (Fraser, 1966) with a bongo-type sampler which he devised. His bongo, with mouth area of 0.172 m^2 on each side, was fitted with a 0.947-mm mesh net on one side and 0.333-mm mesh on the other. The Working Party-3 net was a 1-m ring net with 0.947-mm mesh. Both samplers were towed simultaneously from the port and starboard sides of the vessel at 3 knots. The nets with calibrated ducted-fan flowmeters were towed at a depth of about 5 m.

In 27 paired tows, the bongo net with 0.947-mm mesh filtered 7,632 m^3 of water and caught 4,969 fish larvae (65 per 100 m^3), while Working Party-3 net filtered 31,773 m^3 of water and caught 8,672 larvae (27 per 100 m^3). The catch per unit volume of the bongo was thus about 2.4 times that of the Working Party-3 net. The Wilcoxon test on the paired tows (Table 4) shows a significant difference (P = 0.005) between the catch rates of the 2 samplers.

TABLE 4. Numbers of fish larvae taken per 100 m^3 of water filtered during 27 simultaneous hauls of a bongo net and a Working Party-3 ring net (unpublished data from J. W. Gehringer).

Set no.	Bongo	WP-3	Set no.	Bongo	WP-3
1	11.2	7.7	15	1.3	0.3
2	349.7	40.6	16	10.1	1.8
3	234.9	155.7	17	53.2	23.4
4	185.4	47.1	18	0.7	0.5
5	225.9	9.0	19	4.6	6.3
6	48.3	6.1	20	31.1	36.3
7	7.2	0.3	21	153.5	228.8
8	6.7	3.2	22	235.2	46.2
9	29.3	33.3	23	3.5	2.1
10	24.3	32.6	24	18.5	6.4
11	90.5	29.6	25	11.4	10.4
12	0.7	0.8	26	6.5	1.8
13	4.9	1.5	27	3.5	0.6
14	2.4	1.2			
			Mean	65.0	27.2

The 20-cm MARMAP bongo and Gulf III

Sherman and Honey (1968) tested the 20-cm bongo sampler against the widely used Gulf III encased sampler (Gehringer, 1952). Ten tows were made at 6 knots for 30 minutes with both samplers on the same towing wire about 25 cm apart. The mouth openings of both samplers were the same (20 cm diameter) and the nets used (nylon on the bongo, metal on the Gulf III) were 0.366-mm mesh. Calibrated flowmeters were used to measure the distance towed.

The catches consisted of a mixture of zooplankters, about 80% copepods. The mean catch of copepods in the bongo was 14,483 per 100 m^3 while the Gulf III took only 1,722 per 100 m^3. In a later paper, Sherman and Honey (1971) reported that all of the significant differences between the two samplers occurred among the smaller organisms (median width < 0.38 mm), while there were no significant differences between samplers in the catches of larger organisms (median width >0.40 mm). In no case was there a significant difference between the two nets of the bongo sampler. They concluded that many of the smaller organisms had been extruded through the tail of the Gulf III by high filtration pressure across the meshes.

The Standard MARMAP Sampling Array

The standard MARMAP sampling array (Fig. 1) consists of a 20-cm bongo, a 61-cm bongo, a time-depth recorder (bathykymograph), and either a 12.2 m V-fin depressor or a 45 kg weight. Flowmeters to measure the distance towed and the volume filtered are fitted to all nets. A wire-stop holds the 20-cm sampler on the wire 1 m above the 61-cm sampler which is shackled with a swivel to an eye at the end of the towing wire. The depressor is fastened to a 1-m length of chain which is shackled with a swivel to the lower pad-eye of the 61-cm sampler. The time-depth recorder is fastened to the wire between the samplers. Nylon nets (Nitex) with mesh sizes of 0.253 and 0.333 mm are used on the 20-cm sampler and mesh sizes of 0.333 and 0.505 mm on the 61-cm sampler. Net sizes may be changed for special collections, and occasionally only one size of sampler may be used.

Discussion

It seems clear that plankton samplers of the bongo type collect more ichthyoplankton per unit volume of filtered water than either the traditional bridled ring-net or the more modern encased samplers. Their superior performance is probably the result of the smoother water flow in front of, within and behind the

nets. The tank tests show that the rate of flow through the bongo sampler is quite uniform. A flowmeter located anywhere (except against the wall) would register within 2% of the mean (Table 1).

The bongo samplers, because of their unobstructed mouth openings, reduce the avoidance problems caused by the bridle, pennant and towing wire in front of the ring net. They also reduce the extrusion problem of the encased samplers because of the lower filtration pressure across the meshes. However, further work should be done to reduce, or at least measure, the effects of both avoidance and extrusion, and to study by more sophisticated hydrodynamic methods the behaviour of the net as it is being towed through the water. Only after such studies will more meaningful conclusions be drawn from field collections.

The best results with the bongo sampler will probably be obtained with a judicious balance of towing speed, mesh size, and mouth area to gauze area ratio, based on the size range of the specific components of the plankton community which are of interest. The use of conic sections in the sampler bodies offers opportunities for increasing the volume of water filtered per unit of ship time, but this may cause complications by selectively sampling plankters of different densities.

Although most tows show good agreement between the catches of the two nets on the same sampler, occasional tows show larger differences. These differences seem to be random and average out when the results from several stations are pooled, but they may be real, rather than just sampling error, and reflect the effects of sampling patchy distributions.

Station procedures have been standardized in the MARMAP program so that valid comparisons can be made between collections at different times and places by different ships. The primary objective is to sample all levels of the water column equally to a depth of 200 m, or to within 5 m of the bottom in shallow areas, with a double oblique tow at 1.5–2.0 knots. Because setting the gear over the stern into the propeller wash is highly undesirable, the ship should have a boom long enough to place the samplers in the water well away from the side to avoid turbulence and discharges.

Sampling under the MARMAP program involves maintaining a constant speed of 2.0 knots, with the ship heading into the wind as the gear is being lowered smoothly at 50 m per minute until the desired sampling depth has been reached, and then immediately hauled back at 20 m per minute until the samplers break the surface. There should be no hesitation at the interface, as this would lead to over-sampling the surface layer.

In some operations, like the ICNAF Larval Herring Survey Program (ICNAF, MS 1972), tows have been made at 3.5 knots because some of the ships involved could not maneuver at the slower desired speed of 2.0 knots. On some stations, after the 2.0 knot tow, a second tow is made at 4.5 knots, usually with the 61-cm sampler only fitted with two 0.505 mm nets, in an attempt to sample the larger larvae which may be able to avoid the gear when towed at 2.0 knots. Towing the gear at high speeds is not advocated for routine operations, although the bongo sampler has been towed at 9.0 knots without destroying the gear.

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Note

Construction drawings and specifications for the samplers, nets and accessories may be obtained from the authors.