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DESCRIPTION OF A PAIRED SAMPLER SUITABLE FOR QUANTITATIVE PLANKTON STUDIES

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Abstract

This paper describes a paired subsurface plankton sampler having two 50 cm by 50 cm mouth openings which can be towed horizontally at speeds up to 2.5 m sec^{-1} (five knots) with at least four samplers on a single warp to yield a concurrent series of vertically stratified hauls. When the nets are being shot or recovered, the net frames are held in line with the warp by rubber springs, thus reducing the flow of water into the nets. When the sampler is under tow, the mouths are forced to "open" since the drag on the net overcomes the resistance of the springs. The attachment of the sampler to the warp with a swivel clamp between the net mouths leaves them uncluttered by bridles, minimizing avoidance reactions by the zooplankton. The sampler was evaluated on the basis of catches made during programmes of sampling for western rock lobster larvae *(Panulirus longipes cygnus* George) and Moreton Bay king prawn post larvae *(Penaeus plebejus* Hess). Nets of 1.05 mm and 2.5 mm mesh aperture have been used with this sampler to date.

1. INTRODUCTION

Most vertical distribution studies using plankton and nekton catching devices have been bedeviled by either unreliable and/or complex methods for opening and closing samplers. This sampler was developed in response to a need for a simple, reliable, and robust sampler capable of filtering at least 2,000 m^3 of water per net at a towing speed of 2.5 m sec^{-1}. Up to four pairs of nets had to be fished on a single warp at one time, and two samples per depth were required to facilitate statistical analysis of the data. We did not need a conventional mouth opening and closing type net such as the Bongo net (McGowan and Brown 1966), because of the shallow depths being sampled. A system which accepted only a small proportion of the total volume filtered while it was being shot and recovered was considered to be satisfactory.

The main organisms being sought were the puerulus and phyllosoma larvae of the western rock lobster. The puerulus is a relatively large (total length approximately 20 mm), active but relatively rare nektonic animal (Phillips and Olsen, 1975; Phillips, Rimmer and Reid, in press). The late stage phyllosoma (stages VI - IX) are also rather large (8.3-37.0 mm total length) but much less mobile animals, and are sparsely distributed (Chittleborough and Thomas, 1969; Phillips, Rimmer, Reid and Braine, in prep.). The early stage phyllosoma (stages I - III) are small (total body length about 1.2-3.5 mm), relatively immobile animals and are more abundant (Rimmer, unpublished data). The nets were evaluated during a comprehensive study of the rock lobster population during November 1974 - February 1975, carried out in the area bounded by roughly 29°-32°S and 113°-115°E off the Western Australian coast.

The results of some sampling for the post larval stage of the Moreton Bay king prawn are included for comparison. Sampling for these animals was carried out at shallow stations off Southport, Queensland (approximately 28°S, 153°3'E) during May, June and August, 1973.

2. DESCRIPTION OF THE SAMPLER

Sampler Framework

The sampler frame (Figures 1 and 2) consists of two 50 cm square net frames held apart by a pivoting spacer frame. The net frames are joined together with a common bottom bar and a horizontal axle. The pivoting spacer frame is attached to this axle by two bearings. The return subframe is welded to the back of the pivoting spacer frame. The end of this return subframe acts as an anchorage for the rubber springs that power the return or closing mechanism. A stop welded to the common bottom bar has two functions: it prevents rotation of the pivoting spacing frame backwards, and also acts as the second anchorage point for the rubber springs. The sampler frame is attached to the towing wire by a swivelling wire clamp and a wire guide at the top and bottom respectively on the back of the pivoting spacer frame.

The sampler is made from 19 mm square mild steel tube and 19 mm square steel bar for certain load bearing members. This combination keeps the final weight of the sampling frame to about 13 kg in air, allowing the complete unit to be handled by one or two persons. The entire frame assembly, with the exception of the swivelling wire clamp, is hot-dip galvanised to minimize corrosion. All sealed hollow components are drilled, allowing them to flood when submerged to avoid their being crushed at depth. Table 1 gives details of part number (from Figures 1 and 2), part name, and material used for construction.

Nets

The nets used with this sampler are a modified Working Party 3 design (UNESCO, 1968) having a cylinder cone type construction but square in mouth plan. A description of the nets is given by Phillips and Rimmer (1975).

Flowmeters

A T.S.K. towing depth/distance recorder (Tsurumi Seiko Co. Ltd. Yokohama, Japan) was mounted in a flowmeter mount in the mouth of one of the nets on each sampler. This provided a record of the volume filtered and a profile of the depth vs. distance at which the sampler was towed. The flowmeter was positioned mid-way between the centre and the outside rim of the net mouth in order to get the best estimate of flow through the net (Gehringer and Aron, 1968).

Depressors

A strong depressive force is required when towing several samplers simultaneously on one warp. A modified multiplane kite otter (Colton, 1959) has been found to be the most effective and useful depressor to use with these samplers. Fibreglass V-Fin depressors were tested but were not suitable for use with more than two samplers on the warp. They do not exert the same depressive force as, and are much more easily damaged than, the kite otters. Kite otters were used exclusively for the larval lobster work. A V-fin was used for the prawn post larvae sampling where only two samplers were required on the warp.

Accumulators

A telescoping hydraulic accumulator fabricated by Hydraulic and Pump Service, Perth, W.A. was incorporated into the towing system to improve the capability of the samplers to remain at a constant depth and to reduce the strain on the gear. Without the accumulator, the path of the samplers undulated with the movement of the ship, and the samplers were subjected to very considerable stress from the resulting fluctuations in warp strain.

3. OPERATIONS

Rock Lobster Larvae Sampling

The samplers were rigged with 1.05 mm mesh aperture nets and towed for 30 minutes at 1.0 m sec^{-1} when sampling for the early stage larvae. The late stage larvae were caught using 2.5 mm mesh aperture nets towed for 75 minutes at 2.5 m sec^{-1}. Hauls on the continental shelf were made with samplers at 10, 20 and 30 metre depths; hauls taken off the continental shelf had samplers at depths of 10, 25, 50 and 75 metres.

The samplers used in this programme were towed on a 25.4 mm (1 inch) circumference wire rope over the stern of the ship. The kite otter was shackled to the end of the warp and the nets attached at appropriate intervals as the warp was paid out. The ship just maintained steerageway during this period. The samplers were shot with the warp nearly vertical and the net mouths were held parallel to the warp by the tension of the rubber springs. The plane of the net mouths was parallel to the direction of the sampler movement during this period, minimising the flow of the water into the nets (Figure 3.1). After the last net was attached, the final length of warp was paid out as the ship accelerated to the normal towing speed. This resulted in a short, descending oblique haul. Once the warp was fully paid out, the increased horizontal movement of water through the nets forced the net mouths to become perpendicular to the plane of movement of the water. This rotated the spacing frame forward so that it took up an angle approximately equal to the wire angle (Figure 3.2, Plate 1) causing the rubber springs to stretch. The nets are "open" in this position, and the net mouths are uncluttered by bridles or other towing points. At the end of the haul, the ship was slowed to minimal forward speed, reducing the drag on the nets. This allowed the rubber springs to contract, and pull the net mouths in line with the spacing frame and warp. The nets were then in the "closed" position (Figure 3.3, Plate 2) and filtered only a minimal volume as they were recovered.

Underwater photography and observations have indicated that the net mouths in the "open" position were vertical when only one rubber spring was used and about 4° from the vertical when two rubber springs were used with the 1.05 mm mesh aperture nets towed at 1 m sec^{-1}. The volume filtered was reduced by about 0.2% in a 30 minute haul; this amount was not large enough to cause concern and two rubber springs have been used routinely to achieve more positive "closure" of the sampler.

Figures 4 and 5 illustrate the paths taken by the deepest samplers on the warp during the course of typical hauls with 2.5 mm and 1.05 mm mesh aperture nets, as obtained from traces of the depth/distance recorders. The steps in the descending and ascending portions of the haul represent the points where other samplers were being attached and removed from the warp. The slight tendency for the samplers to rise during the course of a haul is thought to be caused by clogging. Maximum practical durations for hauls before serious clogging began off the Western Australian coast were 30 and 75 minutes for the 1.05 mm and 2.5 mm nets towed at 1.0 and 2.5 m sec^{-1} respectively.

Tables 2 and 3 show the percentages of the haul taken at the selected depth, and at other depths during shooting and recovery of the sampler. The figures shown refer to the technique using the kite otter, with the ship just underway during shooting and recovery of the samplers. The range in percentage of water filtered during launch and recovery reflects the effect of weather conditions. As weather conditions became progressively worse the percentage of water filtered during launch and recovery operations increased simply due to handling delays on deck. Although the deepest 2.5 mm and 1.05 mm mesh nets filtered 12 and 27% respectively, of the total volume at the "wrong" depth, this error was considered acceptable. This volume can be read from the depth/distance recorder trace and can be used to adjust the calculated density of the animals if the error becomes unacceptable.

Prawn Post Larvae

An array of two samplers fitted with 1.05 mm mesh aperture nets on a single warp, using a 0.91 metre (three foot) fibreglass V-fin were successfully used for sampling king prawn postlarvae. Because of the vessel's size, sampling was restricted to periods of calm weather and as a result no accumulator was necessary. The V-fin kept the nets at a constant depth throughout the tow. A flowmeter was placed either into the left net only, or both nets, to record the volume filtered. Hauls of 30 minutes duration at a speed of 1.0 m sec^{-1} were made at two of the three depths sampled (7 m, 14 m, or 21 m) simultaneously.

Maintenance of Samplers

Little maintenance is required to keep these samplers in good working order. The bearings, hinges, springs and threads of the clamps are sprayed with a water repellent lubricating spray at the beginning of each five day cruise, and lubricated with grease at four to six week intervals to ensure free operation. The galvanised coating on the sampler frames has prevented rusting for the two years the samplers have been in use. A piece of neoprene foam tubing was attached over the bracket that holds the ends of the rubber springs to prevent the nets from being torn should they become wrapped around it. This tubing, and the rubber springs, required replacement after six months continuous use.

4. RESULTS

Functional Efficiency

The sampler functioned well virtually all of the time. It has been used under weather conditions as severe as Beaufort force 8 winds and sea force 5 with a force 6 swell. In these rough conditions, some problems have been encountered in deploying the sampler. Foremost amongst these was tangling of nets on the warp or the return subframe during launching. This was easily noticed and quickly corrected. The sampler sometimes turned over before it entered the water. This was prevented by having one end of a line attached to one of the top corners of one net frame, and the other end held by a person on deck; the line was released when the sampler was in the water and streamed clear of the net mouths. The samplers have been fished as deep as 400 m without any signs of difficulty.

If the samplers were recovered too fast (>1 m sec^{-1}), they were prevented from closing fully due to the increased drag on the nets. Severe clogging had the same effect. In these cases the greater than normal amount of water filtered during recovery could be determined from the depth-distance slide, and calculation of larval density could be adjusted accordingly.

Sampling Efficiency

If both nets on a twin sampler frame are sampling the parent population equally, better information about the abundance and distribution of the animals may be obtained than by using a single net. The question of equal sampling of the parent population by the two nets on a single frame was tested by χ^2 analysis of the number of individuals of the various larval stages caught. Only hauls of five or more individuals of the nominated larval stage were included in the analysis. The first hypothesis tested was that for any individual haul, the catch in one net would be different to the catch in the other net. The second hypothesis was that over a series of hauls from the same depth, the total number of animals caught by one net would be significantly different from the total number of animals in the other net. Both of these hypotheses were rejected, and it is concluded that one side of the sampler did catch the same number of animals as the other. The data for testing the first hypothesis have been omitted for the sake of brevity. The summarized results are given in Table 4; this table also tested the second hypothesis. All of the bias χ^2 values were not significant, which suggested that over a series of hauls, even though there was a difference in the number of larvae caught in the two nets on a sampler, this difference was random and did not favour one side of the sampler over the other. This was probably related to the distribution of the animals in the water. Three of the phyllosoma stations showed marginally significant heterogeneity χ^2 values ($p = 0.05$-0.04) when each series was examined. In each of these three groups of hauls, two pairs of samples showed significant differences in the number of individuals caught by the left and right nets, and the significant heterogeneity was caused by those hauls. Snedecor (1946 page 192) has suggested "that pooled data with their corresponding chi square contain evidence about the hypothetical ratio only if the several sample ratios are homogeneous as evidenced by a small chi square". The wide range in size of catches (Tables 5 and 6) from nearby areas in a relatively short time suggested that the animals occurred in clumps. The differences in catches between the left and right nets suggest that unequal sampling of one or more patches occurred during the hauls. The number of hauls having significant individual differences in catches between nets fell as the animals moved offshore and as they moulted to stage II and later larvae. For these reasons, the differences in catches obtained, and the marginally significant χ^2 values are not thought to have contradicted the condition quoted in Snedecor's statement. This unequal sampling of the contagious distribution could be improved by taking a longer tow to integrate this partial sampling of clumps.

Tables 5 and 6 give summarized details of the performance of the samplers, including the number of hauls included in this description, the total catch for each net, the range in numbers caught by each net and the mean catch per net. Also included is the total and mean volume filtered per net, the range in volumes filtered and the mean density of animals. The density figures are used to determine the percentage of the catch in the left and right nets, and the 95% confidence limits. In all instances the expected 50:50 ratio of catch in the left to catch in the right net fall within the 95% confidence limits, as expected from the χ^2 results.

It has not been possible to compare the performance of the left and right sides of the net with other animals of different swimming speeds (i.e., larval fish, euphausiids, pteropods, etc.) because of programme limitations. We feel that the early stage phyllosoma indicate the behaviour of animals that are unable to actively avoid the sampler. The post larval prawns are more active swimmers and may be capable of avoiding the nets to a greater degree than phyllosoma. No evidence is forthcoming from the data to indicate that any post larval prawns avoid selectively one side of the sampler. Estimates of the abundance of the very active puerulus stage have been obtained using these samplers and the same operating technique as for late stage phyllosoma. Although estimates of density agree well with the density estimates obtained using a 3.05 metre (ten foot) Isaacs Kidd Midwater Trawl and a 1.8 metre (six foot) Tucker Trawl, not enough animals have been caught to allow statistical comparisons to be made (Phillips, Rimmer and Reid, in press).

5. SUMMARY

The sampler has proved to be an effective instrument for obtaining instantaneous measurements of the abundance and vertical distribution of both early and late stage phyllosoma larvae of the western rock lobster. Up to four samplers on a single warp have been fished to depths of 150 metres at one time.

Estimates of the abundance and vertical distribution of king prawn post larvae in depths to 21 metres have also been obtained using two pairs of samplers on a single warp at one time.

The samplers are capable of catching the puerulus stage of the western rock lobster; however the catches have not been large enough to allow statistical comparisons with the results of catches with other gear.

This sampler has been used effectively in all weather conditions up to the physical limits of the operators. It has stood up well to hard usage under rough conditions with a minimal amount of maintenance. Construction of the sampler frame has been kept simple and inexpensive.

Construction details are available on blueprints from the authors.

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TABLE 1

PARTS AND MATERIALS LIST FOR SAMPLER FRAME (FIG. 2 & 3)

Part Number	Name		Material
1	Net frame-outside section		19 mm square x 500 mm, 16 gauge mild steel tube
2	Net frame-top section		19 mm square x 219 mm, 16 gauge mild steel tube
3	Net frame-bottom section		19 mm square x 480 mm, mild steel tube
4	Common net bar		19 mm square x 380 mm mild steel bar
5	Net frame, inside section		19 mm square x 865 mm mild steel bar
6	Spacing subframe legs		19 mm square x 500 mm, 16 gauge mild steel tube
7	Spacer on spacing subframe		19 mm square x 126 mm, 16 gauge mild steel tube
8	Bearing bracket		184 mm x 62.5 mm x 6 mm mild steel plate
9	Spacer		42.5 mm O.D. x 12.5 mm mild steel tube
10	Axle		32.5 mm O.D. x 19.5 mm heavy walled mild steel tube
11	Quick release cable clamp:	body	38 mm x 38 mm x 15.8 mm mild steel plate
		hook	162 mm x 6 mm diameter stainless steel rod
		spring	60 mm x 1 mm diameter stainless steel wire
12	Hinged cable clamp:	base	38.1 mm x 76 mm x 19 mm mild steel plate
		clamping plate	19 mm x 76 mm x 19 mm mild steel plate
		screw	9.5 mm diameter x 65 mm stainless steel rod
		wing nut	Standard 9.5 mm diameter wing nut
		pins	4.7 mm diameter stainless steel rod
13	Cable clamp:	base plate	52 mm x 63.5 mm x 12.5 mm mild steel plate
		clamping plate	52 mm x 63.5 mm x 25 mm mild steel plate
		cable guide	31.7 mm diameter x 32.8 mm mild steel rod
		screw	9.5 mm diameter x 65 mm long stainless steel rod
		wing nut	standard 9.5 mm diameter wing nut
		pins	4.7 mm diameter x 63.5 mm stainless steel rod
14	Return subframe leg		19 mm square x 520 mm, 16 gauge mild steel tube
15	Return subframe brace		19 mm square x 540 mm, 16 gauge mild steel tube
16	Rubber anchorage point, rear		61 mm x 38 mm x 4 mm mild steel plate
17	Rubber anchorage point, front		101.5 mm x 24.5 mm x 4 mm mild steel plate
18	Bearing clamp: upper portion		25.4 mm x 100 mm x 19 mm mild steel plate
	lower portion		25.4 mm x 100 mm x 19 mm mild steel plate
19	Spear gun rubbers		350 mm long by 15 mm diameter unstretched

TABLE II

TWIN SAMPLER WITH 2.5 mm MESH TOWED AT 5 KNOTS FOR 75 min.

Depth of Net (m)	Mean % of total volume filtered at the selected level	Mean % of total volume filtered during launch and recovery	Range %
	SHALLOW STATIONS		
10	97.57	2.43	1.1-3.8
20	96.04	3.96	2.2-5.9
30	94.36	5.64	4.6-6.9
	DEEP STATIONS		
10	98.01	1.99	1.2-3.3
25	94.42	5.58	4.3-6.5
50	92.51	7.49	4.4-9.8
75	87.83	12.17	10.0-15.4

TABLE III

TWIN SAMPLER WITH 1.0 mm MESH TOWED AT 2 KNOTS FOR 30 min.

Depth of Net (m)	Mean % of total volume filtered at the selected level	Mean % of total volume filtered during launch and recovery	Range %
	SHALLOW STATIONS		
10	93.16	6.84	2.1-12.5
20	85.95	14.05	7.0-18.8
30	80.09	19.91	14.3-22.9
	DEEP STATIONS		
10	96.20	3.80	1.2-8.7
25	85.85	14.15	8.8-21.2
50	77.52	22.48	17.7-26.4
75	72.71	27.29	21.0-33.0

TABLE IV

	Bias χ^2	df	Heterogeneity χ^2	df	Total χ^2	df
Stage I Phyllosoma - Shallow Stations						
10	1.18	1	23.57	19	24.75	20
20	1.57	1	24.79	19	26.36	20
30	3.06	1	24.35	19	27.41	20
Stage I Phyllosoma - Deep Stations						
10	0.01	1	30.23*	19	30.24	20
25	0.82	1	27.82*	17	28.64	18
50	2.34	1	28.30	19	30.64	20
75	0.02	1	13.59	13	13.61	14
Stage II Phyllosoma - Deep Stations						
10	0.17	1	31.91*	19	32.08*	20
25	0.04	1	6.27	11	6.31	12
50	0.06	1	8.53	8	8.59	9
75	0.01	1	5.17	6	5.18	7
Late Stage Phyllosoma - Deep Stations						
10	0.33	1	15.85	18	16.18	19
25	0.03	1	5.41	8	5.44	9
Post Larval Prawns - Shallow Stations						
7	1.63	1	17.50	13	19.13	14
14	1.85	1	18.03	19	19.88	20
21	0.04	1	21.99	17	22.03	18

* P = 0.05 - 0.04

"Summary of χ^2 results of individual hauls testing samples for bias and heterogeneity"

TABLE VA

COMPARISONS OF CATCH IN LEFT AND RIGHT NETS (DEPTH/DISTANCE RECORDER IN RIGHT NET)

STAGE I PHYLLOSOMA — SHALLOW STATIONS

Depth of Net (m)	Number of hauls	Total Catch Left	Total Catch Right	Range Left	Range Right	Mean Catch Left	Mean Catch Right	Total Volume Filtered per net (m^3)	Mean Volume Filtered per net (m^3)	Range	Mean Density (no./1000 m^3) Left	Mean Density (no./1000 m^3) Right	% of Catch Left	% of Catch Right	95% confidence limits
10	20	594	632	5-115	2-119	29.7	31.6	6662	333.2	212-425	89.2	94.8	48.5	51.5	44.3-55.7
20	20	847	898	2-326	2-344	42.4	44.9	7725	387.7	300-475	109.8	116.1	48.6	51.4	45.2-54.8
30	20	503	560	2- 94	2-110	25.2	28.0	8675	434.2	288-512	58.0	64.6	47.3	52.7	43.9-56.1
all depths combined	60	1944	2090	2-326	2-344	32.4	34.8	23062	384.4	212-512	84.3	90.6	48.2	51.8	46.9-53.1

TABLE VB

STAGE I PHYLLOSOMA — DEEP STATIONS

Depth of Net (m)	Number of hauls	Total Catch Left	Total Catch Right	Range Left	Range Right	Mean Catch Left	Mean Catch Right	Total Volume Filtered per net (m^3)	Mean Volume Filtered per net (m^3)	Range	Mean Density (no./1000 m^3) Left	Mean Density (no./1000 m^3) Right	% of Catch Left	% of Catch Right	95% confidence limits
10	20	670	674	4- 99	3-100	33.5	33.7	5100	255.0	87-400	137.4	132.2	49.8	50.2	44.5-55.5
25	18	496	525	2- 99	3-120	27.6	29.2	5650	313.9	162-462	88.0	93.0	48.6	51.4	43.7-56.3
50	20	935	870	3-235	2-226	46.8	43.5	7800	390.0	350-525	119.8	111.6	51.8	48.2	45.3-54.7
75	14	221	218	2- 90	2-108	15.8	15.6	6975	498.2	388-613	31.8	31.4	50.3	49.7	40.5-59.5
all depths combined	72	2322	2287	2-235	2-226	32.3	31.8	25525	345.5	87-613	92.8	92.0	50.4	49.6	46.6-53.4

TABLE VC

COMPARISONS OF CATCH IN LEFT AND RIGHT NETS (DEPTH/DISTANCE RECORDER IN RIGHT NET)

STAGE II PHYLLOSOMA

DEEP STATIONS

Depth of Net (m)	Number of hauls	Total Catch		Range		Mean Catch		Total Volume Filtered per net (m^3)	Mean Volume Filtered per net (m^3)	Range	Mean Density (no./1000 m^3)		% of Catch		95% confidence limits
		Left	Right	Left	Right	Left	Right				Left	Right	Left	Right	
10	20	296	286	3-70	3-37	14.8	14.3	5137	256.9	150-437	57.6	55.6	50.9	49.1	41.7-58.3
25	12	233	219	3-39	3-35	18.6	18.3	3925	327.1	200-437	56.8	56.0	50.4	49.6	40.5-59.5
50	9	81	78	1-37	1-31	9.0	8.7	3300	366.7	263-525	24.6	23.8	50.8	49.2	34.1-54.9
75	7	49	48	2-19	1-22	7.0	6.9	3500	500.0	412-588	14.0	13.8	50.4	49.6	29.7-70.3
all depths combined	48	649	631	1-70	1-37	13.5	13.1	15862	330.5	150-588	40.8	39.6	50.7	49.3	44.4-55.6

TABLE VD

LATE STAGE PHYLLOSOMA

DEEP STATIONS

Depth of Net (m)	Number of hauls	Total Catch		Range		Mean Catch		Total Volume Filtered per net (m^3)	Mean Volume Filtered per net (m^3)	Range	Mean Density (no./1000 m^3)		% of Catch		95% confidence limits
		Left	Right	Left	Right	Left	Right				Left	Right	Left	Right	
10	19	221	209	0-55	2-48	11.6	11.0	21375	1125.0	787-1300	10.4	9.8	51.5	48.5	40.4-59.6
25	9	57	59	2-21	3-16	6.3	6.6	11237	1248.6	1150-1375	5.0	5.2	49.0	51.0	31.4-68.6
all depths combined	28	278	268	0-55	2-48	9.9	9.6	32612	1164.7	787-1375	8.4	8.2	50.6	49.4	41.4-58.6

TABLE VI

Comparisons of Catch in Left and Right Nets

Post larval Prawns

Depth of Net (m)	Number of hauls	Total Catch		Range		Mean Catch		Total Volume Filtered per net (m^3)	Mean Volume Filtered per net (m^3)	Range	Mean Density (no./1000 m^3)		% of Catch		95% confidence limits
		Left	Right	Left	Right	Left	Right				Left	Right	Left	Right	
7	14	237	210	2-52	1-38	16.9	15.0	2692	192.3	111-274	88.02	78.01	53.0	47.0	40.5-59.5
14	20	98	118	0-18	3-21	4.9	5.9	4371	218.6	133-316	22.4	27.0	45.4	54.6	36.4-63.6
21	18	112	115	0-16	2-15	6.22	6.39	3651	202.8	141-282	30.7	31.5	49.3	50.7	36.8-63.2
all depths combined	52	447	443	0-52	1-38	8.6	8.52	10714	206.0	111-316	41.3	41.8	50.2	49.8	43.3-56.7

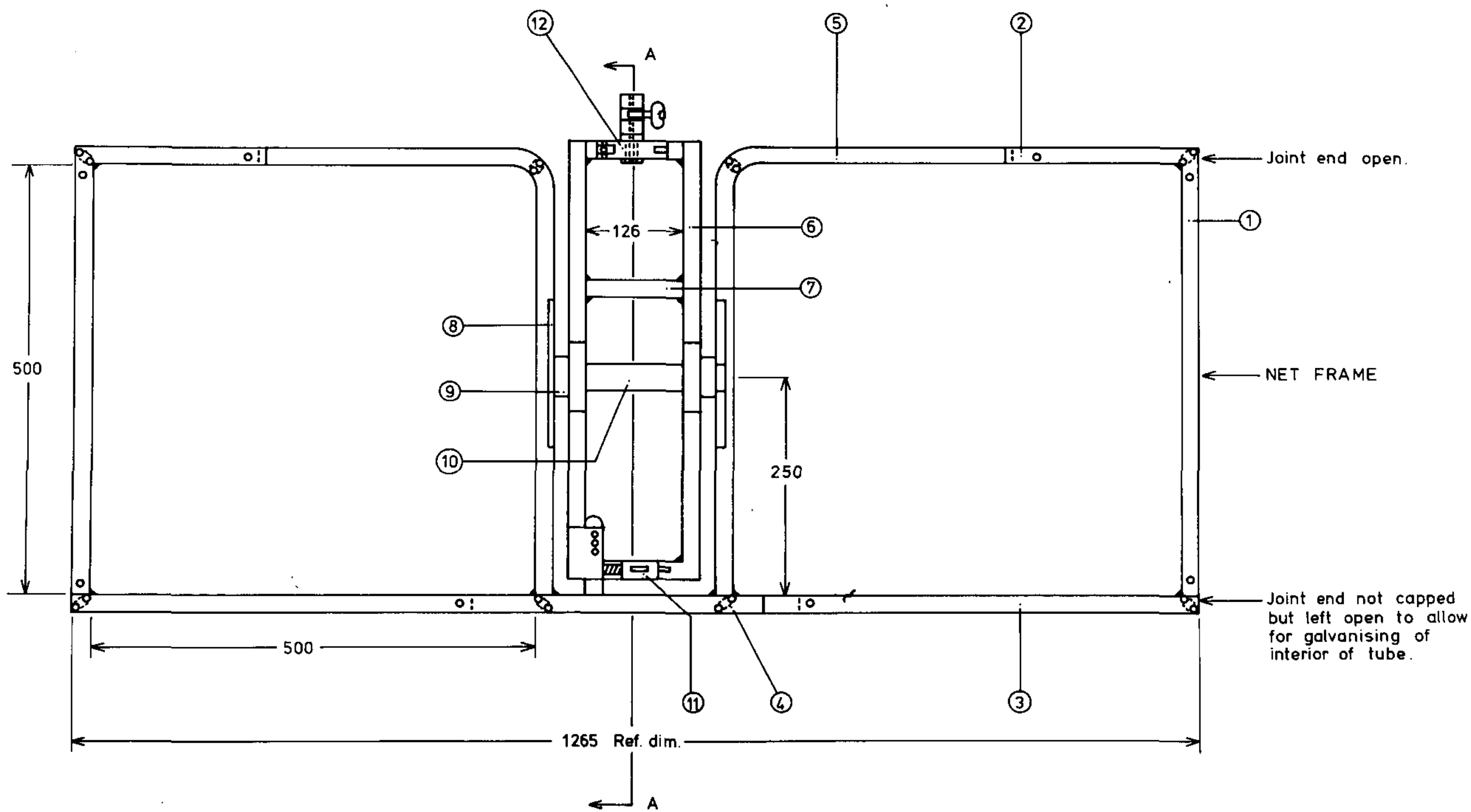
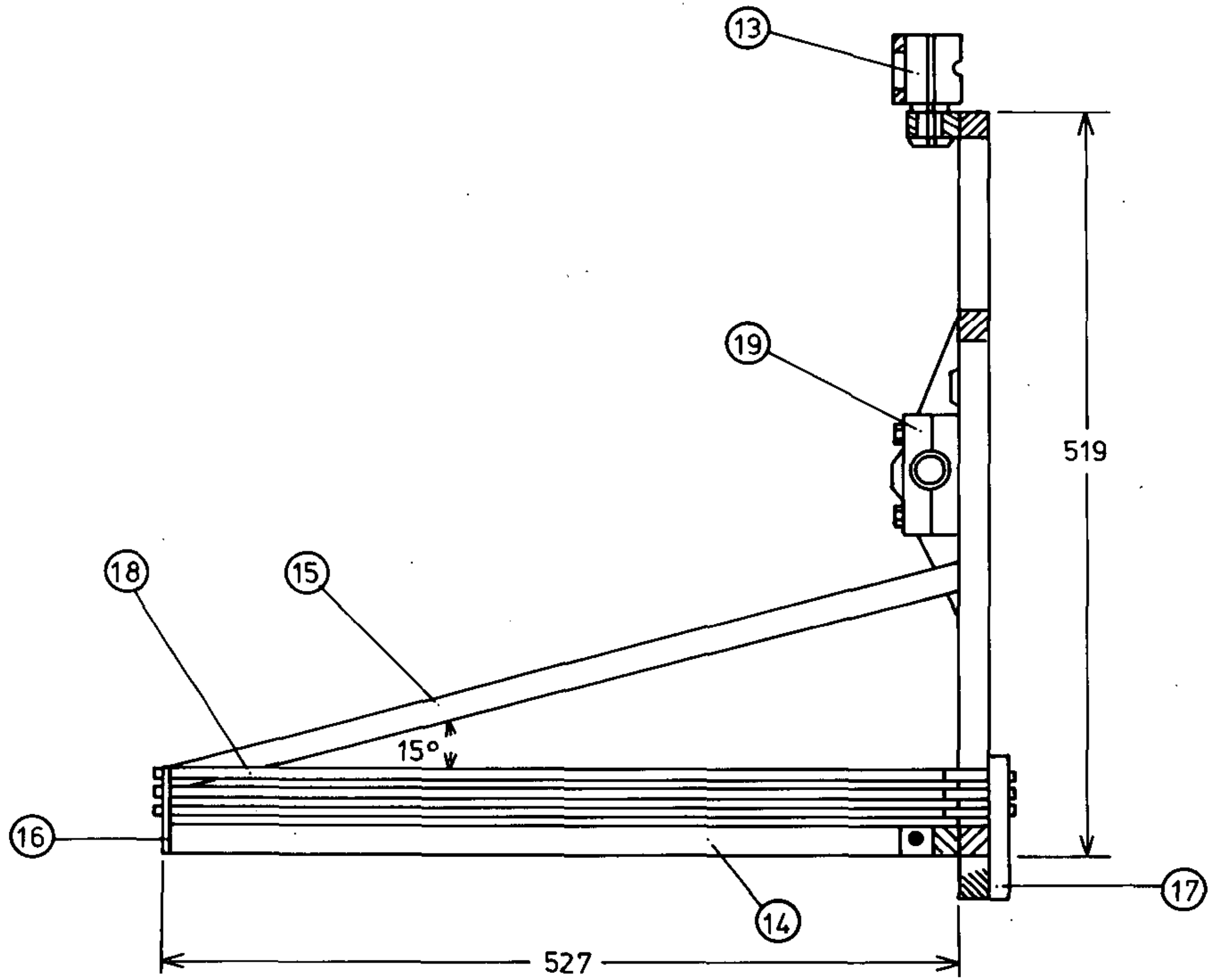


Figure 1. Posterior view of samplers. Circled numbers refer to part numbers listed in Table 1.



SECTION A·A

Figure 2. Section A;A (Fig. 1) of sampler showing return subframe, axle and wire clamps. Circled numbers refer to part numbers listed in Table 1.

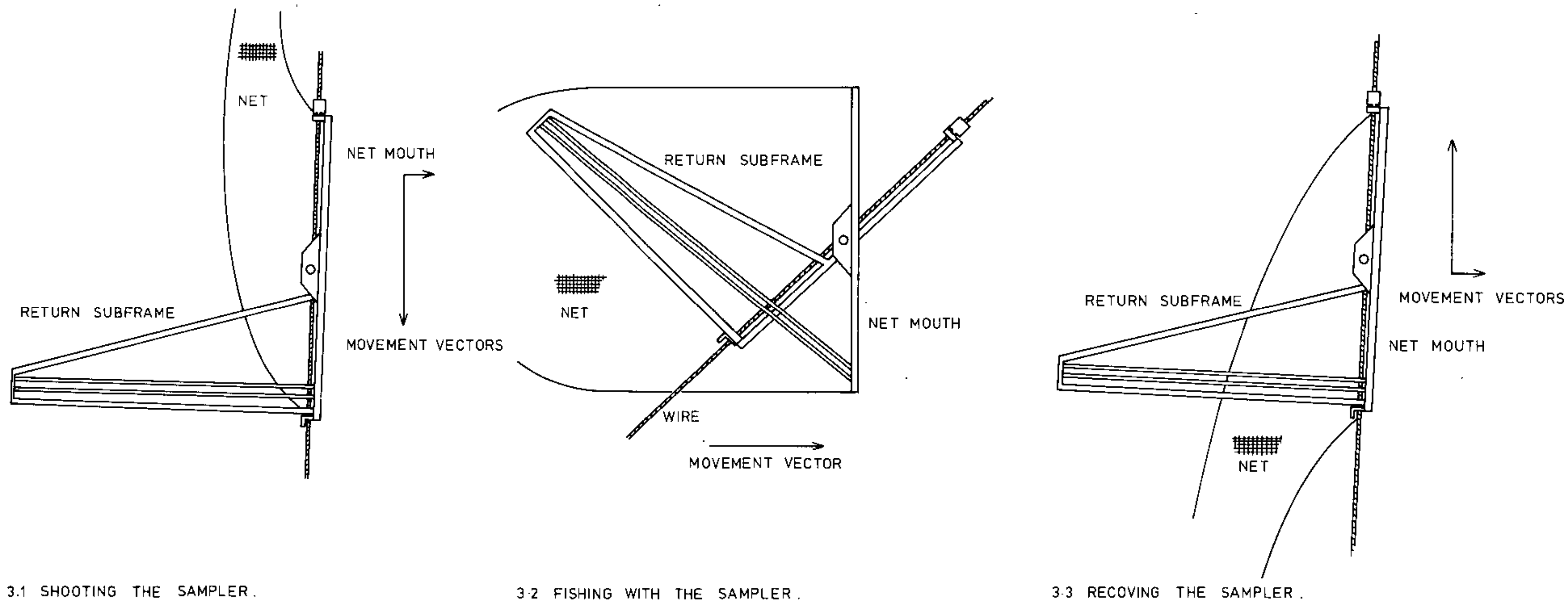


Figure 3. Sketches showing the sampler mouths in the shooting, fishing and recovery position.

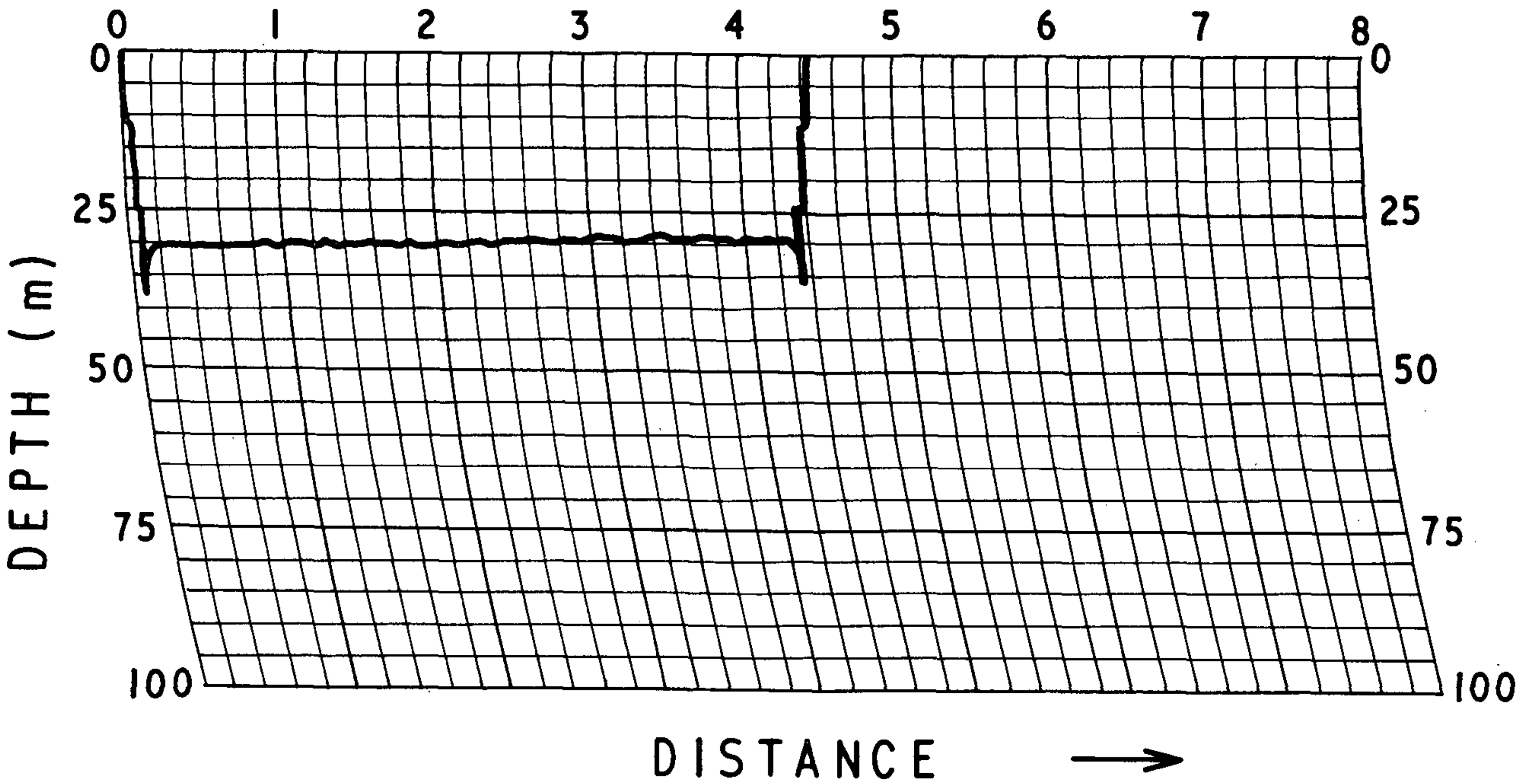


Figure 4. Path of the sampler equipped with 2.5 mm mesh nets. Steps in the descending and ascending trace are caused as additional samplers are put on and taken off the warp.

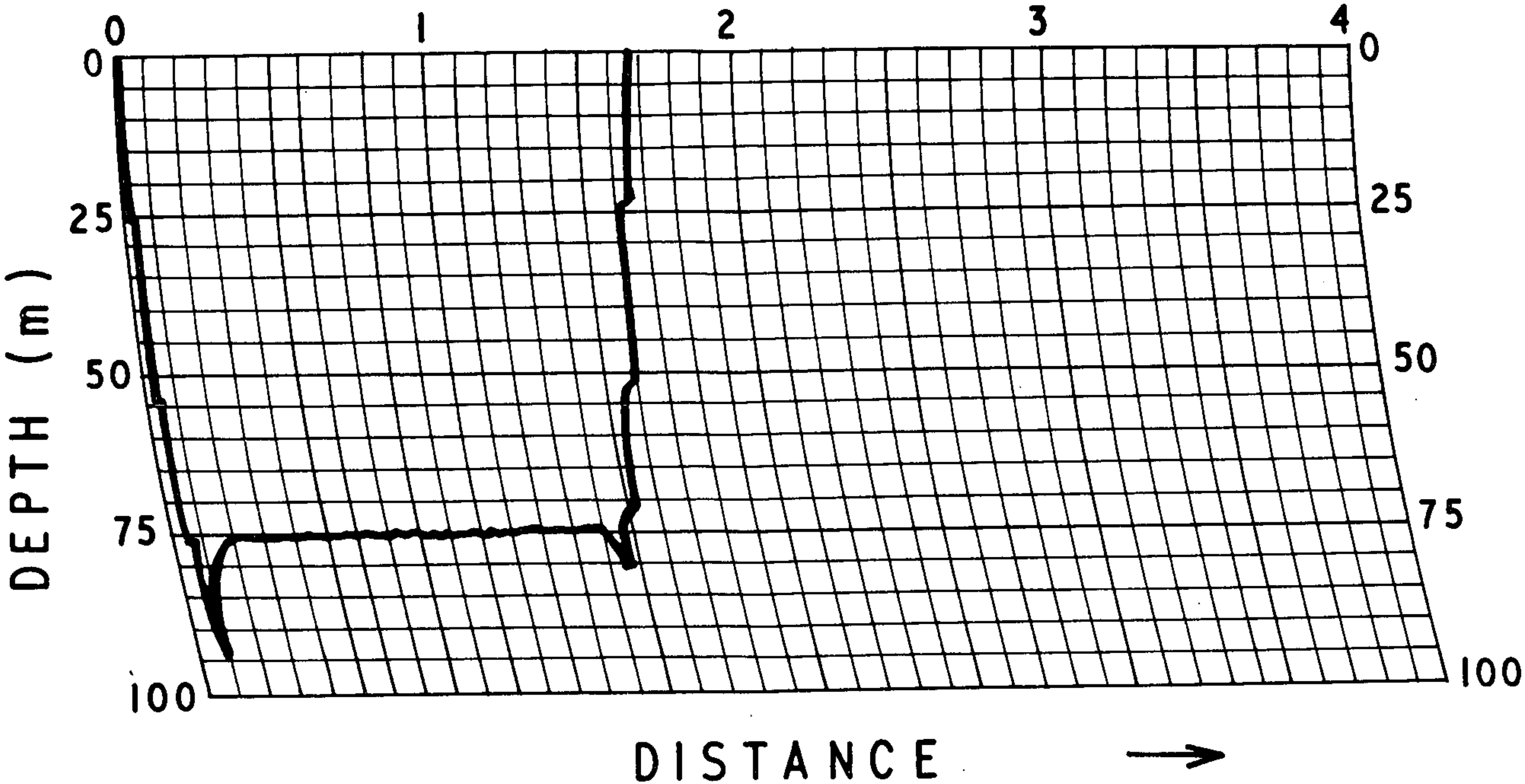


Figure 5. Path of the sampler equipped with 1.05 mm mesh nets. Steps in the descending and ascending trace are caused as additonal samplers are put on and taken off the warp.

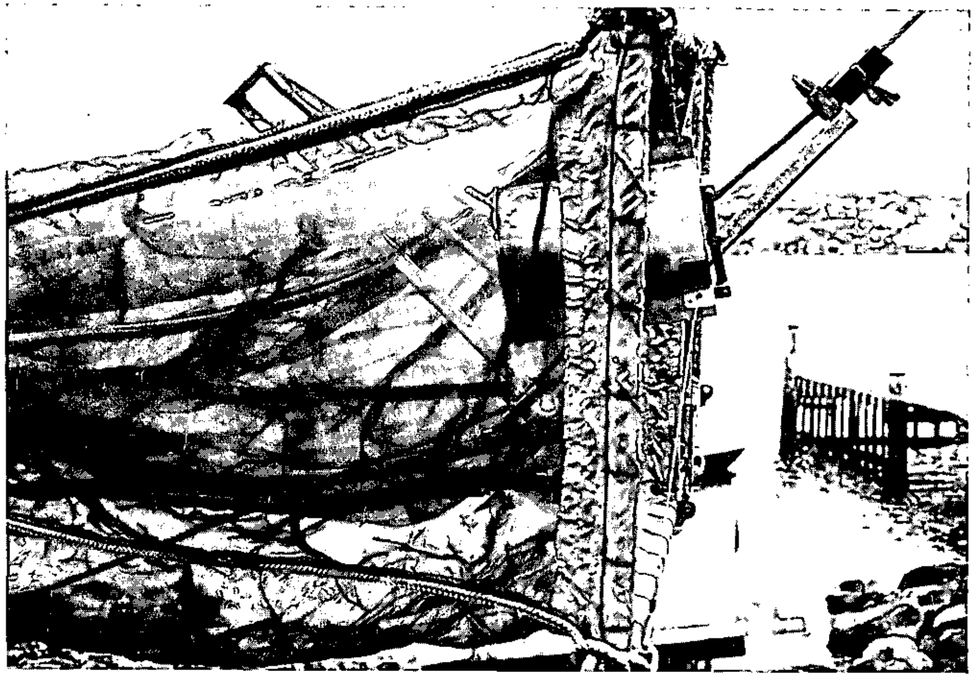


Plate 1 Side view of twin sampler in towing position, with the mouths perpendicular to the direction of travel.

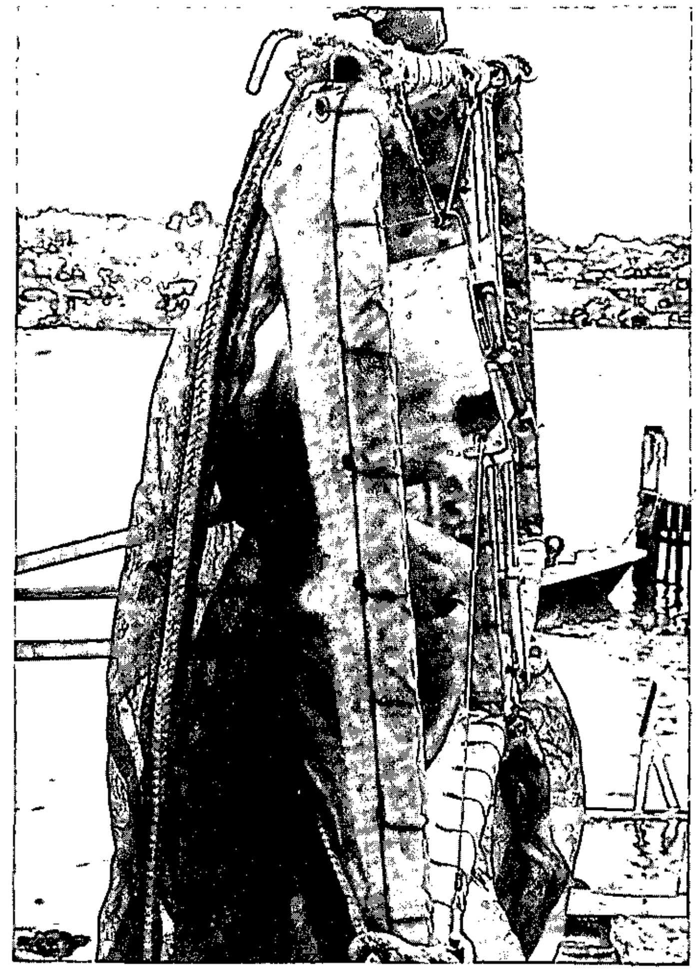


Plate 2 Side view of the twin sampler in the "recovery" position.