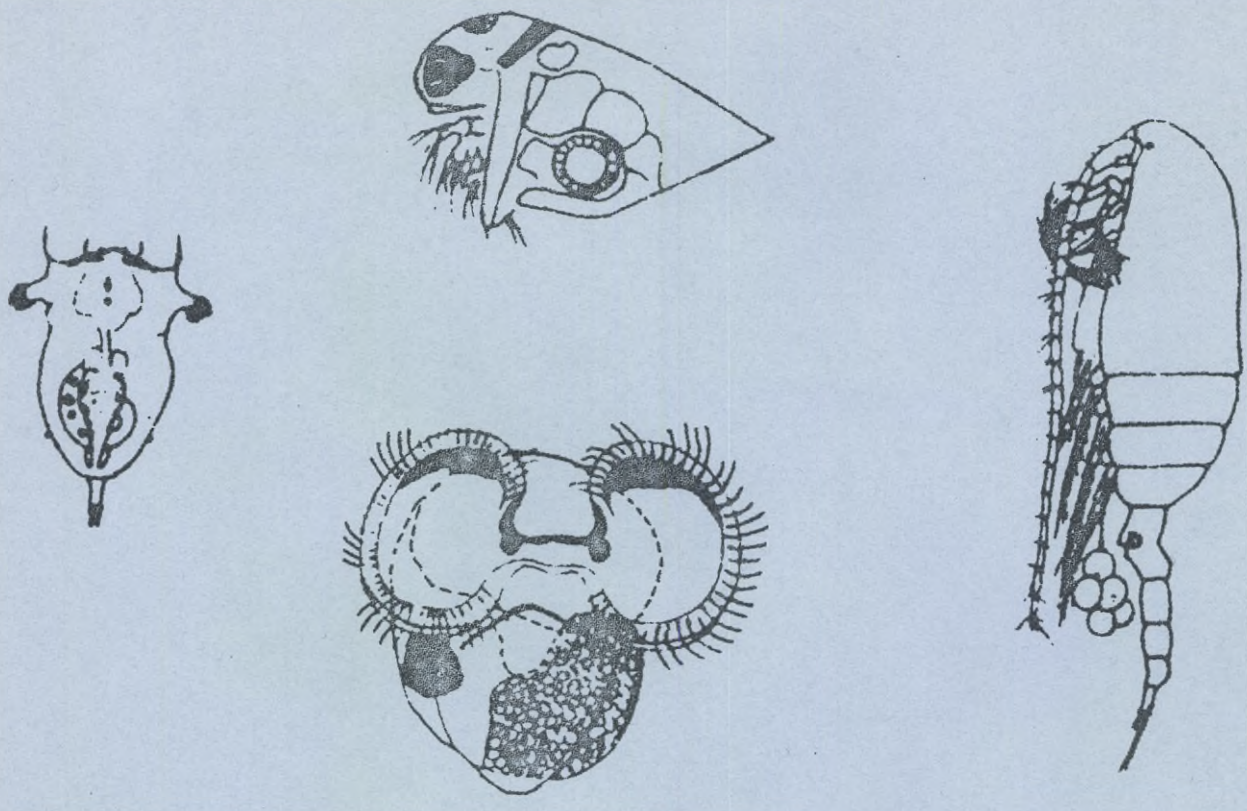

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PLANKTON METHODOLOGY

by

Hans Ackefors

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CONTENTS

This paper will summarize some of the methods used for zooplankton studies and give some information about plankton technique. A few comparisons with phytoplankton methods will also be made. The field methods, the subsampling technique, the analysis in the laboratory. Experimental methods will be discussed only in relation to Swedish investigations.

The technique and methods to be used

The technique to be used in a plankton investigation is dependent on the real issue for the studies, e.g. biomass or production studies, monitoring studies, ecologocal studies, chemical studies, etc. The area which will be studied, is also of great importance when an investigation is to be planned. The technique may be different in a lake, a coastal area or a sea area off the coast. The special hydrography as well as the bottom topography greatly influence the choice of methods and the number of plankton stations which will be visited. Finally, but never the less important is the practical side of the study. Available gears, research vessels and ship time are all very important factors which may be decisive when the investigation is planned.

The plankton stations and the time interval for the field work.

The number of plankton stations and the distances between the different plankton stations are dependent on many things, such as the issue for the investigation, the hydrography, the depth and the bottom topography in the area. As the plankton is not either randomly or homogenously distributed but tends to be more or less patchy in different areas it is essential for many types of investigations to visit more than one station and/or to take more than one sample at each station. It is, however, important to know that the petchiness of plankton seemed to have been exaggerated by some authors. In fact, samples have been taken by gears where it has been impossible to see the effect of vertical distribution according to the hydrography and the

effect of diurnal migration. In a shallow lake or a coastal area, where the hydrography of the water body is greatly influenced by wind force or by currents, it is important to have a more dense net of stations than in a sea area with rather stable conditions. In a large sea area it is recommended to have a net of stations with nearly the same distance between each station. In an area consisting of many small basins, as in the Baltic, it is convenient to have a station in the deepest part of each basin. The distance between the stations is greatly influenced by the changing salinity and temperature conditions, as in the Baltic area where the salinity and temperature decreases the further to the north one moves into the Baltic. The well-known poor oxygen conditions in some areas also influence the number of plankton stations as well as the distance between them.

When planning an investigation in a polluted coastal area outside a town or in a polluted fjord, plankton investigations have in many cases been forseen. From my point of view, I think it is of a very great importance to make both phytoplankton and zooplankton investigations to study and follow year to year the composition of the fauna as well as the production of, especially, the phytoplankton. A high production of phytoplankton will give you a "secondary pollution" in the form of decreasing oxygen condition due to decaying organic matter, in the bottom water. It is also of utmost importance to study the uptake of chlorinated hydrocarbons and heavy metals by the plankton organisms.

The plankton stations to be visited can be placed in many ways. One way is to have one station in the most polluted part of the area and then the other stations at points where the pollution conditions decrease to about 50, 25 and 10% of the conditions of the first station concerning e.g. the concentration of nutrient salts. Finally it is valuable to visit stations in a non polluted area to get a reference station. In many cases the polluted water consists of an upper stratum of more diluted salinity water, above the more heavy bottom water. Then it is necessary to get vertical hauls with nets in both strata

for zooplankton studies. Phytoplankton samples should be taken in the upper 20-m layer and in many cases it is enough with an integrated sample from 20 m to the surface.

The analysis of zooplankton samples in a polluted area can be restricted in the following way:

Usually there is a lack of manpower for analyzing the samples and very often you have no trained personell with good knowledge of taxonomy. Then it is necessary to analyze not more than e.g. the first 500 specimens of each sample. In a tropical and subtropical area, however, where you have many species this methodology is not applicable. Normally you have to identify the copepods to species. In a tropical or subtropical area it is probably necessary to restrict the analysis to genera or to the group concerning the copepods. Other plankton specimens you can identify only to genera or to groups. Then you can follow the percentage compostion of the fauna from year to year in a simple way. The standing crop of plankton can be measured as wet weight or dry weight and if possible converted to the content of carbon. The uptake of chlorinated hydrocarbons as DDT, PCB, etc. and heavy metals, as mercury, copper, etc. is important to follow if you have resources to analyze it.

The phytoplankton must also be analyzed to identify species or genera. Braarud (1969) stated that no single species can be regarded as an indicator of the polluted waters. The main pollution effect is found in the quantitative regional distribution pattern of the total population, or its predominant species.

The time interval between the sampling occasion is dependent on the issue as well as the practical resources for the investigation. In general the conditions change more quickly in a coastal area or a lake in comparison with a sea area. Plankton stations in a coastal area are more influenced by wind conditions. With changing winds the hydrographical conditions are changed e.g. the water temperature may sink or rise 5 - 10^{o}C in a few hours.

For biomass or production studies it is necessary to take samples as often as possible to follow the life-cycle of the most important plankton species. The time interval may be adapted to the lifespan of the different developmental states in order to follow the generations during a year. As the speed of the development is slowed during the cold season the samples can be taken with longer intervals than during the season with warmer water. For zooplankton studies in the Baltic this means that one sampling occasion per month during winter may be enough. During spring to autumn the samples have to be taken at least once a week.

For ecological studies it is often necessary to take samples many times during a day and a night to see the effect of diurnal migration. As a contrast it is worth mentioning, that for some monitoring studies, it is only necessary to take samples 1 - 4 times a year. In such cases it is only possible to follow the changes in compositon of the fauna with reference to different species, or to study the uptake of chlorinated hydrocarbons or heavy metals in the organisms due to human activity.

Suitable plankton gears to catch different fractions of plankton concerning size range.

The plankton consists of phytoplankton and zooplankton. Most phytoplankton are less than 100 μ but the size range of zooplankton is from 2 μ to 1 m in diameter (2 μ - 10^6 μ), that means a difference of 6 magnitudes between the smallest and the largest organisms. It is therefore impossible to catch the whole range of organisms with one type of gear. The nanoplankton, microplankton, mesoplankton, macroplankton and the so called micronekton must be taken by different gears and different techniques. In general there are more organisms per m^3 of the smaller species than of the larger ones. Therefore the sampling volume of water must be adapted to the species concerned in the study. The division of gears according to the working parties inside UNESCO will be followed in this paper (Tranter, 1968).

The plankton fraction less than 200 µ, often called nanoplankton and microplankton, include everything from the smallest protozoa to the eggs and larvae of many organisms as well as of other organisms such as rotifers, adults of small copepod species, etc. Water bottle samples (plankton samples), or pump samples, are recommended. The size of the sampling volume may vary from 100 ml to 100 litres. Usually a 10 litre water-bottle gives a significant sample of forms up tc about 150 µ in size. Some people prefer to sample the organisms at the larger end of the size range (75 - 200 µ) or the sparsely distributed organisms with a net.

In Sweden, zooplankton organisms up to 1 mm (1000µ) have been sampled by different authors with a Ruttner sampler (2.7 1), a Rodhe sampler (5 1) (Rodhe, 1941), a Bergman sampler (23 1) (Lindquist 1961), an Ackefors sampler (23 1) (fig. 1) (Ackefors 1971a).

Smaller mesoplankton in the size spectrum from 10 mm downward to a width of at least 200 µ is sampled by plankton nets. The Working Pary no. 2 has agreed upon a net of the following type (fig. 2). The shape is cylindical-conical. The length of the cylindical front section is 95 cm and the conical end section is 166 cm both with a filtration ratio of 3:1 and giving a filtration ratio for the total net of 6:1. The mouth opening is 57 cm in diameter and the sampling area is thus 0.25 m^2. The net material consists of nylon Nytal 7 P with mesh aperture width of 200 µ. The net is furnished with a Nansen closing system.

There exists many types of nets for plankton studies. some of the old types still in use -- Hensen net, Apstein net, Juday net, Nansen net -- are described by Fraser (1962) Tranter (1968), (figs. 3 and 4).

The mesh size of the plankton net must be adapted to the special investigation to be made. For different sea areas, or for different types of lakes, no standard net can be used in all areas. According to an old agreement inside ICES the mesh size of 160 µ should be used

in the Baltic area. However, this mesh size is too coarse to get all the nauplius stages of the copepods present in the Baltic proper, If the population dynamics of the copepods will be studied in the area, it is necessary to use a mesh size of 90 μ, which is a compromise between the problem of clogging and the smallest mesh size, to sample the youngest nauplius stages to 100% (cf. Ackefors 1969a).

In order to be able to fractionate plankton hauls without using ordinary plankton nets, with a closing device which is very much time-consuming in deep areas, the multi-depth sampling technique has been developed. Several discrete samples can be taken at one haul (fig. 5) (Bé, 1962; Motoda 1963).

The smaller mesoplankton can also be taken with different types of samplers. They are used for horizontal or oblique hauls and some of them can be charaterised as high-speed samplers; Clarke-Bumpus sampler (fig. 6) (Clarke & Bumpus 1940, Edmonson & Winberg 1971), Hardy continous plankton recorder and the standard plankton indicator (figs. 7 & 8) (Hardy 1936, 1939), the Hardy plankton indicator (fig. 9) (Glover 1961), the Gulf III (fig. 10) (Gehringer, 1952) and modifications of this sampler (Bary et al., 1958; Clarke 1964). A modified Hardy continous plankton recorder, with sophisticated electronic equipment for taking discrete series of samples, instead of a continous ribbon, has been developed by Longhurst et. al (1966). The strips of filtering gauze are advanced by an electronic drive every 30 sec., so that a series of descrete samples are taken representing the filtrate from about 20 m^3 water. The flow through the net, the temperature and depth range during each sampling period are recorded on the paper chart of an electronic recorder simultaneously.

A multi-purpose plankton sampler for catching fish larvae, eggs, and also their planktonic competitors and predators as well as phytoplankton, was designed by Beverton & Tungate (1976) (Fig. 11). The sampler, 2.5 m long and 0.8 m in diameter, is fitted with interchangeable conical nylon nets. The smaller auxiliary samplers are attached to the main larval sampler for catching smaller zooplankton and phytoplankton.

A sophisticated net-changing device for use with the Lowestoft multipurpose sampler is now available (fig. 12) (Harding et al., 1971). The amount of water filtered is registered by an electric-flowmeter and the depth is recorded by a pressure transducer.

Larger mesozooplankton are often distributed relatively scarce. The working party no. 3, inside UNESCO recommended a sampler of coarse mesh that would sample the larger organisms in as quantitative a manner from a large quantity of water, but would prevent the retention of the smaller, more numerous, organisms. It was considered that a high-speed sampler would be designed for filtering large quantities of water at high speed. An encased sampler wihh a net of mesh aperture of 1 mm or a simple unencased net ("interimnet") with the same mesh size was proposed (fig. 13), The sampler should filter at a rate of 20 m^3/mm; and would be able to be taken to a depth of 200 m at a speed of 6 knots. The sample should also be fitted with an acoustically operated opening-closing action, a flow meter and a depth sensor (net sond) telemetering to the surface.

The simple unencased net should have a mouth of 1 m^2, with a cylindical front section, 57 cm long, and a conical after part, 200 cm long. The mesh aperture should be 1 mm and the towing speed 2 - 3 knots. A flow meter is to be placed 25 cm inside the ring.

The methods used for catching larger plankton and micronekton was dealt by the working party no. 4. The pelagic organisms concerned was in the range of 2.0 to 10.0 cm which means large decapods, fish larvae, small adult fish, small cephalopods, large euphausiids, etc. The type of sampler which was recommended for this type of animals was the Isaacs- Kidd midwater trawl (Isaacs & Kidd, 1953). Two sizes are recommended, either 6 feet or 10 feet and the mesh size of the net being 2.5 mm. This finer mesh can be supported by an outer net with meshes about 6.5 cm. The Isaacs-Kidd midwater trawl has been modified for opening and closing the trawl when towed. (Isaacs & Brown, 1966).

The Tucker net for catching micronekton has now been modified with and opening-closing device (fig. 14) (Davies & Barham, 1969). The

advantage with this net is that it is easy to handle from a small ship and it is haulable on standard hydrographic wire. The device consists of a maintenance-free mechanical construction. The drawback is that the gear collects only one sample per haul.

A new midwater trawl based on the Tucker net with an opening and closing equipment, acoustic release gear and depth telemetering pinger has been constructed by Clarke (1969). The net is designed to rish. The mouth of the trawl has an area of 8 m^2 and with the mouth at 45^o from the vertical (fig. 15).

Filtering efficiency, flume experiments and hydrodynamic studies.

It is important to know the efficiency of the gear you use. It is, however, rather difficult and time consuming to investigate the actual filtration coefficient of the used gear and the filtration coefficient will also change during the time of the haul due to the clogging effect. The literature in this field is so comprehensive that I have to give you only a few literature references for further studies.

Papers concerning the filtration coefficient and the flow pattern associated with plankton samplers have been published by Tranter & Heron, 1967; Tranter & Smith 1968; Smith et. al 1968 (fig. 16).

Flume experiments on the hydrodynamics of samplers and nets are of great importance. The results of velocity profiles of bridled nets in comparison with unbridled nets by Mahnken & Jossi (1967) are very important to understand as where to fix the flow meter in the gear. They found that the velocity of water showed maximum near the margin of the mouth and a distinct minimum at the centre of bridled nets. Harding & Arnold (1971) made valuable investigations on the hydrodynamics of a high-speed encased plankton net.

Research work about the avoidance of samplers has been collected in a nice paper by Clutter & Anruku 1968.

Preservation, subsampling and counting of zooplankton samples.

The smallest fraction of zooplankton ($< 100\ \mu$) and phytoplankton is normally analyzed according to the technique described by Utermöhl (1958). The samples are preserved with different types of jodine solutions, e.g. Lugol's solution (20 g potassium jodid, 10g acetacid in 200g aqua dest.). The samples, or parts of it, are permitted to settle in small vessels with thin glass bottoms. These are then counted from below with an inverted microscope (Utermöhl, 1958). Such samples are always taken with a sampler or water bottle but never with a net.

Bigger zooplankton ($> 100\ \mu$) are normally caught by some type of net. The samples are concentrated on filtres and washed into small bottles. The preservation of this material is made with neutralized formalin (40% formaldehyde) placed in the sample bottle to make about 4% final concentration of formaldehyde. Normally such samples have to be subsampled before counting, because the net catches too many specimens. This can be done with a pipette of a known volume e.g. 5 ml after the sample has been stirred in one liter of water. I myself want to recommend tha subsampling apparatus by Kott (1953). This device is handy and open and it is very easy to work with. You first get 10 tenths and afterwards you can subsample again if you want to analyse ? hundredths of the sample.

The subsample is put into a counting chamber, or a Petridish, before you examine the sample with a binocular dissecting microscope. The counting chamber is much bigger than what is used with the Utermöhl technique for microplankton. The chamber can be made of Plexiglass about 10 cm in diameter and about 1 cm high. Four to six parallell bars in the bottom and lines at right angles to the bars are etched in the

bottom. With such a chamber it is much easier to control the sample. When examining the organisms we prefer light coming from below through the bottom of the counting chamber.

When taking subsamples and samples it is important to know how large of a sample you have to take in order to get results with good statistical confidence. This has been discussed by many authors e.g. Lund et al. 1957. The sampling volume can never be adapted to both the abundant and to the vary scarce species in the water. The species of special interest for the investigation must then be decisive. You can test the sample volume or the size of the subsample with a simple formula:

The error in %; $f = \pm 2 \cdot \frac{100}{\sqrt{n}}$ where n is the number counted and the error (f) is given within the 95% confidence limit. If you count 25 specimens of one species, $f = \pm 40\%$.

The number of organisms to be counted are dependent on the issue for each investigation. For certain prodution studies where it is only necessary to determine the biomass, or chemical studies, it is often enough to know the proportions between the most important genera. For ecological studies it is necessary to determine the proportions of the species and very often the proportions of the different developmental stages within the species. For real production studies you are obliged to determine the developmental stages of the most important plankton species.

The choice of gear and method for plankton studies.

The choice of gear is always dependent of the issue of the investigation, e.g. distribution studies, ecological studies etc. Horizontal gears, both nets and samplers, (Hardy continous plankton recorder, Gulf III, Beverton & Tungate sampler) (cf. figs. 7, 10, 11) are useful for distribution studies over wide areas. You can also study the

amount of fish larvae and eggs in an area by doing oblique or horizontal hauls. For some ecological studies they can also be used. The method with horizontal gears must always be used to sample scarce species. Large samples for chemical studies can also be taken by horizontal gears.

The international herring larvae surveys in the North Sea area, arranged by ICES member countries, is a good example where samples suitable for horizontal or oblique hauls are used. Oblique hauls from surface to bottom and to surface again are made during a 30 minute interval at each station with a Gulf III sampler. A wireless net sond is used so that all samples taken between the surface and the bottom are of an equal time interval. The results of the surveys are expressed as the number of larvae per m^2 according to the formula:

$$L = \frac{N \cdot D}{V} \qquad \text{and} \qquad V = \frac{A \cdot S \cdot T}{61.023}$$

Where:

L = Number of larvae per m^2

N = Number of larvae in the sample

D = Maximum depth of the sample

V = Volume of water sampled in m^3

A = Area of the nose cone in m^2

S = Speed of the vessel should be constant, 5 knots = 101,33 inches/second

T = Duration of the haul in seconds.

To get a more complete picture of the whole plankton fauna from bottom to surface in an area it is often necessary to use plankton gears suitable for vertical hauls. In the Baltic proper we have taken fractionated vertical hauls from bottom to surface with a Nansen net furnished with a closing device. The interval for the hauls has been chosen according to hydrographical conditions. One haul is made between thermocline and surface (about 20-0 m), one between halocline and thermocline (about 60-20 m), another one in the poor oxygenated bottom layer from about 100 m to 60 m, and so on. This produces a rough draft about the ecology of certain species, the diversity of species as well as of

production in the area. Net hauls can be considered as a semi-quantitative method (cf. Ackefors 1969a).

To get more detailed information about the ecology of species it is necessary to use a plankton sampler or a pump where you get a sample from a fixed point in the water column (cf. Ackefors 1969b). This technique must always be used when studying the smallest fraction of zooplankton -- the microplankton (nanoplankton) -- or phytoplankton. The sampler technique, when taking a certain volume of water, is also used for quantitative studies.

With a small sampler (Rodhe 1941, Ackefors 1971) (cf. Fig. 1) it is possible to get the most detailed information about the ecology of a species if many hydrographical parameters are measured at the same time and in the same point of the water column where the samples are taken (cf. Ackefors 1969b). Such field studies are very suitable when studying the influence of temperature, salinity, oxygen, light, etc. upon the vertical distribution of the species. The sampler technique can also be used to investigate the diurnal migration of certain species. Small samplers and pumps are not so suitable to use for studying bigger organisms than 1 mm, which normally are rather motile. In such cases it is necessary to use samplers which take larger volumes of water.

Hydrographical data

In order to be able to interprete the results of a plankton investigation it is necessary to measure a lot of physical-chemical parameters. In many cases this can be done very simply with *in situ* instruments. The most dominant factors for all life in sea water are salinity and temperature which nowadays can be measured with a salinometer. The temperature can also be measured very easily and quickly with a bathythermograph. There is a great advantage to measure these data just before the plankton sampling. As soon as you have got the data you can decide

at what intervals the samples should be taken, e.g. samples above $15^{o}/_{oo}$ S and samples below this salinity. A secchi disk can measure the water visibility and give you much information about light conditions, the amounts of plankton and particles in the water. The method is very simple and very valuable. Normally water samples are taken from different depths to measure oxygen, phosphate, nitrate, etc. At least the oxygen concentration is, in some sea areas as the Baltic, very important to know when plankton investigations are made. Besides these parameters all data about wind direction, wind force, air pressure and weather conditions should be noted.

The results and data processing

It is essential that the results of all plankton analyses are written in the form of simple tables in order to facilitate publishing the data later. In many cases a data processing system can be used and it is very convenient to combine hydrographical and biological data in the same system. The information is initially punched on cards and later transferred to magnetic tape. Then the data are stored for future work when the real scientific work starts. It is very important that all investigations and all results are made in such a way that they are easy to transfer later to punch cards if there is no possibility for some reasons to do it immediately.

Plankton faunae

One of the biggest problems when analysing plankton samples is the lack of comprehensive faunae. This is especially true for tropical and subtropical areas but even for temporal and boreal waters. There are a lot of popular or real scientific literature which gives a good survey of the plankton world e.g. Hardy (1956), Fraser (1962), Raymont (1963), Wimpenny (1966). There are also a lot of good and popular faunae e.g. Newell & Newell (1963), Wickstead (1965), Wimpenny (1966) but they are far from complete. On the other hand, there are many paper or books dealing with certain taxonomic groups. A good survey of this is given by Newell & Newell (1963).

A very comprehensive series of genera or families are continously issued by the International Council for Exploration of the Sea (ICES) since 1949 and edited by specialists round the world (Fiches d´identification du zooplankton: Sheet 1 -(1949)). Unfortunately these papers, as well as most other papers, give very little information about developmental stages. There are often great difficulties in finding information about the nauplius and copepodite stages of copepods. Because of this fact there may be problems in identifying species, Very good old literature is available for determining copepods and cladocerans in northern waters e.g. Lilljeborg (1900), Sars (1903), Oberg (1906), Kraefft (1910). In the two latter papers the developmental stages of copepods are also described.

A very good faunae is available for the Mediterranean Sea (Trégouboff & Rose 1957) which can also be used partly in other areas. Especially for copepods there are faunae for many areas e.g. Owre & Foyo (1967), Brodskii (1967). Concerning the Baltic proper two papers describe the whole fraction of the fauna bigger than 150 µ, viz. Ackefors 1969a and Ackefors & Hernroth (in print).

Experimental work

Most ecological field work should be followed by experimental work in the laboratory in order to understand what is the master factor for e.g. the distribution in the water. A lot of physiological and ecological work has been made with crustaceans especially bigger calanoids or bigger decapods etc. But there are also papers about experimental work with small copepods cladocerans less than 1 mm. I want to stress the importance of such experiments in order to understand the ecology of copepods and other plankton organisms. It is possible to demonstrate e.g. the preference or tolerance of salinity and temperature for very small organisms (Ackefors and Rosén, 1970; Ackefors 1971b).

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Legends

Fig.1.A plankton sampler "type Ackefors" with a capacity of 23 litres(2). A.The sampler is modified for taking zooplankton samples.B.The sampler is modified for taking phytoplankton and water samples.(Ackefors,1971a).

Fig.2.The type of net proposed by Working Party no.2 inside UNESCO for taking smaller mesoplankton.(Tranter,1968).

Fig.3.Different plankton samplers according to Fraser (1962). 1).A townet 2). A paravane net;3)The Nansen net; 4)The Gulf III sampler.

Fig.4.Different plankton samplers according to Fraser (1962) and Tranter (1968). 1) The vertical closing net; 2) The Clarke-Bumpus net; 3)The Bossanyi net ; 4)The Hensen net.

Fig.5.The Motoda net for vertical hauls(Motoda,1963).

Fig.6.The Clarke-Bumpus plankton sampler(from Edmondson & Winberg,1971).

Fig.7.The Hardy continous plankton recorder (from Hedgpeth,1957).

Fig.8.The standard plankton Indicator (from Hardy,1936)

Fig.9.The 'Hardy' Plankton Indicator,as used to sample plankton by fishing vessels working on the herring grounds.(Fraser ,1962).

Fig.10.The Gulf III Plankton Sampler.The upper picture shows the encased sampler and the lower one the naked plankton net with the plankton bucket receiver.

Fig.11.The multiple high-speed plankton sampler (Beverton & Tungate,1967).

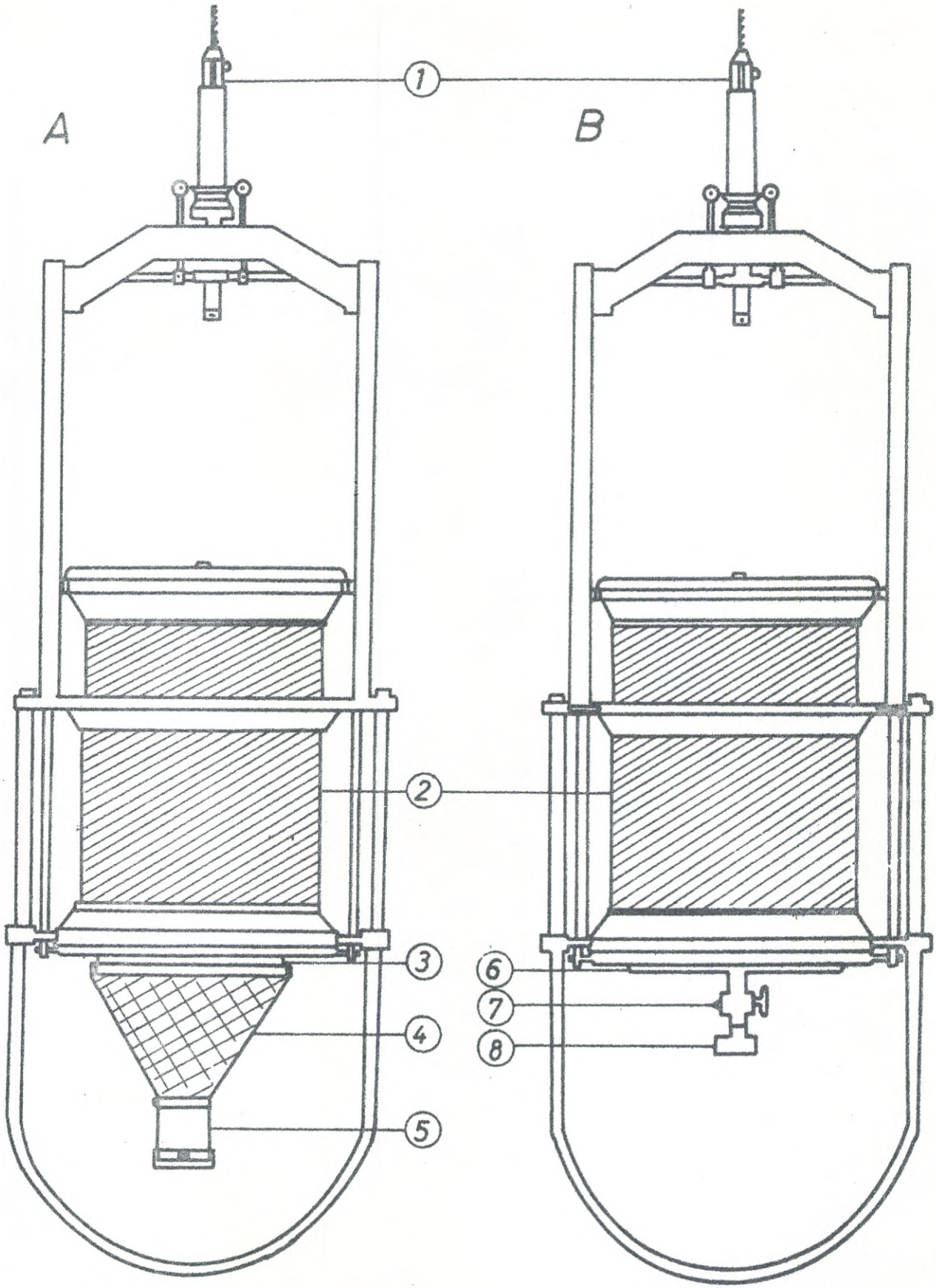
Fig.12.The net-changing device for use with the Lowestoft multipurpose sampler (Harding et al.,1971).

Fig.13.The simple unencased net 'the interim net' proposed by the Working Party no.3 inside UNESCO for taking larger mesozooplankton.(Tarnter 1968).

Fig.14.A chematic drawing showing the operating principle of the Tucker net (Davies & Barham,1969).

Fig.15.The operation of the rectangular opening-closing trawl.a)The net is payed out to the fishing depth ,b)the open position ,c) after closure while it is hauled to the surface,d)the rectangular opening-closing trawl in the open,fishing position (Clarke,1969).

Fig.16.The effect of encasing the net on filtration efficiency (Tranter &Heron,1967).



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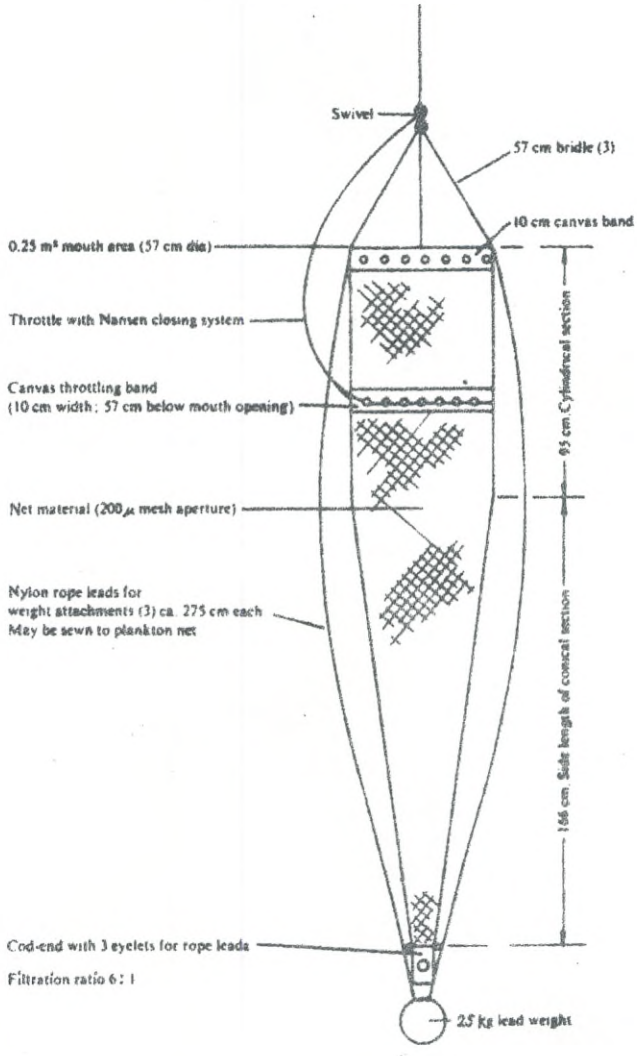

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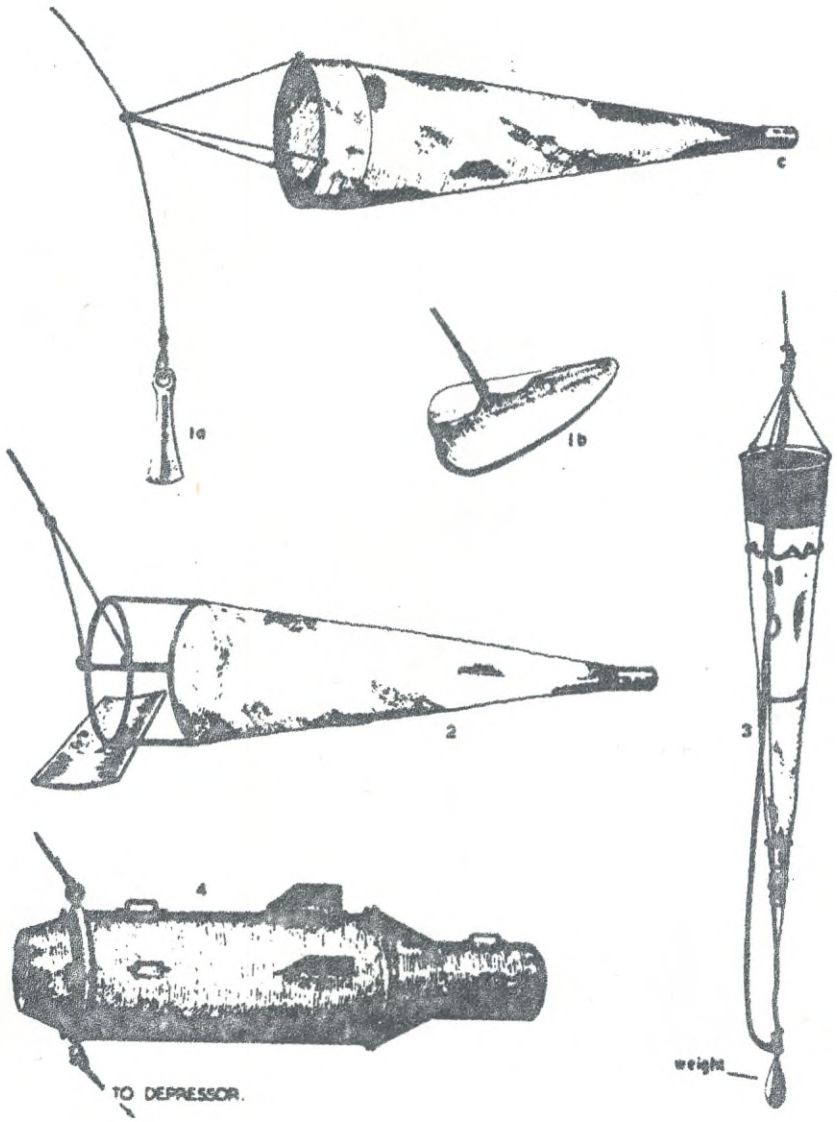


Fig.3. Different plankton samplers according to Fraser (1962). 1) A townet 2) A paravane net 3) The Nansen net 4) The Gulf III sampler.

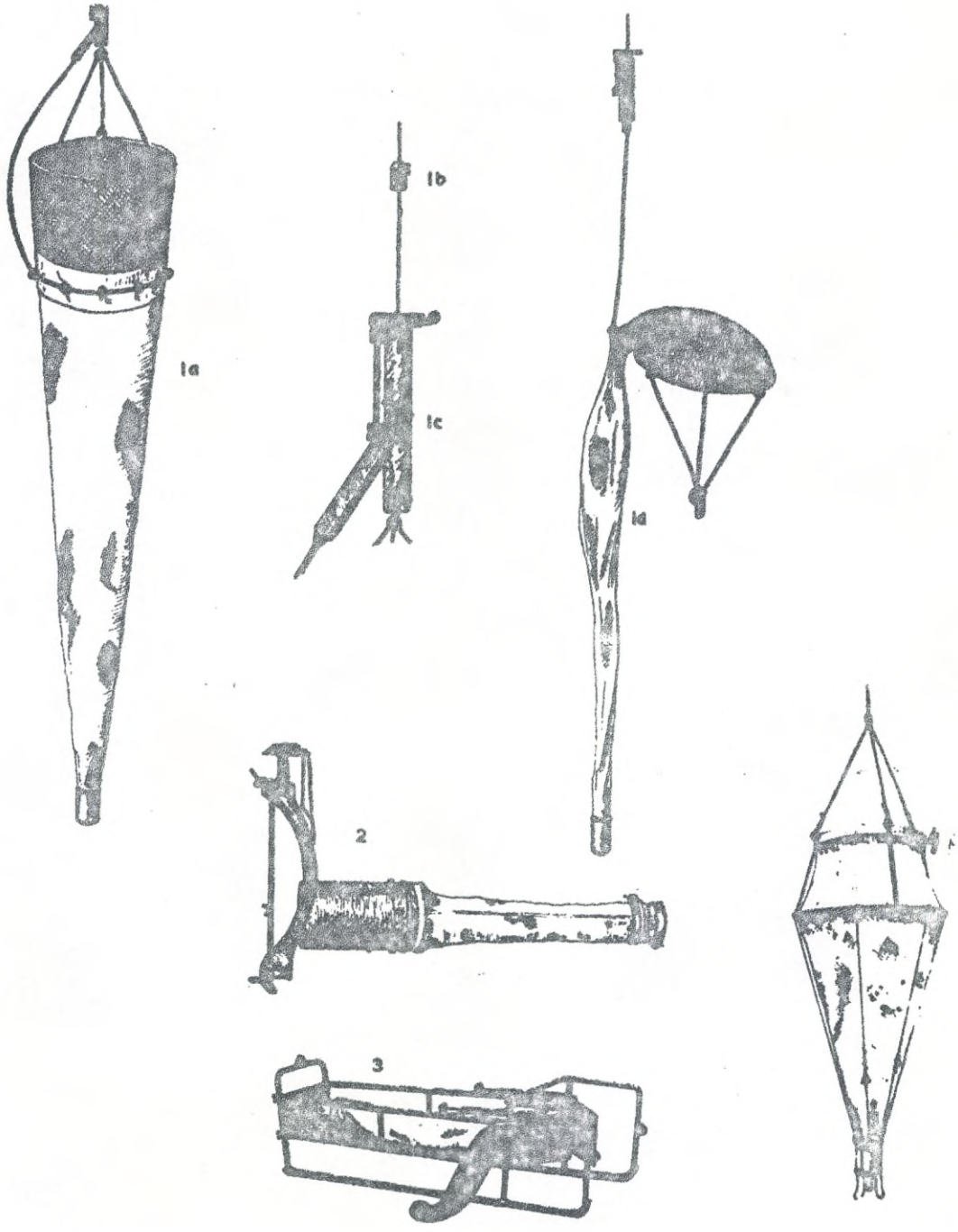


Fig.4.Different plankton samplers according to Fraser (1962) and Tranter (1968). 1) The vertical closing net 2) The Clarke-Bumpus net 3) The Bossanyi net 4) The Hensen net.

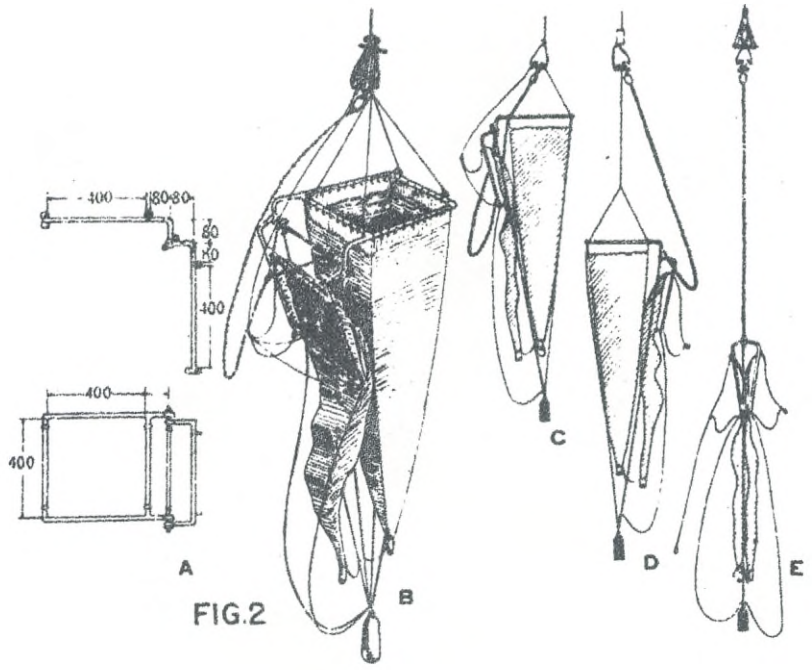


Fig.5. The Motoda net for vertical hauls (Motoda,1963).

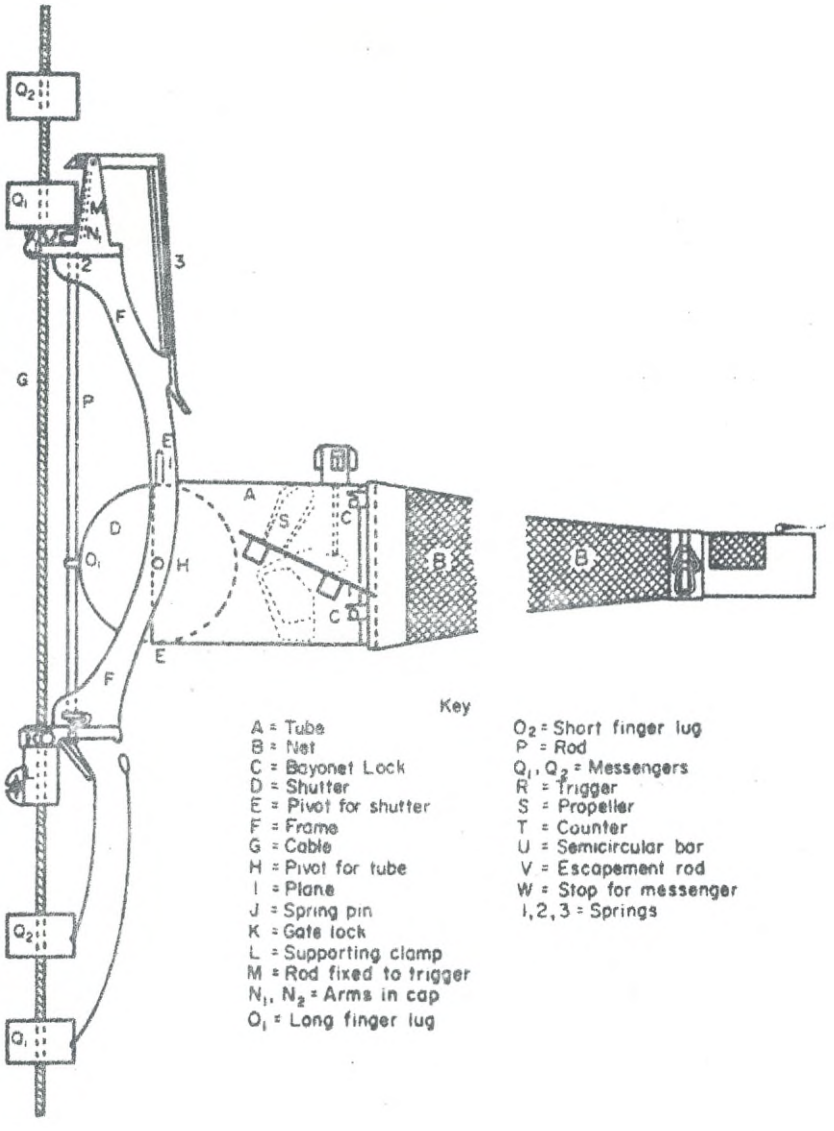


Fig.6. The Clarke-Bumpus plankton sampler (from Edmondson & Winberg,1971).

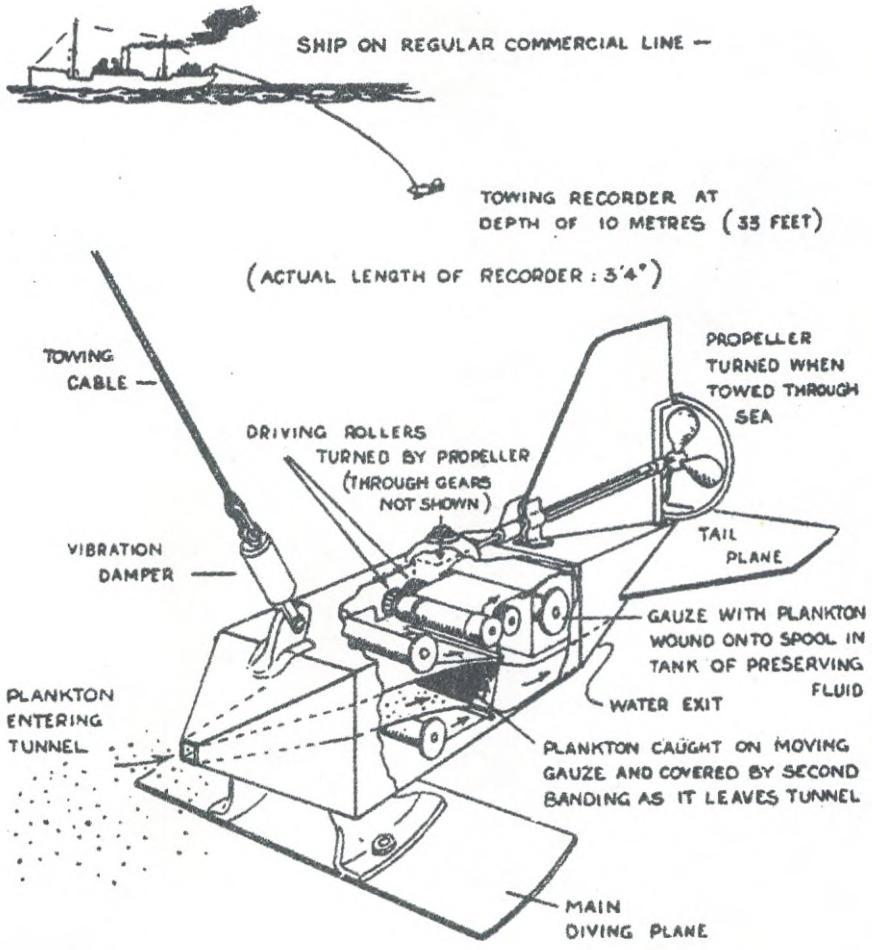


Fig.7. The Hardy continous plankton recorder (from Hedgpeth,1955).

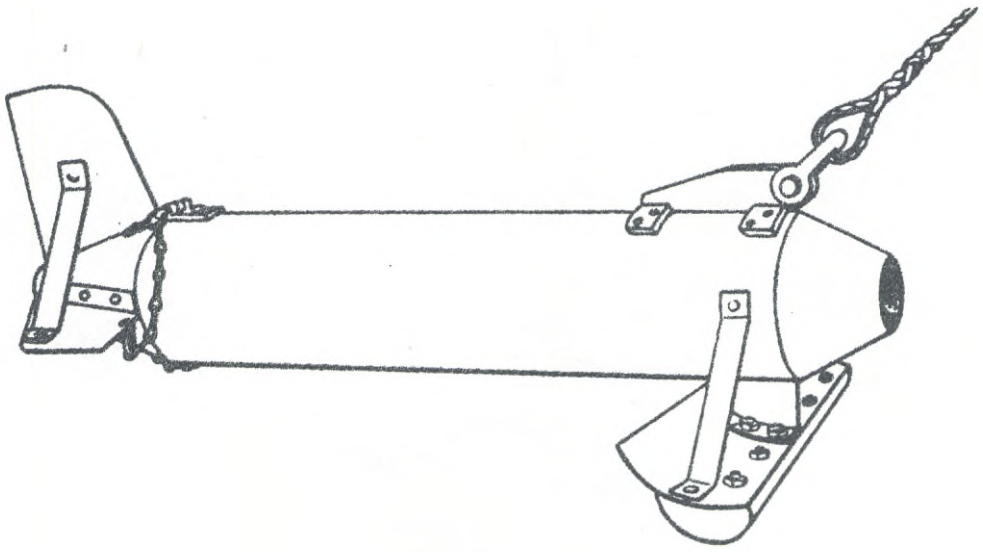


Fig.8. The standard plankton Indicator (from Hardy,1936).

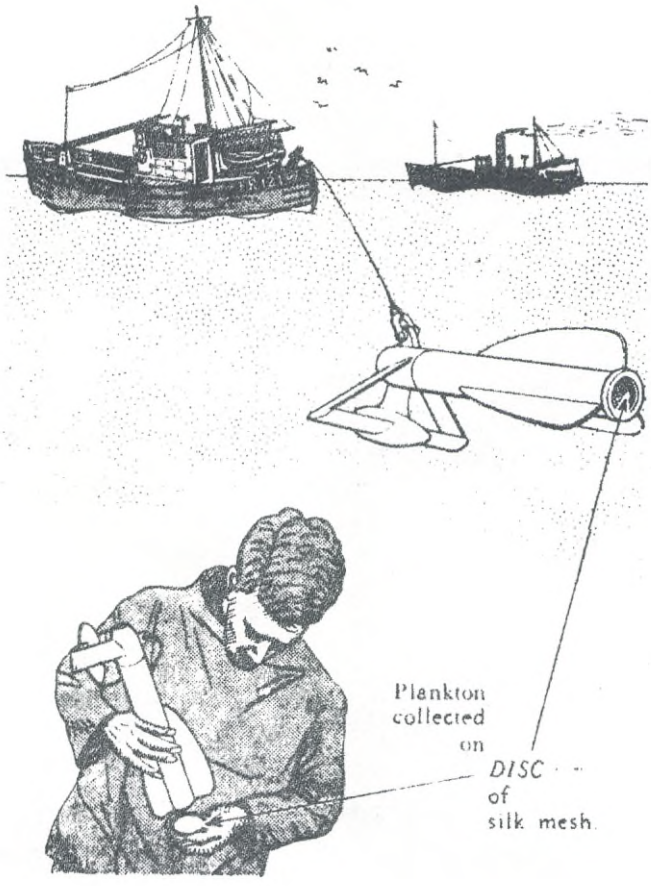
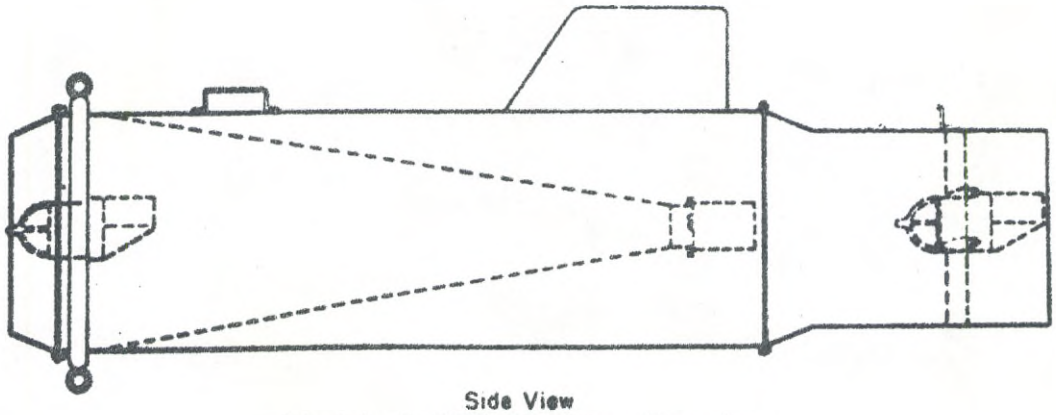
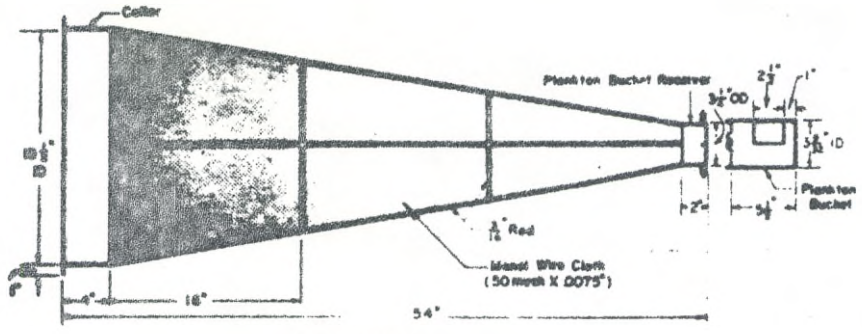


Fig.9. The Hardy Plankton Indicator, as used to sample plankton by fishing vessels working on the herring grounds (Fraser, 1962).



Side View
Model Gulf III Plankton Sampler



Side View
Net

Fig.10. The Gulf III plankton sampler.The upper figure shows the encased sampler and the lower one the naked plankton net with the plankton bucket receiver.

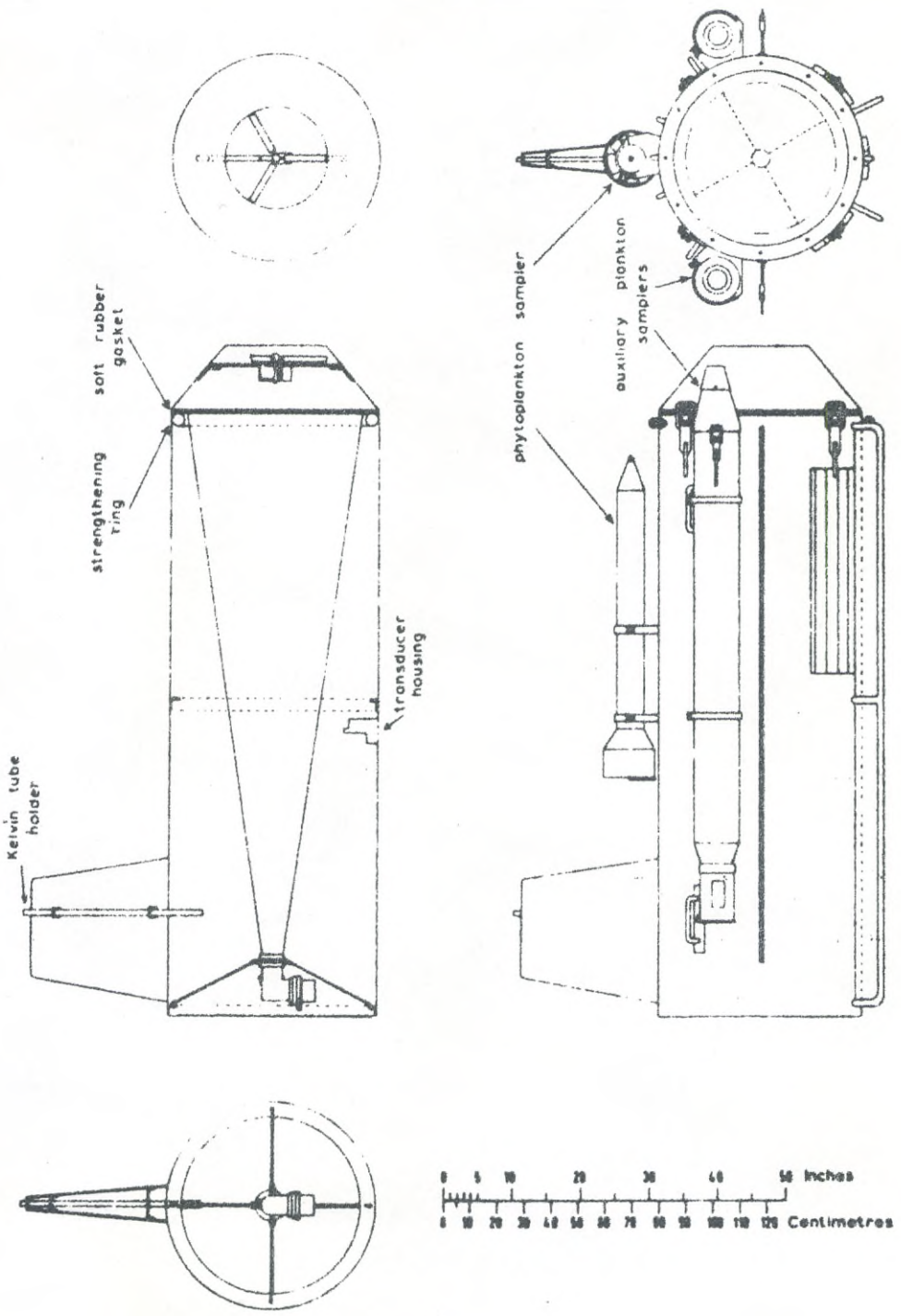


Fig.11. The multiple high-speed plankton sampler (Beverton & Tungate,1967).

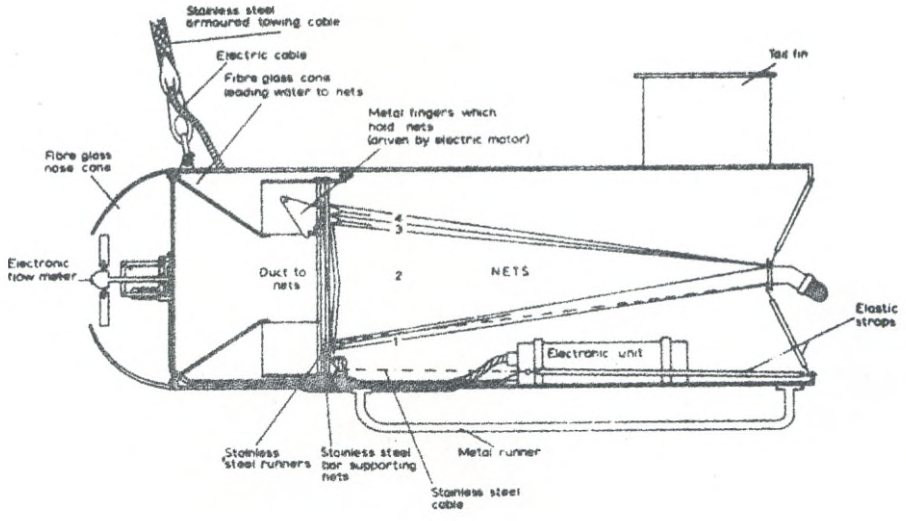
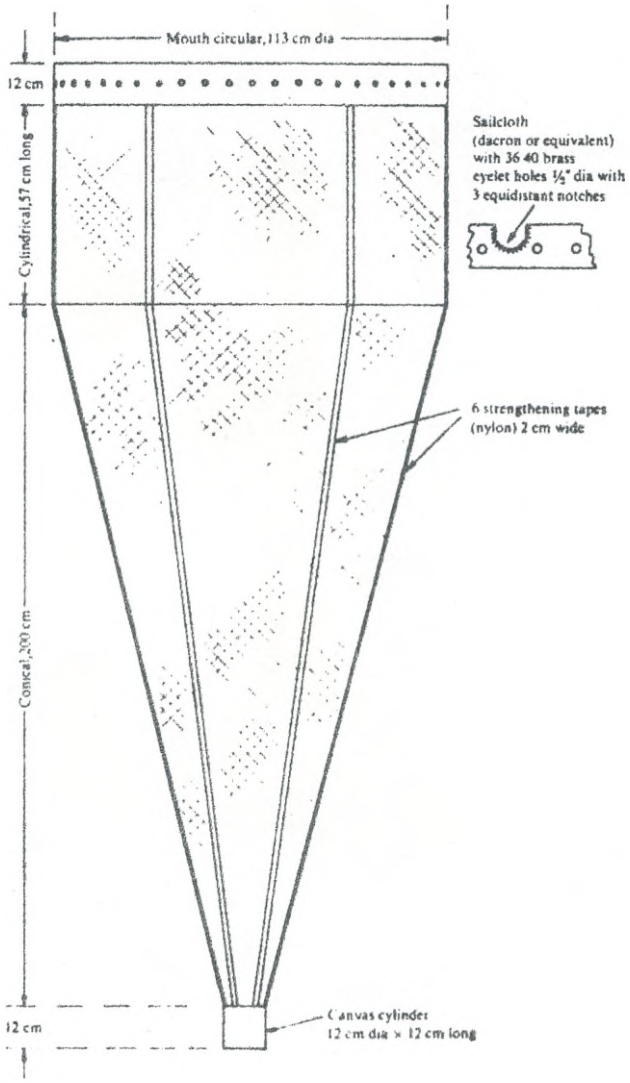


Fig.12. The net-changing device for use with the Lowestoft multipurpose sampler (Harding et al., 1971).



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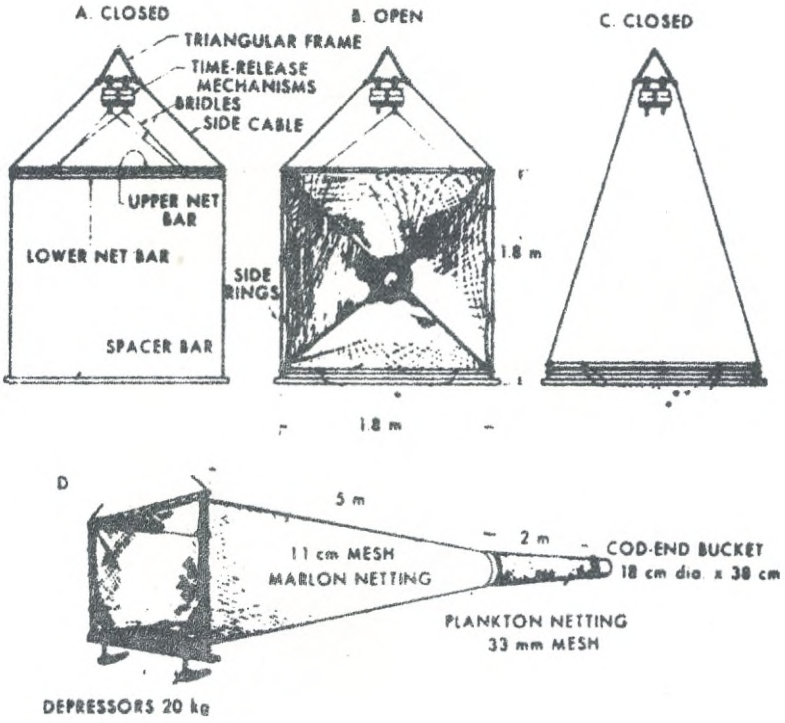
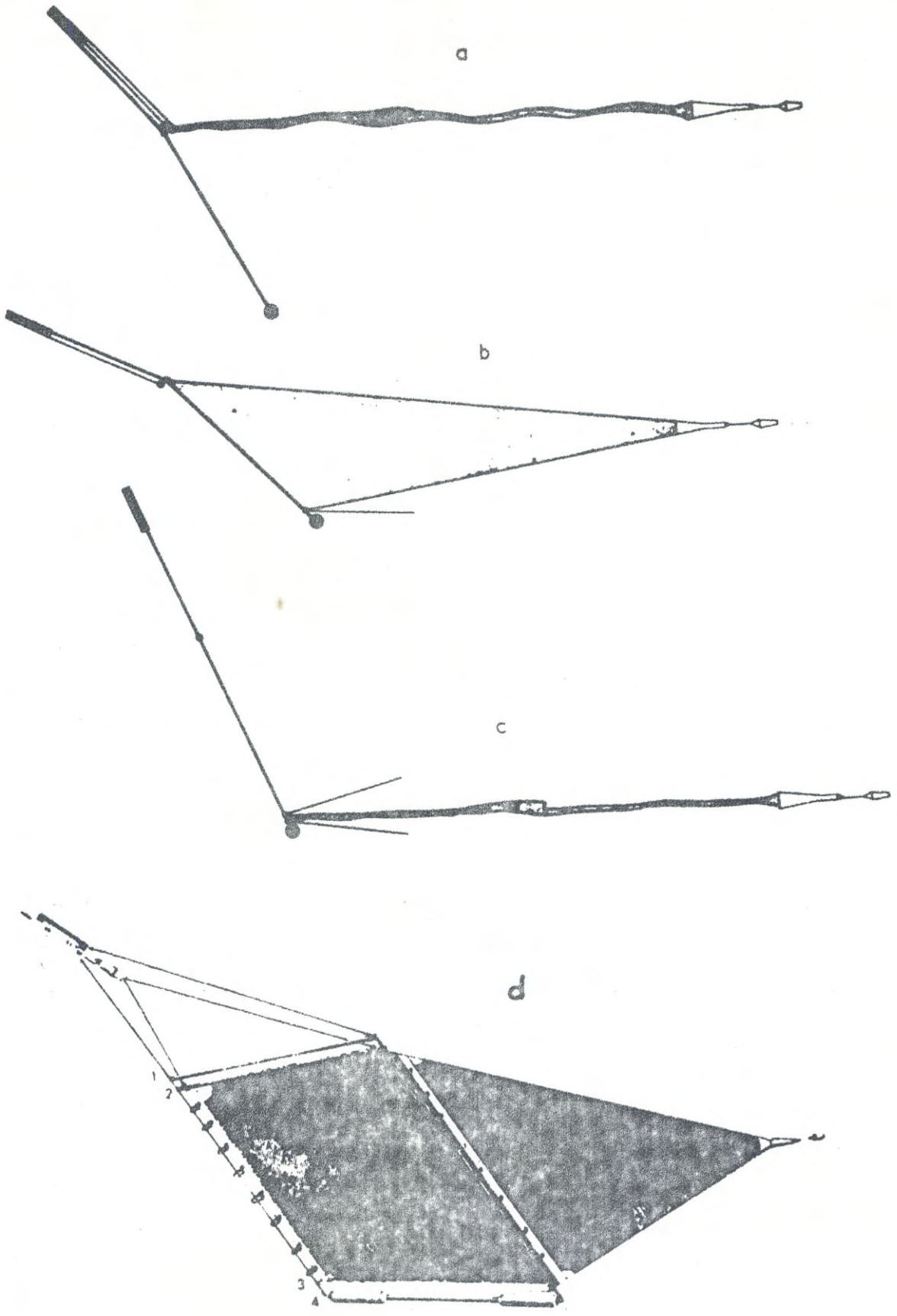


Fig.14. A schematic drawing showing the operating principle of the Tucker net (Davies & Barham,1969).



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Unit Towed	Towing Velocity (kt)				Mean
	2	4	6	8	
(a) 	1·12	1·10	1·09	1·10	1·102
	0·88	0·88	0·87	0·86	0·872
	0·75	0·77	0·75	0·77	0·760
	0·69	0·68	0·70	0·71	0·695
	0·66	0·68	0·67	0·68	0·672
	0·65	0·67	0·67	0·69	0·670
(b) 	0·84	0·84	0·82	0·81	0·827
	0·44	0·48	0·47	0·48	0·467
	0·48	0·52	0·51	0·53	0·510

Fig.16. The effect of encasing the net on filtration efficiency (Tranter & Heron,1967).