STUDIES ON THE COMMERCIALLY IMPORTANT FISHING GEARS OF VEMBANAD LAKE

THESIS

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DOCTOR OF PHILOSOPHY

BY
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CERTIFICATE

This is to certify that this thesis is an authentic record of the research work carried out by Mr. Pauly, K.V., under my supervision and guidance in the Department of Industrial Fisheries, Cochin University of Science and Technology, in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY of the Cochin University of Science and Technology, and no part thereof has been presented for the award of any other degree, diploma or associateship in any University.

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DECLARATION

I, Pauly, K. V., do hereby declare that the thesis entitled "STUDIES ON THE COMMERCIALLY IMPORTANT FISHING GEARS OF VEMBANAD LAKE" is a genuine record of the research work done by me under the supervision of Dr. C. Hridayanathan, Reader, Department of Industrial Fisheries, Cochin University of Science and Technology, and has not previously formed the basis for the award of any degree, diploma or associateship in any University or Institution.

Cochin - 682 016.
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Pauly, K.V

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INTRODUCTION

For many hundreds of years, man has been provided with one of his principal sources of food by the living creatures of water. The importance of this source has increased in recent years due to the requirements of the multiplying human population. This valuable resource is exploited by fishing, which is one of the few remaining examples in the world today of ancestral hunting activities in humans. It involves the much more general and wider issues of adaptiveness, creativity and learning. It raises all the great questions of our relationship to Nature, the problem of managing a complex system and of finding a balance between yield and risk. And studies on fishing gear and methods provide the essential background knowledge for the understanding, development and exploitation and management of any fishery.

But, not till the 18^{th} century did anyone consider it worthwhile to mention fishing gear and fishing methods in any detail. French encyclopaedists were the first to give publicity to catching methods (Brandt, 1972). The first more detailed discussions of catching methods for practical fishermen were written by zoologists interested in fisheries at the end of the last and the beginning of this century. These publications can be considered the first steps made in fishing gear research. But the current international and world-wide interest of fisheries science in fishing gear and methods were born on the occasion of the first International Fishing Gear Congress of FAO held at Hamburg in 1957. The successive Fishing Gear Congress held in London, 1963; Norway, 1967 and Reykjavik, 1970 and the World Symposium on Fishing Gear and Fishing Vessel Design held in Canada in 1988 have kept up the interest and contributed to the development of fishing gear technology.

Fishing technology, as a scientific discipline, was founded and developed mostly by Russian and Japanese scientists. It represents a generalisation of practical experience accumulated by several generations of fishermen all over the world. The theories worked out by F.I. Baranov and M. Tauti as well as by subsequent investigators, contributed to a better understanding of the fishing and related processes and of the interaction between fish, fishing gear and craft.

Studies on fishing gear technology can undoubtedly make a considerable contribution to the progress of fisheries in a developing country like India. From pre-historic times, the Indian population has been intimately interwoven with the fish and fisherfolk. In India, fishing used to be a hereditary vocation carried down through generations, with the entire families getting involved in it in some way or other. But due to the lack of any research-oriented studies and organised attempts to educate the traditional fishermen, fishing remained an occupation for subsistence and was carried on with whatever crude implements that were available at hand from time immemorial from both marine and inland sources. It was only after the second World War and attainment of independence that revolutionary changes have occurred in the outlook on fisheries in our country.

In the period immediately following the country's independence, research activities in fisheries were carried on in a limited way by the Central Fisheries Stations (both marine and inland) under the Ministry of Agriculture, Fisheries Departments of some of the Provincial/State Governments, Marine Survey of India, Zoological Survey of India, the Zoology Departments of some Universities and some biological laboratories of well established colleges. The Indian Council of Agricultural Research acted as the coordinating body in such activities and provided financial assistance (Govindan, 1983).

Establishment of the Indo-Norwegian Project at Quilon in Kerala in 1952 was a milestone in the development of Indian Fisheries on modern lines. The massive development of the existing institutions and establishment of new ones in the subsequent years in the Central sector like CIFT in 1957, CIFNET in 1960, CIFE in 1961 under the developmental programs of successive five year plans provided the required fillip to the research and development efforts in the field of fisheries in the country. The net result of all these has been that India has now established herself in the fisheries map of the world as the 8^{th} in rank in the matter of fish production with a landing of

29,25,347 MT , out of which 16,20,502 MT was marine and 1,20,485 MT was contributed by inland fishery resources (FAO, 1988).

The state of Kerala which forms the south-western part of peninsular India, occupies a prominent place among the maritime states of India, accounting for almost a quarter of the total landing of 1.6 million tonnes (Jacob. *et al.* 1987). Fish and fisheries play a crucial role in the well-being of Kerala's economy and the State had until recently held the first position among the maritime states, in total fish landings. But it has now slipped to the second position, behind Maharashtra. The disparity in increase of production between Kerala and the all-India level, in recent years, is obviously due to the fact that marine fishing activities have already reached a near saturation level, while the development in many other states have taken place only during the last one and a half decades. This is more evident in the fact that the fish production in general in Kerala during the last two decades was more or less stagnant with slight spurts now and then, while there was a leap in production in many other states. The decline in the total fish landings of the State was accompanied by decreasing profitabilities, particularly of fishing units in the mechanised marine sector, which were also hit by fast rising fuel prices. This has naturally focused attention on the backwater and other inland fishery resources. But, as the technological advances that proved successful in marine the sector cannot be applied to the inland fisheries, the problem that confronts the planners is how to upgrade and expand the catch capability and production of the artisanal sector. In this context, it is imperative that the inland fishery resources of the state be considered more seriously from the development and management perspectives.

Though in comparison with other states, Kerala has a lesser extent of inland water area, when seen in the light of its total land area, the importance of this sector can be understood. This inland water resource comprises of rivers, ponds, reservoirs, lakes, estuaries, backwaters and lagoons. Of these, the most important one as far as fisheries is concerned is the backwaters which has a total area of about 50,000 hectares (Sanjeevaghosh, 1987). These water bodies lie spread over ten coastal districts of the State. The rich and varied fishery resources of these backwaters contribute immensely to the socio-economic and cultural progress of the state. During 1987-88, landings from the backwaters was estimated at 27,835 tonnes. The sector provides the main source of income for about 41,600 active fishermen coming from 32,800 fishermen families, the total population of which comes to more than 1,97,200. An equally large number are engaged in the allied activities of processing and marketing.

Though mechanisation and motorisation have revolutionized the marine sector, fishery resources of the backwaters are still exploited by traditional or artisanal fishing methods and gears. Since the fishing opportunities vary at different parts of the backwaters, both as regards species and as regards the nature of the fishing ground, and also because of variations in weather, currents, other environmental factors and local availability of materials and skills, a variety of different types of traditional fishing gear have been developed over the centuries. Though most are successful only on a sustenance level, the more specialised gear such as stake nets, Chinese nets and gill nets are operated on a commercial level and contribute to the enhancement of the total production and economy of the state. Hence the importance of these gears cannot be overlooked even when used in local areas and for a limited time only.

In spite of the strategic importance of the inland fishing methods and gears, comprehensive accounts regarding their design, construction, operation and economics are scanty. Probably the earliest work in this field is that of De (1910) in which fishing gears of the Eastern Bengal and Assam are mentioned. Hornell (1924, 1925 & 1938) discussed those prevalent in Ganga and Madras Presidency. Those of Mysore and Travancore have been described by Bhimachar (1942) and Gopinath (1953) respectively. The fishing methods of Chilka lake have been described by Jones and Sujansingani (1954). Job and Panthalu (1958) described with illustrations various types of traps used particularly in inland waters. Mention should also be made of the work of Ahmed (1956), Saxena (1964) and Joseph and Narayanan (1965) elucidating respectively the fishing methods and gear of

East Pakistan, river Ganges near Allahabad and river Brahmaputra in Assam. Lal (1969) has described some of marine and inland fishing gears operated in the different parts of the country. George (1971) has given an account of the inland fishing gears and methods of India.

The Vembanad lake with an area of 256 sq. km and a length of 90 km. is the largest lake in Kerala, and the largest brackish water system of the south-west coast of India. It extends between latitudes $9^{o}30'$ and $10^{o}12'$ N and longitudes $76^{o}10'$ and $76^{o}31'$ E (Fig. 1.1). Two main processes are responsible for the formation of Vembanad lake viz. an initial tectonic phase and the second natural sedimentation process affected by waves, currents and tides (Mallik and Suchindan, 1984). The main source of fresh water for the lake are the rivers Periyar, Muvattupuzha with its branch Ithipuzha, Meenachil, Manimala, Pamba and Achankoil (Nair, 1971; Murthy and Veerayya, 1972 and Kurup and Samuel, 1983).

The lake system has all the characteristics of a typical tropical estuary as discussed by many previous workers (Qasim *et al.* 1969 and Madhupratap *et al.* 1977). Detailed investigations on the physico-chemical parameters of the lake were made by a series of workers (Balakrishnan, 1957 ; George and Kartha, 1963 ; Ramamritham and Jayaraman, 1963 ; Cherian, 1967 ; Qasim and Gopinathan, 1969 ; Josanto, 1971 ; Wellershaus, 1973 ; Shynamma and Balakrishnan, 1973 ; Balakrishnan and Shynamma, 1976). Nair (1965) distinguished three well-defined seasons during his studies in Cochin backwaters, viz. pre-monsoon (Feb-May), monsoon (June-September) and post-monsoon (October-January), which was adopted by later workers also (Pillay *et al.* 1975 ; Pillai, 1978 and Kurup, 1982). The above well defined seasons are adopted in the present work also.

The lake is also reported as one the most productive areas in the south-west coast of India (Qasim *et al.* 1969 and Pillay *et al.*1975). The species diversity and the total biomass were reported as very rich in the study area especially during the pre and post-monsoon seasons (Desai and Krishnan Kutty, 1967 ; Gopinathan, 1972 ; Haridas *et al.* 1973 ; Madhupratap and Haridas, 1975 ; Silas and Parameswaran Pillai, 1975 and Pillai, 1978). The distribution and abundance of fishes in Vembanad lake were studied by many workers (Pillay, 1960 ; George, 1965 ; Reghu, 1973 ; Noble, 1974 ; Kurup and Samuel, 1980a, 1980b, 1981a, 1981b, 1981c and 1985a). Kurup (1982) has described 139 fish species from the lake, of which 22 species were fresh water, 35 species were true estuarine in habitat and 82 species were marine migrants. Kuttiyamma (1975) has reported on the relative abundance and seasonal variations in the occurrence of the post-larvae of three species of penaeid prawns in the Cochin backwaters.

The rich and varied fishery resources of the lake are exploited by the fishermen using diversified methods and gears.

These are variously designed to suit the local conditions and fish species. The fishing gears of the backwaters of Kerala were described by Hornell (1925, 1938 & 1950), Panikkar (1937), Gopinath (1953), Shetty (1965) and Kurup (1982). In spite of these works, detailed information of a technical nature, on which further research works to improve the overall efficiency of the gears can be based, is not available. Hence a detailed study on the design, construction, operation and operational economics of the commercially important fishing gears viz. stake nets, gill nets and Chinese nets operated in the Vembanad lake is undertaken in this research work.

Mode of presentation

The classification followed in general is that of Brandt (1959 & 1972), the design details are presented according to the pattern in the F.A.O. Catalogue of Fishing Gear Design (1975) and for description of the gears, the general rules proposed by Percier (1959) are followed. The above standards were followed to minimise as far as possible the ambiguities that might occur.

As far as possible, all information has been included in the drawings. Abbreviations and symbols (Appendix 1) have been selected so as to be self-explanatory as possible.

As far as possible, the main design drawings are to scale and the scale is then indicated in metric equivalents. For obvious reasons, this scale cannot refer to both netting and framing lines. To overcome this, basic drawing rules had to be adopted.

Stake net : The width of netting panels or sections is drawn according to half the stretched netting and the depth or length according to the fully stretched netting.

Gill net : The length is drawn according to the length of the float line and depth according to the fully stretched netting.

General outline drawings eg., of the rig of a complete gear, which are meant to facilitate the understanding, as well as detail drawings of components, are not to scale. Instead, essential dimensions are given. Materials are indicated only when considered necessary.

Of the metric system, which has been adopted throughout for dimensions, only the unit metre (m) and millimetre (mm) are utilized. In order to avoid over-crowding of the drawings the units are sometimes omitted. They can, however, always be recognised from the context and mode of presentation, the metre is used for larger dimensions such as length of footropes and headlines. The millimetre is used for smaller dimensions such as mesh size (stretched), diameters of ropes, lines or floats.

The unit for weight is the kilogram (Kg) and gram (g). Buoyancy of floats are given in Kilogram-force (Kgf) or gram-force (gf).

Materials are indicated by abbreviations which are preferably based on terms in common international use, such as polyamide (PA), lead (Pb) and wood (WD).

The size of netting yarns is designated according to the tex system and R-tex was adopted as the unit. Denier equivalents are also presented wherever possible because of its general applicability. For monofilament, the diameter in millimetre is given.

The mesh size is given in millimetre (mm) and defined according to what is commonly called `mesh size stretched'. This corresponds exactly with the practical method of mesh size measurement, i.e., the length of one mesh lumen plus the length of one knot.

The dimensions of net panels or sections in width and length or depth are defined by the number of meshes in a straight row along the edges, where applicable. When both edges in one general direction are tapered, the dimension in this direction is still given along a straight row of meshes. The figures for the number of meshes are arranged in the drawings in such a way that misinterpretation with regard to the direction they refer to and confusion with dimensions in millimetres (mm) are excluded. When applicable, upper, lower and side panels are denoted by symbols (Appendix 1) to facilitate understanding of the design drawing.

When whole sections, such as codends, are of knotless netting, the symbol for the same is attached to the mesh number designating one of the main dimensions of this section.

The shape of netting sections is indicated by the cutting rate at its edges. Horizontal or vertical edges in the drawing obviously designate straight line of knots without any bar cuts. For tapered edges, point cuts are specified by N and bar cuts are specified by symbol B. AB indicates all bar cut while AP indicates all point cut.

The hanging ratio (E) is given as the numerical value of the decimal fraction of the length of the rope divided by the stretched length of the respective netting section and is shown where considered essential (e.g. E = 0.6).

Ropes are drawn by thick lines and specified by their length in metres, the material and diameter in millimetre (e.g. PE ϕ 4). Abbreviations for materials used in rope-making are given in Appendix 1.

Because of the variety of items for the specification of accessories, a certain amount of improvisation had to be accepted. They are mostly shown in the additional detail or schematic drawings and in such a way as to be self-explanatory. Designations by terms or symbols are restricted to the absolute minimum and only the most essential dimensions or properties are given.

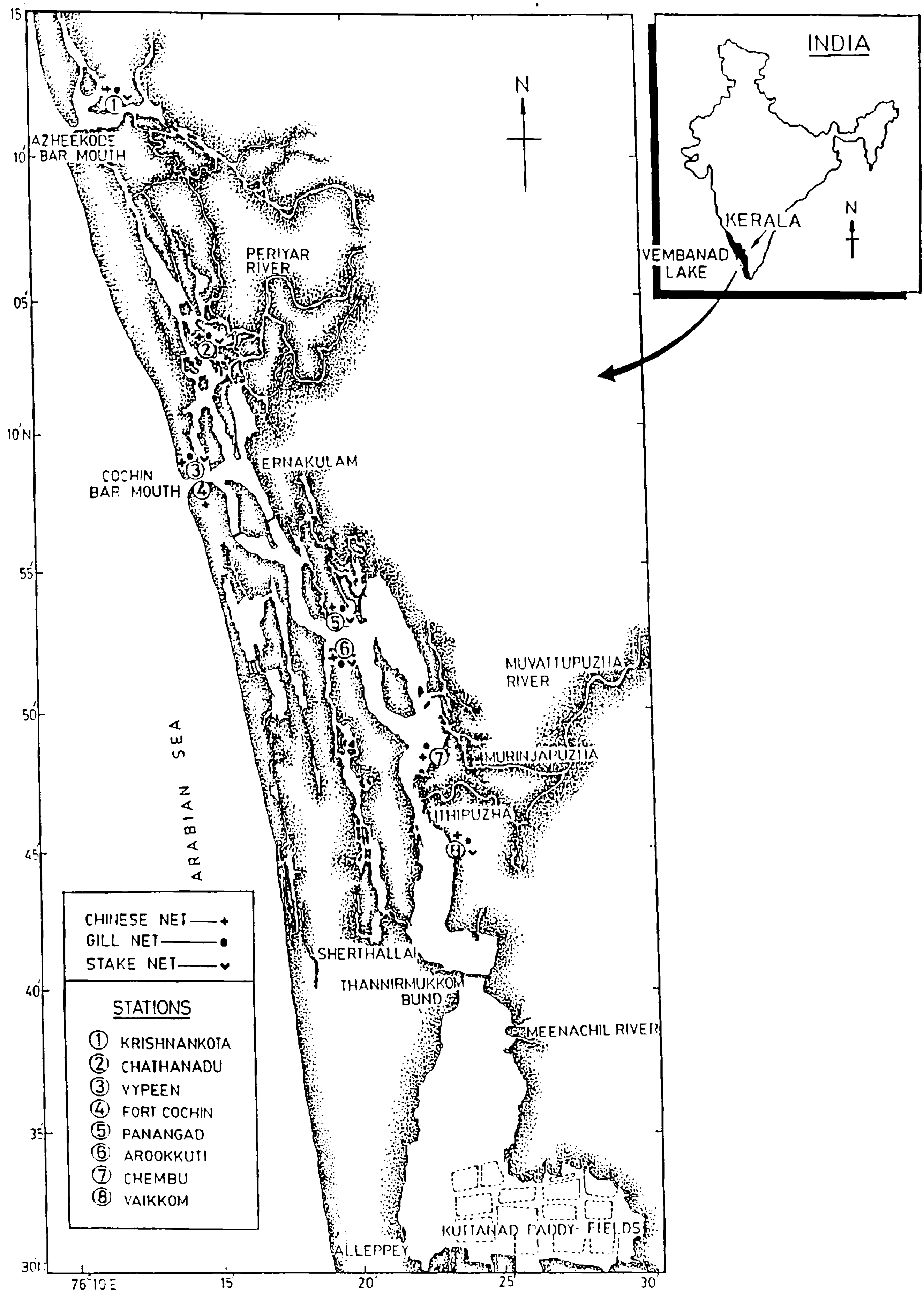

FIG. 1.1 LOCATION OF STATIONS 1 TO 8 IN VEMBANAD LAKE, SHOWING PREVALENCE OF TYPES OF FISHING GEAR.

APPENDIX 1

Abbreviations and symbols used for the designs

~	=	approximately
	=	circumference
Ø	=	diameter
	=	current
	=	thickness
	=	upper panel
	=	lower panel
	=	side panel
	=	mesh
	=	knotless (raschel type)

Alu	=	aluminium
PE	=	polyethylene
PA	=	polyamide
WD	=	wood
PP	=	polypropylene
MAT	=	material
CR	=	coir
TC	=	thermocole
GR	=	granite
PVC	=	polyvinyl chloride
JU	=	jute
MONO	=	monofilament
Pb	=	lead

C H A P T E R – II

STAKE NET

2.1. Introduction

The stake net, known as `Oonni vala' in the Malayalam language, is very common in the backwaters of Kerala, especially in the Vembanad lake. They constitute the most important gear used for backwater fishing in the state. The stake net is a conical bag net set in streams and tidal waters to filter out small fish and prawns that are swept along its course. Since the fishing principle is filtering, it can be effectively used only where and when a strong current runs.

As per the classification of fishing gear by Brandt (1972), the stake nets come under the group of nets termed as stow or gape nets without wings, which in turn fall under the class of bag nets. This class of nets can be defined as bags of netting which are kept open vertically by a frame on the opening side, and horizontally by the current. The fish or other prey entering more or less voluntarily are caught by filtering. These gears have evolved from older models constructed of materials other than net. In the Eastern and South-Eastern European fishery there exists wooden constructions built in running waters in the shape of large funnels with rectangular openings.

These are the predecessors of the fixed stow nets now in vogue in many parts of the world, operated in running waters, particularly in the estuaries of large rivers. In most cases these nets are very large and the net bags, kept stretched by the current are usually set in rows, side by side, between stakes and hence the name stow nets on stakes or simply stake nets. In certain places, as in the Vembanad lake, the frames are not used, as the stakes themselves maintain the necessary tension. In the `Kona jel´ a common stow net of the lower Brahmaputra, the frames are replaced by split bamboos kept cross-shaped in the opening of the bag (Joseph and Narayanan, 1965).

Another type of stow net `Day ´ is used in the Mekong river in Cambodia. It is not fixed to stakes but moored by a system of anchors; the number and arrangement of which depend on the size of the net itself, on the size of the mesh and on the force of the current (Hickling, 1961). This practice of anchoring the stow net without the aid of stakes is in fact an innovation, since setting of the net on stakes becomes difficult where deeper waters and hard bottoms are found. Such bag nets anchored at the bottom or even floating free are used in many countries (Davis, 1958). The opening of such nets are affected either by providing a more or less complete frame at the mouth or by making use of floats. A similar type of gear known as `Dol net´ which is very common along the North West coast of India has been described by Rai (1933), Pillai (1948), Gokhale (1957) and Ramamurthy and Muthu (1969). The three different types of base systems associated with `Dol´ operations have been detailed by Sehara and Karbhari (1987). Jones (1959) and Pillai and Ghosh

(1962) have described a type of bag net, `Behundi jal' with a wide mouth narrowing towards the codend, used in the estuaries of West Bengal.

Hornell (1938) and Lal (1969) have described the stake nets operated in the backwaters of Kerala. But neither the design details nor the economics of operation were highlighted in the study. Menon and Raman (1961) have made special reference to the stake nets while observing the prawn fishery of the Cochin backwaters. Kurian and Sebastian (1986) have furnished a short description of the stake nets of Kerala and a similar type of net, the `Thokavala' or `Gidasavala', operated in the Godavari and Krishna deltas.

In Kerala the stake nets are operated in almost all the districts lying along the coast. The district-wise distribution pattern of the nets are listed below.

No.	District	No.of nets	Percentage
1.	Quilon	918	7.12
2.	Alleppey	2758	21.38
3.	Kottayam	759	5.88
4.	Ernakulam	6293	48.78
5.	Trichur	812	6.29
6.	Malappuram	39	0.30
7.	Calicut	157	1.22
8. 9.	Cannanore } Kasargode	1164	9.02
	TOTAL	12900	

Though these nets are mainly operated in the backwaters, they are also seen in the bar mouths and even in inshore seas. In Kerala there are a total of about 12,900 stake nets in operation (Sanjeevagosh, 1987).

2.2 Objectives

In spite of the employment potential of the stake net fishery and its commercial importance to the state, no in-depth work has so far been undertaken to study either the design details or the methods of operation of these nets. Therefore it is the objective of this work (1) to study the details pertaining to the design, construction and operation of the stake nets operated in the Vembanad lake, and (2) to suggest modifications in the design and construction of the net with a view to (a) reduce the cost of the net and (b) increase the efficiency.

2.3. Materials and methods

A primary survey of the Vembanad lake to determine the regions where the stake nets are used in appreciable numbers was conducted. Based on the results of this survey six centres (Fig.1.1) were appropriated and a random sample of forty nets from these centres were selected for an entire and specific study. Field surveys were conducted in all the six centres to gather the needed data on the design, construction and operation of these nets. The mode of operation was monitored at each centre by accompanying the fishermen to the respective sites during the setting and hauling of the nets.

No scientific evidence can be cited to prove that the gear that emerged best during comparative fishing has the optimum performance characteristics. Better nets could be designed and evaluated, if the process of measurement and calculation are also applied (Crewe, 1964). Many attempts have been made to determine the drag of a netting panel. The curved profile assumed by a netting panel when water flows past it, is a function of the forces acting on it. The determination of this shape and its drag is complicated. The drag of the panel depends on the material, type of knot, mesh size, diameter of twine, ratio of diameter to bar size, angle of setting of mesh, angle of inclination of the panel and viscosity of the medium.

To evaluate the influence of the above referred factors on drag, many investigations have been carried out. Terada *et al.* (1915) and Tauti *et al.* (1925) quoted by Kawakami (1959) and Baranov (1960) are probably the first to initiate studies on the drag of netting panels. Based on their works, formulae have been put forward to calculate the drag of netting panels placed perpendicular to the flow. Many Japanese workers (Fugita and Yokota, 1951; Miyamoto *et al.* 1952; Nomuro and Nozawa, 1955 quoted by Kawakami, 1959) have investigated the hydrodynamic interference between knots and twines, the effect of different kinds of knots, shape of mesh and inclination of netting.

Voinikanis-Mirskii (1952), investigated the hanging coefficients and found that the drag is inversely proportional to the hanging coefficients. Fridman (1973) while proposing a formula to determine the drag of netting placed perpendicular to the flow, states that for calculation of the Reynolds number (R_e), the diameter of the bar should be taken and not the overall dimension of the net. Tauti *et al.* (1925), Revin (1959) and Fridman (1973) have determined the drag of panels inclined at different angles.

Fridman (1973), based on experiments with netting panels of different shapes, conical nets, combined nets etc. states that the resistance of a complete net is approximately equal to the sum of the resistance of the simple parts that combine to form a net. This opens up new potentialities for the calculation of drag in similar nets.

The stake nets are comparable to trawl nets in that both are basically conical bag nets. It is the amount of water flowing through the net, an expression of the resistance or drag offered by the net in both cases, which facilitates the ballooning of the net and fishing efficiency.

Drag of nets

Empirical formulae are used for calculating the total drag of trawl by Koyama (1962a and 1967). An equation for mid-water trawl is proposed by Reid (1977). For bottom trawls

MacLennon (1981) proposes an equation in which the coefficients are worked out on the basis of drag measurements. Fridman and Dvernick (1973) calculated the drag of trawls, based on drag coefficient of netting panels inclined at different angles. But this is more applicable to mid-water trawls. A similar approach for the calculation of drag of bottom trawls was followed by Kowalski and Giannotti (1974 a, 1974b). Dickson(1979) followed an approach of summation of resistance of parts, which is more comprehensive. Here, the calculation of drag is made without considering the drag of sweep line, otter board and warp.

Knowledge of the forces acting on the gear and the resistance or drag of the gear would help in improving the performance of the existing ones. Since no comparable work has so far been undertaken on the stake nets, the approach of Dickson (1979) is adopted, with suitable modifications, for calculating the drag of the existing type of stake net and to develop a more efficient design.

Calculation of net drag

The drag \`D´ of a stake net during operation, when set against the current is the resultant of the drag area, \`A´ and the hydrodynamic stagnation pressure, \`q´. The relation can be expressed as

$$D = q \cdot A$$

where $q = \frac{1}{2} \rho . v^2$

Therefore $D = \frac{1}{2} \rho . v^2 . A$

where ρ = density of water (kgf. $sec.^2$ $m.^{-4}$) as a function of temperature and salinity.

v = velocity of water (m. $sec.^{-1}$)

Drag area `A'

The total drag of the net is the sum of the drags of the various netting panels that make up the net, the float and the lines such as the framing line at the mouth, float line and the codend rope.

The main body of the stake net can be considered as a cone with 25 percent of the codend completing the apex of the cone (Fig. 2.1). The rest of the codend is considered as a cylinder. The first panel of the stake net, due to its distinct dimensions and attachments to the framing line and to the rest of the panels is considered to be rectangular and having an inclination more or less similar to the main body.

During operation, in nets with square-shaped mouth, the mouth of the cone assumes a circular shape (Fig.2.2) while in those with rectangular-shaped mouth, the cone assumes an elliptical configuration rather than a circular one (Fig 2.3).

Periphery of the circle

The periphery of the mouth of the cone is given by $2\pi r$. Since the cone proper is assumed to start only from the second panel onwards, the radius (r) of the mouth of the cone is proportioned from the horizontal and vertical openings at the mouth of the net.

Periphery of the ellipse

Spiegel (1962) quoted by Dickson (1979) puts forward the following method for estimating the periphery of an ellipse by taking into consideration the major and minor axes of the ellipse,

$$\text{Periphery} = a \cdot 2 \cdot \pi \left[1 - \left(\frac{1}{2}\right)^2 \cdot K^2 - \left(\frac{1 \cdot 3}{2 \cdot 4}\right)^2 \cdot \frac{K^4}{3} \left(\frac{1 \cdot 3 \cdot 5}{2 \cdot 4 \cdot 6}\right)^2 \frac{K^6}{5} - \left(\frac{1 \cdot 3 \cdot 5 \cdot 7}{2 \cdot 4 \cdot 6 \cdot 8}\right)^2 \cdot \frac{K^8}{7} \cdots\cdots\cdots\cdots\cdots \right]$$

where $K = \sqrt{\dfrac{a^2 - b^2}{a^2}}$

a is the semi major axis of the ellipse

b is the semi minor axis of the ellipse

Setting angle of meshes, `θ'

The mesh configuration and the consequent netting area is determined by the setting angle `θ', of the meshes. This angle is found out from the primary hanging coefficient (E_1) of the cone, which is the mounted depth of the cone or the ratio of horizontal length (l) to the stretched length (L) at the mouth of the cone, and is defined as l/L.

This can also be expressed as the function of the mesh angle,

$$E_1 = l/L = \text{Sin } \theta$$

from this the setting angle θ is found out.

Angle of attack of the netting panel

From angle θ, the vertical hanging coefficient (E_2) can be obtained by finding the cosine of angle θ. This value when multiplied with the sum of the products of the number of meshes in depth and mesh size of the corresponding panels that form the cone, gives the hung depth of the cone (H_c). It also includes 25 percent of the codend that is considered to complete the cone, forming its apex.

Now, to find the angle of attack, the cone can be considered to be cut open and flattened out so that the perimeter is in a straight line (Fig.2.4), and the flattened sheet aligned at an angle `α' to the horizontal or the water-flow. The angle

'α' is the angle of attack of the netting of the cone, calculated using the relationship,

$$\text{Sin } \alpha = \frac{r}{H_c}$$

where r = radius of the cone,

H_c= the hung depth of the cone.

For nets with rectangular-shaped mouth, where the cone mouth is elliptical, the condition becomes,

$$\text{Sin } \alpha = \frac{\bar{r}}{H_c}$$

where $\bar{r}$ is the mean radius of the ellipse and is found out using the relationship

$$1/2 \text{ perimeter } . \bar{r} = \pi . a . b$$

Drag of cone

The drag of the conical portion of the net is given by

$$D_c = \Sigma A_c . q$$

where $$q = \frac{1}{2} \rho . v^2$$

ρ is the mass density of water and is taken to be 103.8 kgf.sec^2 m^{-4} at 30^{o}c and salinity 30 ^{o}/oo, (Fridman, 1986),

v is the velocity of water current,

A_c is the cone drag area of individual panels and is the product of the nominal developed area of the twine (A_m) in a netting panel and the coefficient of drag at the inclination of the panel. It is defined as,

$$A_c = C_{d\alpha} \cdot A_m$$

Nominal developed area, A_m

The nominal developed area of netting yarn A_m, is the surface area in m^2, of the various panels of the net and is worked out using the following formula (Reid, 1977),

$$A_m = m \cdot n \cdot 4 \cdot a \cdot d \cdot 10^{-6}$$

where m is the number of meshes across,(for trapezoidal pieces `m' becomes $\frac{m_1 + m_2}{2}$

n is the number of meshes in depth,

a is the bar size in mm and

d is the twine diameter in mm.

Here the modification of drag due to the influence of knots in the netting is not considered, since the same is accounted for in the calculation of drag coefficients.

Calculation of drag coefficients

To calculate the drag of cone, the coefficient of drag at α^0 ($C_{d\alpha}$) is to be found out. Though there are different methods for calculating the drag coefficient, the approach of Crewe (1964) is the most successful and hence is followed.

As per this method, the drag coefficient at 90^0 (C_{d90}) and 0^0 (C_{d0}) are first calculated separately. Since in practice the plot of sheet netting drag is almost linear in the range of angles 0^0 to 30^0, C_{d90} and C_{d0} is combined to calculate $C_{d\alpha}$ in the following manner

$$C_{d\alpha} = 0.5 \, (C_{d90} - C_{d0}) \frac{\alpha}{30^0} + C_{d0}$$

Calculation of C_{d90}

For the calculation of C_{d90} the following equation is applied

$$C_{d90} = C_{dsc} \cdot C_t \cdot k_{ct} \cdot \left(\frac{1}{1-s}\right)^2 \qquad \ldots\ldots\ldots\ldots\ldots(2.1)$$

where

C_{dsc} is the drag coefficient of a smooth cylinder which allows for change with Reynolds number,

C_t is the factor that allows for type of twine used and usually has values 1 to 1.2. In the present calculation the product of C_{dsc} and C_t is taken as 1.

k_{ct} is the knot correction term which is computed from the relationship

$$k_{ct} = \left\{ 1-(\frac{d_k}{d} . \frac{d}{a})\right\} + \left\{C_k . \frac{\pi}{8} (\frac{d_k}{d})^2 \frac{d}{a} \right\} \quad ...(2.2)$$

where

d_k is the knot diameter,

d is the bar diameter and

C_k is the knot drag coefficient and is taken as 0.47 as for a sphere.

The denomination $(\frac{1}{1-s})^2$ in equation (1) is the speedup term and can also be expressed as $(\frac{V_e}{v})^2$, where $\frac{V_e}{v} = (\frac{1}{1-s})$and is the factor by which the exit velocity of water through the mesh aperture is greater than the approach velocity.

`s´ is the solidity of the mesh and is defined as the ratio of the solid or blocked area to the surface area of the mesh, and can be expressed as

$$s = \frac{\left[\frac{d}{a} (1- \frac{k^d}{d} . \frac{d}{a})\right] + \left[\frac{\pi}{8} . (\frac{k^d}{d})^2 . \frac{d}{a} \right]}{\sin \theta \ . \ \cos \theta} \quad .....(2.3)$$

A simpler approach to find solidity of a panel is to relate the developed area of the twine in a panel (A_m) to the actual working area of the panel (A_M) in the following manner,

$$\frac{A_m}{A_M} = \frac{d}{a} . \frac{1}{\sin \theta \ . \ \cos \theta} = \text{Simplified solidity.}$$

where $\quad A_M = m \ . \ 2a \ . \ \sin \theta \ . \ n \ . \ 2a \ . \ \cos \theta$

Substituting (2.2) & (2.3) in equation (2.1), C_{d90} takes the following form

$$C_{d90} = C_{dsc} \cdot C_t \left[\left\{ 1 - \left(\frac{d_k}{d} \cdot \frac{d}{a} \right) \right\} + \left\{ C_k \cdot \frac{\pi}{8} \cdot \left(\frac{d_k}{d} \right)^2 \cdot \frac{d}{a} \right\} \right]$$

$$\left[\frac{1}{1 - \dfrac{\frac{d}{a}\left\{1 - (\frac{d_k}{d} \cdot \frac{d}{a})\right\} + \left\{\frac{\pi}{8} (\frac{d_k}{d})^2 \frac{d}{a}\right\}}{\sin\theta \cdot \cos\theta}} \right]^2$$

Calculation of C_{d0}

The coefficient of drag of a netting panel set at an angle θ^o to the water-flow is found out in the following manner

$$C_{d0} = C_{dsc} \cdot C_t \left\{\sin^3\theta + (C_f \cdot \cos^2\theta)\right\} \left\{1 - (\frac{d_k}{d} \cdot \frac{d}{a})\right\} + \left\{C_k \cdot \frac{\pi}{8} (\frac{d_k}{d})^2 \frac{d}{a}\right\}$$

As in the calculation of C_{d90}, here also $C_{dsc} \cdot C_t$ is taken as 1 and C_k to be 0.47 as for a sphere.

C_f is the skin friction coefficient and its value is taken as 0.07.

Effect of high solidity panels

In certain panels, the solidity is found to be comparatively higher than that of other panels. In such cases, when the solidity term is $s \geq 0.3$, then $\frac{Ve}{V} = \frac{1}{1 - s} > \sqrt{2}$ and the drag coefficient, dependent on $(\frac{1}{1 - s})^2$, would become > 2. This condition occurs for panels with large $\frac{d}{a}$ and small setting angle θ, and is indicative of the commencement of 'form drag'.

Form drag is a condition occurring in front of and in the codend. The water entering these panels does not escape by speeding up locally through the restricted mesh openings, but rather by speeding up the water-flow through the meshes of preceding panels with lower solidity.

This condition is indicated in Fig. (2.5), which represents the apex of the cone. Panel N can be considered as a high solidity panel and M the preceding panel with lesser solidity, i.e. $s_n > s_m$. The approaching flow of water in panels M and N are represented by V_{em} and V_{en} respectively. This condition is expressed by Dickson (1979) in the following manner

$$\text{Flux into panel N} = \text{Flux out of panel N}$$

$$V_n \cdot A_{PN} = V_{en} \cdot A_{PN} (1-s_n)$$

$$V_n = V_{en} (1-s_n)$$

where A_{PN} is the developed area of the panel N and s_n its solidity.

Then,

$$\frac{V_n}{V} = K_n = \frac{V_{en}}{V} (1-s_n)$$

and

$$\frac{V_{en}}{V} \text{ is not greater than } \sqrt{2}$$

Dickson (1979) puts $\frac{V_{en}}{V} = \sqrt{2}$ in order to get rid of as much water as possible through the panel N. Then the drag coefficient for such a panel becomes,

$$C_{d90} = C_{dsc} \quad C_t \left[\left\{1 - (\frac{d_k}{d} \cdot \frac{d}{a})\right\} + \left\{C_k \cdot \frac{\pi}{8} \cdot (\frac{d_k}{d})^2 \cdot \frac{d}{a}\right\} \right] \cdot 2$$

Now, the panel ahead of the panel N is to be considered, and for this the flux into and out of the two panels are taken together.

Flux into panels M and N = Flux out of panels M and N

$$V_m (A_{PM} + A_{PN}) = V_{em} \cdot A_{PM} (1-s_m) + V_n A_{PN}$$

and

$$\frac{V_m}{V} = K_m = \left[\frac{V_{em}}{V} \left\{A_{PM}(1-s_m)\right\} + K_n \cdot A_{PN}\right] \frac{1}{A_{PM} + A_{PN}}$$

where

A_{PM} and A_{PN} are the developed area of the panels M and N respectively.

After two or in some cases more panels are considered in this manner the value of $\frac{V_{em}}{V}$ is found to fall below $\sqrt{2}$. Then all preceding panels can be considered as uninfluenced by the succeeding panels and the speed of water within them to be the same as that of the water current.

Then the drag coefficient for the intermediate panel is given by

$$C_{d90} = C_{dsc}\, C_t \left[\left\{ 1 - \left(\frac{d_k}{d} \cdot \frac{d}{a} \right) \right\} + \left\{ C_k \cdot \frac{\pi}{8} \cdot \left(\frac{d_k}{d} \right)^2 \cdot \frac{d}{a} \right\} \right] \left(\frac{V_{em}}{V} \right)^2$$

where now,

$$\left(\frac{1}{1-s_m}\right)^2 < \left(\frac{V_{em}}{V}\right)^2 < 2$$

This can be considered as a simplification since in the actual situation velocities in panels cannot really change in jumps from panel to panel.

When the water speed within and outside a panel are different, it presumably affects C_{d0} and hence, the value used in such cases is

$$C_{dol} = 0.5\, C_{d0} \left\{ 1 + \left(\frac{V_m}{V}\right)^2 \right\}$$

Then the drag coefficient at angle α can be calculated in the following manner

$$C_{d\alpha} = 0.5\,(C_{d90} - C_{dol}).\frac{\alpha}{o} + C_{dol}$$

Codend drag

In the calculation of the cone drag, 25 percent of the codend was considered to form a part of the cone. The remaining part is considered to form a cylinder, rather than a cone. This cylindrical portion does not contribute to the drag of the net in the same proportion as does the cone. Hence the drag offered by this part of the codend has to be considered separately as an appendage to the rest of the net. For this calculation an expression quoted by Fridman (1973) for the drag of a netting sheet parallel to the current, is used

$$R_0 = 1.4 \,.\, l^{-0.14}\left(1 + \frac{5d}{a}\right)\left(0.9 + 0.04\,\frac{E_1}{E_2} + 0.55e^{-2.4.\frac{E_1}{E_2}}\right) F.v^{1.96}$$

where

R_0 is the drag of the cylindrical part in kgf.

l is the length of the cylindrical portion of the codend in m.

d is the twine diameter in mm

a is the bar length in mm

E_1 and E_2 are the hanging coefficients

F is the developed area of the netting

v is the velocity in m/s and

-0.14 is the term expressing the entrainment of the water developed around the last part of the cone and codend.

Appendage drag

The appendages that are to be considered in the case of stake net are the framing line at the mouth, the float used at the codend, the float line and the codend rope. For the prototype and experimental nets aluminium floats were used. The drag of a sphere (D_f) is given by

$$D_f = 0.47 \cdot \frac{\pi}{4} \cdot d^2 \cdot q$$

where

d is the diameter of the float in m, and

q is the hydrodynamic stagnation pressure.

Drag of ropes and lines

The ropes and lines used in a stake net can be considered to have a cylindrical shape and having an angle of attack, θ , to the flow of water and the drag force (D_r) acting on it can be computed from the cross flow principle (Hoerner, 1965).

$$D_r = (C_{D\ basic} \cdot \sin^3 \theta + \delta C_D)\ (0.5\ \rho v^2)\ (d_1 \cdot l_1) + D_f$$

where

$C_{D\ basic}$ is the coefficient of drag of the twine perpendicular to the flow and is taken as 1.1.

δC_D is the frictional component.

D_f is the ground friction force acting on the lower section of the framing line. Since the net is stationary this force is not taken into consideration in the present work

d_l and l_l are the diameter and length of the rope respectively.

Total drag of stake net

Summation of the above explained drags such as

1. drag of cone D_c
2. drag of codend R_0
3. drag of float D_f and
4. drag of ropes and lines D_r gives the total drag (D) of the net.

The above calculations were carried out by developing a spread-sheet model especially for this work on `Lotus 1-2-3' programme of the Lotus Development Corporation, USA.

In accordance with the set objective of increasing the efficiency of the existing nets, a new net with a lesser solidity or a net that offered a lesser resistance was developed after analysing the data collected on the design details of the prototype (square-mouthed type). This was achieved by reducing the number of panels ,increasing the mesh size of different panels and employing cutting ratios to effect a uniform taper instead of the present practice of using rectangular pieces of netting and affecting take-up ratios to obtain the required shape. The efficiency of the new net has to be compared with the existing commercial type. For this the principal dimensions viz., the perimeter of the mouth and total length of the net were selected to match that of the most popular type of nets in the study area.

The new net was field tested against the prototype to compare the total drag and relative catching efficiency. The total drag and current speed were measured using the mechanical tension meter (Sivadas, 1978) and the speed log (Sivadas *et al.* 1983) respectively. The prototype was designated as net A, net with the new design as net B and the rectangular-mouthed net of existing design as net C.

Corollary to the drag calculations, the following studies were also undertaken in the new net, making necessary alterations in the original spread-sheet as and when required.

Influence of mesh size on total drag

The influence of mesh size on total drag was ascertained by calculating the total net drag for a series of mesh sizes for each panel, keeping all the other parameters constant. The calculations are made only for the new net and the results are represented graphically.

Influence of twine diameter on total drag

The pattern of change in the total drag offered by the net for twines of different diameters used for each panel were calculated . The new net was utilized for this study since it had a fewer number of panels and also due to its more streamlined design, which reduced the influence of other effects.

Influence of depth of panels on total drag

The total net drag in relation to the angle of attack and the nominal twine area were calculated for different depths of each panel of the new net and the results were graphically illustrated.

2.4. Results and discussion

The nets operated in the Vembanad lake can be broadly classified into a) Units with square mouth and b) Units with

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2.4. Results and discussion

The nets operated in the Vembanad lake can be broadly classified into a) Units with square mouth and b) Units with rectangular mouth. The square-mouthed nets have all four sides of the mouth nearly of four meters, while the nets with rectangular mouth have their horizontal span about four meters and the vertical span varying with the depth of the region of operation. Though the latter type invariably had a greater perimeter, no relationship was observed between the perimeter and the total depth of the net. This was true with the square-mouthed units as well.

Details of gear

Essentially the stake net is a stationary filtering device set in moving water, which screens or filters out the catch which are swept more or less passively by the current, and is retained by the force of the current. The net is held in position by stakes, driven into the muddy bottom. These stakes form the base system. The net provides considerable obstruction to the flow of water when it is set in position. Hence, depending on the size of the net, force of current and the nature of the bottom, the base systems are modified to provide additional support. The stakes usually occur in linear sets or series, each set being known locally as an `Oonnipadu′. The number of units in each `Oonnipadu′ vary considerably depending on the depth and width of the backwaters and the nature of the bottom. The distance between two stakes is maintained at 4 m. in accordance with the regulation of the State Fishery Department.

Base systems

Three types of base systems associated with the stake net operation were observed in the various centres. In station No.2, 7 & 8 where the current is relatively weak, the simplest type of base system is employed (Fig.2.6a). Here, each net is tied to two main stakes, vertically driven into the bottom, known as `Thaimaram´. These are supported by two other poles, known as `Charu´, of lesser girth placed obliquely as props, one to each `Thaimaram´.

In station No.1, 5 & 6 where the current is stronger and where larger nets are used, a more enduring method is employed for the base system (Fig.2.6b). Here, the supporting pole is known as `Kaikutti´ and is of the same girth as that of the `Thaimaram´. Moreover both are fixed in such a way that they lean towards each other, with their upper ends meeting a few feet above the water level at the high tide, while the lower ends stand apart. During operation, the lower pair of loops of the net are tied to the `Kaikutti´ and the upper pair to the `Thaimaram´.

In station No. 3, which is nearer to the bar mouth and experiencing the maximum current, the base system, though basically similar to the second type ,is further strengthened by tying the `Thaimaram´ to another pole, the `Thangu kutti´, fixed in front of it at a distance approximately thrice the depth of the operating area (Fig.2.6c). The `Thangu kutti´ is fixed obliquely with the slant opposite to the direction of water-flow. A ring to which a rope is attached is slipped over this pole and the other end of the rope is tied to the `Thaimaram´ tightly.

The fixation of the stake is done with the help of two canoes tied together with two logs placed across them (Fig.2.7). The canoes are kept stationary at the designated spot by fixing two temporary poles, one for each canoe. A rope is tied to the stake a little below the midpoint and the ends are held by men in the two canoes. A short cross-bar is tied to the stake towards its upper end. This wooden stake is then raised vertically and carefully lowered towards the lake floor. Then by repeatedly raising the pylon using the rope and then forcefully lowering it with the help of the cross-bar, it is driven as deep as required.

The net

The net itself is a conical bag with an elongated,tapered codend. A number of rectangular panels go into the construction of the net (Fig.2.8a). The first panel is made of four separate pieces of netting which are not seamed at their sides. The meshes at the periphery of these pieces are hung on to a rope which is made into a loop at the four corners. Two to four meshes from adjacent pieces go into the corresponding corner loop (Fig 2.8b). The name of the next few panels differ slightly from place to place, but are commonly called, the `Kayattuvala´, the `Vavala´ and the `Thelikanni´. The second panel `Kayattuvala', has a stretched length greater than the first panel. The remaining panels have progressively diminishing stretched lengths and are specified by the number of meshes they have in their circumference, except the cod end, which is known as the `Chuvadu'.

The design details of the square mouthed prototype, the newly designed net and the rectangular net are given in Figs (2.9, 2.10 & 2.11) respectively. Net B, though based on a new design, was fabricated with more or less the same perimeter and overall length as that of the prototype to facilitate comparative studies. The rectangular-mouthed net being bigger in overall size, was not taken for comparative studies.

Operation

The net is set when the low tide begins, at which time the fishermen paddle out to the stakes in a canoe with the nets. Two persons are essential for setting the net. Before setting the net, the codend is closed by passing a rope several times around it (Fig.2.12). This rope is known as the codend rope and runs the entire length of the net and is loosely tied to one of the stakes. Then the float is tied to the codend using a float line. The net is then paved out, beginning with the codend up to the first panel. At the first panel, the bottom pair of loops are first tied to the stakes with a pair of ropes. These hauling lines, are then pushed down with a pole forked at one end. The knot employed for this is such that one end of the line runs along the stake upward, passes through the upper loop and is used for tying the same to the stake at the top (Fig.2.13). The tidal action maintains the spatial configuration of the net during operation. The net is operated on an average for 5 hours, till the ebb tide begins to slacken. The fishermen return to the stakes and first untie the lower loops by simply pulling the hauling line at the surface. Continued hauling of this line brings the lower edge of the mouth to the surface. The upper loops are then untied and the whole net beginning with the mouth, is gradually hauled into the canoe and brought ashore, where the catch is finally taken out by unleashing the codend rope.

During certain periods of the year, jelly fish and Salvinia spp., locally known as `African Payal´ causes considerable economic losses to the backwater fishery. (Menon, 1971). Accumulation of these weeds in the stake net reduces its filtering capacity and as a result, the efficiency. During such times the fishermen return to the stakes occasionally to remove the catch and the debris, without hauling in the complete net. This is done by pulling the codend rope towards the stake, drawing the codend alone to the canoe, facilitating the release of the catch.

Net drag

Reduction in the total drag offered by a net indicates its better filtration rate and smooth flow inside, which manifests in the efficiency of the net. The net drag calculations of the prototype and that of the newly fabricated net are given in Tables (2.1 and 2.2) respectively and that of the rectangular mouthed net in Table (2.3) Parameters such as the nominal developed twine area, solidity, cone drag area etc. of the various panels of the two types of stake nets presently in vogue and that of the newly designed net are also given. To facilitate comparison, a consolidated account of the result of these calculations is given in Table.(2.4).

The stretched length at the cone mouth for net A was 11.58 percent greater than that for net B. This would normally increase the angle of attack. But in net A, since the stretched length of the first panel is less than that of the second panel, this does not take place. Instead, the greater stretched length of the second panel contributed to an increase in the secondary hanging coefficient, as a result of which the hung length of the cone was increased. This actually achieved a reduction in the angle of attack after offsetting the increase due to a greater perimeter. But the drawback of this condition is that there is an unnecessary increase in the nominal twine area of the net, which contributes to an increase in drag nullifying the gain achieved by a reduced angle of attack.

This aspect is highlighted by the fact that in spite of net A having a smaller angle of attack (8.11^{o}) than net B

(8.42^{o}), the total drag was 13 percent more than that of net B. This was because the total nominal twine area of net A was 19 percent more than that of net B. This unequivocally establishes that the developed twine area is a prime component in total drag.

The contribution of the cylindrical part of the codend towards the nominal developed twine area for nets A and B were 1.55 and 2.81 percentage respectively. But the corresponding share of these parts to the total drag was only 0.41 and 1.17 percent respectively. This was because this part of the codend was aligned parallel to the flow of water and hence could not create any appreciable drag. This condition holds true only in the case of an empty net. In actual fishing conditions, codend drag increases considerably with the accumulation of catch.

The contribution of appendages towards the total drag was equal in both nets, since the floats and ropes employed were identical.

As is evident, the biggest contribution to total drag was from the cone proper, and was 99.08 percent for net A and 98.24 percent for net B.

Solidity of panels is another major contributing factor to the drag of net. All panels except the first, second and fourth of net A were high solidity panels. But in net B, first, second and third panels were low solidity panels, as a result of which, the contribution of these panels to the total drag was proportionately less than that for the other panels. The high solidity area netting was 88.6 percent in net A, while it was only 69 percent in net B. This naturally contributed to the reduction of total drag for net B in comparison to net A.

The increased mesh size of the panels employed in net B and the cutting rate employed to effect tapering contributed to the reduction of the total nominal developed twine area by as much as 19.1 percent, in comparison with net A.

The above modifications were responsible for the reduced total drag of net B, which was only 190.875 kgf. This was 13 per cent lesser than that for net A which was 219.442 kgf. The calculated and measured drag for nets A, B and C are provided in Table (2.5). The ratio between the calculated and measured drag for all three nets were greater than 0.9, indicating the accuracy and reliability of the drag calculation.

Influence of mesh size on total drag:

The curve for plots of total drag of the net against different mesh sizes for the various panels of net B is given in Fig.(2.14). An increase in the mesh size of any panel results in a decrease in the total drag of the net. But the rate of decrease in total drag with increase in mesh size gradually abates and the curve flattens out, indicating that increase in mesh size beyond a particular limit will not alter the drag appreciably. This shows that the mesh size of panels is inversely related to the total drag of the net, but is not proportional. Any change in mesh size affects the `d/a´ value which consequently transforms the knot correction and solidity terms.

Alterations of the mesh size influence C_{d90} and C_{d0}, the coefficients of drag at 90^{o} and 0^{o}, affecting the resultant coefficient of drag at the particular angle of attack, $C_{d\alpha}$. Any modification in mesh size also changes the nominal developed twine area (A_m). And since the drag of a panel is the product of $C_{d\alpha}$ and A_m, any change in mesh size alters the drag of that panel, affecting the total drag of the net accordingly.

It is also seen that, though the pattern of change in total drag with increase in mesh size of the panel is almost similar for all the panels, the maximum influence on drag for a given increase in mesh size is evidenced in panels with smaller mesh sizes.

Though it is possible to ascertain an optimum mesh size for each panel from the mesh size-drag curves, for practical fishing, this should not be taken as the only criterion for fixing the mesh size of the different panels. This is because, mesh size of the panels has to be determined after taking into consideration the minimum size of the target species and the pattern of escapement through various panels also. Hence drag is only one of the factors to be taken into consideration while fixing the mesh size of the panels.

Effect of twine thickness on total drag

The relationship of total drag to twine thickness of each panel for net B is graphically represented in Fig. (2.15). Increase in twine diameter of any panel was found to proportionately enhance the total drag of the net. Therefore, it can be assumed that thinner the twine diameter, lesser the total drag, resulting in better filtration rate and consequently, possibility of better catch, which is true in the case of gill nets also (Baranov, 1914 and Andreev 1955).

Though twine diameter is of high significance for the efficiency of fishing gear, it must be considered together with the wet knot breaking load, which is an important practical property of net material because it indicates the ability of the netting for withstanding stress during fishing (Klust, 1982). Figure (2.16) gives the relationship between wet knot breaking load and diameter of twisted netting yarns made of different kinds of fibre. The curve for nylon lies above that for polyethylene, since the former is stronger than the latter. Similarly the curve for polyester lies below that for polyamide since it is stronger than polyamide. This in practical sense means greater twine diameter will have to be used in the case of polypropylene and polyethylene, than required for nylon, to achieve the same strength. In stake nets, since most of the panels have small mesh size, utilizing polyethylene or polypropylene adversely affect the mesh lumen, which reduces the filtration rate. This justifies the use of polyamide for most of the panels with small meshes.

The introduction of knotless nettings have further enhanced the filtration rate of the lower panels, because of the reduction in the area occupied by knots. But in the first few panels with larger mesh size, introduction of polyethylene is found to have only marginal detrimental effect, since the total twine area of these panels are less. Moreover these panels have a low solidity. In net B, the first three panels were made of polyethylene. This is advantageous when the cost factor, an important aspect to be considered during designing, is taken into consideration.

Further reduction in material as well as drag can be achieved, if the exact strength that is required for a stake net of given size could be ascertained.

Influence of panel depth on drag

The pattern of drag variation in relation to angle of attack and twine area with different panel depths in net B are given in Fig. (2.17).

The drag of a netting panel set against a water current is the product of the hydrodynamic stagnation pressure and the drag area of the panel. The latter is dependent on the twine surface area and the coefficient of drag at the particular angle at which the netting panel is inclined to the water-flow. It is the cone that sets the constituent panels at this angle of attack, which is dependent on the cone length, for a given cone mouth. Hence an increase in the depth of the panel increases the cone length. And since the cone mouth was not altered, the effect of an increased cone length was a lowering of the angle of attack (Mukundan, 1989) resulting in a reduced net drag. But, increasing the panel depth increases the total twine surface area affecting a corresponding enhancement in the drag.

Thus the effect of an increase in the depth of a panel is a lowering of the angle of attack and an increase in the twine surface area. These two factors have a mutually antagonistic effect on the total drag . Hence, as long as the influence of a lower angle of attack offsets the influence of an increased twine area, the total drag will fall. This is evidenced in the first two panels of net B The remaining panels have a higher solidity or twine surface area and hence any increase in the panel depth only contribute to a further increase in total drag.

The results of comparative fishing of nets A and B are given in Table.2.6. For comparing the catch efficiency of prototype and the newly designed net, paired `t´ test was employed. The data were converted to logarithms by adding 1 to each observation. The difference were worked out for each operation and `t´ was worked out as per the formula

$$t = \frac{\sqrt{n}\,|\bar{d}|}{S}$$

where n is the number of observations

$\bar{d}$ is the mean of the difference

S is the unbiased estimate

This `t´ is having degrees of freedom n - 1. In station No. 3 all the calculated values of `t´ are significant (Prawn, fish and total) at 5 percent level. This shows that, the catch in net B is significantly higher than that of net A.

In station No. 5 the calculated values of `t´ for prawn and total catch were found to be significant at 5 percent level. But that of fishes is found to be not significant at 5 percent level.

In station No.6 the `t´ values were significant for prawn, fish and total catch at 5 percent level, showing that the catch in net B to be significantly higher than that of net A.

Thus, in the light of the above results obtained during comparative fishing and from the calculations, it can be confirmed that the modifications affected in the design of net B has been in the positive direction. A significant achievement of the new design is the attainment of a higher filtration rate which manifests in a faster flow of water through the net (Hamuro, 1964) resulting in a better catch. Further studies with regard to the maximum strength required for the stake net during operation and the escapement pattern through different regions of the net, can help in formulating designs with lesser drag, better filtration and improved catch.

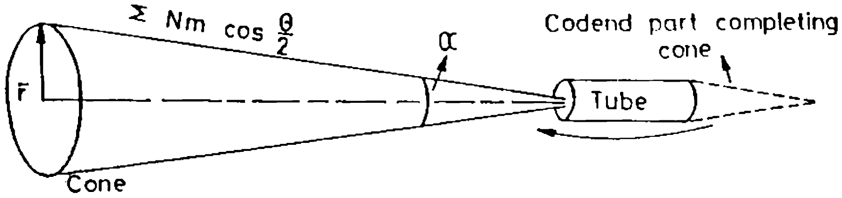


FIG. 2.1 CONCEPT OF STAKE NETS AS A CONE AND CYLINDER.

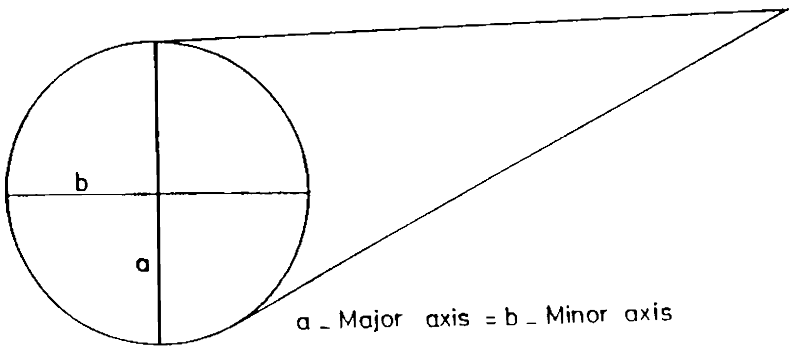


FIG. 2.2 CONE MOUTH AREA OF THE SQUARE-MOUTHED NET

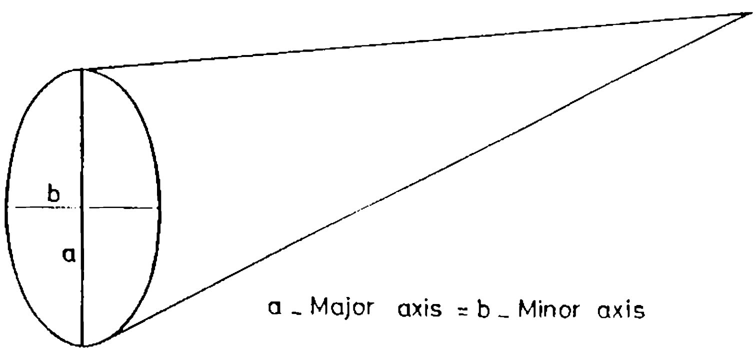


FIG. 2.3 CONE MOUTH AREA OF THE RECTANGULAR-MOUTHED NET.

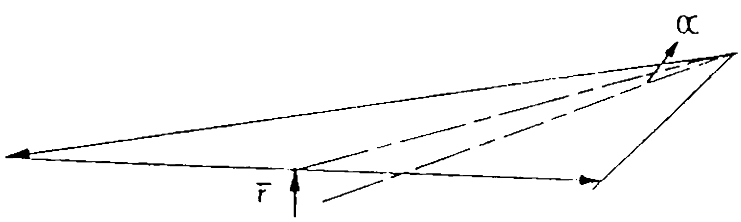


FIG. 2.4 CUT OPEN AND FLATTED CONE.

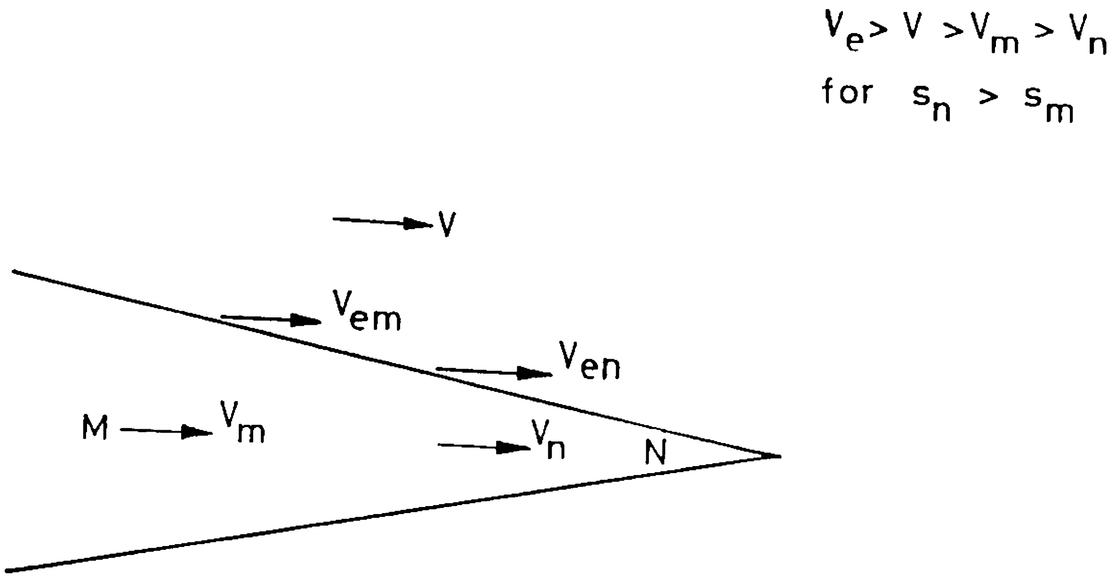


FIG. 2.5 FORM DRAG FORMATION.

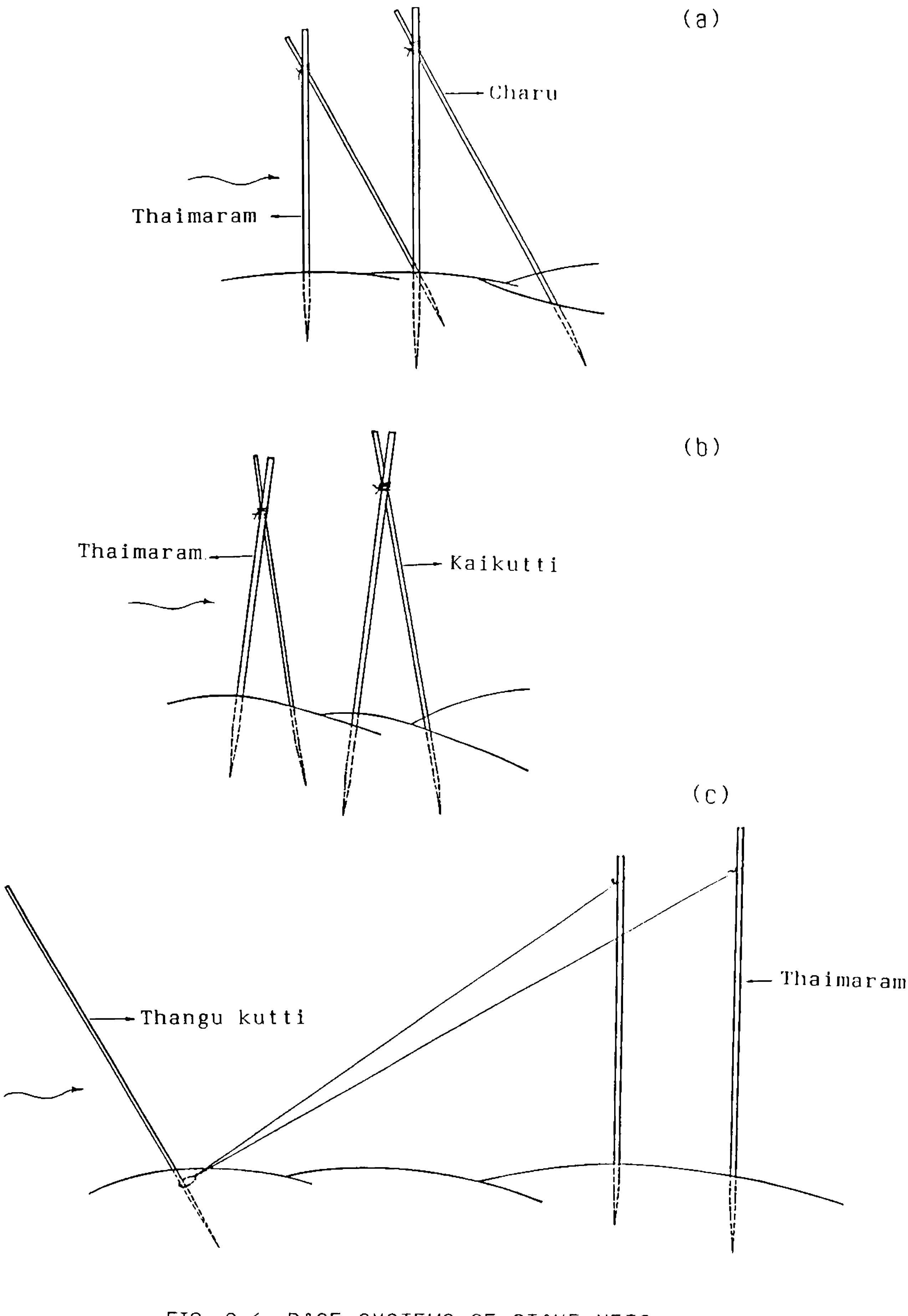


FIG. 2.6 BASE SYSTEMS OF STAKE NETS.

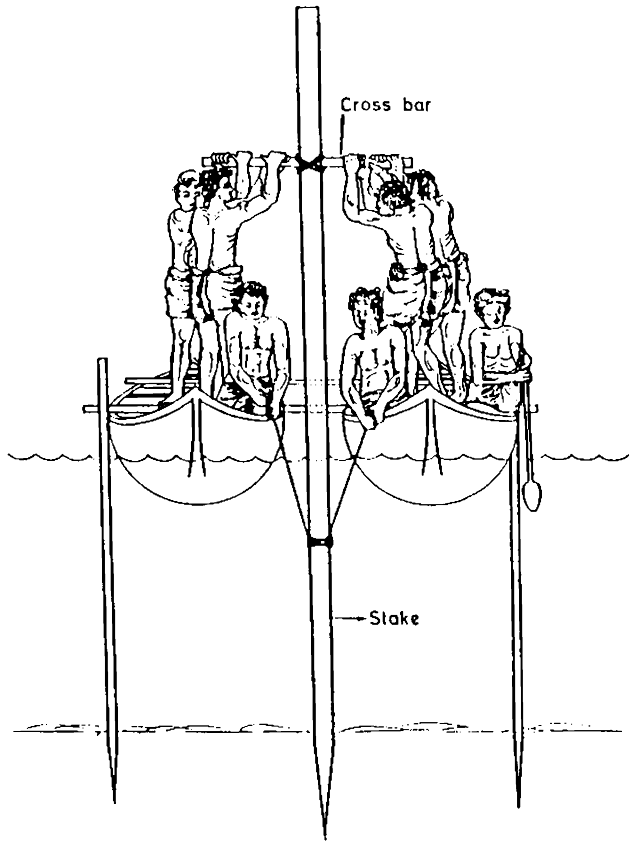


FIG. 2.7 FIXING OF STAKES.

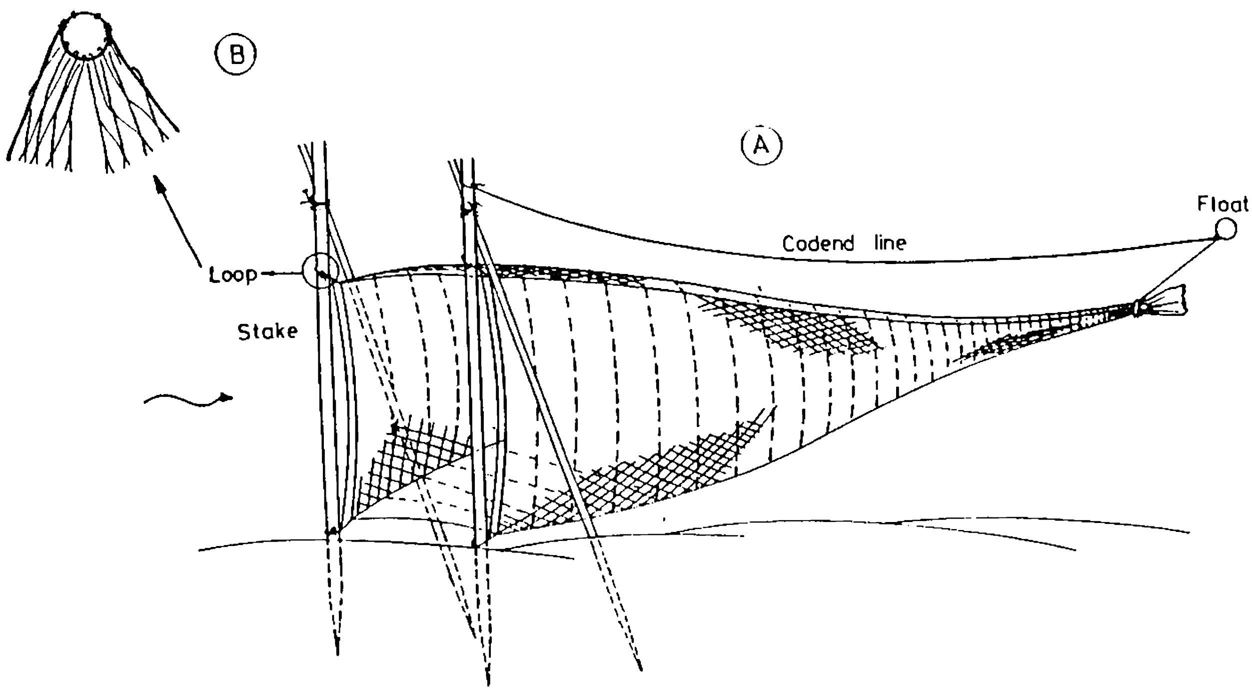


FIG. 2.8 (A) ILLUSTRATION OF A TYPICAL STAKE NET.
(B) CORNER LOOP.

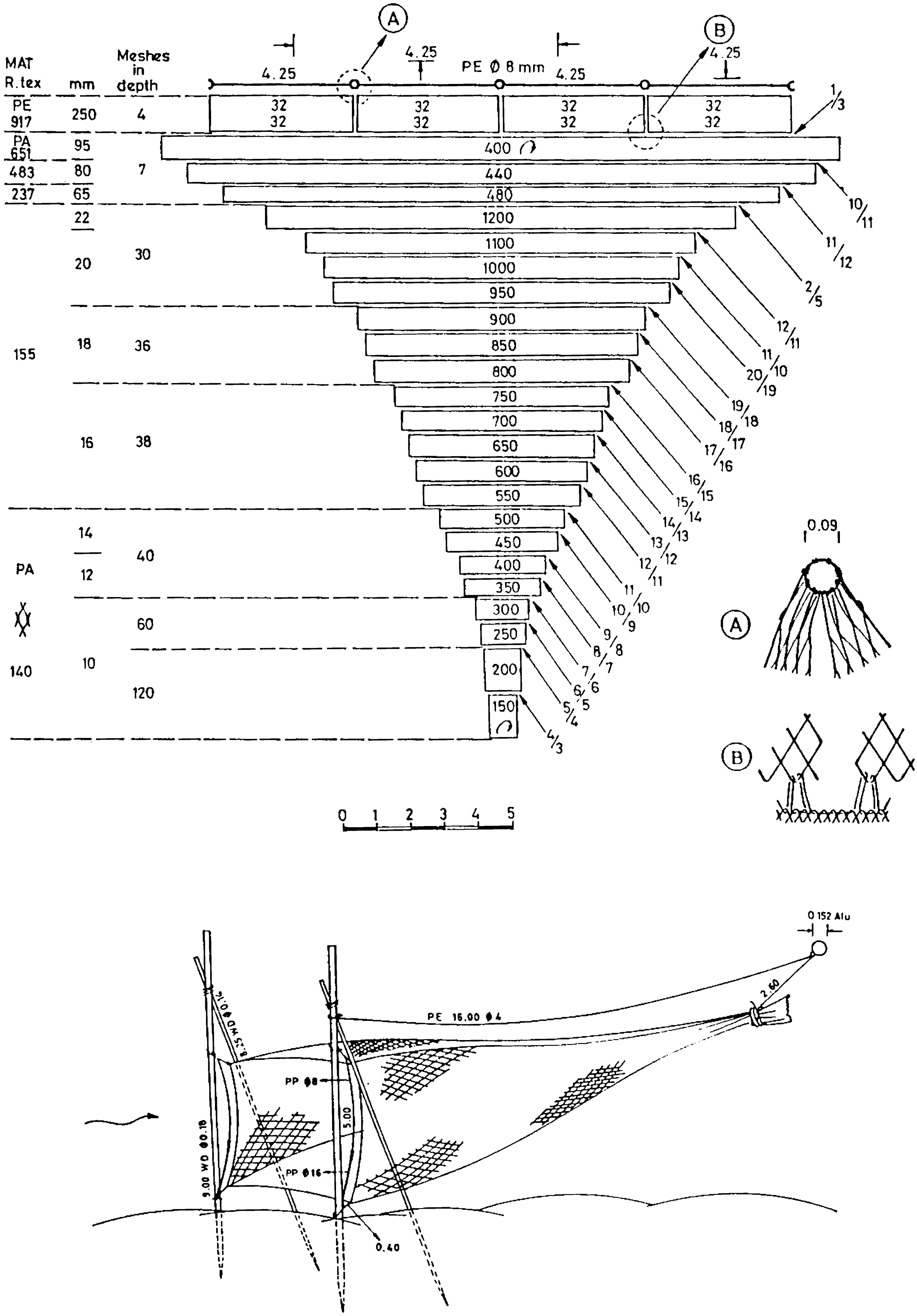


FIG. 2.9 DESIGN OF PROTOTYPE (Net A).

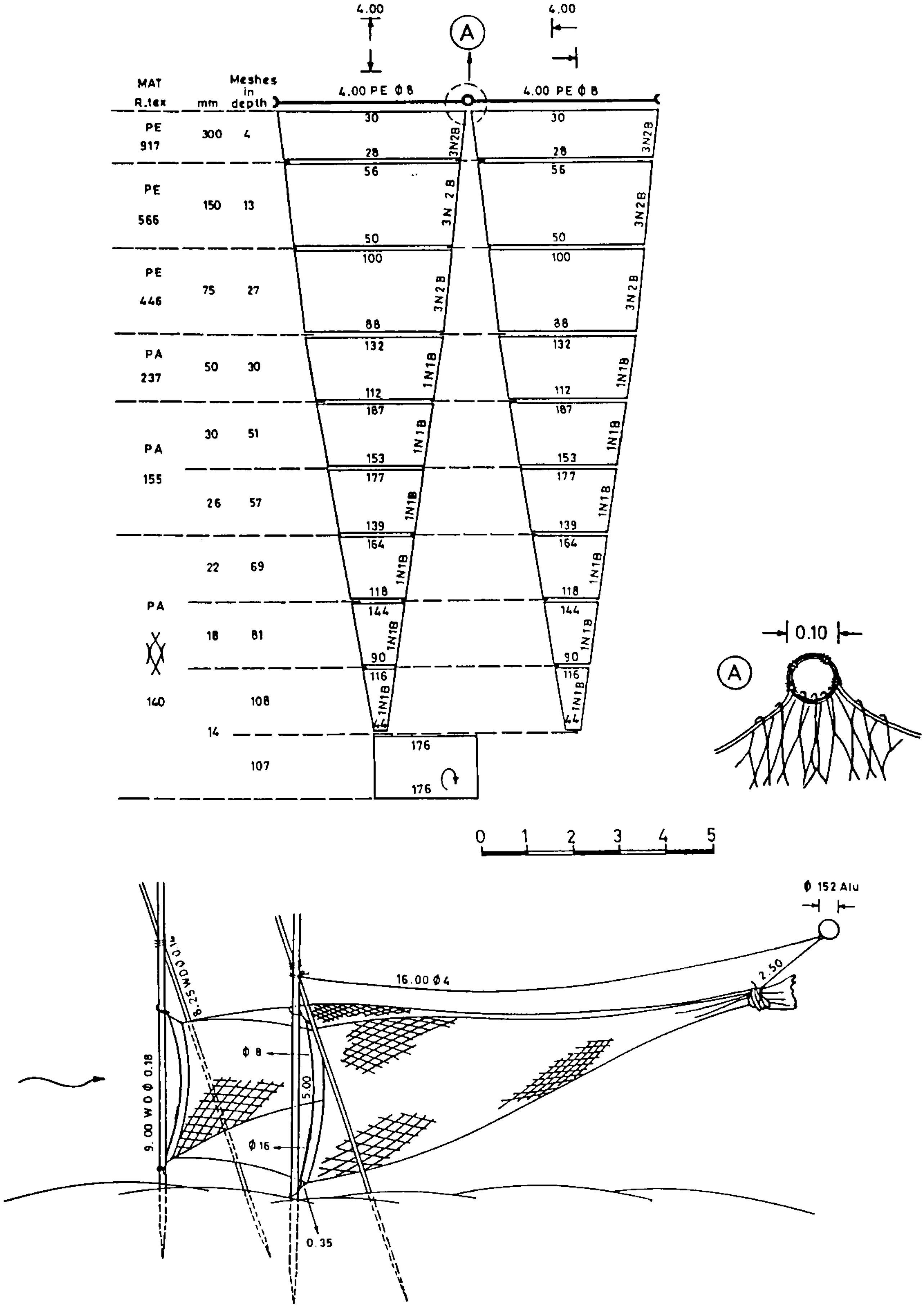


FIG. 2.10 NEW DESIGN (Net B).

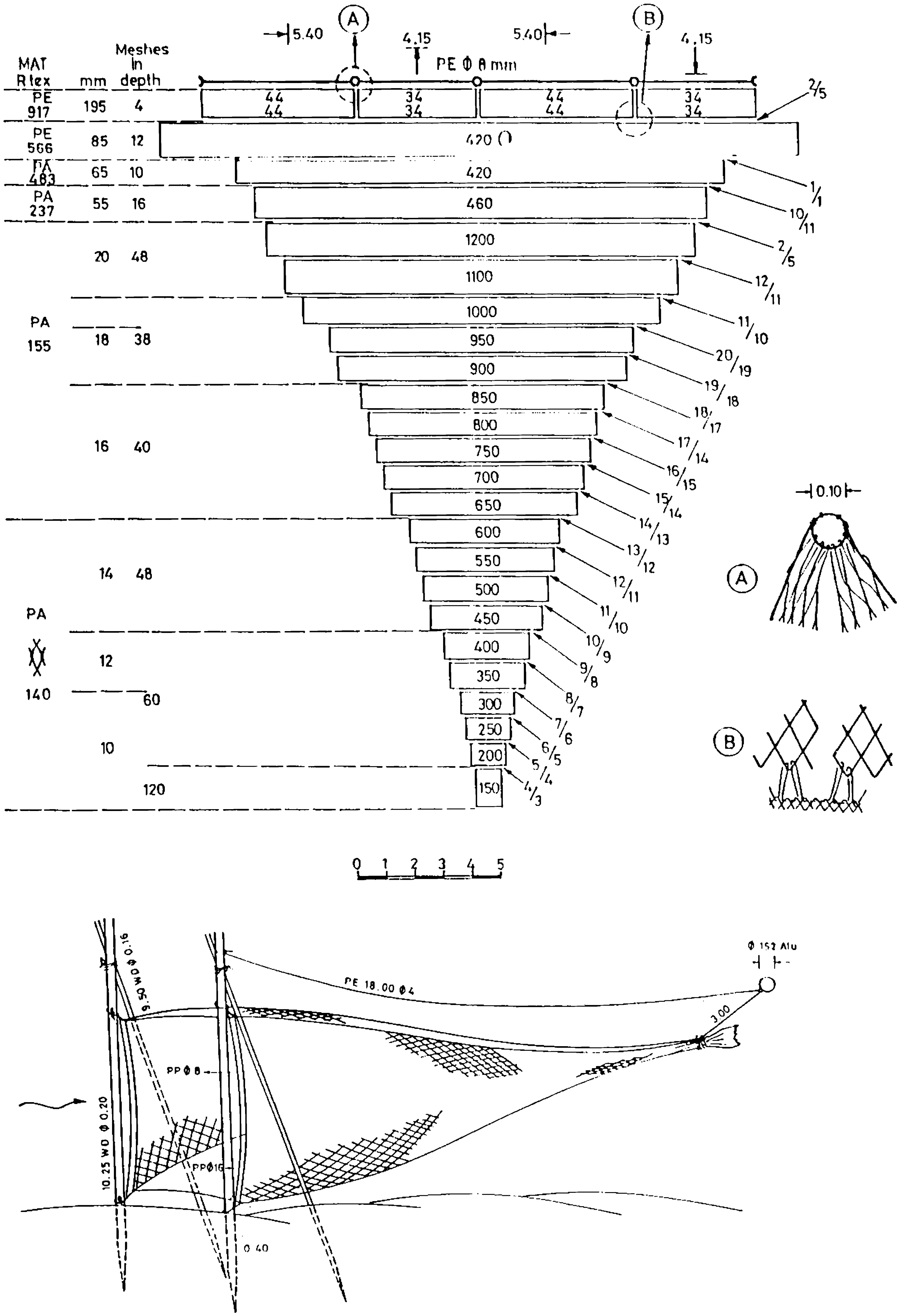


FIG. 2.11 DESIGN OF RECTANGULAR- MOUTHED NET (Net C).

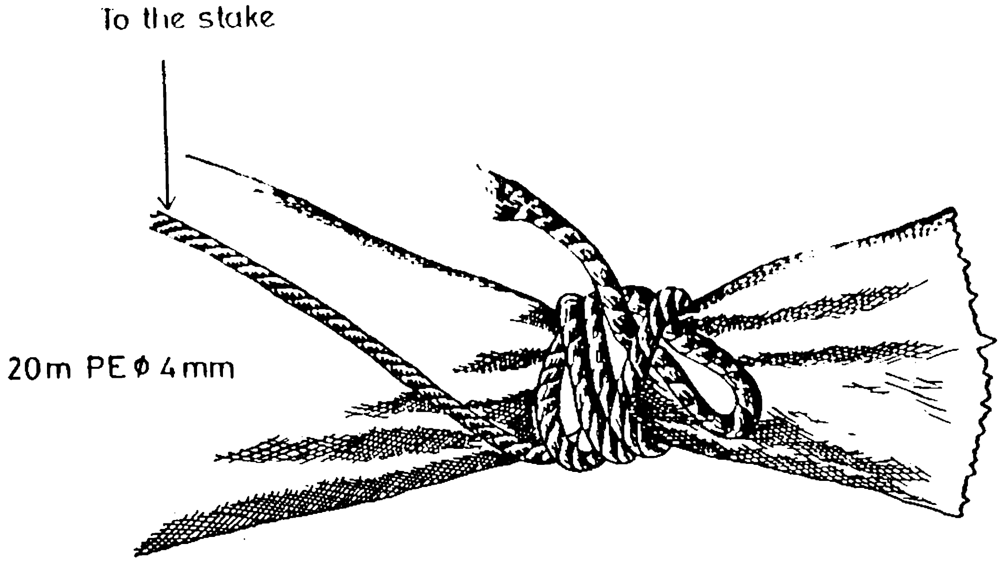


FIG. 2.12 Method of tying the codend.

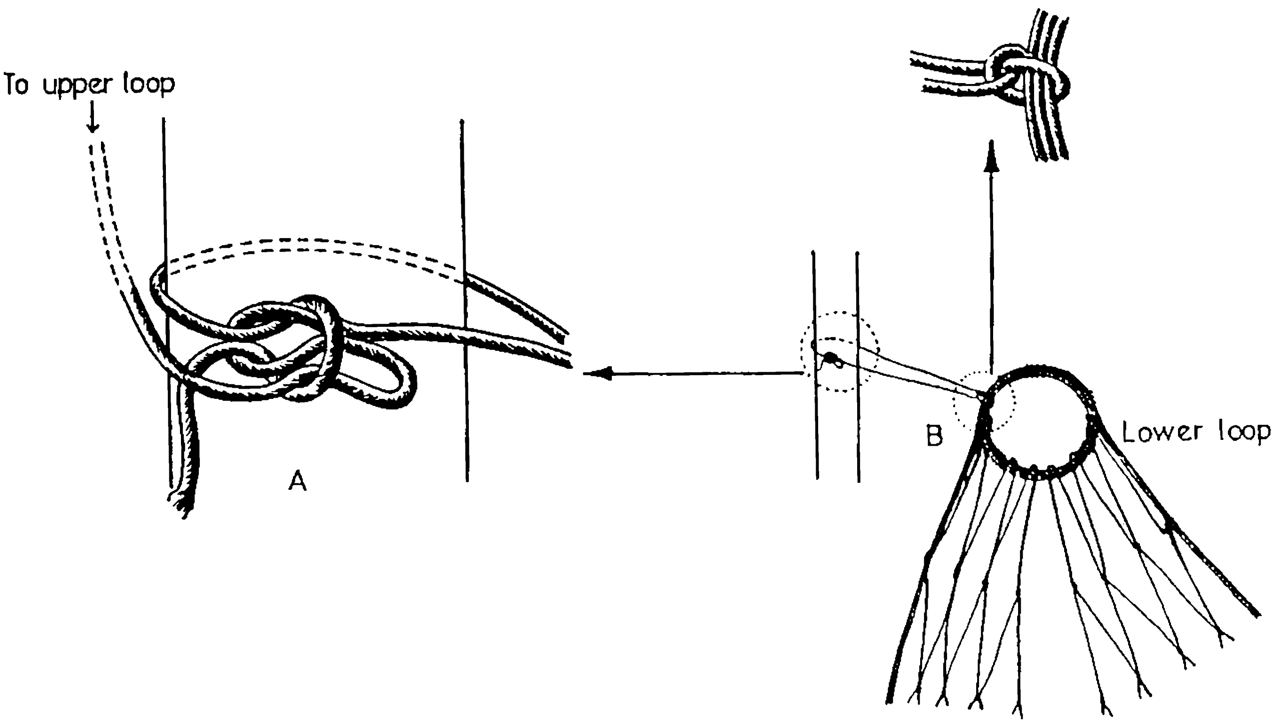


FIG. 2.13 ATTACHMENT OF THE NET TO THE STAKE.

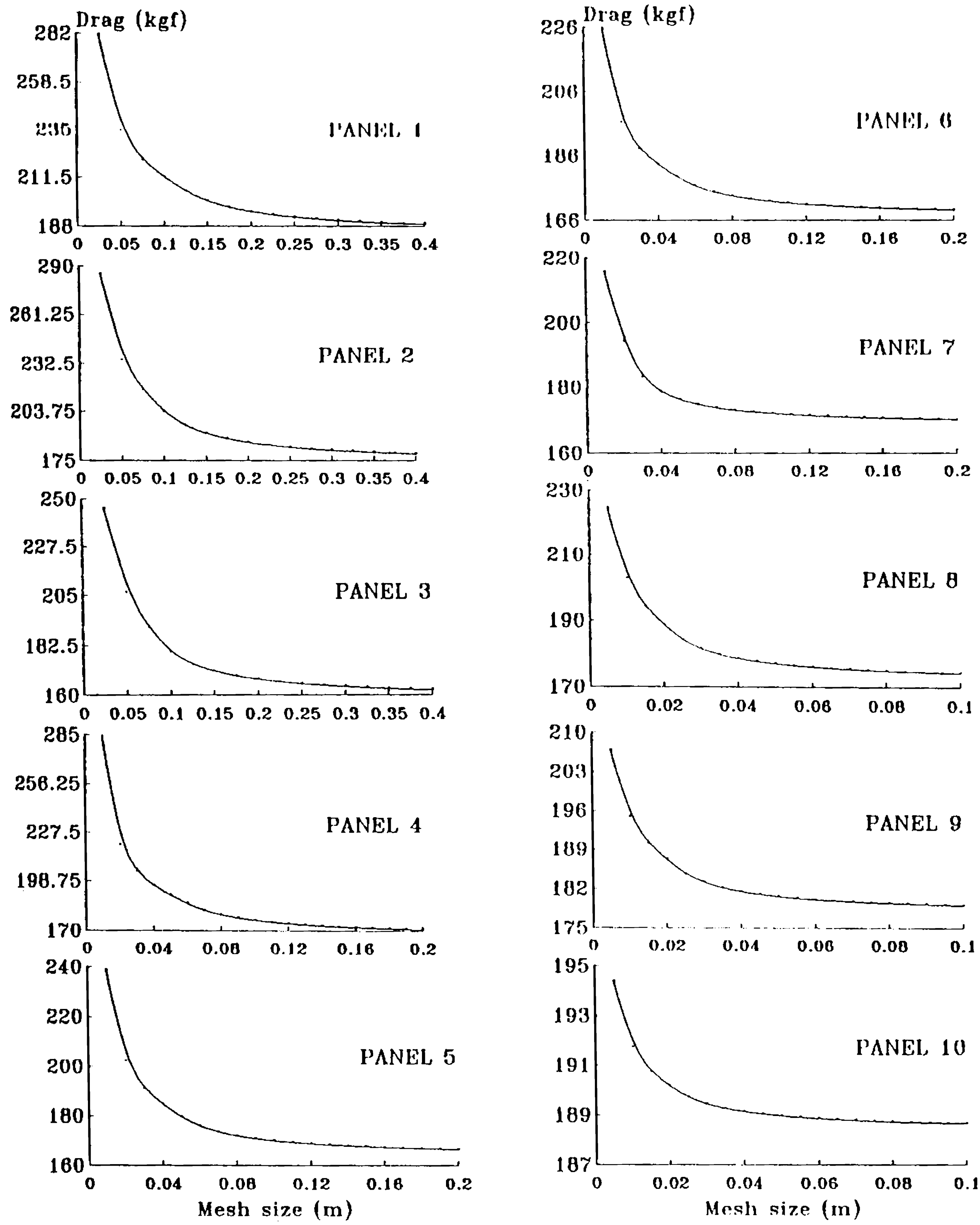


FIG. 2.14 INFLUENCE OF MESH SIZE ON TOTAL DRAG FOR THE DIFFERENT PANELS OF NET 'A'.

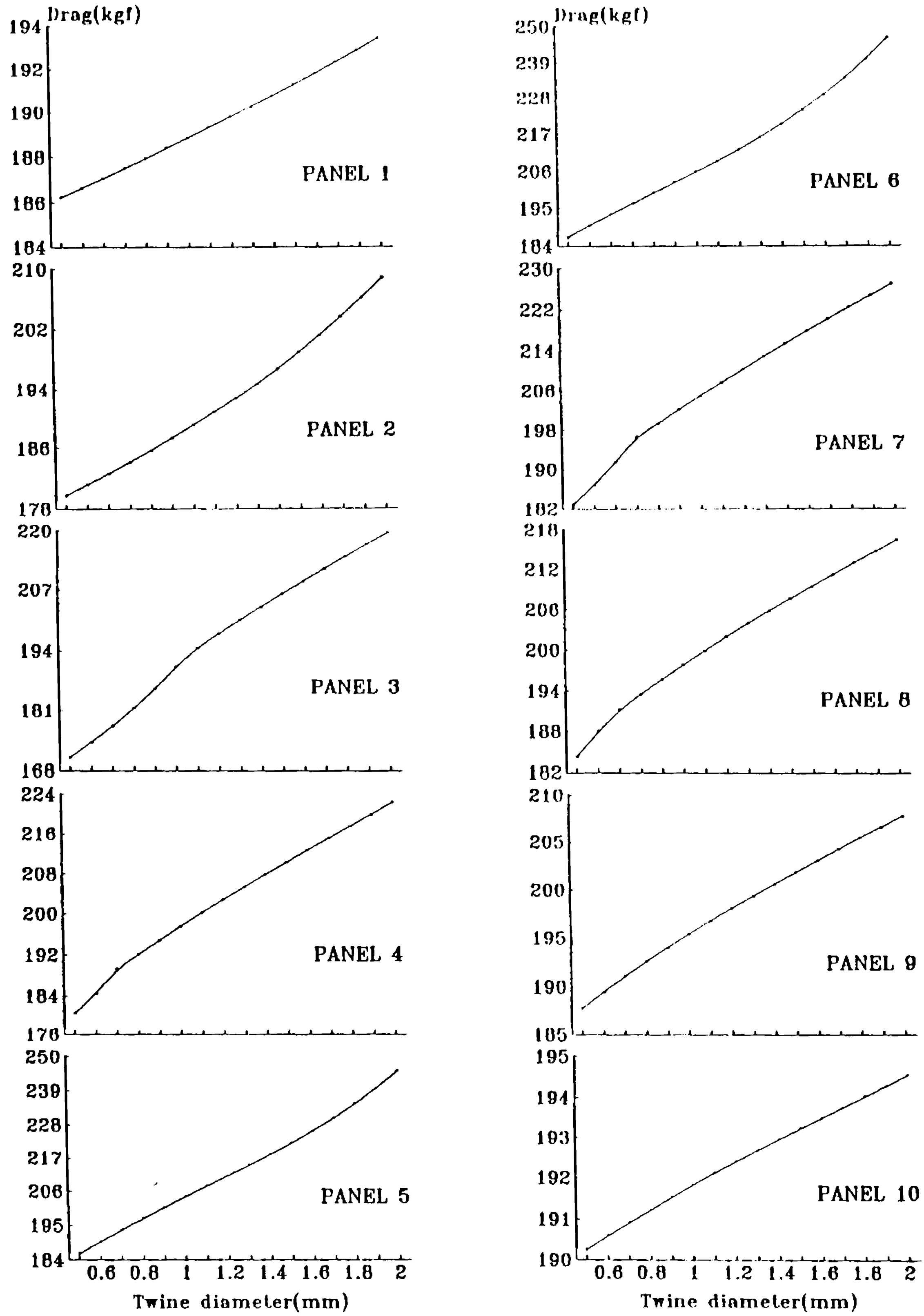


FIG. 2.15 INFLUENCE OF TWINE DIAMETER ON TOTAL DRAG FOR FOR THE DIFFERENT PANELS OF NET 'A'.

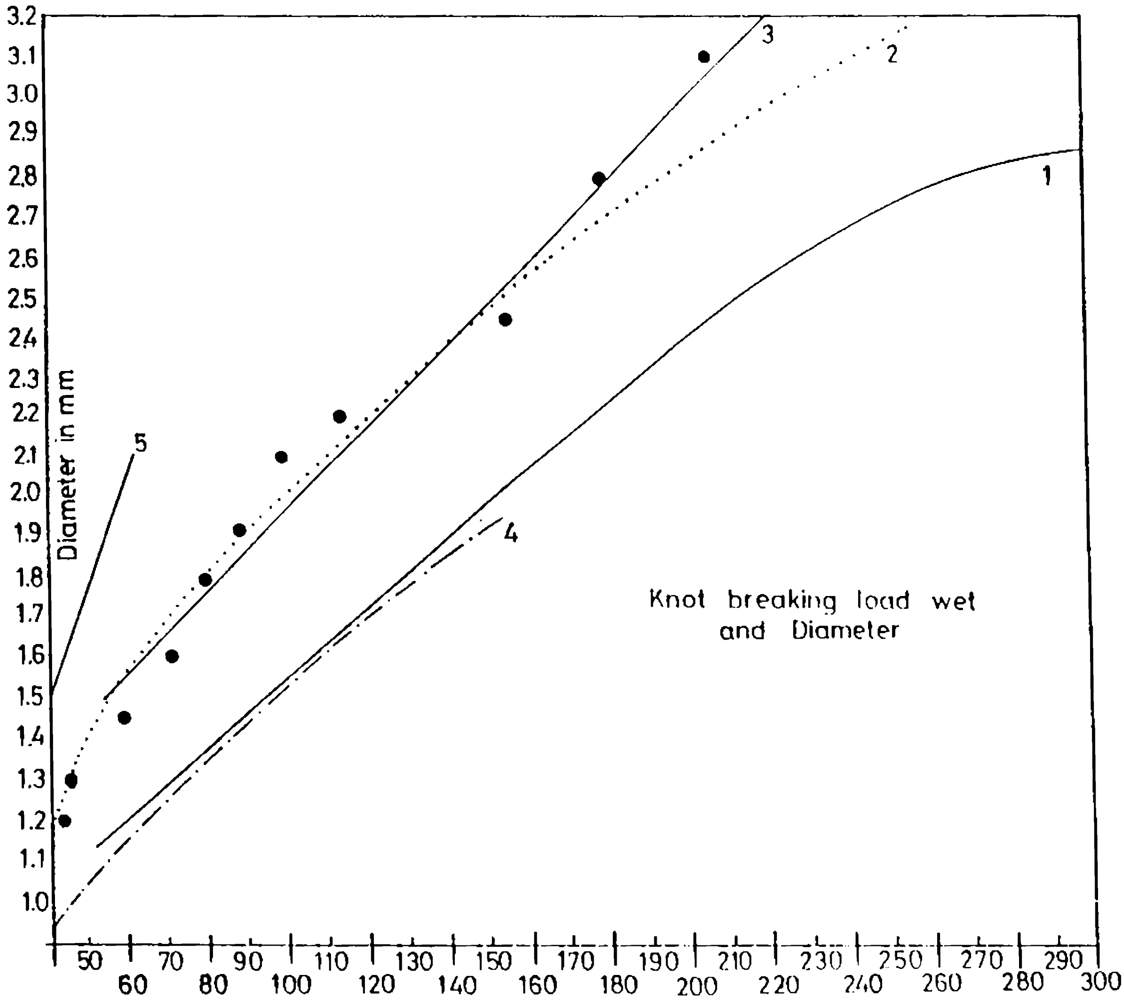


FIG. 2.16 RELATIONSHIP BETWEEN WET KNOT BREAKING LOAD AND DIAMETER OF TWISTED NETTING YARNS MADE OF DIFFERENT KINDS OF FIBRE.

(1) PA Continuous filaments
(2) PP Continuous filaments
(3) PE Monofilaments (wires)
(4) PES Continuous filaments
(5) PA Staple fibre & PP split fibres
(average values)

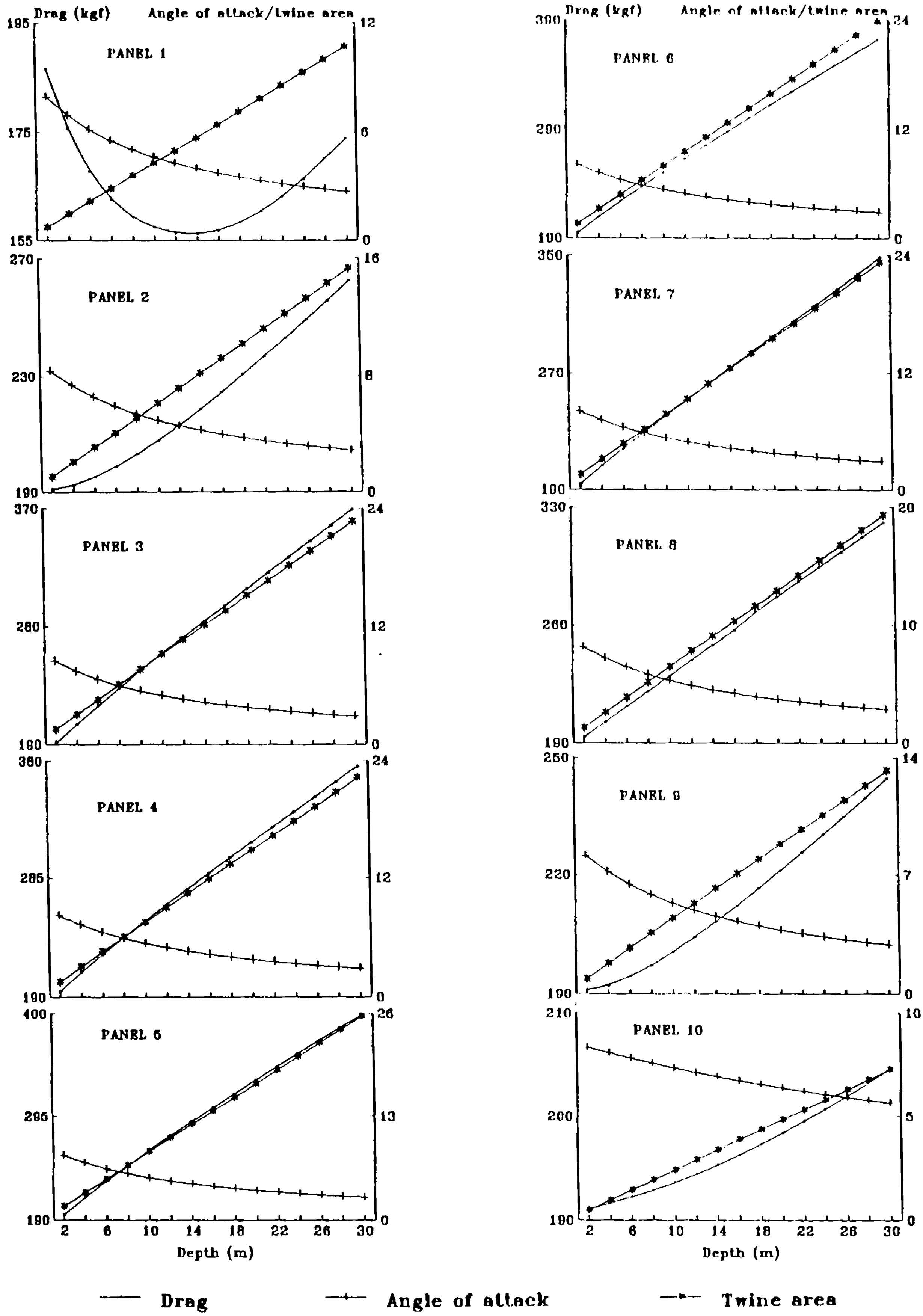


FIG. 2.17 DRAG VARIATION IN RELATION TO ANGLE OF ATTACK AND TWINE AREA WITH VARYING PANEL DEPTHS.

TABLE 2.1 DRAG CALCULATIONS OF NET 'A'.

Panel	No of meshes depth'm'	Uppr. edg	Lowr. edg	across'n'	Mesh size (m)	Diameter of twine 'd' (m)	No. of parts
1	4	32	32	32.00	0.250	0.001526	4
2	7	400	400	400.00	0.095	0.001205	1
3	7	440	440	440.00	0.080	0.001041	1
4	7	480	480	480.00	0.065	0.000760	1
5	30	1200	1200	1200.00	0.022	0.000628	1
6	30	1100	1100	1100.00	0.020	0.000628	1
7	30	1000	1000	1000.00	0.020	0.000628	1
8	30	950	950	950.00	0.020	0.000628	1
9	36	900	900	900.00	0.018	0.000628	1
10	36	850	850	850.00	0.018	0.000628	1
11	36	800	800	800.00	0.018	0.000628	1
12	38	750	750	750.00	0.016	0.000628	1
13	38	700	700	700.00	0.016	0.000628	1
14	38	650	650	650.00	0.016	0.000628	1
15	38	600	600	600.00	0.016	0.000628	1
16	38	550	550	550.00	0.016	0.000628	1
17	40	500	500	500.00	0.014	0.000688	1
18	40	450	450	450.00	0.014	0.000688	1
19	40	400	400	400.00	0.012	0.000688	1
20	40	350	350	350.00	0.012	0.000688	1
21	60	300	300	300.00	0.01	0.000688	1
22	60	250	250	250.00	0.01	0.000688	1
23	120	200	200	200.00	0.01	0.000688	1
25% codend	30	150	150	150.00	0.01	0.000688	1
75% codend	90	150	150	150.00	0.01	0.000688	1

Cdsc.Ct	1.000000
Ck	0.470000
Cf	0.070000
HR at mouth (m)	17.000000
No of meshes at mouth	128.000000
Mesh size at mouth (m)	0.250000
Horizontal opening (m)	4.000000
Vertical opening (m)	4.000000
Length of legs (m)	0.400000
Diameter of floats (m)	0.152000
Number of floats	1.000000
Weight of ropes (kg)	1.150000
Mass density of water (kgf-sq.sec/m^4)	103.800000
Velocity of water flow (m/s)	1.050000
Primary hanging coeft. = Sin 0 = E1	0.531250
Secondary hanging coeft. = Cos 0 = E2	0.847215
Angle (deg)	32.089951

Continued ....

Semi Major axis of cone 'a' (m)	1.8658078368
Semi Minor axis of cone 'b' (m)	1.8658078368
Periphery of cone (m)	11.7232163863
Setting angle of meshes '0' (deg)	17.9691997535
Angle of attack ' ' (deg)	8.1099622983

Panel	Am(sq.m.)	AM(sq.m.)	Simplified solidity	SOLIDITY (s)	Cd 90	Cd0	Cd alpha	Ac
1	0.390656	9.390642	0.041601	0.14243406	1.337417	0.1039533405	0.270676	0.105741
2	0.641060	7.415672	0.086447	0.29313609	1.933013	0.1160846646	0.361672	0.231853
3	0.513005	5.784635	0.088684	0.30057740	1.929917	0.1154287145	0.360686	0.185034
4	0.331968	4.165923	0.079687	0.27060811	1.820472	0.1142559853	0.344878	0.114489
5	0.994752	5.113204	0.194546	0.64426575	1.846260	0.0910539059	0.328298	0.326575
6	0.828960	3.873640	0.214000	0.70563795	1.830886	0.0883430238	0.323876	0.268480
7	0.753600	3.521491	0.214000	0.70563795	1.830886	0.0883430238	0.323876	0.244073
8	0.715920	3.345416	0.214000	0.70563795	1.830886	0.0883430238	0.323876	0.231869
9	0.732499	3.080600	0.237778	0.77989426	1.812096	0.0861178273	0.319411	0.233969
10	0.691805	2.909456	0.237778	0.77989426	1.812096	0.0861178273	0.319411	0.220970
11	0.651110	2.738311	0.237778	0.77989426	1.812096	0.0861178273	0.319411	0.207972
12	0.572736	2.141066	0.267500	0.87154805	1.788608	0.0852542735	0.315490	0.180692
13	0.534554	1.998329	0.267500	0.87154805	1.788608	0.0852542735	0.315490	0.168646
14	0.496371	1.855591	0.267500	0.87154805	1.788608	0.0852542735	0.315490	0.156600
15	0.458189	1.712853	0.267500	0.87154805	1.788608	0.0852542735	0.315490	0.144554
16	0.420006	1.570115	0.267500	0.87154805	1.788608	0.0852542735	0.315490	0.132508
17	0.385280	1.150354	0.334923	1.07465267	1.735327	0.0926715810	0.314703	0.121249
18	0.346752	1.035318	0.334923	1.07465267	1.735327	0.0926715810	0.314703	0.109124
19	0.264192	0.676126	0.390744	1.23775956	1.691215	0.1104155378	0.324086	0.085621
20	0.231168	0.591610	0.390744	1.23775956	1.691215	0.1104155378	0.324086	0.074918
21	0.247680	0.528224	0.468892	0.58850634	1.775593	0.0705076334	0.300977	0.074546
22	0.206400	0.440186	0.468892	0.58850634	1.775593	0.0705076334	0.300977	0.062122
23	0.330240	0.704298	0.468892	0.58850634	1.775593	0.0705076334	0.300977	0.099395
25% Cod	0.061920	0.132056	0.468892	0.58850634	1.775593	0.0705076334	0.300977	0.019637
75% Cod	0.185760	0.396168	0.468892	0.58850634	1.775593	0.0705076334	0.300977	0.055910

Total nominal twine surface area (sq.m)	11.986583
Drag of cone 'Dc'(kgf)	217.414220
Drag of codend 'Ro'(kgf)	0.895429
Drag of floats 'Df'(kgf)	0.488001
Drag due to ropes 'Dr'(kgf)	0.644000
	==============
TOTAL DRAG OF NET 'D'(kgf)	219.441649
	==============

TABLE 2.2 DRAG CALCULATIONS OF NET 'B'.

Panel	No of meshes depth'm'	Uppr. edg	Lowr. edg	across'n'	Mesh size (m)	Diameter of twine 'd' (m)	No. of parts
1	4	30	28	29.00	0.300	0.001526	4
2	13	56	50	53.00	0.150	0.001205	4
3	27	100	88	94.00	0.075	0.001007	4
4	30	132	112	122.00	0.050	0.000760	4
5	51	187	153	170.00	0.030	0.000628	4
6	57	177	139	158.00	0.026	0.000628	4
7	69	164	118	141.00	0.022	0.000688	4
8	81	144	90	117.00	0.018	0.000688	4
9	108	116	44	80.00	0.014	0.000688	4
25% Cod	26.75	176	176	176.00	0.014	0.000688	1
75% Cod	80.25	176	176	176.00	0.014	0.000688	1

Cdsc.Ct	1.000
Ck	0.470
Cf	0.070
HR at mouth (m)	16.000
No of meshes at mouth	120.000
Mesh size at mouth (m)	0.300
Horizontal opening (m)	4.000
Vertical opening (m)	4.000
Length of legs (m)	0.350
Diameter of floats (m)	0.152
Number of floats	1.000
Weight of ropes (kg)	1.150
Mass density of water (kgf-sq.sec/m^4)	103.800
Velocity of water flow (m/s)	1.050
Primary hanging coeft. = Sin 0 = E1	0.444
Secondary hanging coeft. = Cos 0 = E2	0.896
Angle (deg)	26.388

Continued ...

Semi Major axis of cone 'a' (m)	1.83504588
Semi Minor axis of cone 'b' (m)	1.83504588
Periphery of cone (m)	11.52993330
Setting angle of meshes '0' (deg)	20.06907511
Angle of attack ' ' (deg)	8.41535144

Panel	Am(sq.m.)	AM(sq.m.)	Simplified solidity	SOLIDITY (s)
1	0.4248384000	13.4599330203	0.0315631883	0.1082281502
2	0.9962940000	19.9868401961	0.0498474992	0.1701894610
3	1.5334596000	18.4058782358	0.0833135795	0.2822027498
4	1.1126400000	11.7967803770	0.0943172598	0.3186385314
5	1.3067424000	10.0601395936	0.1298930684	0.4351031480
6	1.1763997440	7.8491212628	0.1498766173	0.4996286961
7	1.1780651520	6.0709403413	0.1940498647	0.2581161314
8	0.9389053440	3.9587519555	0.2371720569	0.3121788197
9	0.6657638400	2.1832939630	0.3049355017	0.3947125896
25% Cod	0.0906949120	0.2974232632	0.3049355017	0.3947125896
75% Cod	0.2720847360	0.8922697897	0.3049355017	0.3947125896

Panel	Cd 90	CdO	Cd alpha	Ac
1	1.2402306572	0.1113018789	0.2696407525	0.1145537459
2	1.4208359748	0.1165949267	0.2995223730	0.2984123431
3	1.8706946682	0.1262828806	0.3709468514	0.5688320103
4	1.9181360560	0.1248402449	0.3763604863	0.4187537314
5	1.8872575508	0.1144843146	0.3631261446	0.4745123297
6	1.8699125586	0.1092180136	0.3561657364	0.4189932812
7	1.7242238836	0.1073187672	0.3340991805	0.3935906018
8	1.8753295945	0.1055461928	0.3537686811	0.3321553052
9	1.8397094786	0.0955296491	0.3401610863	0.2264669511
25% Cod	1.8397094786	0.0955296491	0.3401610863	0.0308508798
75% Cod	1.8397094786	0.0955296491	0.3401610863	0.0925526394

Total nominal twine surface area (sq.m)	9.69588813
Drag of cone 'Dc'(kgf)	187.51605461
Drag of codend 'Ro'(kgf)	2.22645975
Drag of floats 'Df'(kgf)	0.48800118
Drag due to ropes 'Dr'(kgf)	0.64400000

TOTAL DRAG OF NET 'D'(kgf)	190.87451554
	=============

TABLE 2.3 DRAG CALCULATIONS OF NET 'C'.

Panel	No of meshes depth'm'	No of meshes Uppr. edg	No of meshes Lowr. edg	No of meshes across'n'	Mesh size (m)	Diameter of twine 'd' (m)	No. of parts
1	4	156	156	156.00	0.195	0.001526	1
2	12	420	420	420.00	0.085	0.001205	1
3	10	420	420	420.00	0.065	0.001041	1
4	16	460	460	460.00	0.055	0.000760	1
5	48	1200	1200	1200.00	0.020	0.000628	1
6	48	1100	1100	1100.00	0.020	0.000628	1
7	38	1000	1000	1000.00	0.020	0.000628	1
8	38	950	950	950.00	0.018	0.000628	1
9	38	900	900	900.00	0.018	0.000628	1
10	40	850	850	850.00	0.016	0.000628	1
11	40	800	800	800.00	0.016	0.000628	1
12	40	750	750	750.00	0.016	0.000628	1
13	40	700	700	700.00	0.016	0.000628	1
14	40	650	650	650.00	0.016	0.000628	1
15	48	600	600	600.00	0.014	0.000688	1
16	48	550	550	550.00	0.014	0.000688	1
17	48	500	500	500.00	0.014	0.000688	1
18	48	450	450	450.00	0.014	0.000688	1
19	60	400	400	400.00	0.012	0.000688	1
20	60	350	350	350.00	0.012	0.000688	1
21	60	300	300	300.00	0.010	0.000688	1
22	60	250	250	250.00	0.010	0.000688	1
23	60	200	200	200.00	0.010	0.000688	1
25% coden	30	150	150	150.00	0.010	0.000688	1
75% coden	90	150	150	150.00	0.010	0.000688	1

Cdsc.Ct	1.000000
Ck	0.470000
Cf	0.070000
HR at mouth (m)	19.100000
No of meshes at mouth	156.000000
Mesh size at mouth (m)	0.195000
Horizontal opening (m)	5.400000
Vertical opening (m)	4.150000
Length of legs (m)	0.400000
Diameter of floats (m)	0.152000
Number of floats	1.000000
Weight of ropes (kg)	1.350000
Mass density of water (kgf-sq.sec/m^4)	103.800000
Velocity of water flow (m/s)	1.050000
Primary hanging coeft. = Sin 0 = E1	0.627876
Secondary hanging coeft. = Cos 0 = E2	0.778313
Angle (deg)	38.893620

Continued ...

Semi Major axis of cone 'a' (m)	2.443016
Semi Minor axis of cone 'b' (m)	1.878118
Periphery of cone (m)	13.637639
Setting angle of meshes '0' (deg)	22.458037
Angle of attack ' ' (deg)	8.209601

Panel	Am(sq.m.)	AM(sq.m.)	Simplified solidity	SOLIDITY (s)	Cd 90	Cd0	Cd alpha	Ac
1	0.371367	8.376677	0.044333	0.15140958	1.359420	0.129065	0.297390	0.110441
2	1.032444	12.855421	0.080312	0.27173444	1.813494	0.140048	0.368993	0.380964
3	0.568386	6.264609	0.090730	0.30614850	1.913745	0.140569	0.383157	0.217781
4	0.615296	7.859974	0.078282	0.26500700	1.782234	0.139429	0.364181	0.224079
5	1.446912	8.133930	0.177886	0.58655575	1.830886	0.113949	0.348843	0.504745
6	1.326336	7.456102	0.177886	0.58655575	1.830886	0.113949	0.348843	0.462683
7	0.954560	5.366134	0.177886	0.58655575	1.830886	0.113949	0.348843	0.332992
8	0.816149	4.129240	0.197651	0.64828070	1.812096	0.109691	0.342597	0.279610
9	0.773194	3.911912	0.197651	0.64828070	1.812096	0.109691	0.342597	0.264894
10	0.683264	3.072818	0.222357	0.72446716	1.788608	0.105630	0.335878	0.229494
11	0.643072	2.892064	0.222357	0.72446716	1.788608	0.105630	0.335878	0.215994
12	0.602880	2.711310	0.222357	0.72446716	1.788608	0.105630	0.335878	0.202494
13	0.562688	2.530556	0.222357	0.72446716	1.788608	0.105630	0.335878	0.188995
14	0.522496	2.349802	0.222357	0.72446716	1.788608	0.105630	0.335878	0.175495
15	0.554803	1.992813	0.278402	0.89329620	1.735327	0.102544	0.325925	0.180824
16	0.508570	1.826745	0.278402	0.89329620	1.735327	0.102544	0.325925	0.165755
17	0.462336	1.660677	0.278402	0.89329620	1.735327	0.102544	0.325925	0.150687
18	0.416102	1.494610	0.278402	0.89329620	1.735327	0.102544	0.325925	0.135618
19	0.396288	1.220089	0.324802	1.02887747	1.691215	0.107522	0.324187	0.128471
20	0.346752	1.067578	0.324802	1.02887747	1.691215	0.107522	0.324187	0.112413
21	0.247680	0.635463	0.389763	0.48919106	1.775593	0.095139	0.325042	0.080506
22	0.206400	0.529553	0.389763	0.48919106	1.775593	0.095139	0.325042	0.067089
23	0.165120	0.423642	0.389763	0.48919106	1.775593	0.095139	0.325042	0.053671
25% Cod	0.061920	0.158866	0.389763	0.48919106	1.775593	0.095139	0.325042	0.020127
75% Cod	0.185760	0.476597	0.389763	0.48919106	1.775593	0.095139	0.325042	0.060380

Total nominal twine surface area (sq.m)	14.470775
Drag of cone 'Dc'(kgf)	279.565536
Drag of codend 'Ro'(kgf)	1.053043
Drag of floats 'Df'(kgf)	0.488001
Drag due to ropes 'Dr'(kgf)	0.756000
	===========
TOTAL DRAG OF NET 'D'(kgf)	281.862580
	===========

TABLE 2.4 COMPARATIVE DRAG CALCULATIONS.

PARAMETERS	Net A	Net B	NetC
Head rope length (m)	17.000000	16.000000	19.100000
Periphery of cone (m)	11.723216	11.529933	13.637639
Semi major axis of the cone 'a' (m)	1.865808	1.835046	2.443816
Semi minor axis of the cone 'b' (m)	1.865808	1.835046	1.878118
Cone mouth area (sq.m)	10.936635	10.578978	14.800232
Setting angle of meshes 'O' (deg)	17.969200	20.069075	22.458037
Angle of attack ' (deg)	8.109962	8.415314	8.208601
Total cone drag area (sq.m)	3.855546	3.369674	4.946202
Total nominal twine surface area (sq.m)	11.986583	9.695888	14.470775
Drag of cone 'Dc' (kgf)	217.414220	187.516055	279.565536
Drag of codend 'Ro' (kgf)	0.895429	2.226460	1.053043
Drag of floats 'Df' (kgf)	0.488001	0.488002	0.488001
Drag due to ropes 'Dr' (kgf)	0.644000	0.644000	0.756000
TOTAL DRAG OF NET 'D'(kgf)	219.441649	190.874516	281.862580

TABLE 2.5 CALCULATED AND MEASURED DRAGS.

PARAMETERS	Net A	Net B	NetC
Measured drag (hgf)	242.780000	202.320000	312.860000
Calculated drag (kgf)	219.441649	190.874516	281.862580
Difference in calculated & measured drag (kgf)	23.340000	11.450000	31.000000
Percentage difference	9.610000	5.676000	9.910000
Calculated/measured drag	0.903900	0.943400	0.900900

TABLE 2.6 PAIRED t - TEST FOR THE PROTOTYPE (Net A) AND THE NEW NET (Net B).

Stn.	n	Prawn			Fish			Total		
		d	S	t	d	S	t	d	S	t
3	20	-0.07856	0.13351	2.63142	-0.07878	0.15520	2.27007	-0.15734	0.19042	3.69519
5	20	-0.07763	0.16072	2.16010	-0.05523	0.17035	1.44984	-0.13286	0.27554	2.15633
6	20	-0.06474	0.10196	2.83994	-0.12908	0.23423	2.46450	-0.19382	0.25441	3.40706

C H A P T E R — III

GILL NET

3.1. Introduction

Single walled nets whose lower edge is weighted by sinkers and upper edge is raised by floats, and with a mesh opening of such a size that fish of the required size group can gill themselves in the netting, are classified as gill nets (Brandt, 1972). According to this classification the double walled nets and trammel nets come under tangle nets, and not along with the gill nets, as is seen in certain other classifications. This is because the catch is affected by entangling in the former type of nets and not by gilling.

It is believed in some quarters, that fishermen noticing how some fish got gilled in nets, started designing special nets to effect their capture by gilling. To facilitate this, the mesh circumference has to be at least marginally smaller than the maximum girth of the fish aimed to be caught. Since the fish are mostly caught by hooking the mesh bars behind the gills, these special nets came to be popularly known as gill nets. It is also quite certain that gill nets could have become effective only after it was possible to manufacture large number of uniform meshes of very fine netting yarn. Due to these reasons, as compared with other fishing gear, gill nets can be presumed to have a relatively recent origin (Brandt, 1972).

Based on the mode of operation, gill nets are of two main types (i) fixed gill nets and (ii) floating gill nets. Both types can be operated in surface, column or bottom waters.

Efforts to improve the efficiency of the simple gill nets necessitated certain modifications in the construction of the net. Based on the modifications made, the gill nets are classified as (i) vertical line gill nets - simple gill nets with vertical lines passed through and secured with the meshes of the netting and connected with the head rope at the upper edge and the foot rope at the lower edge, dividing the net into a series of compartments (ii) framed gill nets - a modified version of the vertical line gill net, having both vertical and horizontal lines passing through the meshes and fastened to them, dividing the net into various sections, and (iii) combination nets - nettings of different mesh sizes are joined together. Combination nets were earlier used as experimental nets, but were assimilated by the fishery to exploit fishes of different species and sizes.

Gill nets operated in the Vembanad lake have been reported by Shetty (1965). Kurup and Samuel (1985 b) while describing the fishing gear of the lake, have also classified the gill nets, noting the absence of certain types described by the former and they grouped gill nets of the lake into Drift and Set nets. Under the drift nets are included the following nets i) `Looppu vala' ii) `Ozhukku vala' iii) `Murasu vala' and iv) `Karimeen vala'. Only one type of net, `Koori vala', comes under the category of set gill net.

Fishing principle

The actual capture of the fish by the net varies in different circumstances and depends on the details of the net construction, and on the dimensions and shape of the fish body. The main principle is that the fish cannot pass through the meshes of the net, and while attempting to pass through the mesh, draws the net onto itself with such force that the mesh advances as far as the base of the abdominal and dorsal fins, preventing further advance of the fish. On attempting to escape backward the fish is unable to develop the same force to strip off the mesh (Baranov, 1977). In the case of larger fish the pressure exerted by the net twine at the opercular region of the fish causes the opercle to open a little and the mesh twine rolls and hooks behind the opercle rendering the backward movement of the fish impossible. Capture of fishes by entangling is also common. Thus a net of given mesh size may catch fish of different sizes, but of course with varying success.

Design elements of the net

Gill net, though relatively passive, is efficient in catching sparsely distributed fish in large water basins like lakes where they can be economically operated from small boats with a minimal investment in manpower and equipment. It is a highly selective gear and a rule of thumb states that few fish are caught whose length differ from the optimum by more than 20 percent (Baranov, 1948). Hence a knowledge of selectivity is needed in managing a commercial gill net fishery, as a proper mesh size aids in obtaining the maximum yield (Kennedy, 1950; Peterson, 1954; McCombie, 1961), protecting small fish (Hodgson, 1933; Anon, 1970), and minimizing escapement of injured or dying fishes (Ishida, 1962; Ueno *et al.* 1965; Thomson *et al.* 1971). Selection can be defined as the process that causes the probability of capture to vary with characteristics of the fish. The factors listed by Clark (1960), Steinberg (1964), and Fridman (1973 and 1986) as most important to gill net selectivity are mesh size, extension and elastic properties of the netting yarn, hanging coefficient, strength, flexibility and visibility of the twine, shape of the fish including compressibility of its body and patterns of behaviour. Panicker *et al.* (1978) conducted selectivity studies with gill nets of three different mesh sizes, twine specifications and hanging coefficients to standardise an optimum net for exploiting the commercial size group of *Hilsa toli* and *Pampus argenteus.*

Mesh size

Adroit choice of mesh size assumes considerable importance as it has a direct bearing on the size composition of the catch. Baranov (1948) interpreted gill net capture as a mechanical process that depends only on the relative geometry of the mesh and the fish, and defined the axiom that since all meshes are geometrically similar and all fish of the same species are also geometrically similar, the selectivity curves for different mesh sizes must be similar. Thus, a given net with a given mesh size can successfully catch fish of a certain size only, which are optimal for the net. With increasing deviation of the fish size from the optimum, the number of fish retained in the net decreases (Fridman, 1973).

Studies of Hickling (1939), Havinga and Deelder (1949), Olsen (1959), Joseph and Sebastian (1964), Sulochanan *et al.* (1968, 1975), Sreekrishna *et al.*(1972) and Sohn (1985) were all aimed at determining an optimum mesh size for gill nets, with reference to a specific species.

Net twine

Other than mesh size, the most important characteristics of a gill net are its visibility and stretchability of meshes. These affect, first the avoidance behaviour of the fish and second, the probability of catching fish that swim into the net.

Visibility

The most important element contributing to net avoidance depends on sight, and in general, less visible nets are more successful. Nets of different colour show severalfold difference in catches (Andreev, 1955; Jester, 1973). Koike *et al.*(1958) have shown that the effect of colour may vary with the time of day and other conditions. Parrish (1969) reviewed experiments on the effect of net colour. Hester and Taylor

(1965), Fridman (1973) and Tsuda and Inoue (1973) discussed the theory of how the visibility of nets depend on their brightness-contrast with the background. Steinberg (1964), finding that more visible nets catch a smaller proportion of large perch, postulated that the larger, older fish approach nets more cautiously.

George *et al.* (1975) studied the efficiency and selective action of coloured gill nets in the Gobindsagar reservoir and Narayanappa *et al.* (1977) conducted similar experiments with frame nets in the Hirakud reservoir. Rao *et al.* (1980) studied the effect of coloured gill nets on the catch of seer, pomfrets, tuna and sharks along the East coast of India. A similar study on the effect of colour of webbing on the efficiency of gill nets for *Hilsa* spp. and pomfrets off Veraval was conducted by Kunjipalu *et al.* (1984).

Elasticity

The material of net twine affects the probability of holding the fish that have swum into the net. When multifilament nylon gill nets appeared in the 1940s, they proved to be 2-3 times as efficient as the linen, cotton or ramie nets they replaced (Pycha, 1962; Konda, 1966). Later on in many fisheries the still more efficient monofilament replaced multifilament nylon twines (Larkins, 1963; Konda, 1966). Comparative catch efficiency of nylon over cotton gill nets in reservoir fishing was found by Mathai and George (1972). Khan *et al.* (1975)

studied the comparative fishing power of monofilament and multifilament gill nets. Pillai *et al.* (1989) studied the suitability of HDPE yarn and twine, in place of nylon, for gill nets and found that nylon nets performed better as regards total catch.

Generally an increased elasticity results in the capture of a larger average size of fish and a wider selection range (Ishida, 1969). An increase in flexibility increases the number of tangled fish, broadening the selection range because the size of tangled fish depends less on mesh size than on the size of the wedged fish (Kennedy and Sprules, 1967). Thus twine flexibility is important to selectivity of fish that are easily tangled, but have less effect on selectivity of fish that are seldom tangled.

Thickness

Nets of thinner twine can catch many times more fish, due to the fact that thinner twines are less visible, easier to stretch and more flexibile. Stretchability and flexibility increase continuously as the twine is made thinner, but visibility has a threshold below which all sizes are equally invisibile to the fish (Hamley, 1975). However, in determining the twine thickness, fishing efficiency is not the only factor that is to be taken into consideration, but also the strength of the net. Reduction in twine thickness increases the wear rate of the net, requires more maintenance and the time for disentangling the fish from the net is longer

Several East European workers have tried to relate gill net efficiency to the ratio of twine diameter to mesh size. Baranov (1948, 1977) and Fridman (1973) have found this ratio to be 0.1 for gill nets on the average and its limits to be between 0.005 for fishing in lakes or rivers, when the catch is small and there are no waves, to 0.026 in drift nets fishing at sea when the fishing and operating conditions are more strenuous.

Construction

Various aspects of net construction affect its ability to fish. The most important of these are the hanging coefficient and rigging.

Miyazaki (1964), based on experiments with drift nets opined that for merely getting the fish into the meshes about 30 percent hanging-in is adequate, but to entangle them, the hanging-in should be between 40 and 50 percent or more and if both gilling and entangling is desired at the same time, a 40 percent ratio is appropriate. Khan *et al.* (1985) conducted comparative fishing experiments with frame nets and has indicated that the net with hanging coefficient of 0.4 to be more effective than 0.5 for *Catla catla.*

Regardless of the fact that there are many common features in the operation of set and drift nets, the principles of calculating the rigging differ considerably. In set nets the total buoyancy of the floats is proportional to the weight of the nets and rigging in water, while the total weight of sinkers is proportional to the buoyancy of the floats. In the case of drift nets, the type of net movement is taken into account. Hence, for nets floating without touching the bottom, the buoyancy must be at least twice the weight of nets, ropes and sinkers. Here the sinkers are used only to accelerate the sinking rate of the bottom of the net and is approximately equal to the weight of the net in water. The required net shapes and tension in a drift net moving along the bottom is obtained by controlling the ratio of the buoyant forces to the ballast and changing the pressure of the lead line on the bottom (Fridman, 1973).

Another aspect of rigging that influences the fishing efficiency of gill net is the sag between the floats. Since buoyant forces in the cork line are applied discreetly, the useful net area decreases due to the sag of the cork line between the floats. Hence the distance between the floats and their number is determined on the basis of the permissible loss of the net area (Fridman, 1973).

Method and time of operation

Selectivity is also affected by the way a net is fished (Treschev, 1963). As different sizes of fish may occupy different habitats, the sizes caught may depend on the location and depth of fishing (Parrish, 1963). Progressive accumulation of catch in the gill net decreases the efficiency of the net, eventually reaching a saturation level when no further increase in catch is possible (Baranov, 1948; Kennedy, 1951). Observations on the lunar and tidal influences on gill nets have been made by Mathai *et al.* (1971) and Pati (1981).

3.2. Objectives

Gill netting is one of the more important methods employed for the exploitation of the backwater fishery. Nevertheless, no detailed work has been attempted so far to study the complete design details of the different types of gill nets used in these backwaters. Hence to set the foundation for further work, it was the objective of this study to reclassify and comprehensively define the design details of gill nets operated at present in the Vembanad lake.

Another objective was to evolve a more efficient gill net for the judicious exploitation of *Etroplus suratensis*, a significant species, which on an average provides 25 percent by weight to the total annual production of the backwaters of Kerala, second only to prawn which provides half of the total catch (Sanjeevagosh, 1987). The single most important means of exploiting this species is by gill netting and hence the relevance of the study which was specifically directed towards determining the following parameters of this gill net, locally known as the `Karimeen vala´,

1. Mesh size

2. Twine size and

3. Hanging coefficient

3.3. Materials and method

Preliminary surveys were conducted at various fishing centres of Vembanad lake to identify the different types of gill nets that are operated in the lake. The results of this survey were taken as a basis to classify the gill nets of the lake.

Existing nets

For the detailed study of the different types of gill nets, station numbers 3,5,6 and 7 (Fig 1.1) were opted, as these centres among them had representation of most types of gill nets. The design details of each type of gill net were collected by conducting periodic field surveys of these centres.

Operational details such as method of operation, time and season of operation, number of persons and canoes required and the major species caught were collected for nets of each type for a period of two years from September 1986 to August 1988.

Development of the new design

To evolve a better design, with appropriate parameters for the gill net `karimeen vala', for the efficient exploitation of the target species *Etroplus suratensis*, the optimum size of the species from both the commercial and biological view point was ascertained. This size class was determined from the growth studies of the species made by Jayaprakash (1980), Sumitra *et al*.(1981) and Thampy *et al*.(1987) and by conducting market surveys to determine the price structure in relation to the size and weight of the fish.

For the design of the new net , the basic dimensions of a single unit, such as its hung length and depth and also the number of such units constituting a complete net, were adopted from the prototype. The other important design elements that contribute to the efficiency of the gear were then experimentally determined for the astute exploitation of this size category.

Determination of mesh size

It is very important to fix the mesh size so that the net catches the fish of a given size with the greatest success. The principles of geometric similarity discussed by Baranov (1948) enunciate the mesh size as a function of the length of the fish caught, and is expressed as

$$a = k \cdot l \qquad \text{.......................(3.1)}$$

where a is the mesh bar size
l is the fish length and
k is the mesh selection factor or the proportionality coefficient constant.

Mesh selection factor

The mesh selection factor is a constant which is species specific. The value of `k´ was determined from the lengths of the target species caught by gill nets of differing mesh sizes but similar in all other aspects and operated under identical conditions. To reduce any anomalies `k´ was also inferred from girth measurements.

By length measurements

Plotting the length-frequency graph for a given net, gives the yield curve of the net. The yield curves of nets with different mesh sizes operating under identical conditions differ (Fridman, 1973). This hypothesis was employed to determine the selection factor. Determination of `k´ is more reliable if instead of two, three or more nets with different mesh sizes are used. Hence for this study three gill nets a1, a2 and a3 of mesh bar sizes 35 mm, 37.5 mm and 40 mm respectively, were taken for experimental fishing. All the other design parameters were kept identical (Table 3.1). The nets were operated on a statistically designed method, during night time and a total of 120 hauls were made. The number of target species caught and morphometric data such as standard length, maximum girth, gill girth, gilled girth and weight of individual fish caught, were recorded separately. The yield curves of all three nets were compared with those of one another.

From the graphs, the optimum length (l_1) of fishes caught by nets with mesh size a1 and the optimum size (l_2) of fishes caught with nets of mesh size a2 were found out. The abscissa of the point of intersection of the yield curves gave the length of the fish (l_{o1}) for which the fishing efficiency of both nets was equal. Similarly l_{o2} for the combination of nets with mesh size a2 and a3 was also found out.

The deviations in the fish length $l_{o1}-l_1$ and l_2-l_{o1} being proportional to the given mesh sizes,

$$\frac{l_o - l_1}{a1} = \frac{l_2 - l_o}{a2} \qquad \text{or,}$$

$$l_o \left(\frac{1}{a1} + \frac{1}{a2} \right) = \frac{l_2}{a2} + \frac{l_1}{a1}$$

applying this in equation (3.1)

$$k = \frac{2 \;.\; a1 \;.\; a2}{l_o \; (a1 + a2)} \qquad \text{......................(3.2)}$$

In similar manner \`k´ was worked out for the combination of nets a2 and a3 also (Table 3.2). The value of \`k´ for *Etroplus suratensis* was then taken as the arithmetic mean of the values obtained by the different net pairs.

The value of \`k´ for the given species, determined from the above calculations was then substituted in equation (3.1) to find the mesh bar size required to capture the fish of the optimum size group.

By girth measurements

This method is based on the assumption that a fish upon swimming into a net, is caught if its head girth is smaller than the mesh perimeter.

The selection factor `k´ is found from the girth measurements using the formula proposed by Fridman (1973),

$$k = 0.25 \cdot n \cdot n_0 \qquad \text{.......................(3.3)}$$

where `n´ is the ratio of the mesh perimeter `4a´ to the maximum circumference of the fish `S´ and is expressed as

$$n = \frac{4a}{S} \qquad \text{..........................(3.4)}$$

n_0 is the ratio of the maximum circumference of the fish to its length, l and is given as

$$n_0 = \frac{S}{l} \qquad \text{..........................(3.5)}$$

The data required for the above calculations were taken from the same catch collected during the experimental fishing conducted for determining the value of `k´ by length measurements (Table 3.3).

The theoretical estimates thus made were further checked by studying the ratio of gilled girth to mesh perimeter and maximum girth to mesh perimeter, following the method described by McCombie and Berst (1969).

Determination of twine size

Calculation of twine diameter required for a particular mesh size, was done by postulating that fishing efficiency of the designed net should at least be equal to that of the prototype. Then, considering the geometric similarity of the nets and assuming the fishing conditions to be same, the condition for twine diameter is

$$d_m = d_p \cdot \frac{a_m}{a_p} \qquad \text{.............(3.6)}$$

where d_m is the twine diameter of the new net in mm
d_p is the twine diameter of the prototype in mm,
a_m is the bar size of the new net in mm and
a_p is the bar size of the prototype in mm.

This is termed the equal efficiency conditions (Fridman, 1973). But, even when factors like current, linear dimensions of the net, hanging coefficients, safety margin and net material are considered to be the same for both nets, the loads imposed on the twine as a result of the efforts of single fish which is gilled or entangled in the single meshes of the net has to be considered. The weight, momentum and strength of the fish increase as the cube of its length and hence also as the cube of the mesh opening, whereas twine strength increases as the square of its diameter (Fridman, 1986). Hence, the twine diameter actually required should be more than that required by hydrodynamic resistance alone and is calculated using the formula

$$d_m = d_p \frac{a_m}{a_p} \sqrt{\frac{a_m}{a_p}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3.7)$$

Determination of hanging coefficient

Three simple gill nets of mesh bar 37.5 mm made of nylon twine 210D x 1 x 2 with hanging coefficients 0.4, 0.5 and 0.6 were selected for the experiments to find the appropriate hanging coefficient for the effective exploitation of *Etroplus suratensis.* All the other design details were kept identical for the three nets (Table 3.4). These nets were operated at all four stations during night time, at low tide. The operating time was maintained at 20 minutes. A total of 120 hauls, in ten cycles of three each were made at the four stations. The number and weight of *Etroplus suratensis* caught by nets of different hanging coefficients were collected separately. Fish, other than the target species, were grouped as miscellaneous and only the total weights of such fish caught in the different nets were recorded. These data were statistically analysed, using the three way ANOVA technique and the model used was

$$X_{ijk} = \mu + \alpha_i + \beta_j + \delta_k + \varepsilon_{ijk}$$

where, X_{ijk} is the weight or number of fish caught in the net with the i^{th} hanging coefficient in the j^{th} operation at k^{th} station

μ is the overall effect

α_i i^{th} hanging coefficient effect

β_j j^{th} operation effect

δ_k k^{th} station effect

ε_{ijk} random error

i = 0.6, 0.5,0.4

j = 1,2,3,..........30

k = 3,5,6,7.

The ANOVA for number and weight of *Etroplus suratensis* caught are presented in Table (3.5) and Table (3.6) respectively. The ANOVA for the weight of other fishes caught is presented in Table (3.7).

Rigging

Following Fridman (1973), the buoyancy required for the botton gill net was determined using the formula

$$Q_t = K_q \cdot Q_n \qquad \text{..............................(3.8)}$$

where Q_n is the weight in water of netting and main lines in Kgf.

K_q is the coefficient of buoyancy ranging between 3 and 6.

The value of K_q for the present calculations was taken as 3 since the net was used at very low currents.

The distance between floats was fixed in such a way that with the usual slack, the loss of area due to sag between floats does not exceed 10 percent of the area of the net. This was ascertained using the following formula.

$$S = 0.75 \cdot H \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.9)$$

where

S is the distance between floats in mm and
H is the depth of netting in mm.

In shallow, calm waters, for nets extending from surface to bottom, sinkers can be avoided. However, to facilitate quick sinking of the net and to maintain its shape in water and also to reduce the possibility of entangling, sinkers were provided as in the prototype.

3.4. Results and discussion

Shetty (1965) and Kurup and Samuel (1985 b) have conducted studies on the fish and fishery resources of the Vembanad lake, and the latter have also classified the various gears employed. Kurup and Samuel (1985 b) noticed the absence of 'Narimeen vala', 'Poomeen vala', and 'Chavala vala', from among the various types reported by Shetty (1965), attributing their absence to the depletion of *Lates calcarifer* and *Chanos chanos*, their target species. The present study also did not come across these nets. The inclusion of 'Karimeen vala' under bag nets by Shetty (1965) is another anomaly pointed out by Kurup and Samuel(1985 b). The present study further confirmed that this net is not a bag net but a gill net, specific for the capture of *Etroplus suratensis*.

The results of the present study enables the reclassification of gill nets operated in the Vembanad lake into three major classes namely, the set gill nets, drift gill nets and encircling gill nets. The drift nets are further divided into two groups - those with foot rope and those which do not possess a foot rope (Fig. 3.1).

Therandi vala

No mention of this net is seen in the works of Shetty (1965) or Kurup and Samuel (1985 b). But Hornell (1938) has cited under drift nets, an important type, called `Kolavala´, used in the vicinity of seaward channels to catch large fishes that enter from the sea. It was made of strong hemp with a mesh of 200 mm bar and had light wood of four feet long as floats and stone sinkers. Though the `Therandi vala´ is a bottom set gill net, it can be reliably considered as a descendant of `Kolavala´. The former is found operated exclusively in Cochin channels and are intended for sharks and rays entering the backwaters. The word `Therandi´ means ray in the local dialect. Similarity in mesh sizes, floats and sinkers also highlight the evolution of `Therandi vala´ from `Kolavala´. The change from drifting the net to setting it could have been necessitated by the increased traffic in the channel.

A conventional `Therandi vala´ is depicted in Fig.(3.2) highlighting the design and construction details. Usually nine to thirteen separate units, each of 20 m hung length are linked together during operation. Each of these units are provided with ten floats tied to the head rope ~ 2 m apart, with fourteen or fifteen meshes distributed in between two floats. The floats are long pieces of *Saccharum spontaneum*, locally known as `Nainkana´, which has a relative density of 0.238 and extrabuoyancy of 0.769 g/cc. (Sathyanarayana and Kuriyan, 1962). The extra buoyancy of each float is approximately 340 gf. Two marker buoys, usually thermocole pieces having a volume of ~ 0.015 m^3, are attached to either ends of the head rope by means of polypropylene ropes of ~ 18 m length and 6 mm diameter. Sinkers are attached to the foot rope at the rate of one sinker for every two floats. They are usually granite pieces weighing ~ 700 g. Two bigger granite stones weighing ~ 25 kg. are used as anchors, one at each end of the net, tied with a coir rope of ~ 20 m length to the foot rope.

This is the only gill net having a head rope of polypropylene and a foot rope of coir. The net proper is made of polyamide of specification 210Dx6x3 or 210Dx8x3. One and a half sheet bend knots are used. No selvedge is provided and a hanging coefficient of ~ 0.4 is maintained in most nets of this type.

Operation.

Two persons are required for the operation of this net. Before going for fishing, the net units are cleaned and joined together and arranged in the canoe. On reaching the area of operation, one marker buoy and one anchor weight are tied to the head rope and foot rope respectively at one end. Then the anchor weight is carefully lowered into the water. The net proper along with the floats and sinkers are then paved out by one person, while the second person keeps the canoe moving in the desired direction. The second marker buoy is attached to the head rope at the end of the last unit with the help of the buoy line, the anchor to the foot rope by means of anchor line, and are lowered into the water. The nets are set across the flow of the current.

The `Therandi vala' is usually operated during night, though occasionally, they are also set during the day time. The operating period ranges from two to three hours. While in operation, the stick-like floats are vertically positioned. Though these nets are operated in the shipping channels, they do not pose any problems to shipping.

The main catch comprises of sharks and rays. Occasionally, even sword fishes are caught in this net.

Loopu vala

`Loopu vala' comes under the category of bottom set gill nets. It was used in large numbers in station Nos.2 and 3 and was also encountered in other parts of the lake, though in lesser concentrations. A comprehensive account of the design details of a representative net of this group is featured in Fig.(3.3). An operating unit of `Loopu vala' comprises of four separate pieces that are joined together end to end at the time of operation. Each of these separate pieces have a hung length of 45 - 50 m. and a hung depth of 2.5 - 3.0 m depending on the nature of the fishing area.

A selvedge of one and half meshes depth was present at the top and bottom, but not at the sides. Both the upper and lower selvedges were made of nylon 210Dx3x3 twine, with a mesh size of ~ 90 mm. and mounted directly to the head and foot ropes respectively. A PVC float having an extra buoyancy of ~ 37.5 gf was provided at every 2 meter on the head rope. The hanging coefficient vary between 0.60 to 0.64 in different units. The same hanging coefficient was affected at the foot rope, which had sinkers of granite pieces weighing ~ 500 g each, one for every three floats. The main netting was fabricated with PA 210Dx1x2 twine and had a mesh size of ~ 75 mm. Two meshes each of the main netting goes into each mesh of the selvedge.

Operation

Though Kurup and Samuel (1985 b) have grouped the 'Loopu vala' under the drift gill nets without foot rope, the present investigation has found these nets to be bottom set and also possessing a foot rope. The anomaly regarding the status of this net could have occurred due to the fact that, occasionally in some regions, the same net was used as a drift net by removing the sinkers, in order to harvest the surface swimming species. But even in such instances, the foot rope was present.

The net was mostly set during the night at the turn of tides when the tidal intensity was at its lowest. Hence it could be handled by a single person. On reaching the fishing ground a marker buoy was tied to the head rope by means of a buoy line and was released. Then slowly rowing the canoe in the desired direction, the fisherman lets go the sinkers one by one, which takes the net and floats along with it. A second marker buoy was attached to the head rope of the last piece. Both the marker buoys were usually plastic cans.

The net was set for one to one and a half hours depending on the current intensity. The major catch comprised of species such as *Daysciaena albida*, *Gerres filamentosus*, *Sillago sihama* and *Tachysurus maculatus*, all resident varieties of the lake and available at all seasons. *Mugil cephalus* and *Etroplus suratensis* were also caught, though not in significant quantities.

Kandali vala

Hornell (1938) has mentioned a 'Kandadi vala' having a two inch mesh bar used in the backwaters of Kerala, operated at nights to catch various medium-sized fishes. No further details regarding the design or operation of this net is provided. Later workers also have not mentioned this net in their works. But the similarity in name and mesh size employed, positively suggests that this net and the 'Kandali vala' encountered during the present study are one and the same. The highly restricted occurrence of this net could be the reason for them being left unnoticed by previous workers.

'Kandali vala' is a bottom set gill net found operated only at stations 2 and 3 . It is the shortest gill net operated in the lake with a maximum total hung length of less then 120 m. Fig.(3.4) provides an illustration of the design details of a typical 'kandali vala'. A complete net is made up of four identical units, each having a hung length of 28 to 30 m. The mesh size employed ranges between 100 mm to 110 mm. The main netting is made of 210Dx4x3 polyamide twines and the knots employed are one and a half sheet bend. The netting is mounted on to the head and foot ropes directly affecting a hanging coefficient of ~ 0.6. This was the maximum hanging coefficient come across in any gill net operated in the Vembanad lake. Usually a hung depth of ~ 2.5 m is employed.

The head rope is provided with a number of floats which are pieces cut from larger PVC floats used for purse seines. They have an average extra buoyancy of ~ 40 gf and are tied to the head rope equidistantly. The meshes are also equally distributed between the floats. The foot rope bears a number of granite pieces, each having a weight of ~ 500 g, functioning as sinkers, at the rate of one sinker for every two floats.

Operation

This net is mostly set in the shallower regions of the lake where the depth of water is almost equal to that of hung depth of the net. This enables the net to cover the complete water column. The marker buoys used are small pieces of thermocole tied to the free ends of the head rope, by means of polyethylene twines.

One person can operate this net, which is usually set during night, at the turn of the tides. The operating time depends on the tidal intensity and varies from one to two hours, the net being operated only at the lower current speeds. The setting of the net is similar to that of the 'Loopu vala'. No anchors are used for these nets. The weight of the foot rope and sinkers together help in maintaining the position of the net.

The target species of the 'Kandali vala' are *Lutjanus argentimaculatus* and *Daysciaena albida*.

Chemmeen vala

This is one of the most popular gill nets operated throughout the Vembanad Lake for harvesting the rich prawn resources. The net has derived its name from the target species prawn, which is locally known as 'Chemmeen'. A recent trend has been the widespread acceptance of nylon monofilament for the main netting, in place of nylon multifilament. Design and construction details of nets of multifilament and monofilament nettings are given in Fig.(3.5) and Fig.(3.6) respectively.

In both types a one and a half mesh depth selvedge made of PA 210Dx2x3 and having a mesh size of 60 mm, is provided at upper and lower edges. For hanging the upper selvedge, reeving is used, whereas the lower selvedge is stapled to the sinker line at every third mesh using PA 210Dx4x3 twine. The main and selvedge nettings are laced together with a take up ratio of 2 1. The most popular mesh size is 34 mm, though mesh sizes ranging from 30 to 36 mm are found to be employed, especially in the multifilament nets.

The monofilament nets are in all instances, 100 meshes deep while most multifilament nets are only ~ 75 meshes deep. This is merely due to the fact that the monofilament nettings are available in this dimension, rather than any conscious change made in the basic design. Another variation between the two types is in the hung length of the individual units that form a complete net. While the individual units of multifilament nets are shorter than those of monofilament nets, in the case of the former, more units are incorporated. This is also attributable to the available dimension of the monofilament netting.

A significant difference in the rigging of the multifilament and monofilament nets is in the distribution of floats and sinkers. In both types, cylindrical PVC floats, of diameter 50 mm and thickness 10 mm and having an extra buoyancy of 22.5 gf each, are used. The sinkers are also identical, being granite stones of ~ 170 g each. But in the multifilament version, 35 percent more extra buoyancy and weight are provided at the headrope and footrope respectively. This is the extra force required to maintain the stretched form of the multifilament net, than is required for the monofilament net, since the former has relatively more material by volume and weight.

Operation

Both types come under the bottom drift gill nets with footropes. The main season for `Chemmeen vala´ operation is from December to June. They are not operated during the monsoon season, but are irregularly operated in the post monsoon season in certain areas. These nets are operated during day and night. During day time they are drifted both at low and high tides, but night-time drifting is restricted to high tides.

Depending on the area and tidal intensity, the drifting time varies from 20 to 40 minutes. Most varieties of prawn are effectively caught by these nets, but the major share is contributed by *Penaeus indicus* and *Metapenaeus monoceros.* Fishes such as *Liza* spp. and *Megalops cyprinoides*, both residents of the lake and available at all seasons are regularly represented in the catch in varying quantities.

Karavala

The `Karavala´ is a common gill net operated throughout the lake and comes under drift gill nets with foot rope. The name `karavala´ has been derived from the target species *Penaeus* *monodon* (Tiger prawn), known as 'kara' in the regional language.

The design and construction parameters of a standard 'Karavala' are presented in Fig.(3.7). A typical net consists of four identical units, each having a number of floats, with an individual extra buoyancy of 22.5 gf, distributed equidistantly on the head rope. The aperture of the floats through which the head rope passes is slightly transposed off the centre of the cylindrical float. The head rope is usually of polyethylene having a diameter of 3 or 4 mm. The float line is rove through the edge meshes of the main netting affecting a hanging coefficient of ~ 0.45. Using a PA 210Dx2x3 netting yarn, every third mesh is fixed. PA 210Dx1x2 or 210Dx1x3 was used for the main netting. Mesh sizes ranging from 40 mm to 50 mm are employed.

A pair of jute ropes of 4 mm diameter forms the footrope and the netting is directly mounted to one of these ropes. The two are tied together at an interval of 40 meshes. Pieces of granite weighing ~ 125 g serve as sinkers and are tied to the foot rope at the rate of one sinker for every four floats.

Operation

These nets are employed mainly during the monsoon and post monsoon seasons. They are mostly operated during night, both at high and low tides. Due to their relatively greater length, normally two persons are required to operate this net.

On reaching the fishing ground, one person paves out the sinkers, taking care to see that no entangling of the net occurs, while the other keeps the canoe moving across the flow of the current. A haul-in line tied to the head rope of the last unit is secured to the canoe, which drifts with the net. The extent of obstruction free area available and tidal intensity determine the drifting time which varies from 20 to 45 minutes.

Though the target species are *P. monodon* and *Macrobrachium rosenbergii*, a variety of small and medium sized fishes are caught by these nets.

Koorivala

Among the gill nets reported by Kurup and Samuel (1985 b), 'Koorivala' has been designated as a set gill net. However, in the present investigation, these nets were found to be bottom drift nets. The various aspects pertaining to the design and construction of the net is illustrated in Fig.(3.8). Formerly, the nettings were made of cotton which has now been replaced by nylon. Most of the nets of this type operated in the lake, are made up of six individual units. Each of these units have 20 PVC floats, each with an extrabuoyancy of ~ 20.3 gf. The polyethylene head rope runs through the centre of the cylindrical floats. The netting is directly mounted onto the head rope by reeving, and every third mesh is fastened with a smaller PA 210Dx2x3 twine which runs along the head rope. The hanging coefficient worked out to 0.4, at the float and sinker lines.

The foot rope is made up of a pair of jute ropes, each with a diameter of 4 mm, tied together with PA 210Dx1x2 netting yarn which runs the length of the foot rope. The netting is mounted by stapling onto the foot rope using PA 210Dx3x3 twine, tied to the foot rope at every 3 meshes. The sinkers employed are granite pieces, each weighing around 85 g, one for every three floats.

Operation

Though these nets are meant for the capture of cat fishes, they catch a variety of other fishes also and hence are operated successfully throughout the year, except during heavy rains when it is dangerous to go fishing. The nets are operated during night and day at high and low tides. Fishing is stopped when the intensity of current is maximum.

Before going out for fishing, the cleaned units are attached end to end and are arranged in the canoe with the floats towards the centre and the sinkers towards one end. The sinkers are carefully arranged one above the other to avoid entangling when the net is paved out. A crew of two is required for operating this net. On reaching the fishing ground, one person keeps the canoe moving across the current and away from the net that is being paved out by the other. A haul-in line of polyethylene with the same diameter as that of the head rope is fixed to the head rope and the free end is tied to the canoe which drifts along with the net. The duration of operation depends on the current intensity and the clear area available for drifting the net and varies from 20 minutes to one hour.

The main species caught are *Mystus gulio*, a resident species of the lake, *Tachysurus subrostratus*, *T. maculatus* and *Dayscieana albida* all available throughout the year. A variety of other species are caught with varying intensity and regularity.

Ozhukkuvala

The `Ozhukkuvala', also known as `Oduvala' in certain areas, belong to the group of bottom drift gill nets without foot rope. Fig.(3.9) comprehensively illustrates the design and construction elements of a typical `Ozhukkuvala'.

A standard net of this category is made up of five separate units of 28 - 30 m hung length and 4 - 4.5 m hung depth. It has a relatively large mesh size which varies from 120 to 140 mm in different nets, with a hanging coefficient of 0.45, in most nets. The main netting is PA 210Dx4x3 twine and is mounted by reeving to the head rope, which bears 20 floats distributed equidistantly, each with an extrabuoyancy of 34.5 gf. Since no foot rope is present, the sinkers, which are granite pieces of ~ 150 g each, are tied directly to the meshes at every 40 meshes.

Operation

Before setting out for operation, first the different units are joined together and then the sinkers are attached one by one. The completely rigged net is placed in the canoe with the floats towards the middle and the sinkers towards one end. Care is taken at the time of paving out the net, since the absence of foot rope coupled with the large mesh size, greatly enhance the possibility for the sinkers to get entangled with the netting.

The net can be operated during day or night and a crew of two is necessary. The proliferation of stake nets have drastically reduced the free area available for drifting, severely affecting the efficiency of these nets which are specifically aimed at widely scattered species and hence require a wider area of operation, to be effective. The drifting time ranges from 45 minutes to two hours depending on the distance available without obstructions and the tidal intensity. On an average, three to five settings are possible in a day. The net is profitably operated during the monsoon and post monsoon seasons with August being the peak season. The major catch comprises of *Mugil cepahlus* and *Daysciaena albida*, both resident varieties of the lake.

Murasu vala

'Murasu vala' is the only surface drift gill net operated in the Vembanad Lake. It is targeted for the capture of *Hyporhamphus* (H) *xanthopterus*, which is locally known as `Kolan'. Hence in certain areas this net is also known as `Kolavala'. This is also the longest of all gill nets operated in the lake and is made as a single unit, dispensing of the general practice of making the nets in smaller identical units and joining them before operation.

The design and construction details of a typical `Murasu vala' is illustrated in Fig.(3.10). The hung length vary between 250 and 275 meters. A unique feature of this net is that, horizontally it comprises of two sections. The upper section is the actual fishing part of the net and is fabricated with PA 210Dx1x2 twine and has a mesh size of 26 mm. It is mounted by stapling with the aid of a PA 210Dx3x3 twine secured to the head rope on either side of each float. The head rope passes through the floats, which are hollow pieces of *Calotropis gigantica*, locally known as `Erukku'. This light wood has a relative density of 0.375 and an extra-buoyancy of 0.624 grams per unit volume. Each piece used in the `Murasu vala' has an average length of 60 mm and being hollow, has an outer and inner diameter of 12 mm and 4 mm respectively.

The lower part functions as the sinker and no particular mesh size or twine specification is mandatory for this part. Nevertheless, a smaller mesh size and thicker twine diameter are usually employed. The depth of this portion depends upon the weight in water, which manifests in its ability to hold the main netting in a stretched condition during operation. The joining ratio adopted between the main netting and the lower portion, in the example illustrated is 3:4 ; 3:4 ; 4:5, but varies depending on the number of meshes in the lower portion which has no direct proportion to the meshes in the main netting.

Operation

These nets are usually operated by a single person from a plank built canoe. The operation is much easier than the other gill nets, since there are no sinkers to cause any entangling. A thermocole piece of ~ 20 cm^3 is tied at either ends of the net, on the head rope with a piece of twine as marker buoys.

The ideal season for harvesting the target species *H.*(H).*xanthopterus* is September - March. The net can be operated by day and night. But during day time, heavy losses occur due to birds which take the catch. The nets are drifted at low currents during the turn of the tide, and depending upon the tidal conditions three to four operations are possible per night. Better catches are noticed during full moon nights. Practically all the target species caught are found to be gilled perfectly. The catch also comprises of *Hyporhamphus* (H) *limbatus* and *Strongylura strongylura*, both resident species and *Strongylura leiura leiura*, a migrant variety, which are commonly seen during November to May.

Karimeen vala

The term `Karimeen´ in vernacular refers to the species *Etroplus suratensis* and hence the net specifically meant for their exploitation came to be popularly known as `Karimeen vala´. Though Kurup and Samuel (1985 b) has classified this net as a drift net, the mode of operation positively suggests that they can be grouped under encircling gill nets - as per the classification of Brandt (1972).

Commercially this is a very important net, since it is the principal mode of exploiting *Etroplus suratensis*, which on an average provides 25 percentage by weight to the total annual production of the backwaters of Kerala. The design and construction details of a standard `Karimeen vala´ is depicted in Fig.(3.11).

A typical net of this class consists of four identical units, each with a hung length of 40 to 50m and a hung depth of 3.5 to 3.75m . The main netting is of PA 210Dx1x2 twine. The mesh size ranges between 65 to 90 mm. The meshes are mounted by reeving method onto the head rope, on which are distributed a number of floats equidistant from one another. The commonly used floats are pieces of *Saccharum spontaneum*, locally known as `Nainkana´, which has a relative density of 0.238 and an extrabuoyancy of 0.769 g/cc.

The sinker line consists of a pair of jute ropes of

~ 4 mm diameter each. The netting is mounted by reeving onto one of them and the two are tied together at every eight meshes. Sinkers, each weighing ~ 100 g, are provided on the sinker line at a distance of 8 m and with 280 meshes in between. The hanging coefficient vary between 0.35 to 0.37.

Operation

A crew of two is required for operation, which is invariably during the night. The operating principle makes use of the behaviour of *Etroplus suratensis*, which frequents rocks or other obstructions with crevices. Hence the fishermen paddle up to a short distance away from such likely spots and then slowly drift in, causing the least possible disturbance. They then very quietly set the net, either encircling the obstruction if water-based, or if nearer to shore covering the particular area, with the canoe between the shore and net. Then they paddle away from the net towards the land and start making noise by hitting on the sides of the boat with the paddle or any other object. The frightened fishes get caught in the net. The net is hauled after about 15 to 20 minutes of setting. An average of 5 to 8 operations are possible before the tide changes.

The net is operated only at low tides and covers the entire water column. Catch is found to be rather poor on full moon days. Species such as *Etroplus maculatus*, *Megalops cyprinoides* and *Wallago attu*, all resident varieties of the lake and commonly occurring, *Ompok bimaculatus*, a migrant variety available rarely during June to November, *Tachysurus subrostratus*, *Puntius sarana*, *Gerres filamentosus* and *Labeo dussumieri* are also caught irregularly and in varying quantities.

Table(3.8) gives the consolidated details, of gill nets operated in the Vembanad lake.

New Design

An improved design has been evolved for the `Karimeen vala', for the efficient exploitation of *Etroplus suratensis* belonging to the optimum size group.

To fix the mesh size, the selectivity factor `k' for the species was ascertained by length-frequency measurements, using nets with mesh bar size 35 mm (a1), 37.5 mm (a2) and 40 mm (a3). The frequency curves of all three nets follow the normal distribution pattern (Fig 3.12). The value of l_{01} of nets a1 and a2 was 169.42 mm and that of l_{02} of nets a2 and a3 was 181.54 mm. Substituting the values in equation (3.2), the value of `k' for nets a1 and a2 was found to be 0.214 ($k_1$) and that for a2 and a3 it was 0.213 ($k_2$). Taking the arithmetic mean, the value of `k' was obtained as 0.213 (Table 3.2).

The selectivity factor was also estimated by maximum girth-frequency studies, for the three nets (Fig. 3.13). The maximum frequency for net a1 was for the maximum girth of 166.73 mm, that for net a2 was 173.46 mm and for net a3 was

184.04 mm. The corresponding length of fish at these girths were 165.5 mm, 172 mm and 183.5 mm respectively. The value of `k´ worked out using the formula of Fridman (1973) was 0.211, 0.218 and 0.218 for nets of mesh bar 35 mm, 37.5 mm and 40 mm. respectively (Table 3.3). The selection factor was 0.216, taking the average for the three nets.

The average value of `k´, from both the length-frequency and girth-frequency studies worked out to 0.215.

With the value of `k´as 0.215, the theoretical estimate of mesh size required to exploit the most desirable size group of *Etroplus suratensis* worked out to 36.5 mm bar size.

The ratios between gilled girth to mesh perimeter and maximum girth to mesh perimeter (McCombie and Berst, 1969) were plotted separately, with percentage frequency distribution of the catch under different mesh sizes, and are given in Fig.(3.14) and (3.15) respectively. There was a shifting of peak to lower values for increases beyond 35 mm bar size. The peak values for mesh bars 35, 37.5 and 40 mm were 1.20, 1.15 and 1.175 respectively. The ratio remaining the same, the size of the fish caught was larger for bigger mesh sizes . Therefore increasing the mesh bar size upto 35 mm shows corresponding increase in the fish size and efficiency, whereas for nets of 37.5 and 40 mm bar there is no proportionate increase in the size of fish. The low efficiency indices of 37.5 and 40 mm bar can reasonably be attributed to the inability of these nets to catch the predominant size group retained in 35 mm bar mesh.

The graph drawn with the ratio of maximum girth to mesh perimeter also showed the same characteristics. The catching efficiency was high when the gilled girth of the fish was 1.15 to 1.20 times as great as the mesh perimeter (Fig. 3.14). At girth perimeter ratios less than 1.14 and beyond 1.20, low efficiency indices were observed. Similarly, high catching efficiency ratios were observed for the three nets when the maximum girth of the fish was 1.14 to 1.20 times the mesh perimeter. The similarity of efficiency indices shown by both the graphs can be attributed to the greater percentage of *Etroplus suratensis* being caught by jamming of the single mesh at the maximum girth region. The declining efficiency at ratios 1.1 and less may be attributed to the escapement of the fish through the mesh and the same beyond the ratio 1.2 to the inability of the fish to enter the mesh. However, the presence of some catch beyond the ratio 1.2 and upto 1.31 in the graphs based on gilled girth and also the graph drawn with maximum girth values can be explained as due to the capture of restricted numbers of larger fishes by entangling.

The study of the ratio between gilled girth to mesh perimeter and maximum girth to mesh perimeter have confirmed the theoretical estimates made for the mesh bar size by length and girth measurement studies, to be ideal for the exploitation of the desirable size group.

The twine diameter required for the gill net with mesh bar size of 36.5 mm was found out, postulating that fishing efficiency of the net should at least be equal to that of the nets that are operated at present. The prototype selected had a mesh bar size of 39 mm and was made of 210Dx1x2 nylon twine having a diameter of 0.37 mm. Using the formula (3.6) proposed by Fridman (1986), the diameter for the new net was found out to be 0.34 mm. But, twines of lesser diameter than 0.37 mm (210Dx1x2) are not manufactured in our country and hence the same was recommended for the new net.

The number and weight of *Etroplus suratensis* and other miscellaneous fishes caught in nets of hanging coefficients 0.6, 0.5 and 0.4 are presented in Table (3.9).

Hanging coefficient 0.4 has shown better preference over 0.5 and 0.6 in the case of *Etroplus suratensis* by number at 43.67, 43.48, 45.28 and 40.84 percentage and by weight at 45, 43.65, 46.05 and 41.45 percentage at stations 3, 5, 6 and 7 respectively (Fig. 3.16). However, hanging coefficient 0.5 has shown better preference in the case of other species by weight, followed by hanging coefficients 0.6 and 0.4 (Fig. 3.17).

From the ANOVA Table (3.5), for the number of *E.suratensis* fishes caught, there is significant difference between hanging coefficients ($p < 0.001$), and between stations ($p < 0.001$). The least significant difference (LSD) for hanging coefficients at 5 percent level for the log of number of *E.suratensis* caught was worked out using the formula

$$\sqrt{\frac{2}{r} \times V_E} \times t_{0.05} = 0.03896$$

The hanging coefficient 0.4 is catching the highest number of *E.suratensis*, followed by hanging coefficients 0.5 and 0.6.

The LSD at 5 percent level for stations is 0.04498. Station 7 is having significantly higher number of fishes, followed by stations 3, 6 and 5. There is no significant difference in the number of *E.suratensis* caught at stations 3 and 6 and 5 and 6 at 5 percent level. Here also the variation between operations is not significant at 5 percent level indicating that the experimental conditions were identical.

In the ANOVA Table (3.6) for weight of *E.suratensis* caught there is significant difference between the hanging coefficients ($p < 0.01$) and between stations ($p < 0.05$). In order to separate which hanging coefficient is having significantly higher catch, the LSD at 5 percent level was worked out by the formula

$$\sqrt{\frac{2}{r} \times V_E} \times t_{0.05} = 0.1673$$

The mean of the log catch for the three hanging coefficients were worked out. There is significant difference in the hanging coefficient 0.4 compared to 0.5 and 0.6. The hanging coefficient 0.4 is having significantly higher catch followed by 0.5 and 0.6.

The LSD at 5 percent level for stations were worked out as 0.19323. Station 7 is having significantly higher catch followed by stations 3, 6 and 5. There is no significant difference between stations 3 and 5.

There is no significant difference between operations at 5 percent level indicating that the experimental conditions were same throughout the operations.

Between hanging coefficients, there is significant difference in the weight of miscellaneous species caught ($p < 0.01$) ANOVA Table(3.7). Also the 'between stations' variations were significant at 5 percent level. The LSD for hanging coefficients at 5 percent level is 0.18736. Hanging coefficient 0.5 is having significantly higher quantity of miscellaneous fishes followed by hanging coefficients 0.6 and 0.4. There is no significant difference between 0.6 and 0.4, indicating that 0.5 is the optimum.

The LSD for stations at 5 percent level is 0.21663. At station 7 miscellaneous fish catch is significantly more compared to stations 5, 6 and 3. However, there is no significant difference in the weight of miscellaneous fishes caught in stations 3, 5 and 6 at 5 percent level.

The total buoyancy required for a single unit of hung length 40 m and depth 3.5 m was calculated as 3705 gf, using equation (3.7).

The maximum permissible distance between floats was calculated making use of equation (3.8) and fixed at 2.6 m , so that the area lost due to sag between floats do not exceed 10 percent of the total area of the netting. However, as smaller floats in larger numbers give better shape and uniform buoyancy to the net, and also due to the practical difficulty in attaching bigger floats, the total buoyancy was distributed in 27 floats each with an extrabuoyancy of 135 gf, attached to the head rope at a distance of 1.5 m between them.

As in the prototype, sinkers weighing 200 g each were rigged on the foot rope at the rate of one sinker for every four floats. But, the granite stones used as sinkers in the prototype were replaced with lead sinkers in the new net. A detailed illustration of the new design for 'Karimeen vala' with the relevant construction parameters is given in Fig.(3.18).

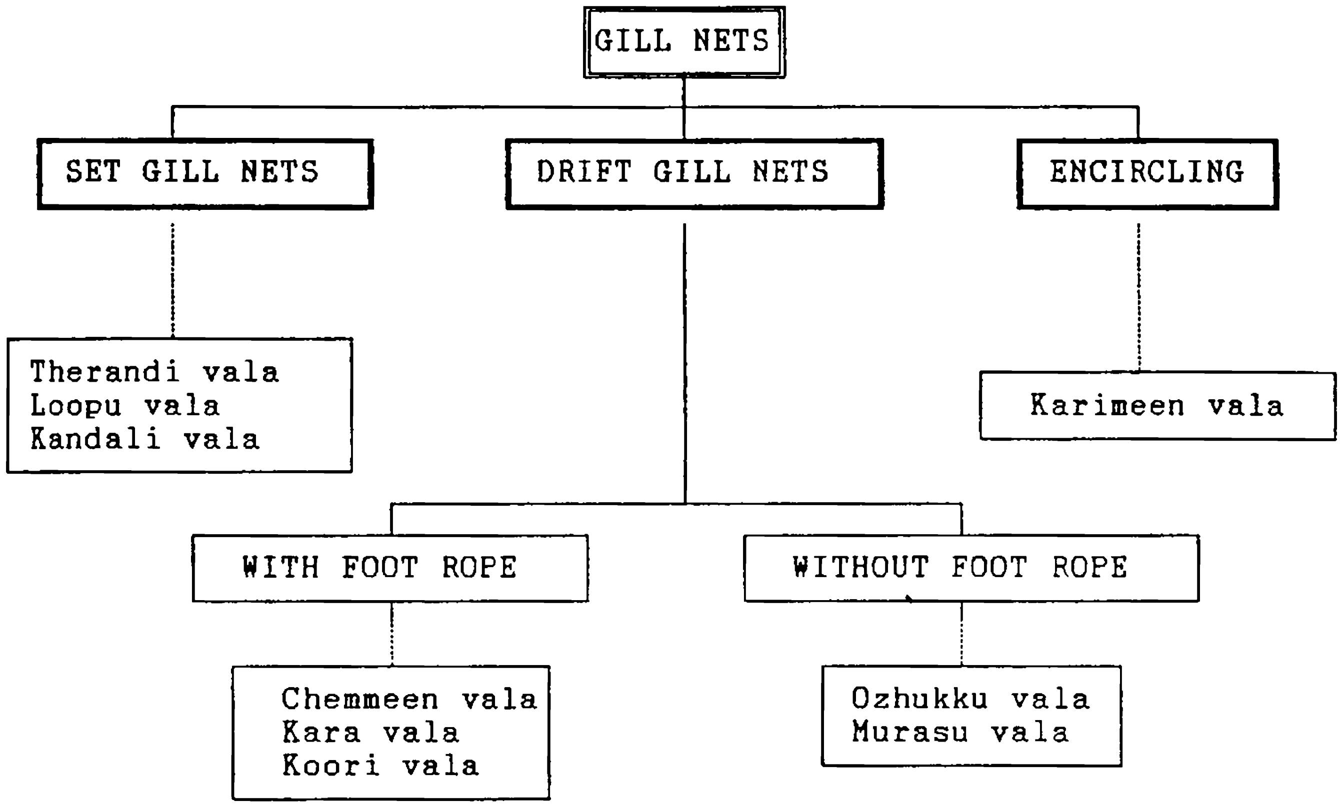


FIG. 3.1 CLASSIFICATION OF GILL NETS OPERATED IN THE VEMBANAD LAKE.

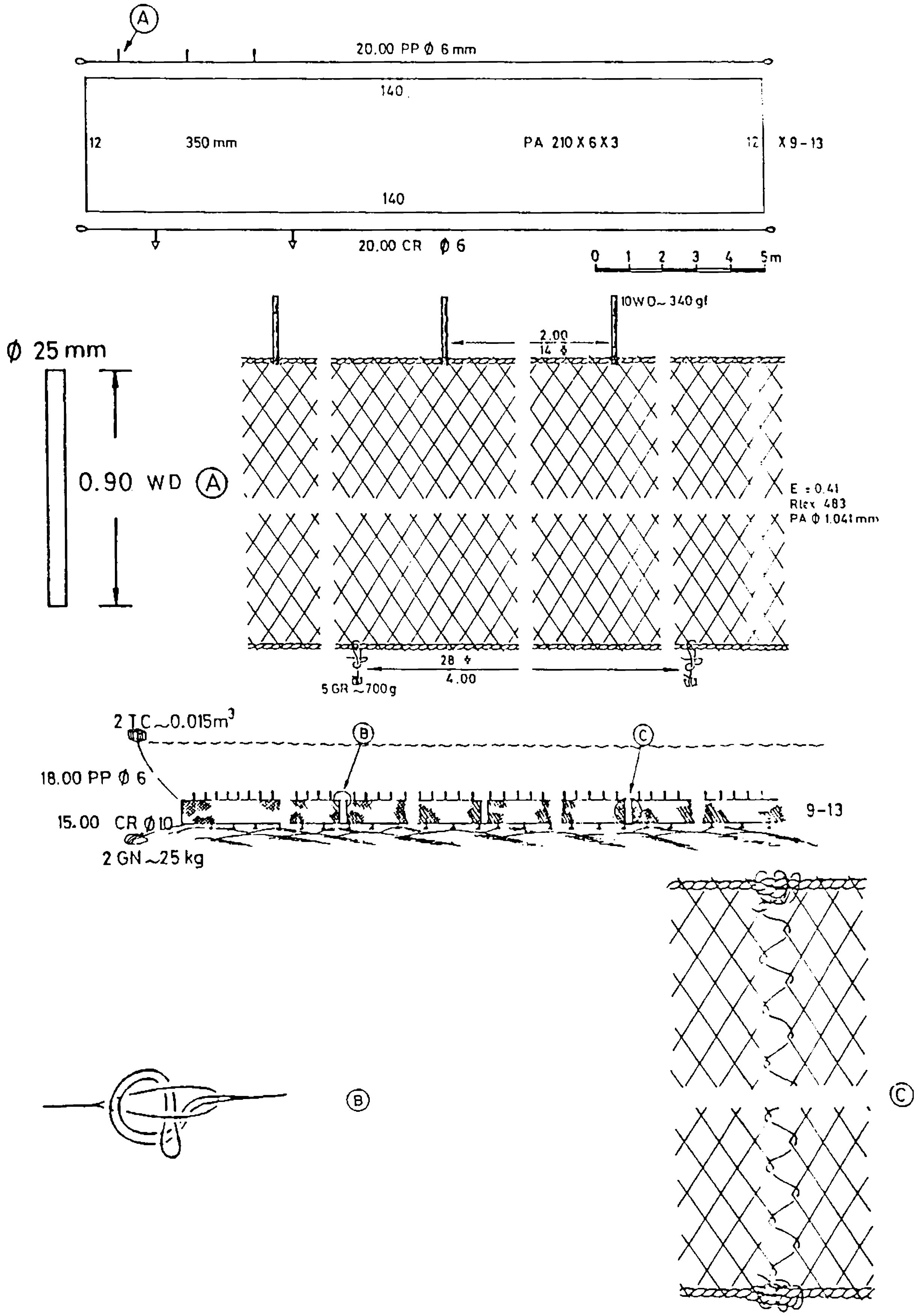


FIG. 3.2 DESIGN OF GILL NET - 'THERANDI VALA'
Shark, Ray.

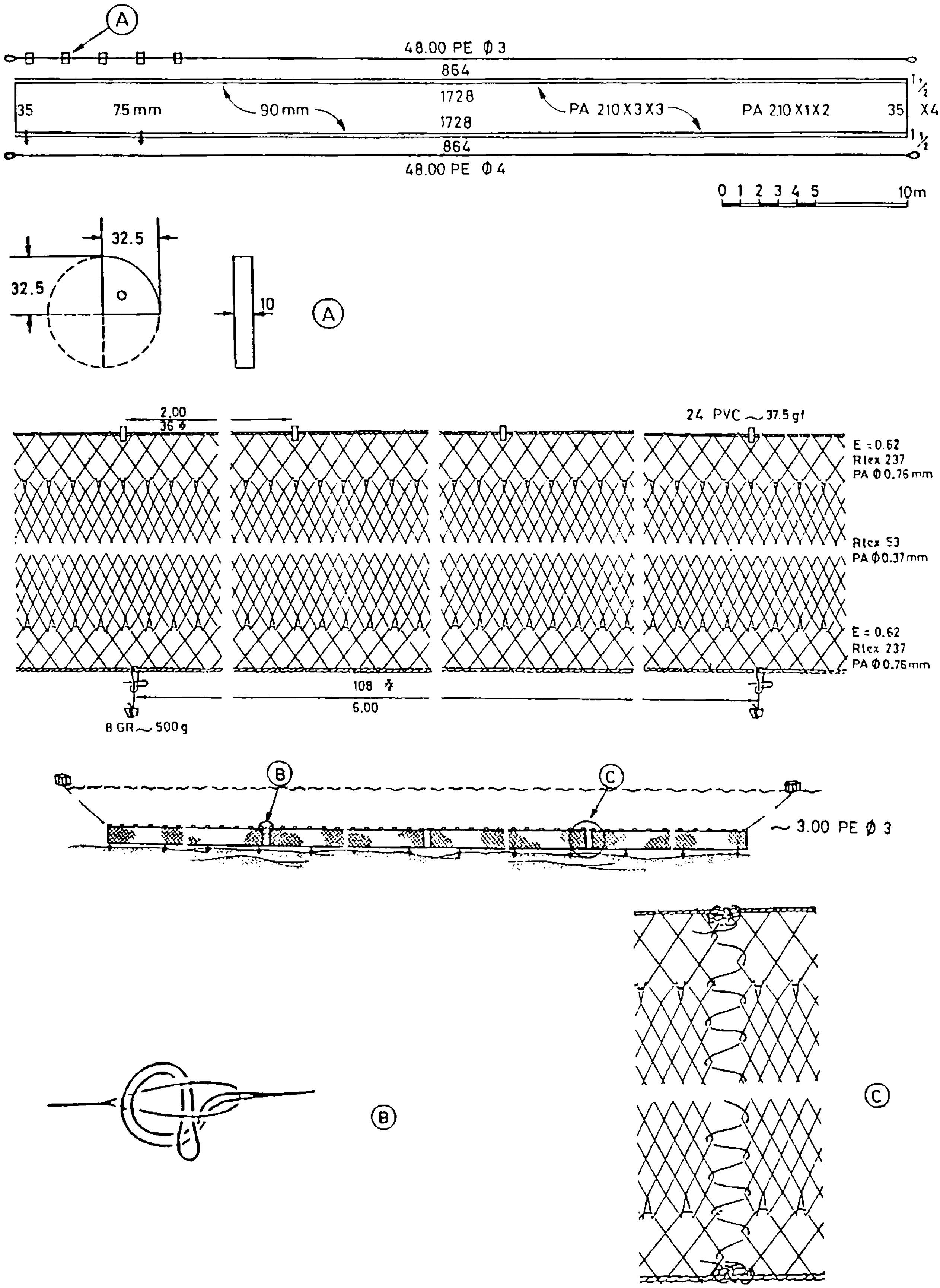


FIG. 3.3 DESIGN OF GILL NET - 'LOOPU VALA'
Jew fish, Silver whiting.

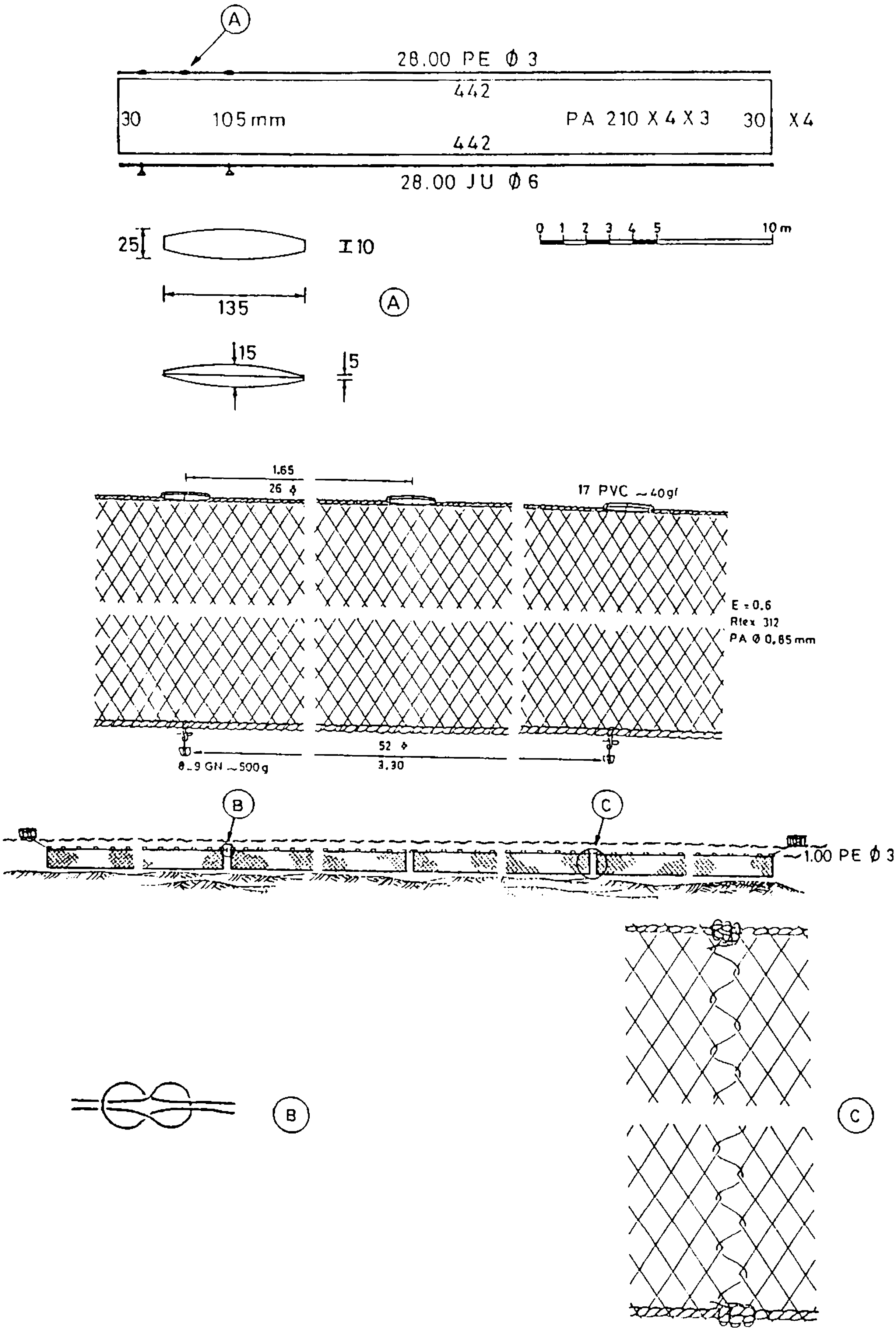


FIG. 3.4 DESIGN OF GILL NET - 'KANDALI VALA'
Red snapper, Jew fish.

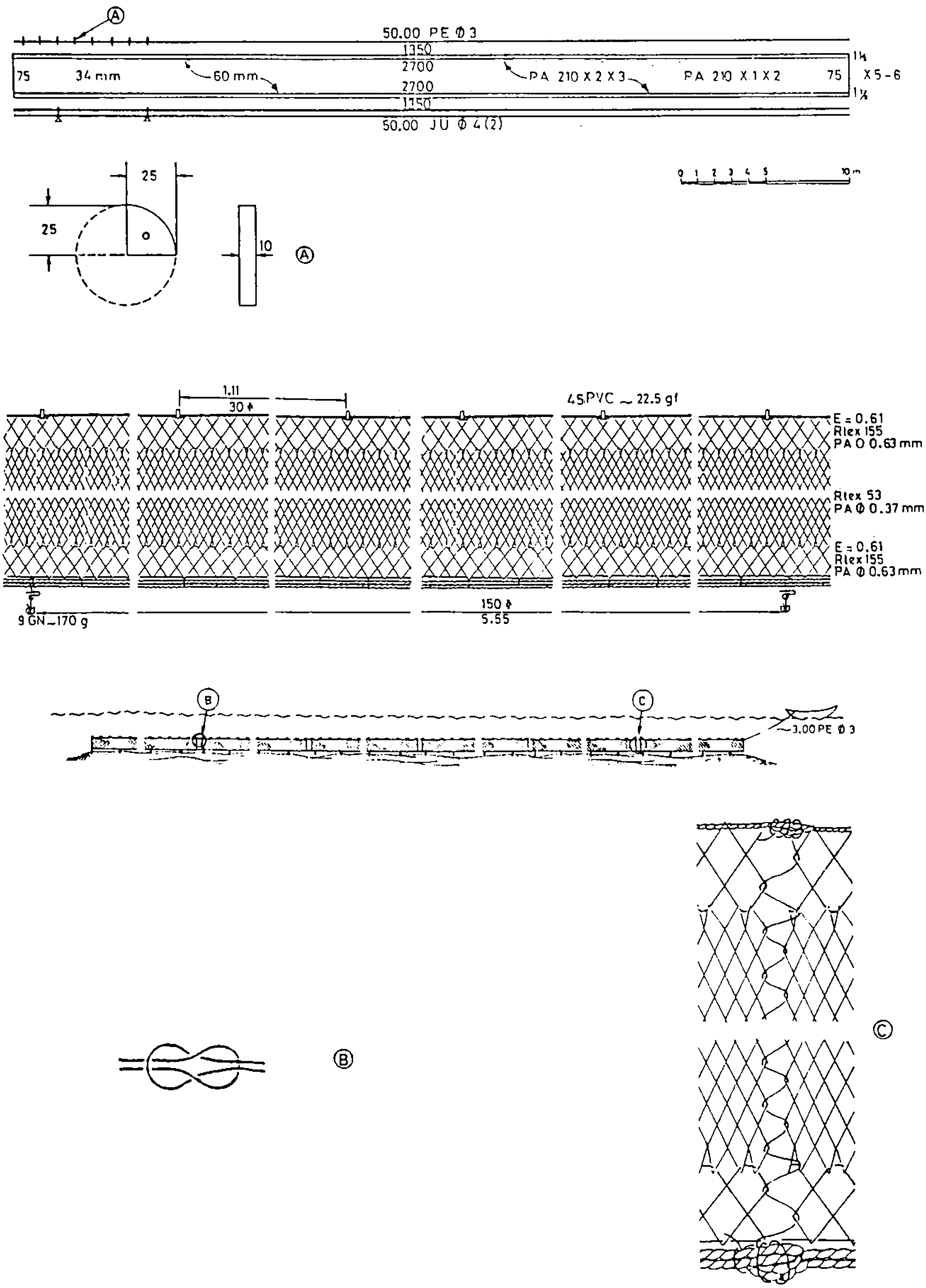


FIG. 3.5 DESIGN OF GILL NET - 'CHEMMEEN VALA' (Multifilament) Prawn.

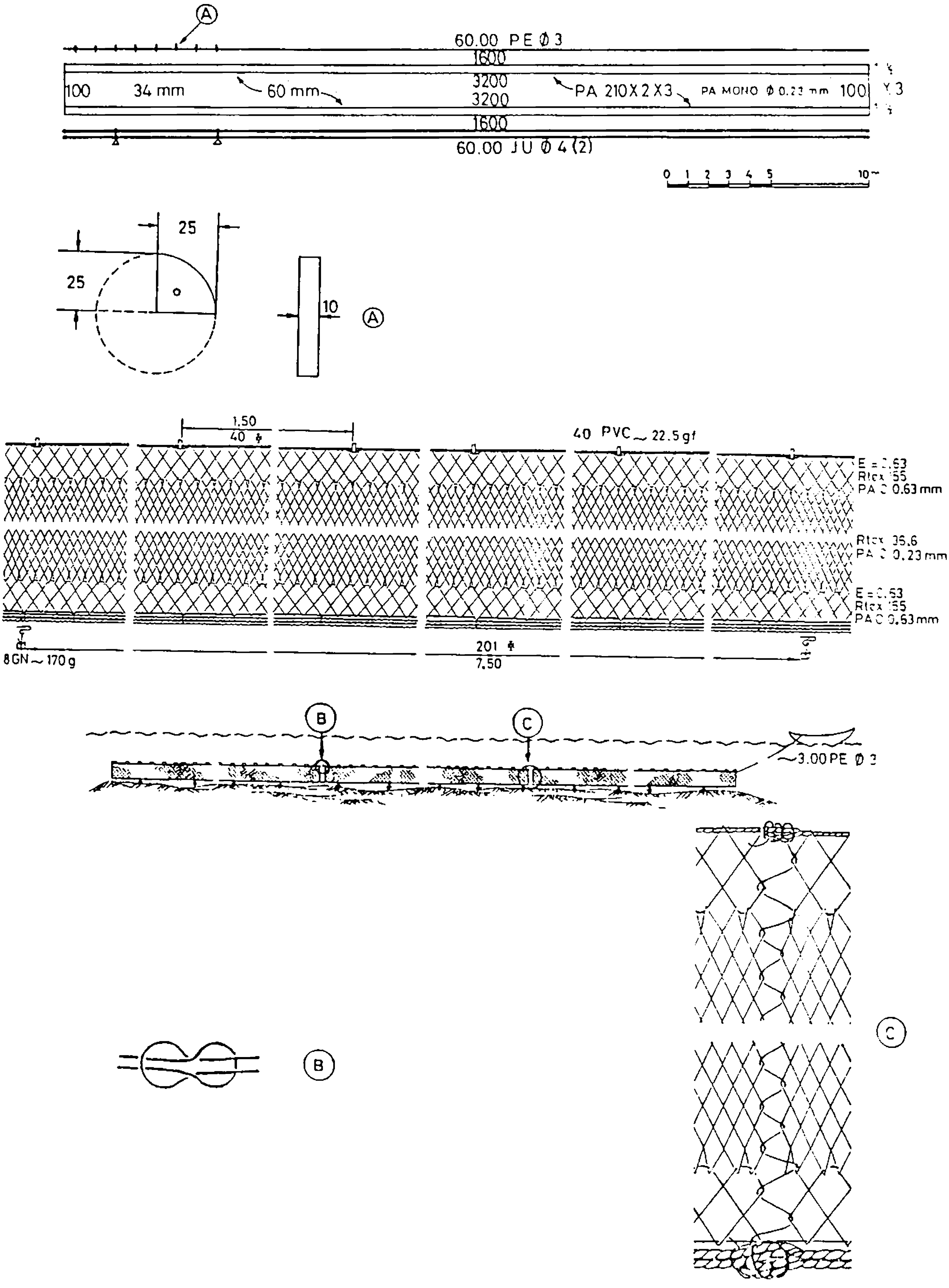


FIG. 3.6 DESIGN OF GILL NET - 'CHEMMEEN VALA' (Monofilament)
Prawn.

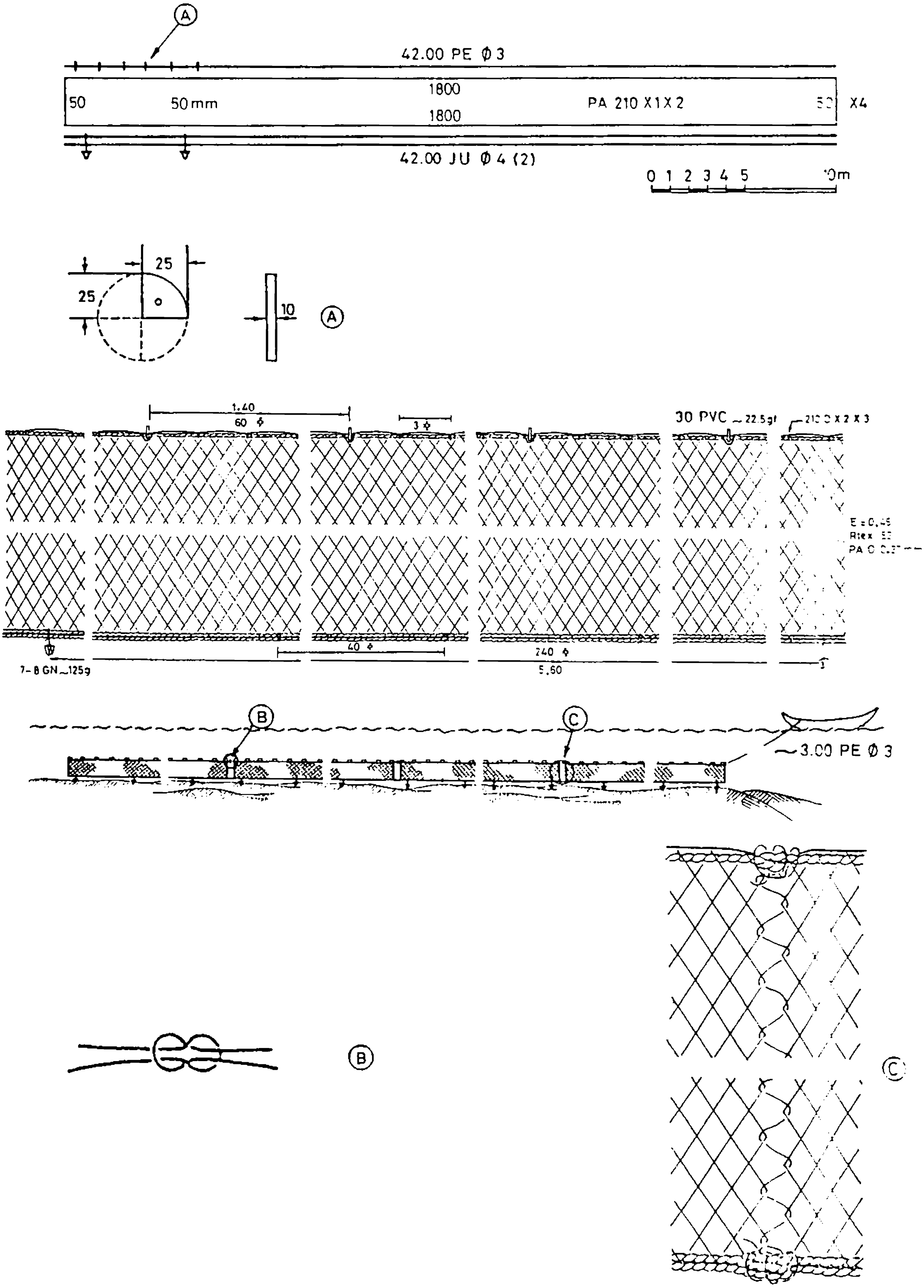


FIG. 3.7 DESIGN OF GILL NET - 'KARA VALA'
Tiger prawn, Indian giant freshwater prawn.

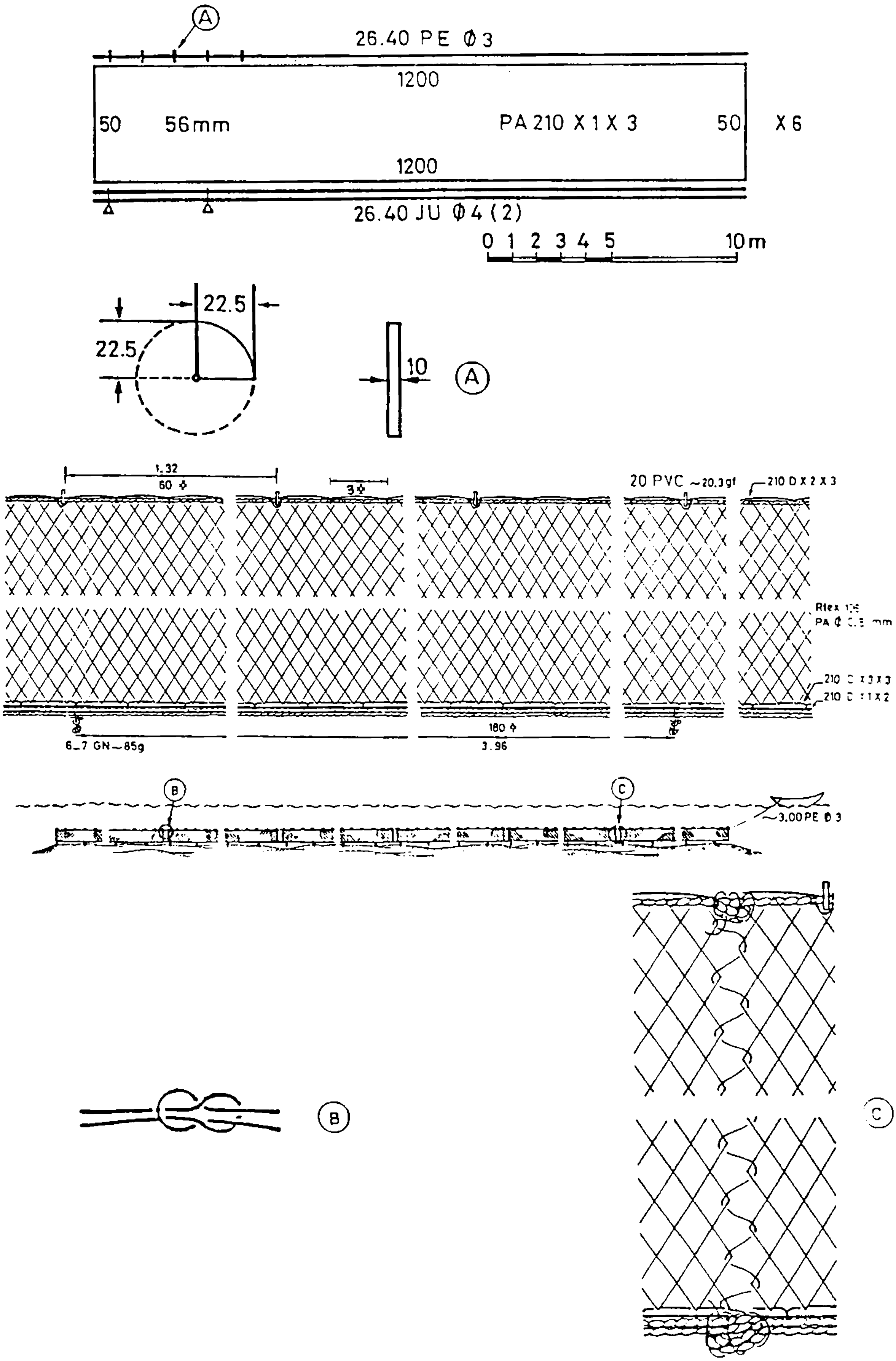


FIG. 3.8 DESIGN OF GILL NET - 'KOORI VALA'
Cat fish

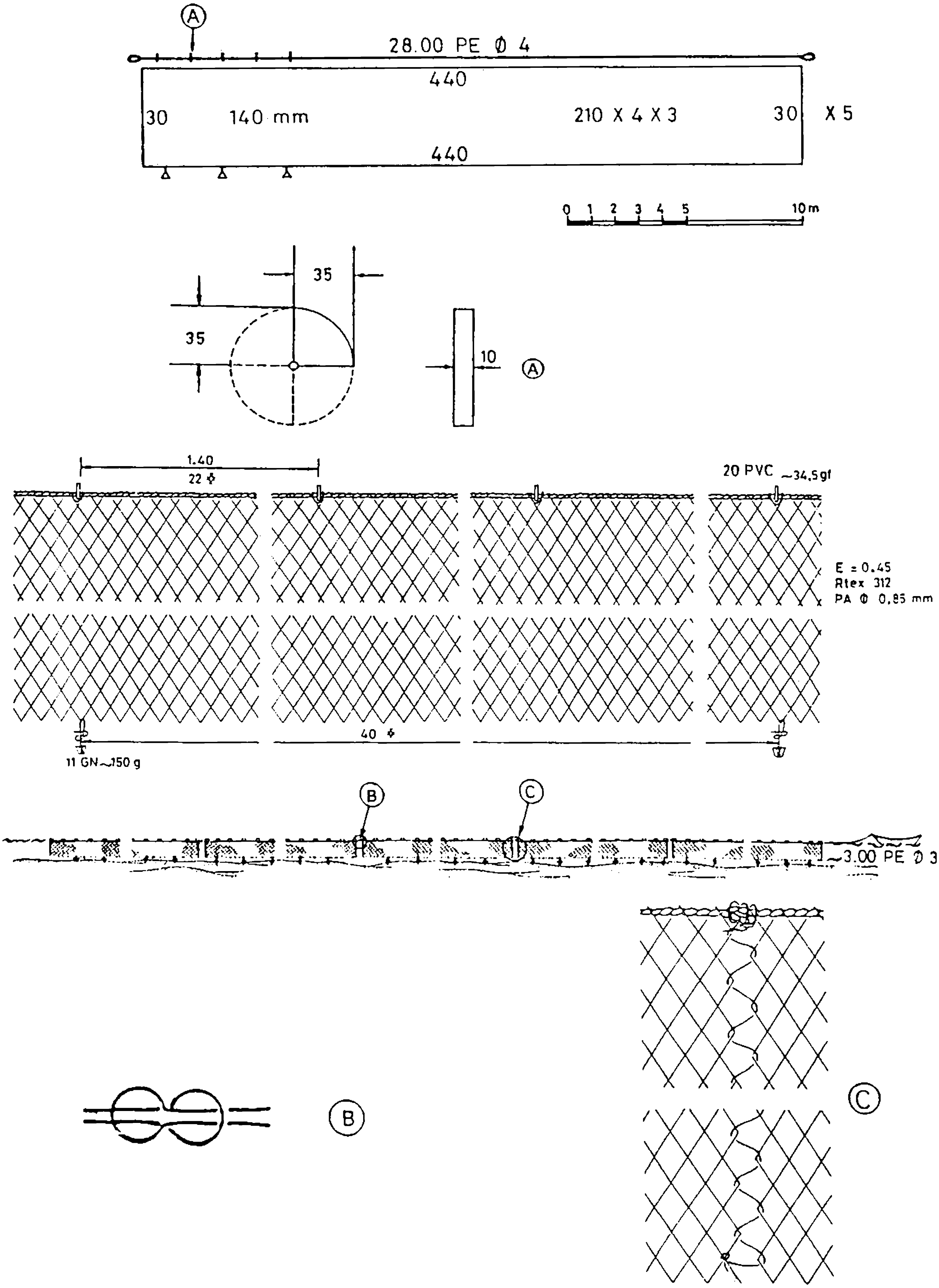


FIG. 3.9 DESIGN OF GILL NET - 'OZHUKKU VALA'
Mullet, Jew fish.

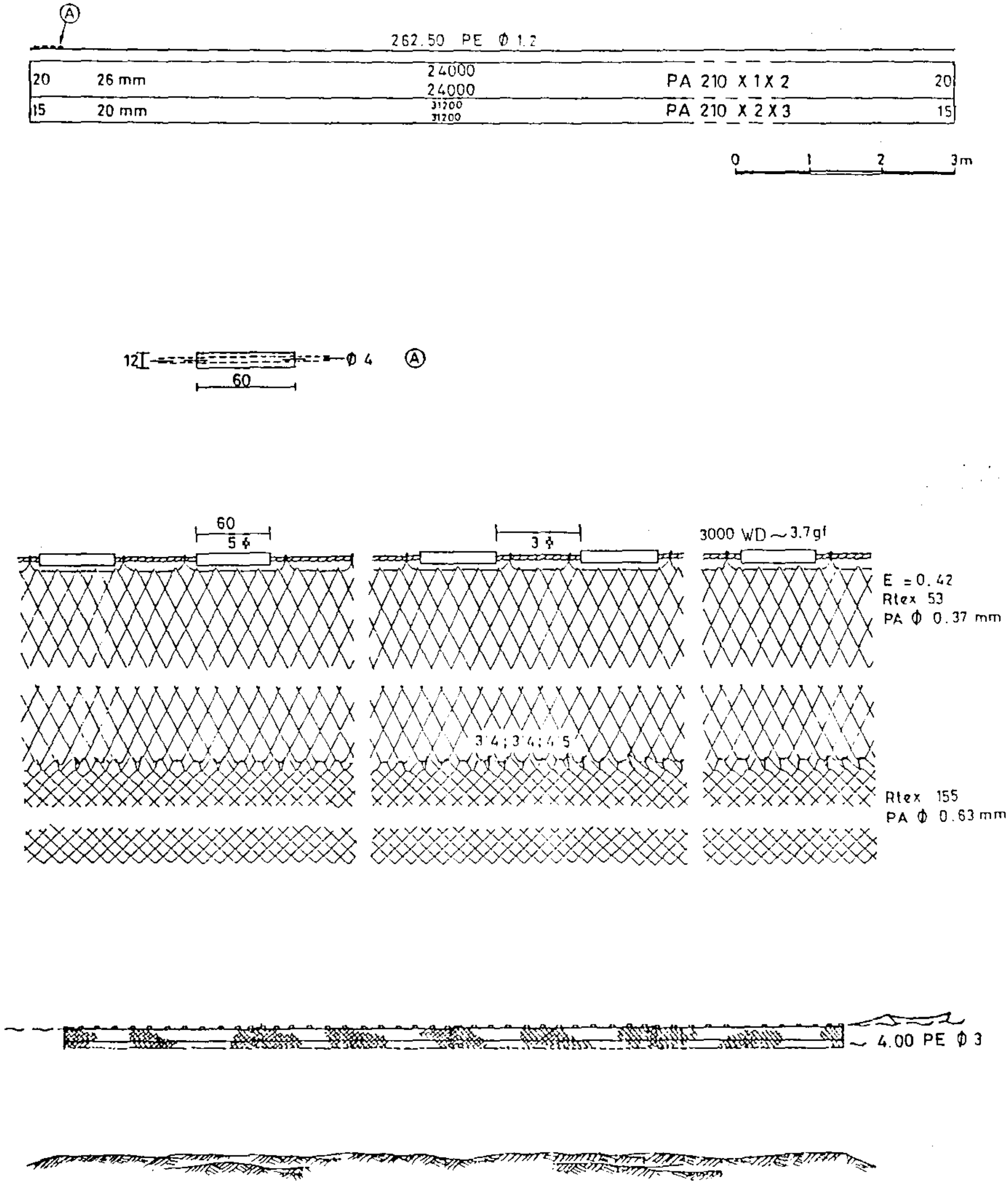


FIG. 3.10 DESIGN OF GILL NET - 'MURASU VALA'
Red-tipped half-beak, Gar fish.

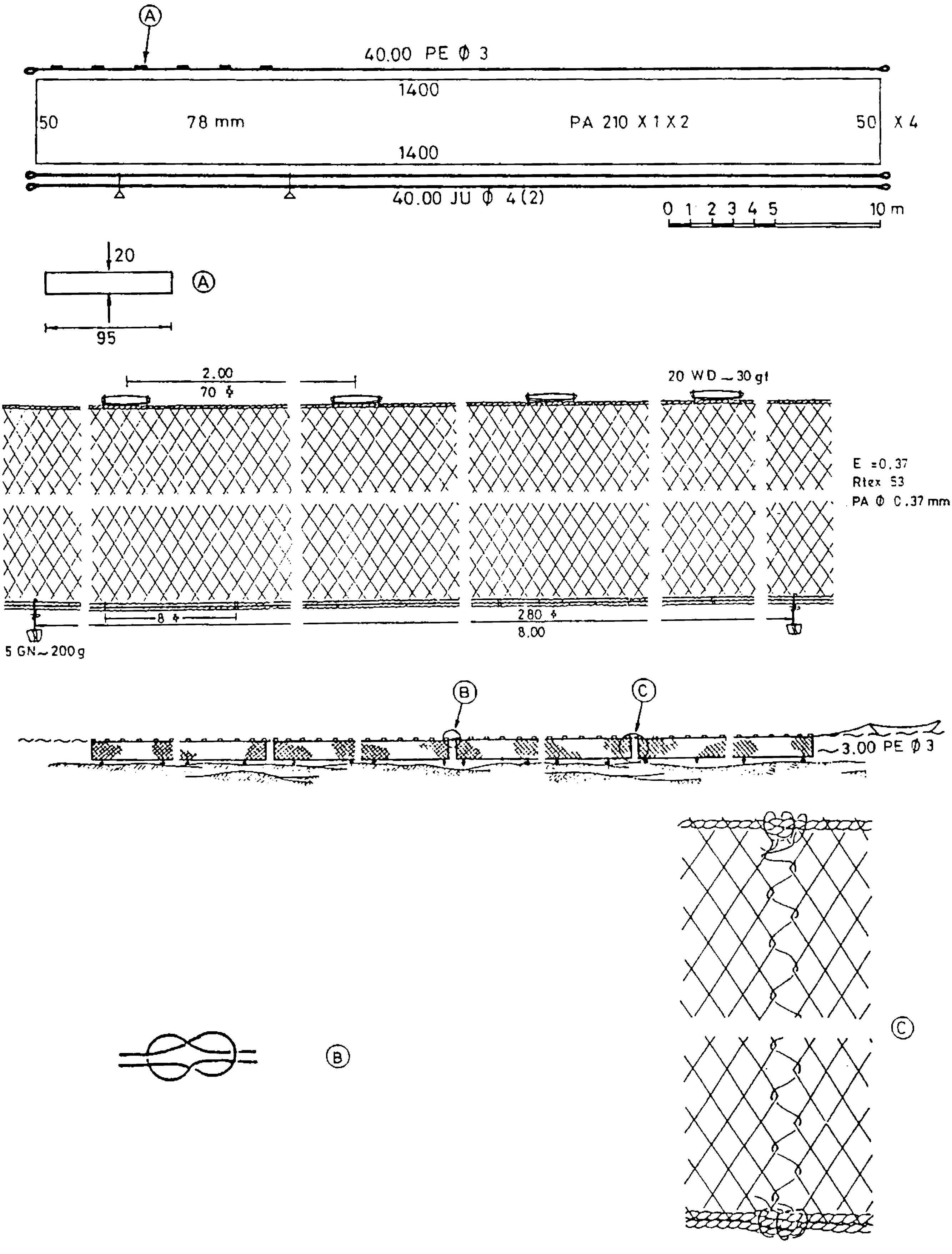


FIG. 3.11 DESIGN OF GILL NET - 'KARIMEEN VALA'
Banded and Spotted Etroplus.

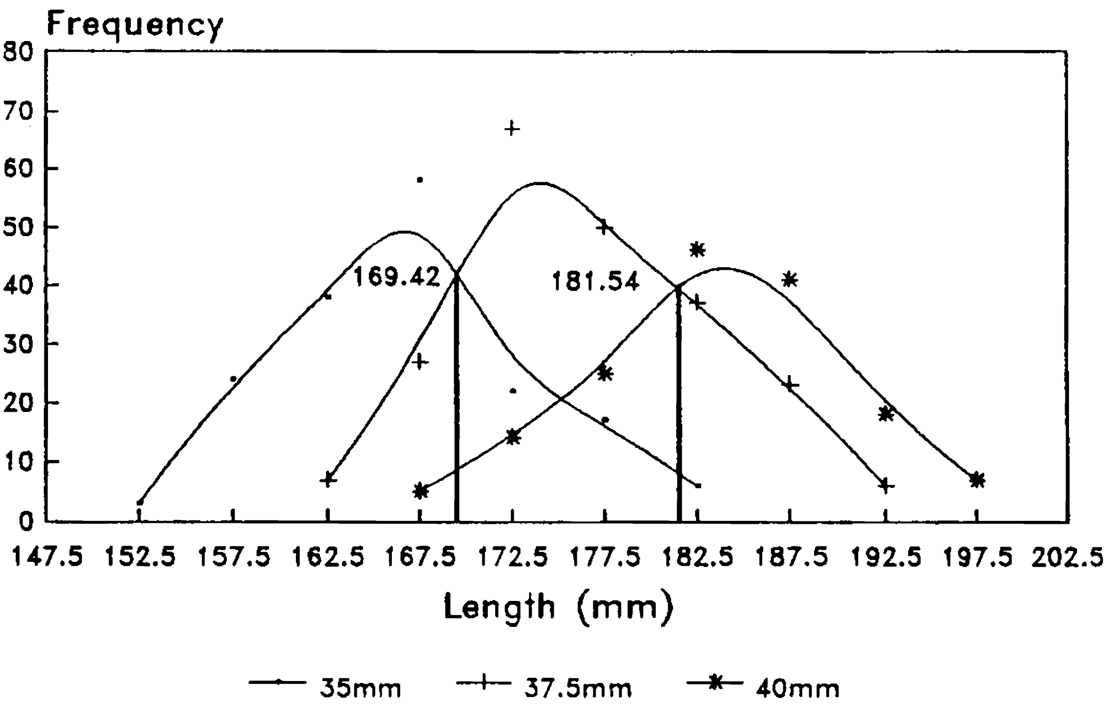


FIG. 3.12 LENGTH FREQUENCY DISTRIBUTION OF E.suratensis IN NETS OF 35, 37.5 AND 40 mm BAR SIZE.

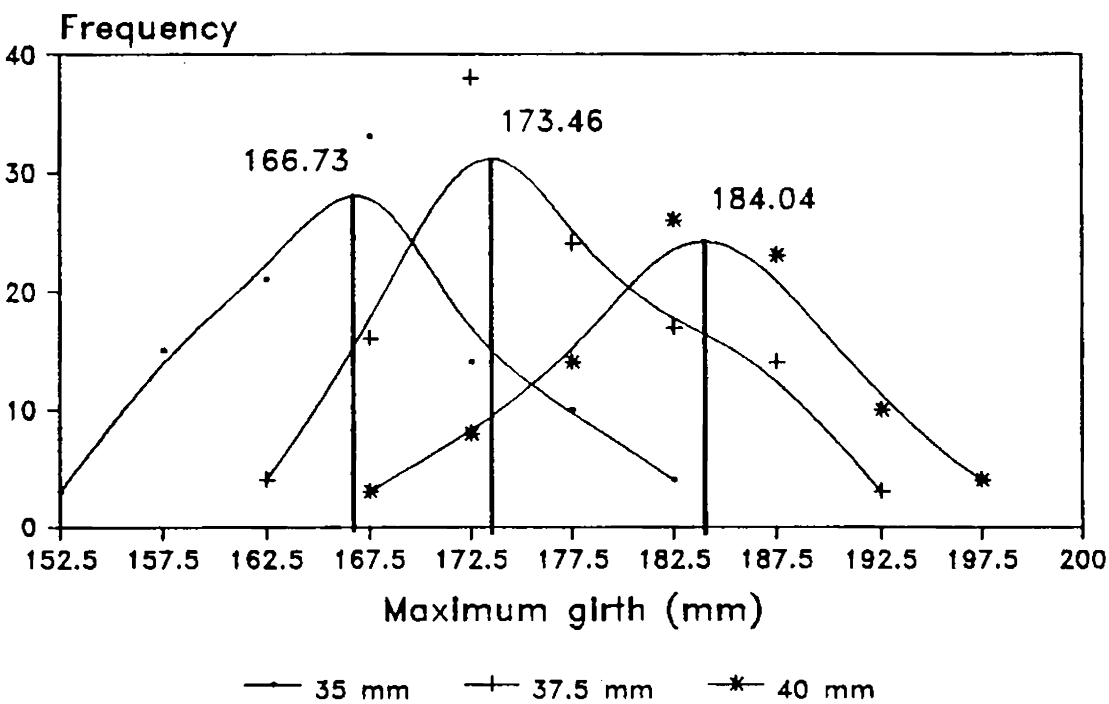


FIG. 3.13 GIRTH FREQUENCY DISTRIBUTION OF E.suratensis IN NETS OF 35, 37.5 AND 40 mm BAR SIZE.

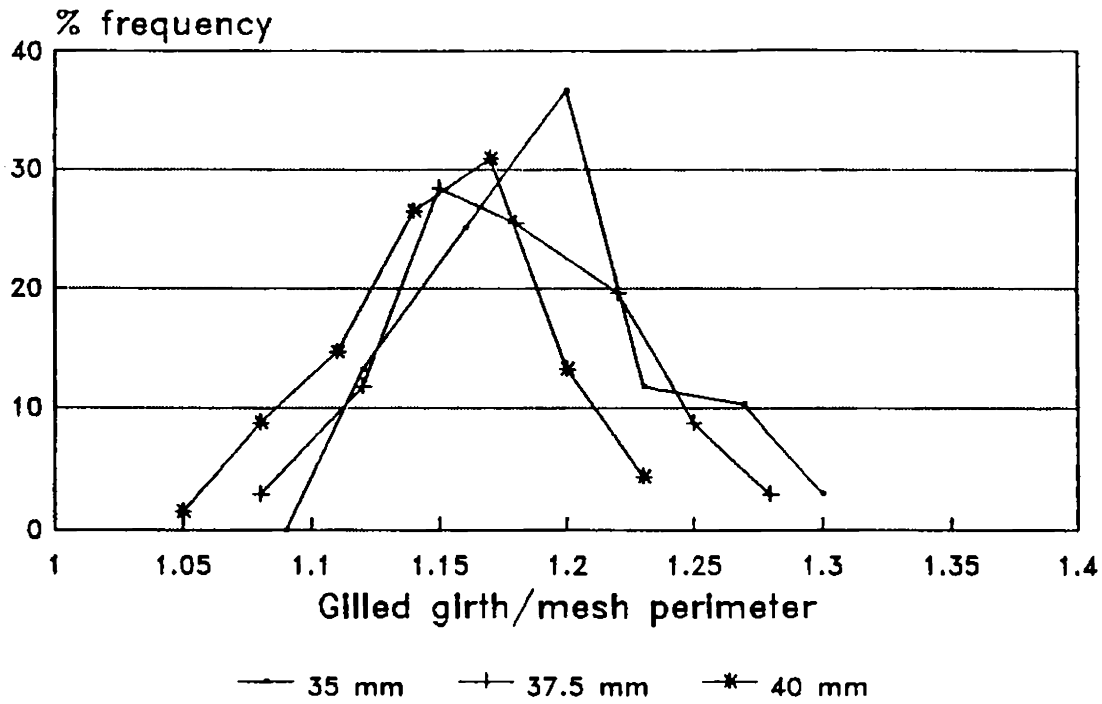


FIG. 3.14 PERCENTAGE FREQUENCY DISTRIBUTION OF _E._suratensis BASED ON GILLED GIRTH TO MESH PERIMETER.

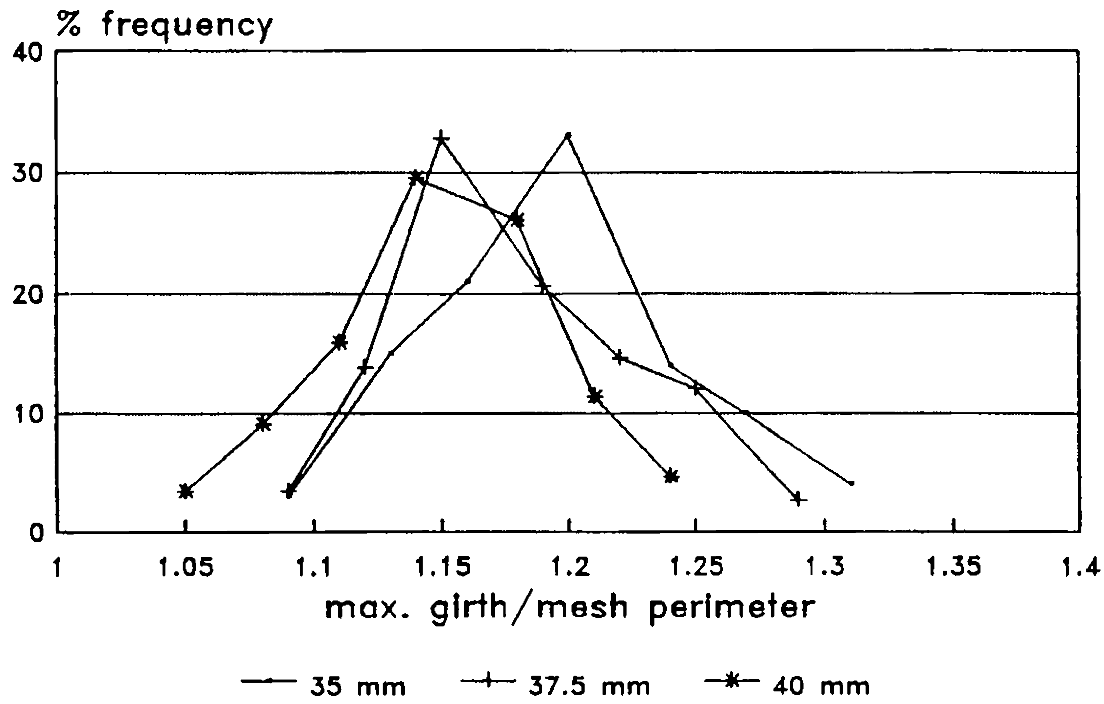
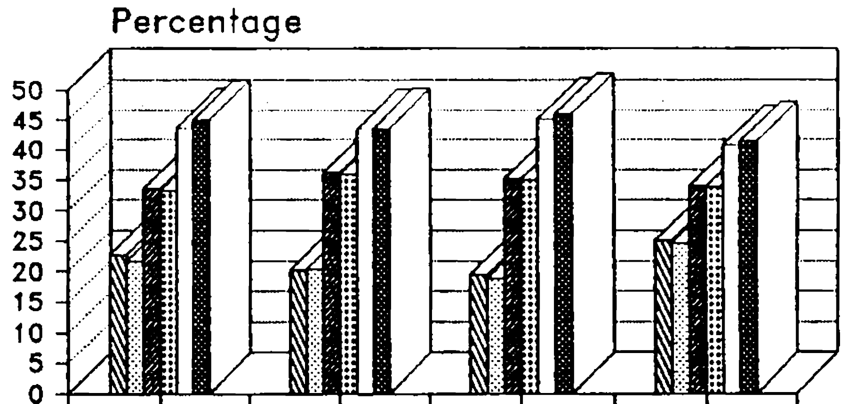


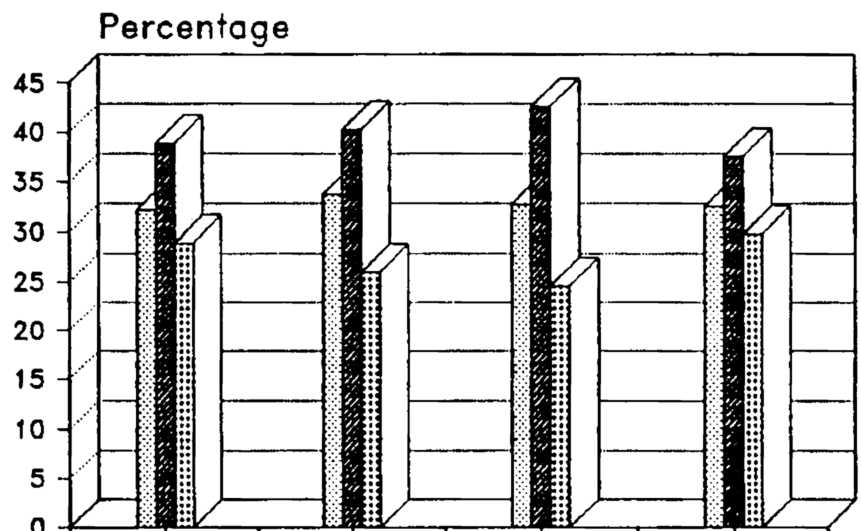
FIG. 3.15 PERCENTAGE FREQUENCY DISTRIBUTION OF _E._suratensis BASED ON MAXIMUM GIRTH TO MESH PERIMETER.



	I Stn	II Stn	III Stn	IV Stn
No. in 0.6 H.C	22.78	20.29	19.5	25.13
Wt. in 0.6 H.C	21.74	20.37	18.86	24.71
No. in 0.5 H.C	33.54	36.23	35.22	34.03
Wt. in 0.5 H.C	33.26	35.97	35.08	33.84
No. in 0.4 H.C	43.67	43.48	45.28	40.84
Wt. in 0.4 H.C	45	43.65	46.05	41.45

Stations

FIG. 3.16 CATCH IN PERCENT BY NUMBER AND WEIGHT FOR <u>E.suratensis</u> IN NETS OF 0.6, 0.5 AND 0.4 HANGING COEFFICIENTS.



	I Stn.	II Stn.	III Stn.	IV Stn.
Wt.in 0.6 H.C	32.25	33.78	32.81	32.58
Wt.in 0.5 H.C	38.89	40.27	42.6	37.6
Wt.in 0.4 H.C	28.86	25.95	24.58	29.82

Stations

FIG. 3.17 CATCH IN PERCENT BY WEIGHT FOR OTHER FISHES IN NETS OF 0.6, 0.5 AND 0.4 HANGING COEFFICIENTS.

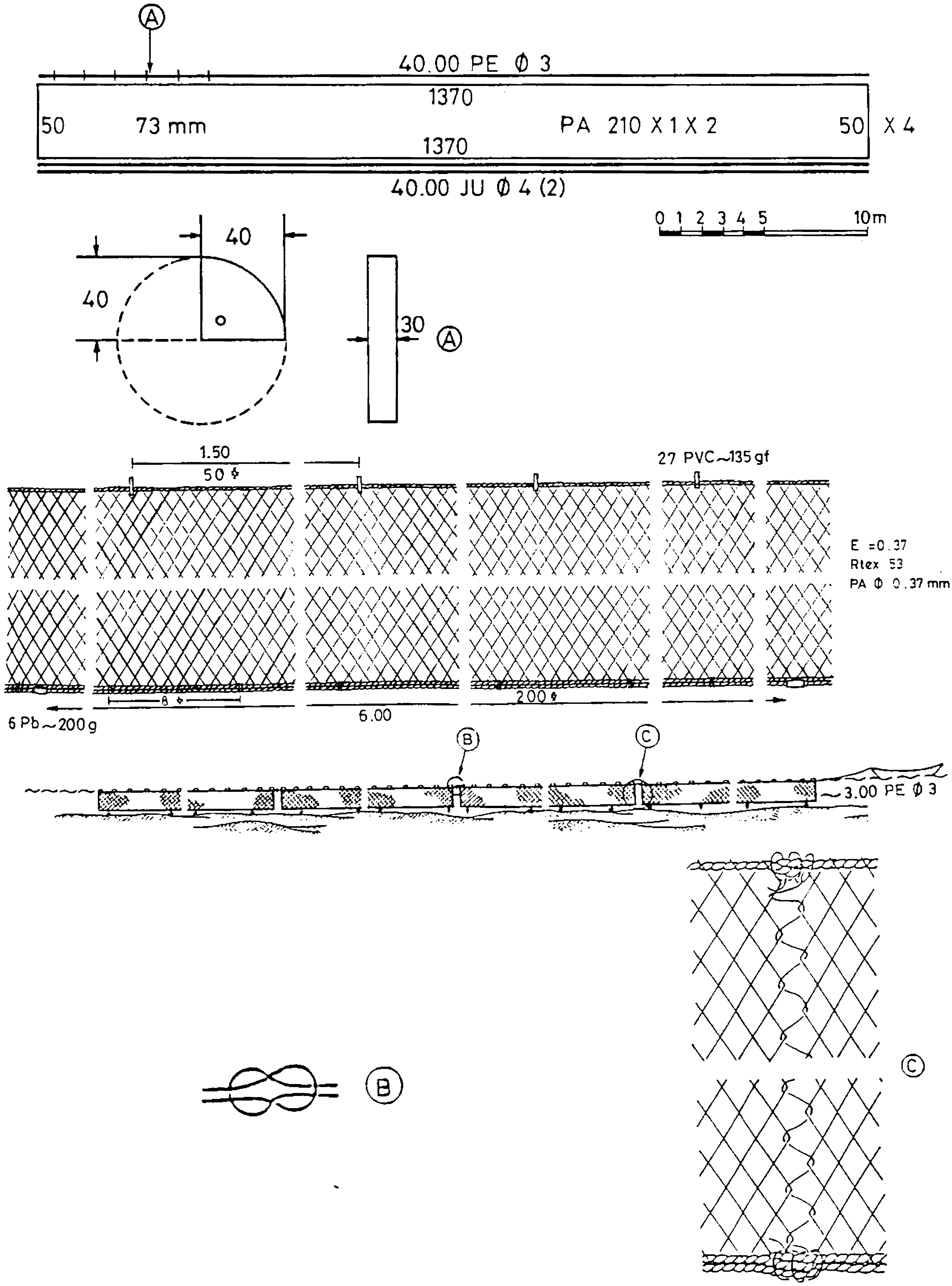


FIG. 3.18 NEW DESIGN FOR GILL NET - 'KARIMEEN VALA'.

TABLE. 3.1 DESIGN DETAILS OF EXPERIMENTAL NETS FOR LENGTH-FREQUENCY STUDIES.

Nets	a1	a2	a3
Material	PA	PA	PA
Twine size	210x1x3	210x1x3	210x1x3
Mesh bar size (mm)	35	37.5	40
No. of meshes in length	1430	1333	1250
No. of meshes in depth	55	51	48
Coefficient of hanging	0.4	0.4	0.4
Horizontal hung length (m)	40	40	40
Vertical hung length (m)	3.5	3.5	3.5
Floats			
Number	20	20	20
Material	PVC	PVC	PVC
Diameter (mm)	70	70	70
Thickness (mm)	10	10	10
Extrabuoyancy (gf) per float	34.5	34.5	34.5
Sinkers			
Number	5	5	5
Material	Granite	Granite	Granite
Weight (g) per sinker	250	250	250

TABLE 3.2 ESTIMATION OF SELECTIVITY FACTOR 'k' BY LENGTH MEASUREMENTS.

Parameters / Nets	a1	a2	a3
Mesh bar size (a) mm	35.00	37.50	40.00
Optimum length fishes caught by nets (mm)	166.73 (l)	173.85 (l)	183.02 (l)
l_{01} (mm)		169.42	
l_{02} (mm)		181.54	
'k_1'		0.214	
'k_2'		0.213	
Mean 'k'		0.213	

TABLE 3.3 ESTIMATION OF SELECTIVITY FACTOR 'k' BY GIRTH MEASUREMENTS.

Parameters / Nets	a1	a2	a3
Mesh bar size (a) mm	35.000	37.500	40.000
Max. girth (S) of prominent size class (mm)	166.730	173.460	184.040
Corresponding length (l) mm	165.500	172.000	183.500
4a	140.000	150.000	160.000
n	0.840	0.865	0.869
n0	1.007	1.008	1.003
k	0.211	0.218	0.218
Mean K =		0.216	

TABLE 3.4 DESIGN DETAILS OF EXPERIMENTAL NETS FOR HANGING COEFFICIENT STUDIES.

Parameters / Nets	a1	a2	a3
Material	PA	PA	PA
Twine size	210x1x3	210x1x3	210x1x3
Mesh bar size (mm)	37.5	37.5	37.5
No. of meshes in length	888	1066	1333
No. of meshes in depth	58	54	50
Coefficient of hanging	0.6	0.5	0.4
Horizontal hung length (m)	40	40	40
Vertical hung length (m)	3.5	3.5	3.5
Floats			
Number	20	20	20
Material	PVC	PVC	PVC
Diameter (mm)	70	70	70
Thickness (mm)	10	10	10
Extrabuoyancy (gf) per float	34.5	34.5	34.5
Sinkers			
Number	5	5	5
Material	Granite	Granite	Granite
Weight (g) per sinker	250	250	250

TABLE 3.5 ANALYSIS OF VARIANCE FOR NUMBER OF *E. suratensis* CAUGHT.

Source	SS	df	ms	F
Total	11.6305614835	359		
Between Hanging coeff.	2.74356612	2	1.371783060	57.861
Between stations	0.4417589872	3	0.147252996	6.211
Between operations	0.7400230373	29	0.025518036	1.076
Error	7.7052133391	325	0.023708349	

Mean for Hanging coefficients		LSD	0.0389610901
0.6	0.2971111965		
0.5	0.4344806454		
0.4	0.5077177388		
Mean for Stations		LSD	0.0449883917
Stn 3	0.4042314713		
Stn 5	0.3741284717		
Stn 6	0.4041170273		
Stn 7	0.469935804		

TABLE 3.6 ANALYSIS OF VARIANCE FOR WEIGHT OF *E. suratensis* CAUGHT.

Source	SS	df	ms	F
Total	196.7392564643	359		
Between Hanging coeff.	39.0760029147	2	19.538001457	44.670
Between stations	3.7541848037	3	1.251394935	2.87
Between operations	11.7676844951	29	0.405782224	0.93
Error	142.1413842508	325	0.437358105	

Mean for Hanging coefficients		LSD	0.1673397192
0.6	1.7342714803		
0.5	2.3150167757		
0.4	2.5099287999		
Mean for Stations		LSD	0.19323437
Stn 3	2.1288232977		
Stn 5	2.1256934385		
Stn 6	2.1278358712		
Stn 7	2.3632701337		

TABLE 3.7 ANALYSIS OF VARIANCE FOR WEIGHT OF MISCELLANEOUS FISHES CAUGHT.

Source	SS	df	ms	F
Total	208.1733753036	359		
Between Hanging coeff.	12.6111453175	2	6.305572659	11.500
Between stations	6.6479144351	3	2.215971478	4.0415
Between operations	10.7190766220	29	0.369623332	0.6741
Error	178.1952389289	325	0.548293043	

Mean for Hanging coefficients		LSD	0.1873642866
0.6	1.9799608342		
0.5	2.3507349868		
0.4	1.9318222967		
Mean for Stations		LSD	0.2166343754
Stn 3	1.8841766982		
Stn 5	2.1011273028		
Stn 6	2.0976760215		
Stn 7	2.2670441345		

TABLE 3.8 DETAILS OF GILL NETS OPERATED IN THE VEMBANAD LAKE.

Local name	No. of Units	Length/ unit(m)	Depth/ unit(m)	Mesh size(mm)	Mat. & Spftn.	E	Floats (material)	Sinkers (material)	Man power	No. of Canoes
Therandi vala	9-13	20	3.5-4	350-370	210x6x3	0.4	Saccharum spontaneum	Granite	2	1
Looppu vala	4	45-50	2.5-3	75	210x1x2	0.37	PVC	"	1	1
Kandali vala	4	28-30	2.5-3	100-110	210x4x3	0.6	"	"	1	1
Chemmeen vala (multifilament)	5-6	50	2-2.5	30-36	210x1x2	0.55	"	"	1	1
Chemmeen vala (monofilament)	3	60	2.5-3	34		"	"	"	1	1
Kara vala	4	40-45	2-2.5	50	210x1x2	0.45	"	"	2	1
Koori vala	6	25-30	2.5	56	210x1x3	0.4	"	"	2	1
Ozhukku vala	5	28-30	3.5-3.75	120-140	210x4x3	0.45	"	"	2	1
Murasu vala	1	250-275	0.35-0.50	26	210x1x2	0.42	Calotropis gigantica	Nylon netting	1	1
Karimeen vala	4	40-50	3.5-3.75	65-90	210x1x2	0.37-0.45	Saccharum spontaneum	Granite	2	1

TABLE 3.9 NUMBER AND WEIGHT OF <u>E.suratensis</u> AND OTHER FISHES CAUGHT IN NETS OF DIFFERENT HANGING COEFFICIENTS.

Hanging coeff.	Stn. No.	Number of E.suratensis caught	Total	Weight of E. suratensis caught	Total	Weight of other fishes caught	Total	TOTAL (Kg)
0.6	1	36		5.00		5.34		10.34
	2	28		4.14		6.51		10.65
	3	31		4.37		6.10		10.47
	4	48		6.85		7.41		14.26
Total			143		20.36		25.36	45.72
0.5	1	53		7.65		6.44		14.09
	2	50		7.31		7.76		15.07
	3	56		8.13		7.92		16.05
	4	65		9.38		8.55		17.93
Total			224		32.46		30.67	63.14
0.4	1	69		10.35		4.78		15.13
	2	60		8.87		5.00		13.87
	3	72		10.67		4.57		15.24
	4	78		11.49		6.78		18.27
Total			279		41.38		21.13	62.51
Gr.Total		158 ¦ 138 ¦ 159 ¦ 191	646	23 ¦ 20.32 ¦ 23.17 ¦ 27.72	94.20	16.56 ¦ 19.27 ¦ 18.59 ¦ 22.74	77.16	171.37

C H A P T E R - IV

CHINESE NET

4.1. Introduction

The Chinese net belongs to that class of nets known as the lift nets or dip nets. They have their origin in the small scoop nets which are pushed beneath a fish that is seen or suspected to be present in a particular area. The dip nets differ from these in that they are lowered into the water in the hope that, over a period of time fish or prawn will swim over them. Strictly speaking, the term `dip net' is a misnomer. The catch is not affected by dipping the net, but by lifting it again from the water, when the fish sought to be caught have gathered over them. The term `lift net' is therefore much more correct (Brandt, 1972).

The earlier lift nets were small baskets made of twigs and bast and were hand operated. Later on netting was used to replace the twigs and bast. This netting was set horizontally and fastened to round or square frames. As the size of the nets increased, transverse rods were used to keep the net spread. These earlier versions were all portable and mostly used to catch crabs which do not escape quickly, unlike the fish. This was due to the fact that being hand operated, these nets could be hauled up only slowly. To overcome this lack of hauling speed, the English fishery developed a hand lift net known as the purse hoop net of Wales, which can be closed by shutting the opening hoop with a line (Davis, 1958). Parry (1954) has described a similar collapsible hand lift net employed by the Malayan fishery. When the nets increased in size again, they were operated by means of a long pole, handled like a lever. A further increase in size necessitated the use of gallows with a working block. These can be considered as mechanised lift nets and can be installed either on shore or on a boat. The Chinese net comes under this mechanised type of lift nets, but works instead on the lever principle.

Santos (1959) has described two types of lift nets, the `Basnig´ and `Bintol´ used widely in the Philippines. Akira (1959) gives an account of dip nets used by the Japanese saury fishery. These nets are supported on sticks fixed to the ship´s side and lights are used to attract the fish into the net. These nets were later adopted by the USSR Far East fishermen with great success (Ben-Yami, 1976). Floyd (1971) has described the construction and operation of a lift net for catching bait fish attracted to light.

In India the Chinese nets are found only in the backwaters of Kerala. But it is a common gear in almost all of the estuaries of China. Iyer (1909) stated that the net is not known in China nor for that matter in any other place except Cochin. But Hornell (1938) observed this to be altogether erroneous, stating to have observed scores of these nets in operation on the way up the Wusung river to Shanhai. Though there is no question about its Chinese origin, these nets were most probably introduced in this area by the Portuguese (Brandt, 1972). The fact that the technical terms in use for the various parts of the net and its supporting structure in Malayalam language are of Portuguese origin, is an exceedingly strong presumptive evidence that this net was introduced by the Portuguese and not directly by the Chinese.

The Chinese nets in Kerala are spread over the five coastal districts of Trichur, Ernakulam, Kottayam, Alleppy and Quilon. There are a total of about 4823 Chinese nets in the state (Sanjeevagosh, 1987).

The Chinese nets operated in the Vembanad lake have reached its present stage of development through gradual evolution from a simpler contrivance for sustenance fishing to the one which is operated on a commercial scale. This gradual development has been attained through the ingenuity of the fishermen who strive to achieve better efficiency, based on their practical knowledge of the gear and the fishery.

Hornell (1938), Gopinath (1953) and Kurian and Sebastian (1986) have all given general descriptions of the gear. George (1962) based on his observations on the size groups of *Penaeus indicus* in the commercial catches of different nets from the backwaters reported that the Chinese net catches showed the maximum sizes in the population mean and modal lengths. George *et al.*(1974) have suggested codend mesh sizes for various backwater gears including the Chinese nets. Inspite of these works, a detailed study on the design, construction and operation of this gear is lacking. Considering the commercial significance of this gear and the large number of fishermen who engage these nets for their livelihood, it is imperative that a detailed work be undertaken to study the various facets of the gear.

4.2. Objectives

Hence, the present work endeavours to classify the Chinese nets operated in the Vembanad lake and to study in detail the design, construction and operation of the gear. Since any information regarding the basic process of designing is lacking, it was also the objective of this study to establish a few important relationships among the different factors like the depth of the area of operation, net size and the various parts of the net proper and its supporting structure.

4.3. Materials and method

Preliminary surveys were conducted in the study area and eight centres viz. Vaikkom, Chembu, Panangad, Arookutti, Fort Cochin, Vypeen, Chathanadu and Krishnankotta were selected to study the Chinese nets in detail. These stations, between them, had representations of all the size categories of Chinese nets. Twenty five units from among those operated at these centres were randomly selected for detailed study on their design, construction and operation. The centres selected for observation are given in Fig.(1.1).

Miyamoto(1959) was possibly the first author to work out regression equations relating horse power of engine and size of trawl gear. Koyama (1962b)also attempted to correlate engine horse power of trawlers with the size of the otter board. An empirical approach has been made by Nair and George (1964) and Nayar and Nair (1972) to establish a few important relationships among the different factors like horse power of the engine and the size of trawl gear and the various parts of the trawl itself. George (1985) has applied the same principle to find out the interrelationship between different parts of the `Edavalai', a lift net operated along the Coromandel coast off Tamil nadu. A similar approach was adopted in this study to work out a relationship between the depth of the area of operation and the net size, the net size with the various parts of the net proper and also with parts of the supporting structures.

4.4. Results and discussion

The gear has two distinct parts viz. the net proper and the supporting structure. It works on the lever principle and is balanced by counter-weights enabling it to be turned in an angle to facilitate the dipping and lifting of the net. Figure (4.1) shows a typical Chinese net with its codend pulled up from inside by means of a line rove through a block hanging from the apex of the outer crane.

The net

Design details of Chinese net are given in Fig.(4.2). The net when attached to its immediate supporting structure is square, gradually assuming a conical shape towards the middle and ending in a bag. The whole net is made up of four identical sections seamed at their sides. Each of these sections consist of three major parts, `Perna´ at the top, `Nilavala´ in the middle and `Sanchi´ at the bottom (Fig.4.3).

Each `Perna´ forms one corner of the net and is triangular in shape. The two outer sides of the `Perna´ has all bars and the inside edge all points. The two adjacent sides with bar cuts are mounted to a line, which in turn is attached to another line by tying at regular intervals. These lines are known as the inner and outer `Borda´. The outer line which is often thicker in diameter, runs along the edge and forms a loop at each of the four corners to facilitate attachment of the net to the supporting frame.

To the inner edges of `Perna´ is attached the body of the net, known as the `Nilavala´ which is conical in shape and tapers downwards. The circumference is made up of four trapezoid pieces joined together at their non-parallel sides. Each of these four pieces are made up of five panels horizontally. Changes in mesh size or material is affected among these panels, as required. The broader side of the uppermost panel of the \`Nilavala' is attached to the inner edge of the \`Perna', which has all point cuts.

To the narrow, inner edge of the lowest panel of the \`Nilavala' is attached the codend, locally known as \`Sanchi'. This portion is also made up of four trapezoid pieces of netting joined together at their non-parallel sides which also has a 1N 1B taper ratio.

Supporting structure

The net is attached to a wooden frame work. The whole structural frame of the Chinese net is supported by two wooden piles driven into the fishing area. These are known as \`Kutti' and are made of coconut tree trunk. When land based they are placed parallel to the shore line. A platform is made from the shore up to the \`Kutti', with small wooden planks and bamboo splits supported by small wooden poles driven into the ground (Fig.4.4). In nets that are situated away from the shore, the platform has to be longer than the inner crane, to support it and also to furnish working space for the fishermen. It should also be strong enough to support the weight of the inner crane and that of the counter-weights. The platform of the water based nets are usually provided with a small thached cabin to provide shelter for the fishermen and also to store the catch.

On the top end of each `Kutti', a groove is made. In these grooves, which function as a socket, is placed between them a wooden beam invariably of teak wood, and known as `Kalsanthi'. The cross section of the body of `Kalsanthi' is square while the ends are narrow and cylindrical in shape. The ends fit into the socket of the respective supporting post. The `Kalsanthi' acts as a pivot and moves to and fro in an arc facilitating the lowering and lifting of the net (Fig.4.5).

On the `Kalsanthi', two cranes, the `Puramkazhukol' (outer crane) and the `Karakazhukol' (inner crane), projecting towards water and land respectively are fixed, forming an angle between them (Fig.4.6). Each of this is in the shape of a triangle, the long sides of which are made up of two wooden poles. The poles of respective cranes meet at their apices where they are joined together by inserting either a strong wooden peg on an iron rod locally called `Chavi'. To impart stability, rigidity and sufficient strength to this large and extended structure, the apices of the two cranes are inter-connected through 3 or 4 wire ropes or mild steel wires. These are known as `Savai' (Fig.4.7). Also, a cross bar is tied to the cranes towards their respective apices, to impart additional strength.

Hanging from the apex of the outer crane is the structure known as `Bras', which is formed by tying together four wooden poles at one end in such a way that their free ends are kept extended, resembling the four edges of a pyramid (Fig. 4.8). The two inner limbs (those lying towards the shore or the platfform) are longer than the two outer limbs (those situated away from the shore or platform) The 'Bras' is suspended from the outer crane with the help of 'Harbola', which is a rope loosely passed around their joints many times. It is occasionally strengthened with an old tyre or wire ropes. Each pole of the 'Bras' is tied to the 'Harbola' with a rope called 'Akshakkayar', so as to prevent them from slipping. A rope known as 'Padachikkayar' is used to tie together the diagonally opposite two poles of the 'Bras', to get the required extend of spread (Fig. 4.9). There is another set of ropes, known as 'Udhara', that are used to tie the inner and in some cases the outer limbs to posts on shore or in shallow water, which helps to maintain the position of the 'Bras' and to aviod any movement that may be caused by strong winds or currents. It is to the free ends of the four poles of the 'Bras' that the net proper is attached by means of the four loops at the corners of the net.

At the apex region of the outer crane, one or more hauling ropes, depending on the size of the net and supporting structure, are tied. The ends of these ropes are left free and reach the ground when the outer crane is in the raised position ie. when the net is in the dipped position. By pulling these ropes the inner crane is brought down, which in turn facilitates the raising of the outer crane along with the net. These ropes are called 'Valikamba' locally. Another set of ropes, 'Kallukamba', are also attached to the two limbs of the inner crane towards its apex. To these ropes are attached the granite stones which function as counter-weights to balance the net. The number and weight of the stones depend on the size of the net.

Construction

The net

The length of one side of the mouth of the net is taken as the net size and is fixed in relation to the depth of the region, which in turn is determined in relation with the operating parameters and the nature of the fishery. Though a variety of species are regularly caught, the target species of the Chinese net are prawns. Mostly those prawns which move about either in search of food or are carried by currents and tides or are attracted towards light would be caught by this net (George, 1962). Hence it is imperative that the operating area has a minimum depth and optimum current, since stronger currents distort the net reducing its efficiency. No nets are operated in regions with less than two meters of water depth.

The relationship between the water depth (D) and the net size (NS) is shown in Fig.(4.10) and expressed in the equation,

$$NS = 2.8\,D + 0.11 \qquad \ldots\ldots\ldots\ldots\ldots (4.1)$$

$(n = 25;\ r = 0.9786;\ p < 0.001)$

where n is the number of observations,
r is the correlation coefficient and
p is the level of significance (Probability).

The relation between net size (NS) and net depth (ND) is represented in Fig.(4.11) and the equation derived from the figure is

$$ND = 0.907\ NS - 0.132 \quad \text{...............(4.2)}$$

$(n = 25;\ r = 0.9937;\ p < 0.001)$

The net is constructed first as four separate units which are joined together to form the complete net. The fabrication of these units start with the triangular corner piece `Perna'. The outer edges of each `Perna' have all bar cut and irrespective of the mesh size or number of meshes, the stretched length of the outer edge (PO) was equal to half the net size and can be expressed as

$$PO = 0.5\ NS \quad \text{...............(4.3)}$$

Thus the outer edges of two corresponding `Pernas' complete one side of the mouth of the net. The inner edge of each `Perna' has all point cut and the stretched length is equal to the net size or twice that of the outer edge.

After `Perna', the `Nilavala' which constitutes the body of the net is made. Each unit of `Nilavala' is a trapezoidal netting comprising of five panels horizontally. The taper at the sides of each panel is affected by employing a cutting ratio of 1N 1B. The broader upper edge of the first panel of `Nilavala' is attached to the inner edge of the `Perna' by working a half mesh between them. As in the case of `Perna', here also, it is the stretched length of the netting that is taken as the criterion and not the mesh size or number of meshes. The net size in relation to the proportionate dimensions of the stretched length of the upper edge of each panel is depicted in Fig.(4.12). The following equations outline the relationships.

$$N1_{stl} = 0.895\ NS + 0.042 \qquad \ldots\ldots\ldots\ldots\ldots(4.4)$$
$$(n = 25;\ r = 0.9984;\ p < 0.001)$$

$$N2_{stl} = 0.65\ NS + 0.045 \qquad \ldots\ldots\ldots\ldots\ldots(4.5)$$
$$(n = 25;\ r = 0.9985;\ p < 0.001)$$

$$N3_{stl} = 0.46\ NS - 0.086 \qquad \ldots\ldots\ldots\ldots\ldots(4.6)$$
$$(n = 25;\ r = 0.9973;\ p < 0.001)$$

$$N4_{stl} = 0.297\ NS + 0.033 \qquad \ldots\ldots\ldots\ldots\ldots(4.7)$$
$$(n = 25;\ r = 0.9944;\ p < 0.001)$$

$$N5_{stl} = 0.199\ NS + 0.009 \qquad \ldots\ldots\ldots\ldots\ldots(4.8)$$
$$(n = 25;\ r = 0.9879;\ p < 0.001)$$

where $N1_{stl}$, $N2_{stl}$, $N3_{stl}$, $N4_{stl}$ and $N5_{stl}$ are the stretched lengths of the upper edge of panels 1, 2, 3, 4 and 5 respectively.

The total depth of `Nilavala' as well as that of each separate panel that goes into its construction was also taken in stretched lengths.

The relation between the net size, total depth of 'Nilavala' (N_d) and the proportionate dimensions of the depth of panels of 'Nilavala' are illustrated in Figures (4.13) and (4.14) respectively. The equations derived from the figures are

$$N_d = 0.557\ NS - 0.074 \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4.9)$$
$(n = 25;\ r = 0.9982;\ p < 0.001)$

$$N1_d = 0.173\ NS - 0.045 \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4.10)$$
$(n = 25;\ r = 0.9936;\ p < 0.001)$

$$N2_d = 0.144\ NS - 0.039 \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4.11)$$
$(n = 25;\ r = 0.9934;\ p < 0.001)$

$$N3_d = 0.112\ NS - 0.031 \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4.12)$$
$(n = 25;\ r = 0.9952;\ p < 0.001)$

$$N4_d = 0.081\ NS - 0.025 \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4.13)$$
$(n = 25;\ r = 0.9758;\ p < 0.001)$

$$N5_d = 0.050\ NS - 0.002 \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4.14)$$
$(n = 25;\ r = 0.9810;\ p < 0.001)$

where $N1_d$, $N2_d$, $N3_d$, $N4_d$ and $N5_d$ are the respective depths of panels 1 to 5 of 'Nilavala'.

A closer observation of the data show that the difference in the stretched lengths of the upper edge of successive panels of 'Nilavala' follow an arithmetic progression starting with 0.25 m and diminishes successively by 0.05 m (Fig. 4.15). The relationship worked out is

$$P_{stl} = 1.023 - 0.174\ P_n \quad \ldots\ldots\ldots\ldots\ldots(4.15)$$

(n = 5; r = -0.9879; p < 0.01)

where P_{stl} is the stretched length of each panel and
P_n is the panel number.

The relationship between panel numbers and depth is given in Fig. (4.16). The linear relationship worked out is

$$P_d = 0.025 - 0.031\ P_n \quad \ldots\ldots\ldots\ldots\ldots(4.16)$$

(n = 5; r = -0.9999; p < 0.01)

where P_d is the panel depth

This analysis shows that as the panel number increases, there is a decrease of 0.031 m in depth.

The codend, which in local dialect is known as `Sanchi' was also fabricated as four separate units having trapezoidal shape. The relationship between the net size, stretched length of the upper edge (C_{stl}) and the stretched depth (C_d) of the codend are depicted in Figs. (4.17) and (4.18). The equations derived are

$$C_{stl} = 0.144\ NS + 0.054 \quad \ldots\ldots\ldots\ldots\ldots(4.17)$$

(n = 25; r = 0.9907; p < 0.001)

$$C_d = 0.209\ NS - 0.15 \quad \ldots\ldots\ldots\ldots\ldots(4.18)$$

(n = 25; r = 0.9341; p < 0.001)

The different panels of `Nilavala' and the codend are joined with one another by working out a half mesh between the respective panels and affecting either a baiting or creasing (Fig. 4.19). A uniform take-up ratio is maintained, depending on the number of meshes present at the corresponding upper and lower edges of the panels. A cutting ratio of 1N 1B is maintained throughout, at the sides of the `Nilavala' as well as the codend to achieve the required taper.

The four separate units, each with a `Perna', `Nilavala' and `Sanchi', are then seamed together at their sides to complete the net. The outer edges of the `Perna' are mounted to the inner `Borda' by clove hitches (Fig. 4.20).

Supporting structures

The dimension of important parts of the supporting structures are also correlated to the net size. The relation between the net size and the length of the limbs of outer crane (OC) is shown in Fig.(4.21). The equation derived from the figure is

$$OC = 1.006\ NS - 1.06 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4.19)$$

$(n = 25;\ r = 0.9993;\ p < 0.001)$

The length of the limbs of inner crane (IC) was related to the length of the outer crane limbs. The relationship between the two is given in Fig. (4.22) and the equation derived is

$$IC = 1.21\ OC + 0.964 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4.20)$$

$(n = 25;\ r = 0.9936;\ p < 0.001)$

The two cranes are fixed on the `Kalsanthi', the horizontal beam that functions as the pivot, by a tenon and mortise joint. The length of the tenon (T) at the base of the limbs of the two cranes was related to the length of the limbs of the inner crane and the relation is as illustrated in Fig. (4.23) and expressed in the appropriate equation.

$$T = 0.020\ IC - 0.001 \quad \ldots\ldots\ldots\ldots\ldots\ldots (4.21)$$
$$(n = 25;\ r = 0.9657;\ p < 0.001)$$

The thickness of `Kalsanthi' was fixed so as to be not less than the length of the tenon of the limbs of the two cranes. The mortises on the `Kalsanthi' run vertically, while the tenon of each limb of both the inner and outer cranes are shaped in such a way that the respective limbs of both the cranes are made to meet at the apices. The distance between the two limbs of the outer crane (OC_{dst}) and that between those of the inner crane (IC_{dst}) on `Kalsanthi' are related to the lengths of the limbs of the respective cranes. The relations are illustrated in Figs. (4.24) and (4.25). The equations derived from the figures are

$$OC_{dst} = 0.251\ OC - 0.008 \quad \ldots\ldots\ldots\ldots\ldots (4.22)$$
$$(n = 25;\ r = 0.9996;\ p < 0.001)$$

$$IC_{dst} = 0.148\ IC + 0.013 \quad \ldots\ldots\ldots\ldots (4.23)$$
$$(n = 25;\ r = 0.9983;\ p < 0.001)$$

The angle at the base of the limbs with the `Kalsanthi' was calculated using the formula,

$$A = \cos^{-1}\left(\frac{C}{2a}\right)$$

where a is the length of limbs of the respective crane

c is the distance between the limbs of the respective crane on `Kalsanthi',

and was found to be about 82.5° and 85.5° for the outer and inner cranes respectively. The angle between the two cranes was also affected by shaping the tenon of each limb and was about 115.5°. It was calculated using the formula

$$A = \cos^{-1}\left[\frac{b^2 + c^2 - a^2}{2bc}\right]$$

where a is the length of `Savai'

b is the distance from the apex of the outer crane to the `Kalsanthi', and

c is the distance from the apex of the inner crane to the `Kalsanthi'

The relation between the net size and length of `Kalsanthi' is shown in Fig.(4.26) and can be expressed by the equation

$$K = 0.339\ NS - 0.052 \quad \ldots\ldots\ldots\ldots(4.24)$$

$(n = 25;\ r = 0.9981;\ p < 0.001)$

The length of `Kalsanthi' is divided in such a way that the two cranes are aligned at the centre. A distance equal to that which separate the limbs of inner and outer cranes on one side, is left on the outside of the outer crane limbs. The remaining portion on either ends from the tenon, which is placed in the socket provided on the `kutti'.

To the apex of the outer crane is attached the `Bras´ with the help of `Harbola´, which encircles the joint of the `Bras´ and the apex of the crane in such a way that the `Bras´ freely hangs from the outer crane. The looseness of `Harbola´ is fixed so that the joint is not congested. The length of the two outer limbs of `Bras´ (OB) are first determined in relation to the net size (NS), and then that of the inner limbs (IB) in relation to the outer limbs. The relationships are shown in Figs. (4.27) and (4.28) and the equations are

$$OB = 0.948\ NS - 0.459 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4.25)$$

$$(n = 25;\ r = 0.9898;\ p < 0.001)$$

$$IB = 1.038\ OB + 0.159 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4.26)$$

$$(n = 25;\ r = 0.9986;\ p < 0.001)$$

The net is attached to the four arms of `Bras´ by the loop formed by the outer `Borda´ at the four corners of the mouth of the net.

The counter-weights are tied to the limbs of the crane towards its apex. The number and weight of stones used are so fixed to ensure a gradual lowering of the net and minimum effort to haul. The first stone is tied close to the `Key´. The succeeding stones are hung about 15 cm. apart from the two limbs alternately.

Operation

The Chinese net operation is based on the fishing principle of keeping the net submerged over an interval of time and then lifting it rapidly out of water so as to catch any fish which happens to be over it (Joseph and Narayanan, 1965). The nets are mostly operated during nights and to facilitate the congregation of prawns, powerful lights are used. Kurian *et al.* (1952) based on comparative study on the effect of light of different intensities and colours in luring prawns and fishes in Chinese nets in Kerala backwaters, have reported that, with increase in intensity of light 200 to 600 percent increase in catch was obtained upto a maximum of 200 watts, after which the catch reduced. The operation of the net commences when the null tide begins and terminates when the speed of flow increases, lest the net get distorted. The net is lowered by lifting the inner crane mannually until the first ballast is lifted from the ground or platform. The net then get slowly lowered, counterpoised by the ballasts.

Depending on the catch, the net is kept immersed for five to fifteen minutes. The net is hauled by pulling the hauling lines, the effort being reduced by the ballasts. The catch from the codend is taken out in an ingenious way. Two lines, locally known as 'Kayyayi' are made use of for this. One end of these lines are attached to the 'Sanchi' or codend at about 25 and 30 cm. respectively from above the bottom of the codend. The free end of these two lines are loosely attached to that side of the mouth of the net, which faces the platform and can be easily reached from the `Kalsanthi' after each hauling. When these two lines are pulled together a bag is formed at the codend, in which the catch in collected and brought to the edge of the net and is finally taken out using a scoop net.

Classification

The analysis of data collected on the Chinese nets operated in the Vembanad lake enables a broad classification of this gear into three size categories viz., Small, Medium and Large. The net size is expressed in terms of the length on one side of the mouth of the net.

Nets with a size upto 9 m. are classified as small nets. They are mainly operated on a sustenance level in the interior areas where the depth in relatively low.

Nets having a size of 9 to 12 m. are categorised as medium nets. About 97 percent of the nets operated in the study area belong to this group.

Nets belonging to the large size group are those with the net size above 12 m. These nets are operated only in the Fort Cochin and Vypeen areas.

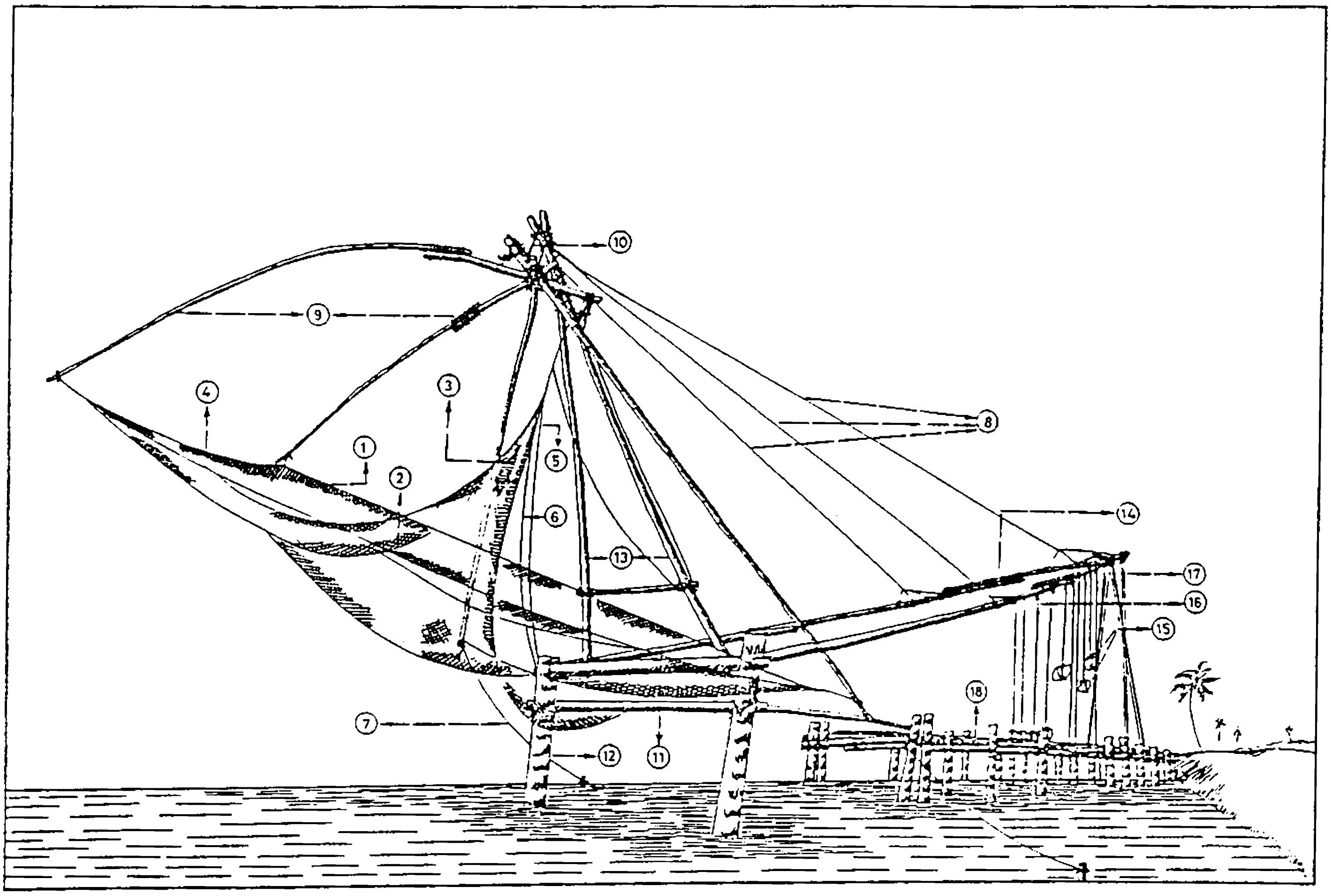


FIG. 4.1 THE CHINESE NET WITH THE CODEND PULLED UP AFTER OPERATION.

1) PERNA
2) NILAVALA
3) SANCHI (CODEND)
4) BORDA
5 & 6) KAYYAYI
7) UDHARA
8) SAVAI
9) BRAS
10) HARBOLA
11) KALSANTHI
12) KUTTI
13) PURAMKAZHUKOL (OUTER CRANE)
14) KARAKAZHUKOL (INNER CRANE)
15) COUNTER-WEIGHTS
16) KALLUKAMBA
17) VALIKAMBA (HAULING ROPES)

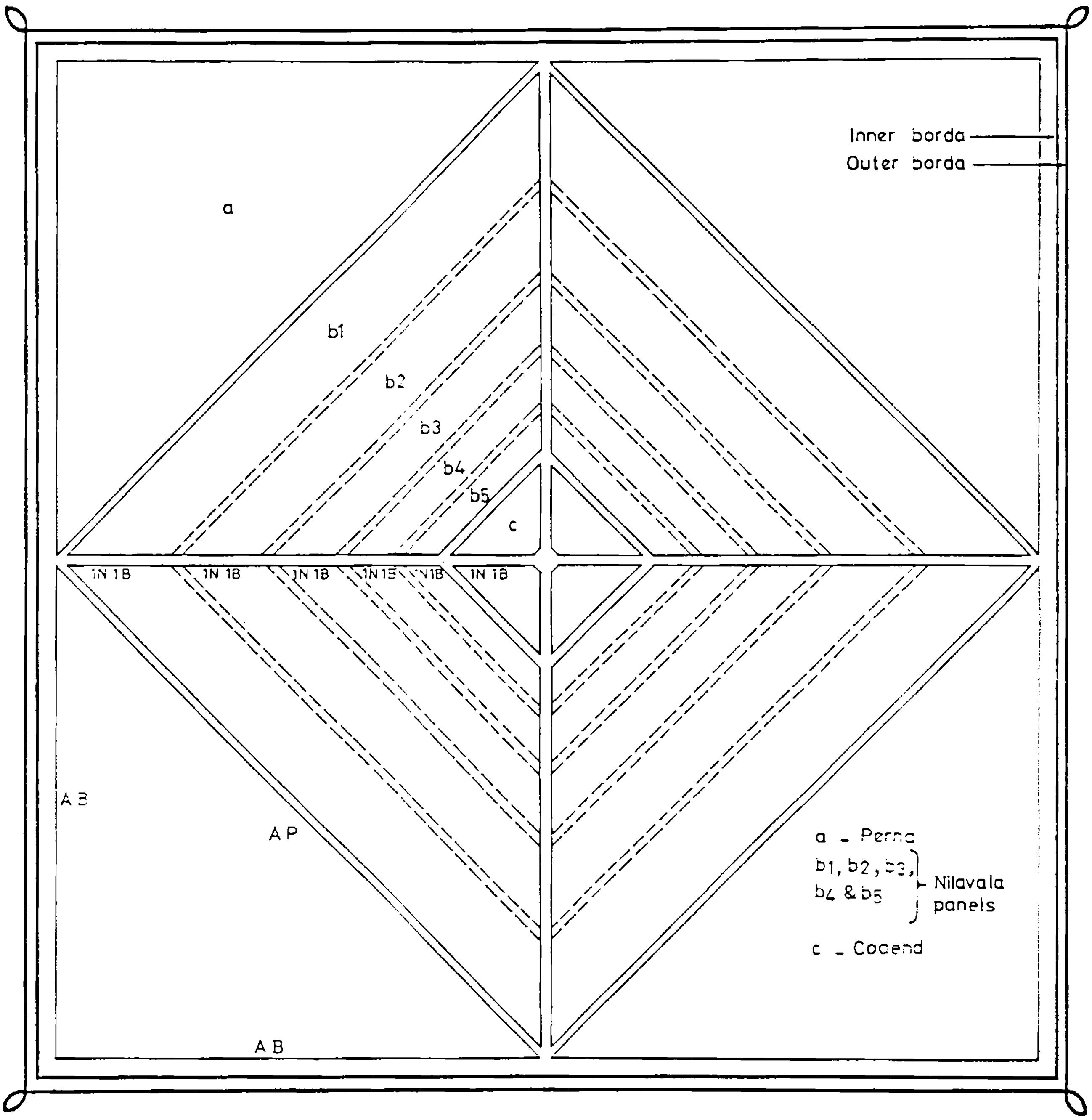


FIG. 4.2 DESIGN OF THE CHINESE NET.

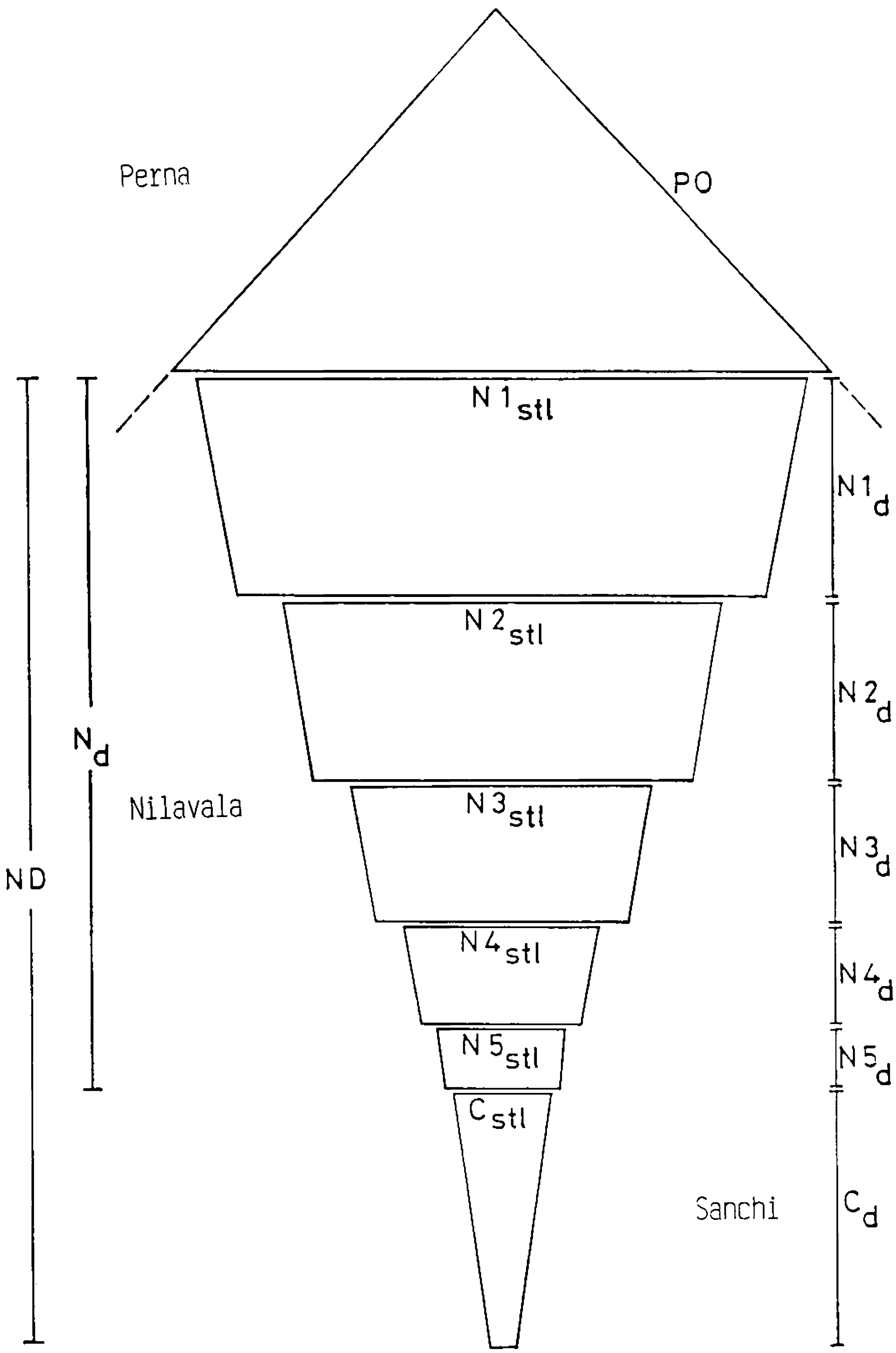


FIG. 4.3 AN IDENTICAL SECTION OF THE NET.

FIG. 4.4 PLATFORM OF THE CHINESE NET.

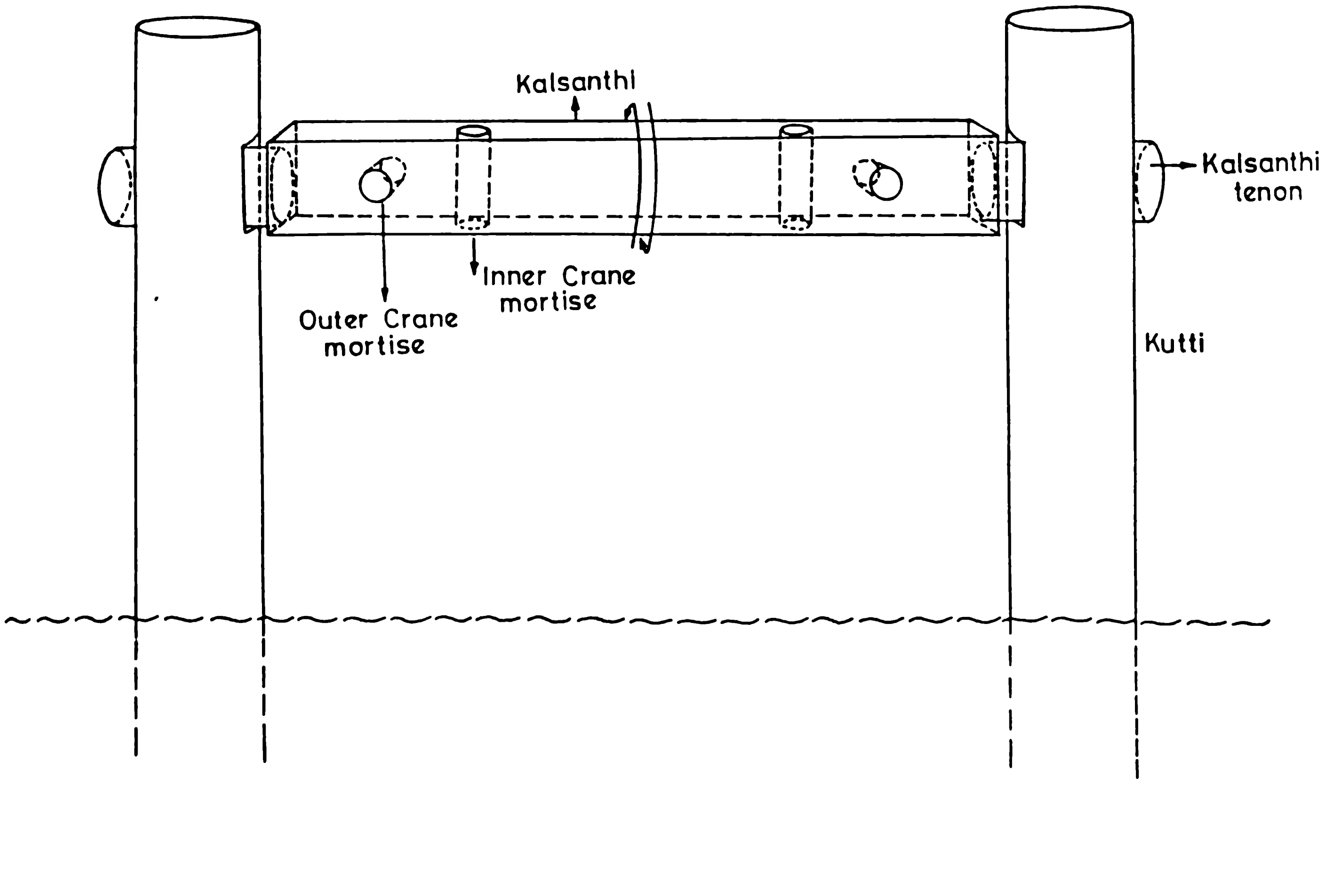


FIG. 4.5 THE TWO 'KUTTI'(PILES) SUPPORTING 'KALSANTHI'.

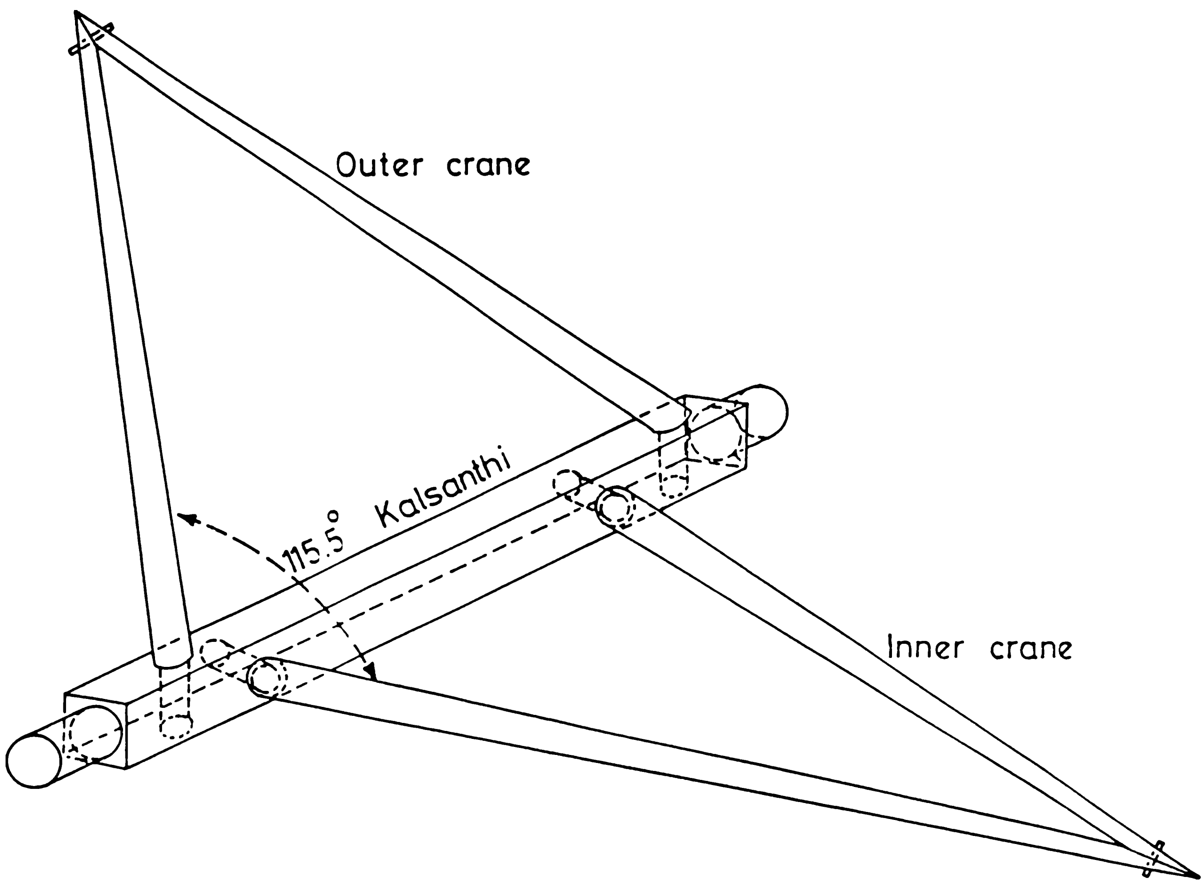


FIG. 4.6 AT⁻ACHMENT OF THE INNER AND OUTER CRANES ON THE 'KALSANTHI'.

FIG. 4.7 'SAVAI'-THE LINES BETWEEN THE OUTER AND INNER CRANES.

FIG. 4.8 'BRAS' AND THE NET.

FIG. 4.9 'PADACHIKKAYAR'-LINES USED TO SPREAD 'BRAS'.

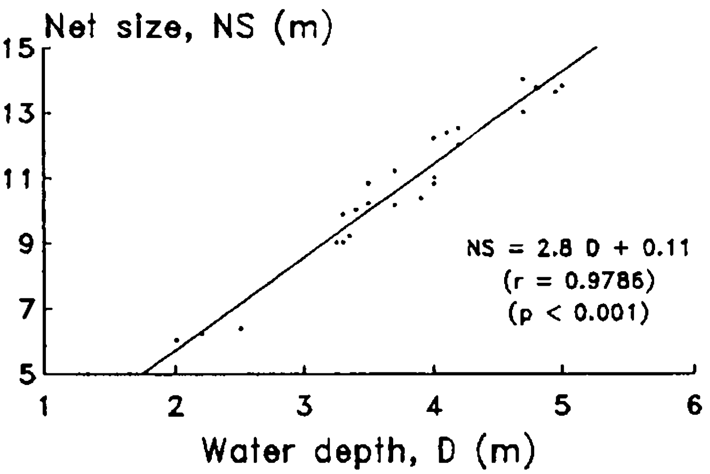


FIG. 4.10 WATER DEPTH vs NET SIZE

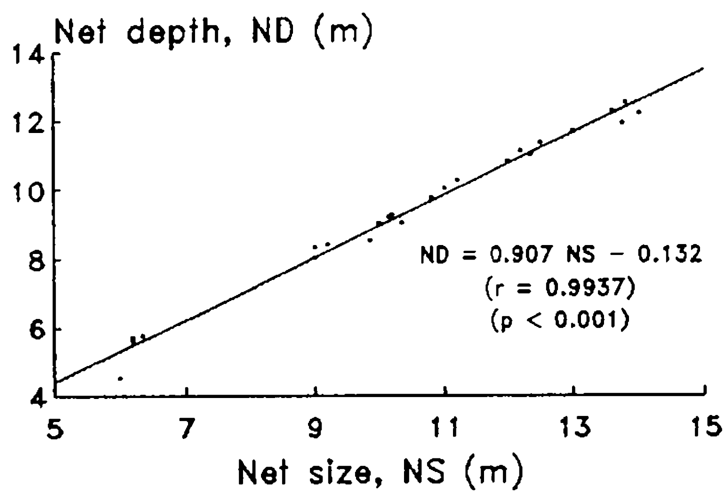


FIG. 4.11 NET SIZE vs NET DEPTH

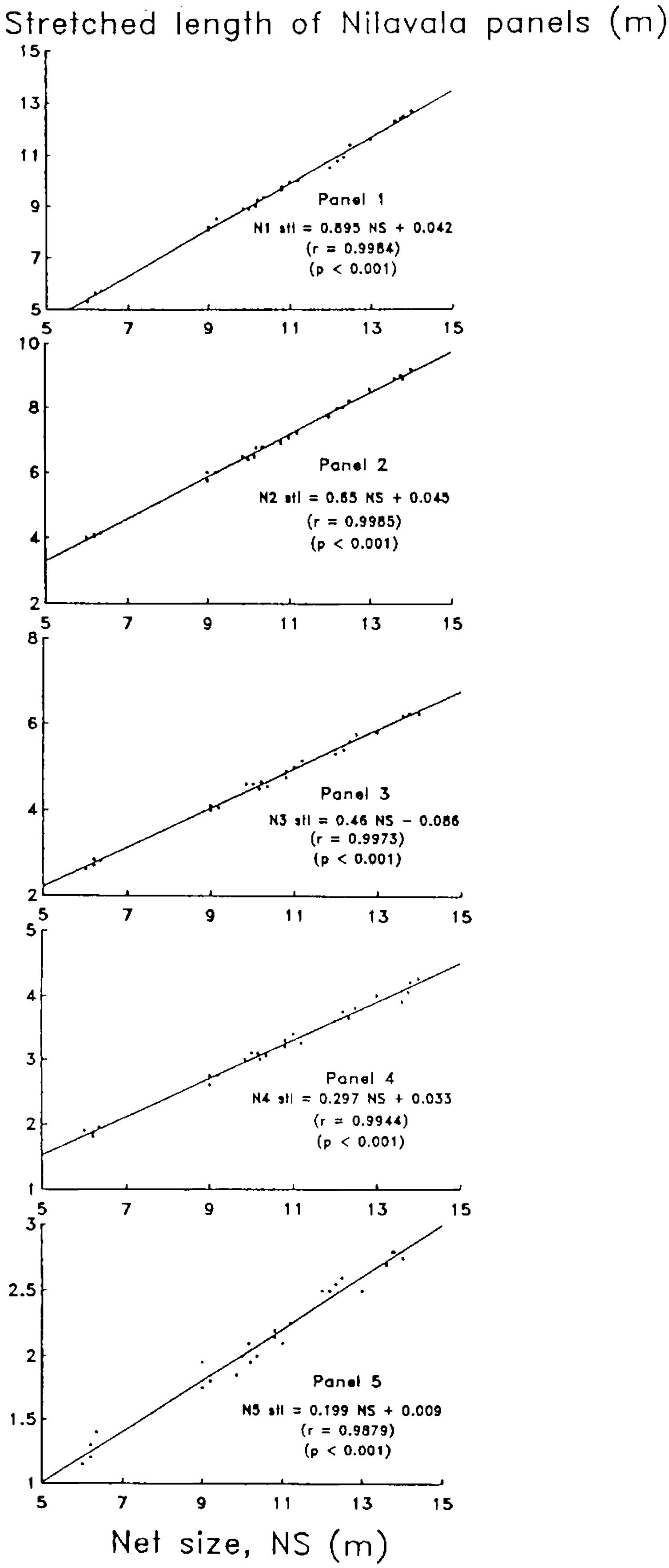


FIG. 4.12 NET SIZE vs STRETCHED LENGTH OF NILAVALA PANELS

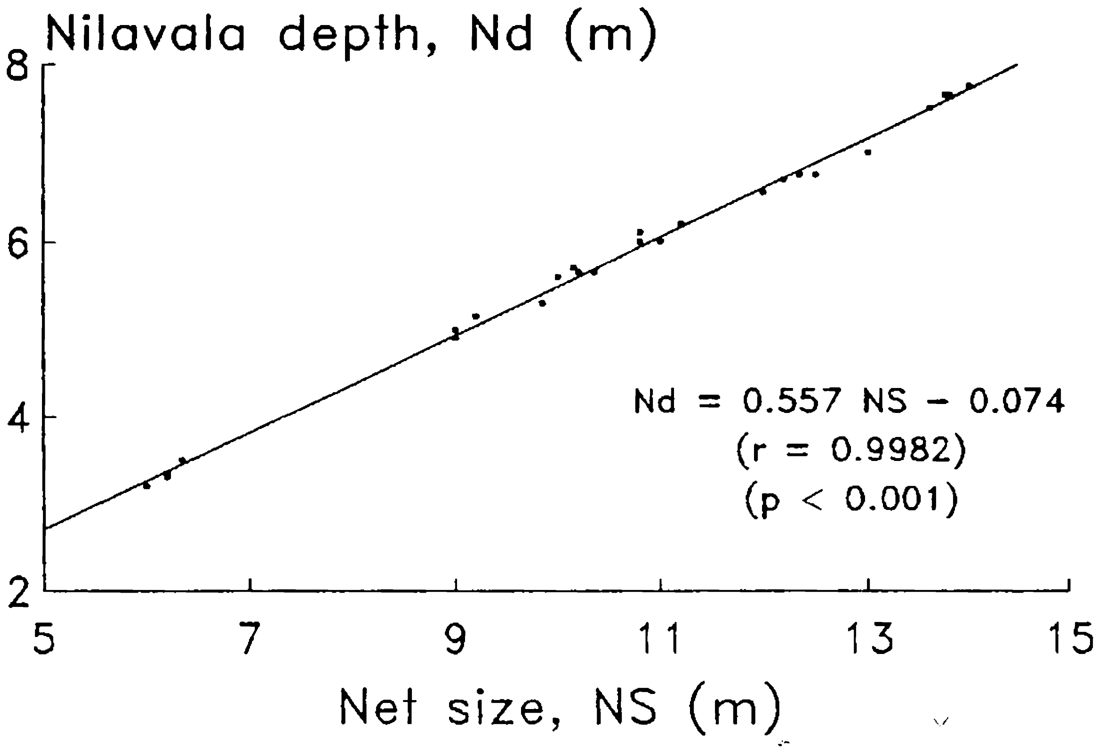


FIG. 4.13 NET SIZE vs DEPTH OF NILAVALA

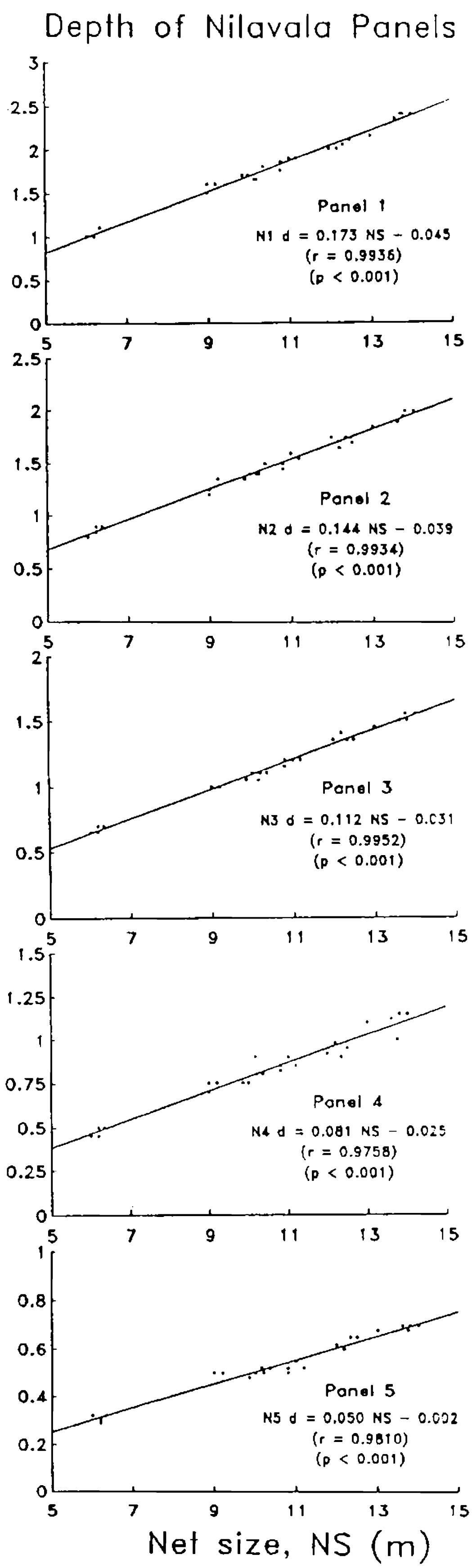


FIG. 4.14 NET SIZE vs DEPTH OF EACH PANEL OF NILAVALA

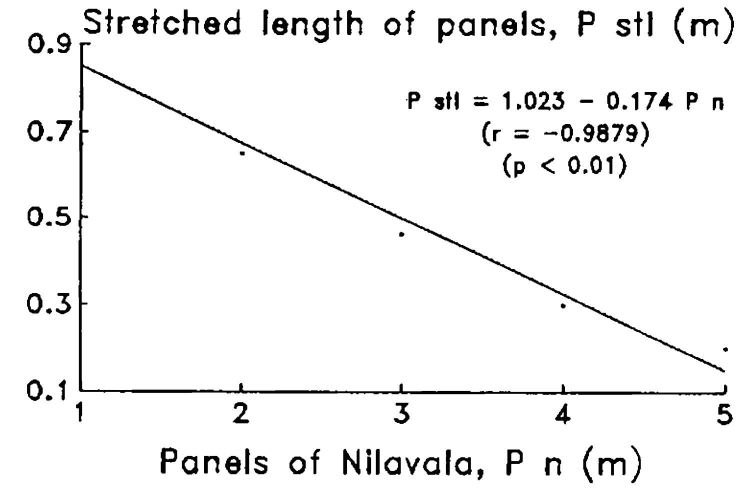


FIG. 4.15 NILAVALA PANELS vs STRETCHED LENGTH OF PANELS

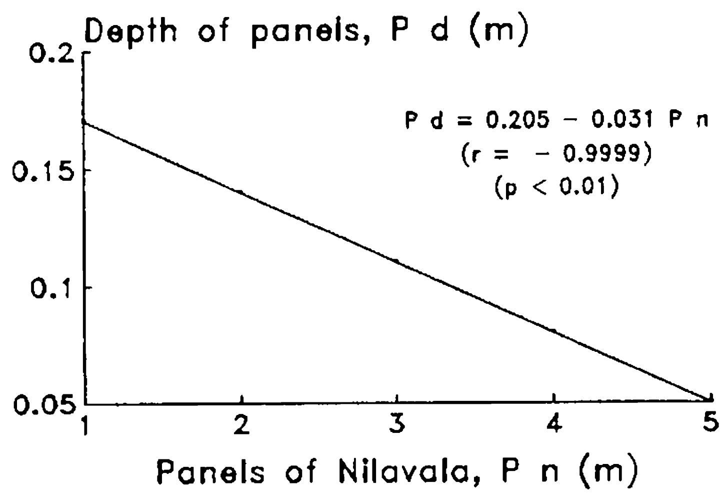


FIG. 4.16 NILAVALA PANELS vs DEPTH OF PANELS

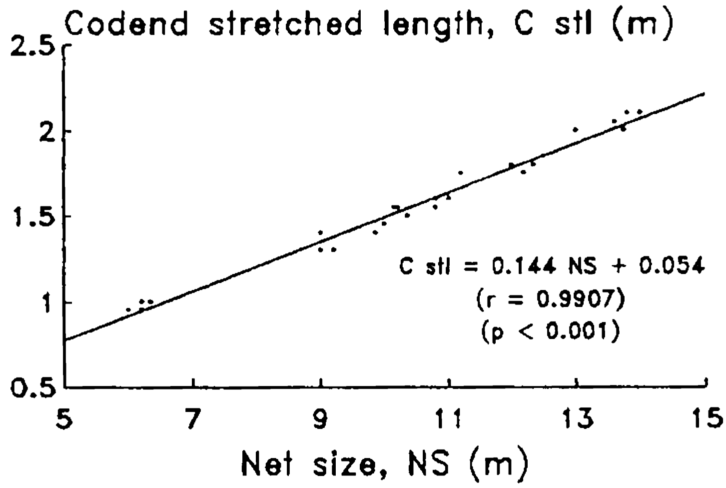


FIG. 4.17 NET SIZE vs STRETCHED LENGTH OF CODEND

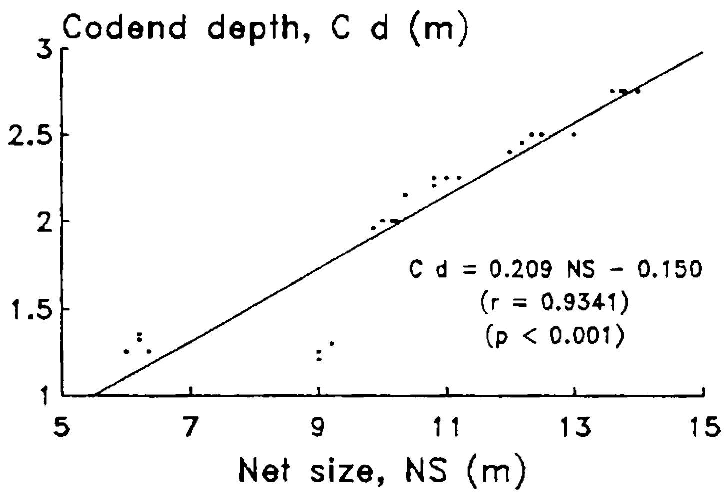


FIG. 4.18 NET SIZE vs DEPTH OF CODEND

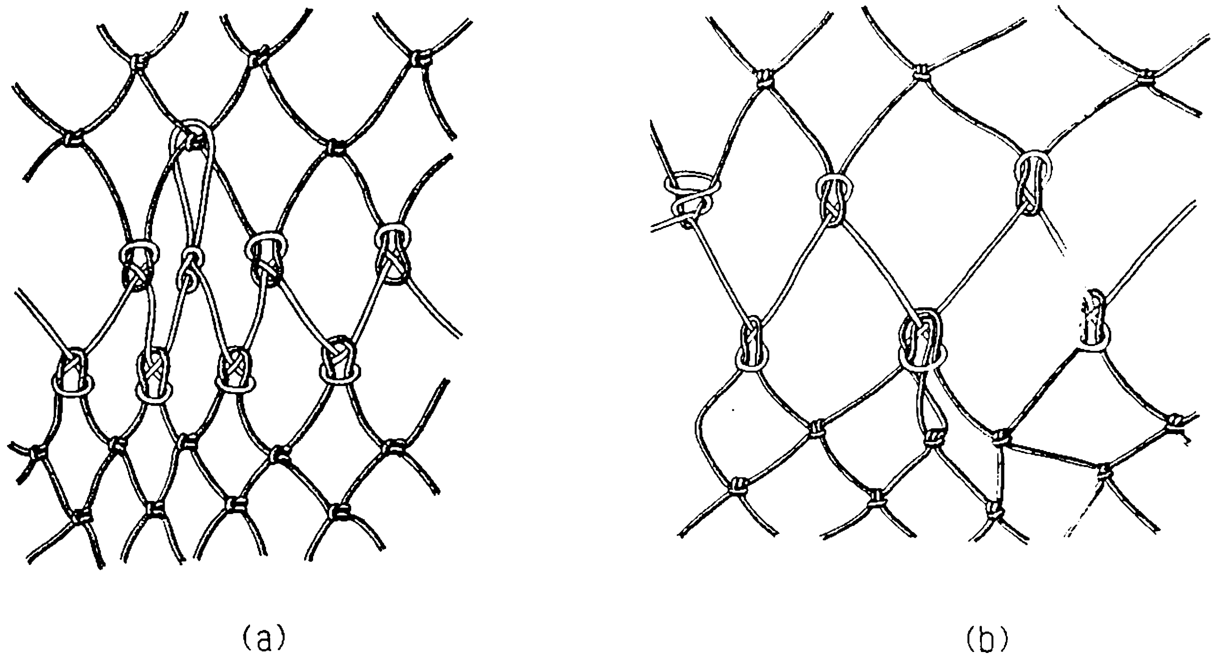


FIG. 4.19 METHOD OF JOINING OF PANELS BY
a) CREASING or b) BAITING.

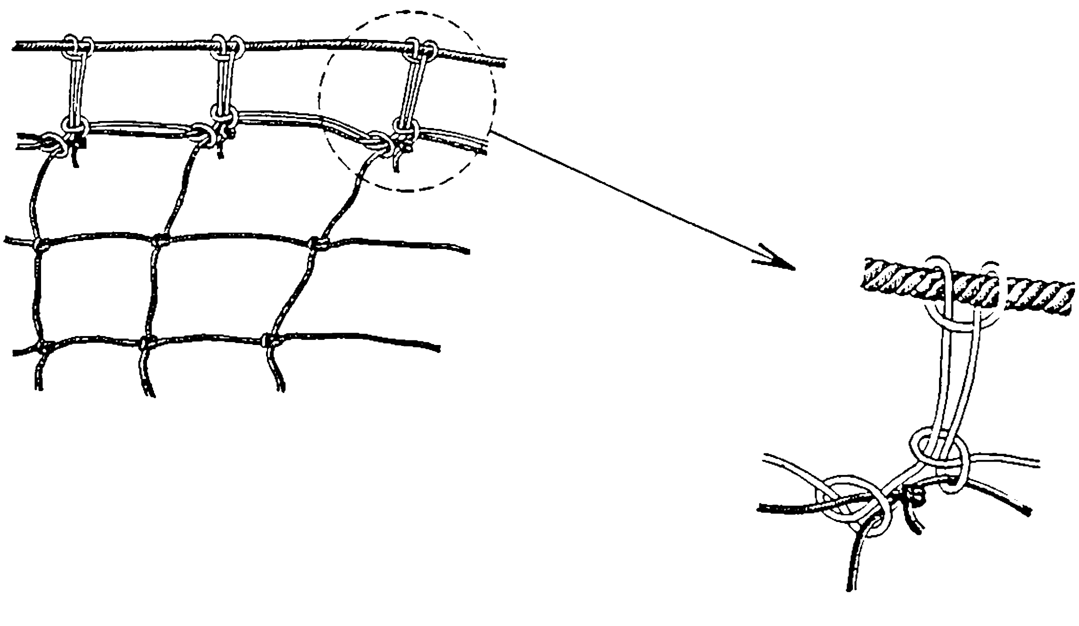


FIG. 4.20 MOUNTING OF 'PERNA' ONTO 'BORDA'.

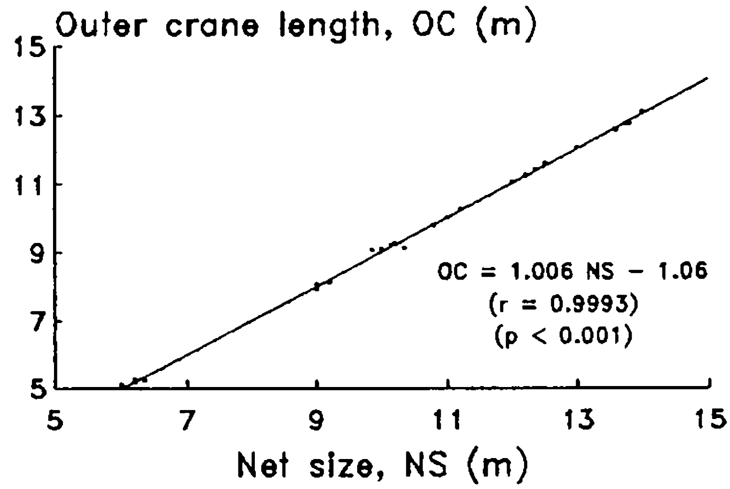


FIG. 4.21 NET SIZE vs LENGTH OF OUTER CRANE

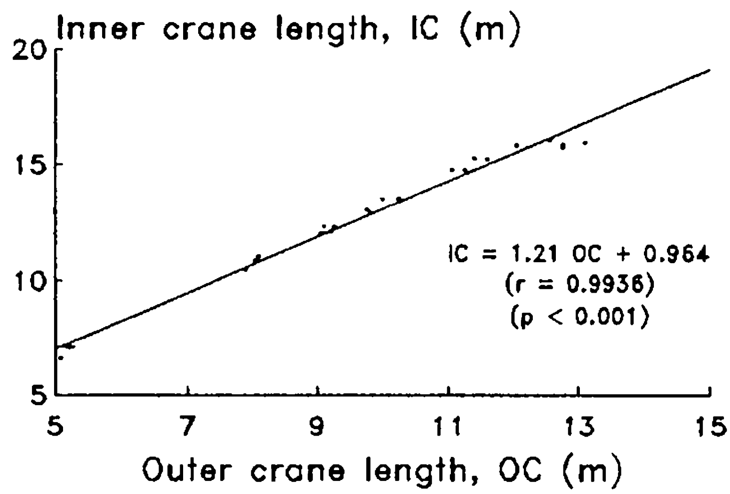


FIG. 4.22 LENGTH OF OUTER CRANE vs LENGTH OF INNER CRANE

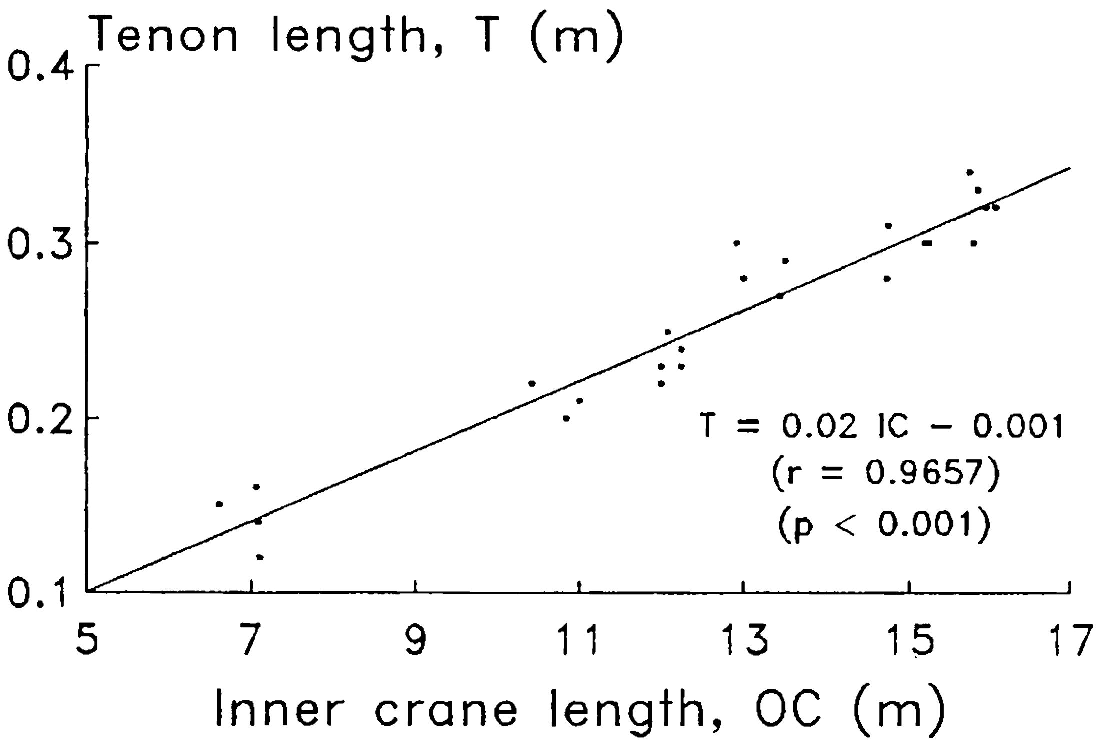


FIG. 4.23 LENGTH OF INNER CRANE vs LENGTH OF TENON

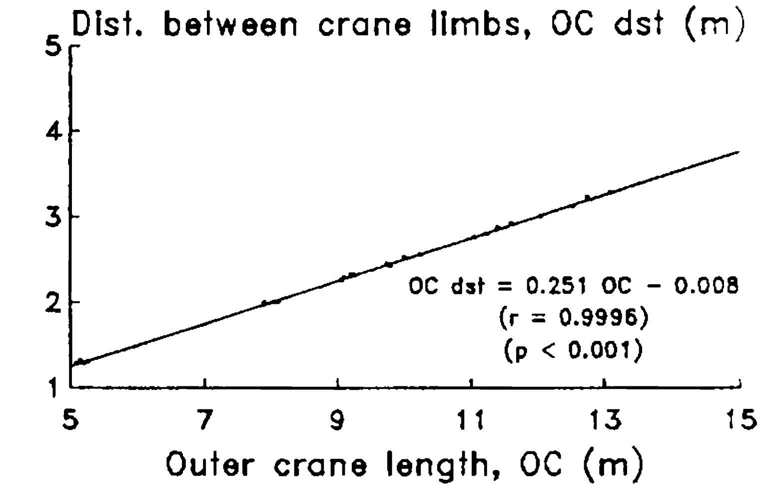


FIG. 4.24 LENGTH OF OUTER CRANE vs DISTANCE BETWEEN THE LIMBS OF OUTER CRANE

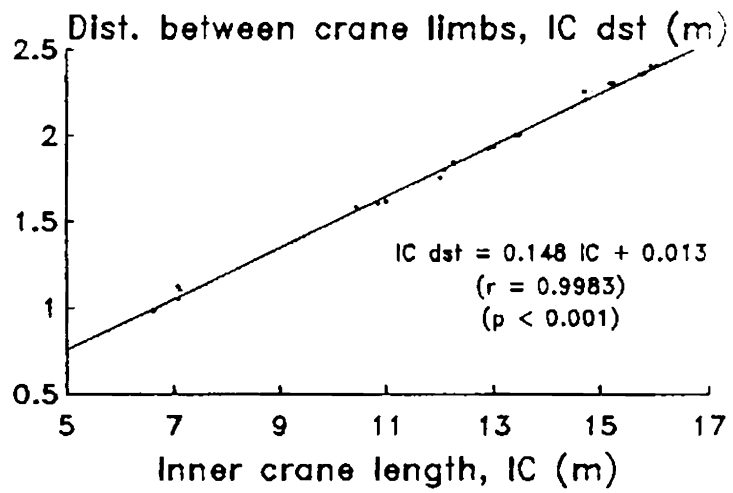


FIG. 4.25 LENGTH OF INNER CRANE vs DISTANCE BETWEEN THE LIMBS OF INNER CRANE

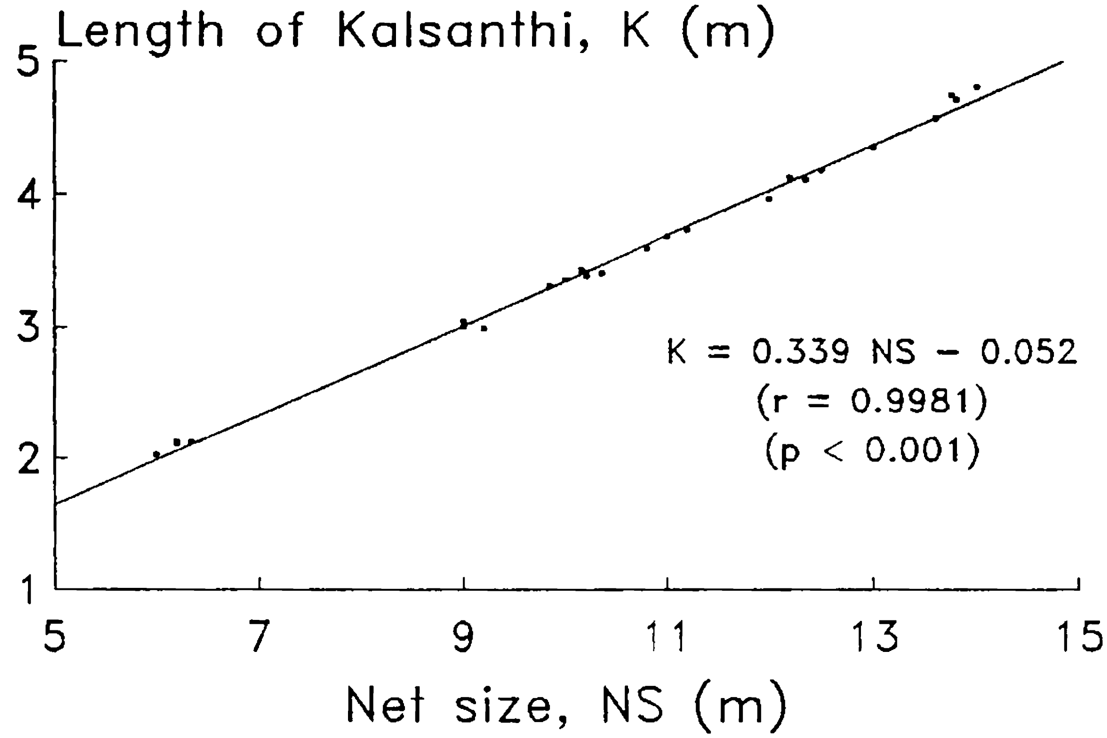


FIG. 4.26 NET SIZE vs LENGTH OF KALSANTHI

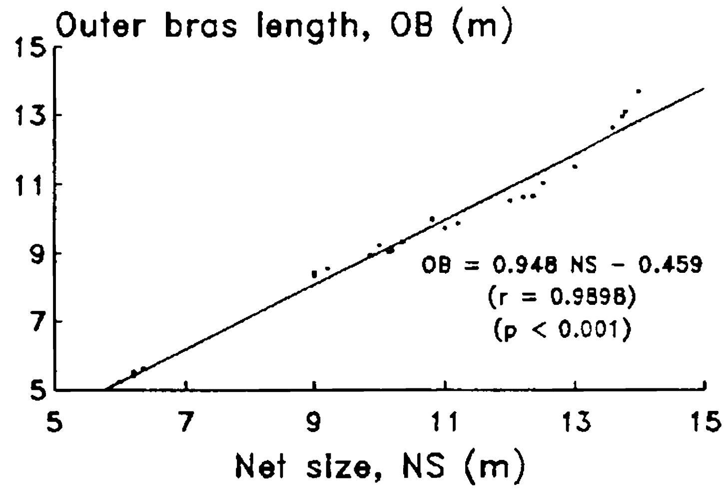


FIG. 4.27 NET SIZE vs LENGTH OF OUTER BRAS

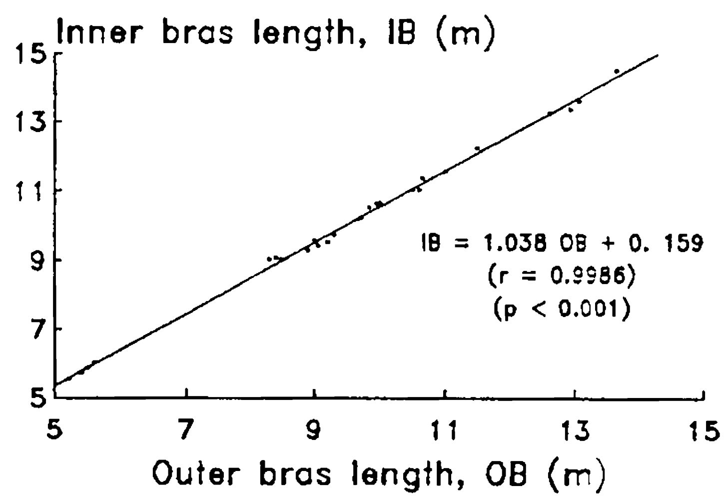


FIG. 4.28 LENGTH OF OUTER BRAS vs LENGTH OF INNER BRAS

C H A P T E R – V

ECONOMIC ANALYSIS

5.1. Introduction

One of the major difficulties in the formulation and implementation of sound development programs in the backwater fishery sector is the lack of basic economic data, which can provide a rational basis for the planning and execution of development, and in assessing their economic and social impact. Few economic analysis studies have been made in marine sector (Yahaya and Wells, 1980 ; Kurien and Willmann, 1982 ; Unnithan *et al.* 1985 ; Sathiadhas and Panikkar, 1988 ; Sadanandan *et al.* 1988 and Dutta et al. 1989). But no systematic study has been carried out to assess the economic feasibility of the gears operated in the backwaters in spite of their employment potential and importance as the most plausible methods for harvesting its fishery resources.

5.2 Objectives

The stake nets, gill nets and Chinese nets - the technical details of which were discussed in the preceding chapters are operated on a commercial level and merits scrutiny regarding their economics of operation. Hence, the objective of this economic analysis is to make an economic assessment of the these three types of gears operated in the lake. A comparative analysis of costs and earnings was also attempted.

5.3 Materials and Methods

Sample frame work

In order to study the economics of operation of the backwater fishing gears, it was required to collect primary economic data from the operators of the gear. Since it would be practically very difficult to collect and record accurate information on the fishing operations and costs and earnings of each and every unit of three types of gear operated throughout the lake , seven leading centres viz. Chembu, Panangad, Arookutti, Fort Cochin, Vypeen, Chathanadu and Krishnankotta were selected as representing the Southern, Central and Northern regions of the lake. (Fig. 1.1). The choice was governed by such considerations as (a) the geographic spread of the centres and accessibility (b) the representativeness of the final sample units to be monitored in the centre and (c) the convenience to collect reliable data from knowledgeable and verifiable sources.

Considerations of manageability indicated that not more than 31 units of Chinese nets, 49 units of stake nets and 24 gill nets could be studied altogether. The choice of sample size depended on the diversity of each type of gear in the centre - a minimum of two individual sample units was thought necessary for representing one particular type of gear in the centre. Table (5.1) gives the location, type and category of the gears, the number of units in operation in the area and the number of units chosen for the study.

It may be noted in this context that the sample despite its small percentage has given due representation to the various categories of different types of gear operated in the region. Details of costs and earnings were collected for a period of two years from 1986 August to 1988 August.

Collection of data

Primary economic data relating to investments, overheads and other fixed expenditures were collected in the initial stages of the study. Details of operational costs and earnings were collected in the course of successive fishing seasons. To facilitate this, a schedule eliciting information on costs and earnings was distributed to each fishing unit. The details recorded in the schedule were noted during regular visits to the centres. This was further verified by cross-checking with the records of fishermen wherever possible and also by oral verification with the operators of the gear. These methods made it possible to ascertain and check the vicissitudes of the different gears and have a first-hand knowledge of their economics.

Data analysis

The data collected during the period of study are presented in the form of costs and earnings tables which gives a picture of the comparative costs, earnings and profitability of the different types and categories of gear for the relevant period.

5.4. Results and Discussion

Stake net

Two categories of stake nets, viz., the square-mouthed (type A) and rectangular-mouthed (type B),are operated in the Vembanad lake, at different stations. Type B was comparatively larger than type A, and required marginally higher investment. These larger units were operated at station nos. 1, 5 and 6 (Fig. 1.1)., where the depth of the operating area was greater. The various economic parameters and profitability ratios of both categories of stake net operated at different stations are presented in Table (5.2).

The capital investments for a stake net included the cost of the net and stakes. The cost of type A nets varied from a low of Rs. 1,600.00 at Vaikkom (station no. 8) to a high of Rs. 1,800.00 at Vypeen (station no.3) and Krishnankotta (station no. 1). Though the cost of stakes were same for both types at a particular station, it was remarkably high at Rs. 850.00 in station nos. 1 and 3 than in other centres, which varied between Rs.300.00 and Rs.150.00. This was because stations 1 and 3 being nearer to the bar mouths, required stronger stakes to withstand the strong currents prevalent in the region. The average capital investment of a rectangular-mouthed unit at Rs.2,716.67 was 16.56 percent higher than the average investment of a square-mouthed units, which was Rs. 2,266.00. In the former type, on an average, the net contributed 79.75 percent, while it was 76 percent in the latter.

Labour and maintenance of the net were the variable costs incurred by the stake nets. The average remuneration per worker ranged from Rs.40.00 to Rs. 50.00 per day, at different stations and was same for both categories operated in a particular station. In both types, on an average, labour formed about 98 percent while maintenance of the net required 2 percent of the total variable cost incurred per unit.

The fixed cost incurred by a stake net operation were rent for canoe, interest at 12 percent on both capital and variable costs, depreciation at 15 percent on net and 10 percent for supporting structure, insurance premium and Government tax. The insurance premium and tax were statutorily fixed at Rs. 150.00 and Rs.20.00 respectively per unit per year.

Thus the average total costs of type A and type B stake nets worked out to Rs.28,012.25 and Rs.28,620.00 respectively. In general type B units had a higher earnings than type A operated in a particular station.

The net profit for both years was maximum for the type

A units of station no. 3 (Rs.6,845.00). This was followed by type B units of station no. 6 (Rs. 6,496.00) and station no. 1 (Rs. 5,825.00). Type A units of stations Nos. 1, 2 and 5 had an average net profit of Rs. 4,645.00, Rs.4,145.00 and Rs.4,355.00 respectively. At Vaikkom (station no. 8), the total earnings per year per net was only Rs.21,000.00. The main reason for this is the reduced number of days of operation in this station, which had very low tidal influence as a result of the construction of the Thanneermukkom Bund. The operating time per day was also less in comparison with other stations. The continued operation of the stake nets at this station in spite of the loss incurred was due to the fact that the labour at this station was constituted by the owners themselves, who further augmented their income by carrying out other methods of fishing, of which, gill netting was the most popular.

Gill net

Ten different types of gill nets are operated at the various centres of the Vembanad lake. Though these nets were species-specific, they also caught other species with varying regularity and intensity. Also, certain types were seasonal while some were operated only at a particular centre. Moreover most of the active fishermen possessed different types of gill nets which they operated according to their perception of the fishery at a given time. Considering these variations, representative samples of the different types of gill nets operated in an area were taken together and their average costs and earnings worked out for two consecutive years (Table. 5.3).

The only capital investment required for a gill net operation was the net, which on an average came to Rs. 1,433.00 per unit. At station no. 3, the average cost of a net worked out to Rs. 1,600.00, while it was only Rs. 1,200.00 at Vaikkom (station no. 8). Stations 2 and 6 also showed relatively higher investment. This could be attributed to the presence of larger number of nets specific for fish, which required thicker twines, resulting in enhanced weights per unit,than was required for nets specific for prawns.

The operating costs for gill net included labour and maintenance. On an average 99.27 percent of the variable cost was incurred as labour charges. This worked out to an average wage of Rs.42.80 per man day. It was highest at stations 3, 5 and 6 (Rs. 22,000.00) and lowest at station no. 2 (Rs. 17,600.00) per year.

Fixed cost included rent for canoe, interest on capital and variable cost at the rate of 12 percent, depreciation on net at the rate of 15 percent, insurance premium at the rate of Rs. 150.00. per unit per year and fee to Government at the rate of Rs. 10.00 per unit per year. The average total fixed cost worked out to Rs. 3,744.00 per unit. The highest total fixed cost was recorded at station no.3 (Rs.4,020.00) and the lowest was at station no. 2 (Rs.3,355.00).

The average total earnings per net ranged from a low of Rs. 23,845.00 at station no. 8 to a high of Rs. 27,881.50 at station no. 6, per net per year. The average for all stations worked out Rs.25,698.19 per unit per year. The profit per year was the lowest at station no. 8 at Rs. 467.56 and was maximum at Arookutti (station no. 6) with an average annual profit of Rs. 1,738.50. The average annual profit per unit for all stations worked out to Rs. 1,270.86.

Chinese net

Three size categories of Chinese nets are operated at the different centres in the Vembanad lake. The investment per unit, among the three groups showed significant difference and investments outlay-wise, these nets could be divided into three categories, viz., high, medium and low investment groups. The low investment units were operated only at Panangad (station no.5) while the high investment nets were found only at Fort Cochin (station no. 4) and Vypeen (station no. 3). More than 97 percent of the nets operated in the Vembanad lake belonged to medium investment category and are operated at all stations selected for this study. The investment profiles and profitability ratios of all three groups are given in Table (5.4).

The average capital investment for a small size unit was Rs. 3,375.00 of which 18.5 percent was for the net and 81.5 percent was for its supporting structure. Out of the average total capital investment of Rs.15,883.33 required for a medium size units, 14.2 percent was required for the net and 85.5 percent for the supporting structure. In the case of large sized units the average capital investment was Rs. 25,570.00 with the net constituting 18 percent and supporting structure accounting for the remaining 82 percent. The variation in capital investment between the different stations for units of this same category could be attributed to the variation in the quality of wood used for the construction of the supporting structure.

Among the variable cost, labour contributed 92.5 percent in the small, 95.7 percent in the medium and 98.1 percent for the large units respectively. The difference in labour could be attributed to the number of crew required for the operation of each size category, with the small units requiring only a single person, the medium size units requiring 2 to 3 persons and the large size units requiring 5 to 7 persons. The fuel costs for small units was Rs. 861.00, Rs. 796.00 for medium and Rs. 945.00 for large units. The low fuel cost in the medium-sized nets could be attributed to the less number of operating days for this category. Maintenance cost contributed 1.25 percent in small, 1.6 percent in medium and 0.9 percent in large units respectively.

Interest on capital and variable cost at 12 percent, depreciation on net at 15 percent and on supporting structure of 10 percent, insurance premium and tax constituted the fixed cost for the Chinese nets. The average total fixed cost for a small, medium and large nets was Rs. 2,617.87, Rs. 7,425.03 and Rs. 17,615.05 respectively. The average total earnings for a small unit was Rs. 16,900.24, for a medium unit Rs. 45,395.72 and for a large unit, Rs. 1,44,268.50. The average profit yielded for a small net was Rs. 331.37, for medium Rs. 7,572.53 and for a large unit, it was Rs. 30,083.51.

Profitability ratios

Based on the available data, the economic efficiency of the different type of gear was ascertained by working out the profitability ratios and is presented in Table(5.5)

Average return on variable cost was maximum for the large size Chinese net at 30.77 percent followed by the rectangular-mouthed (Type B) stake nets at 24.7 percent, medium size Chinese nets (23.35 percent), square-mouthed (Type A) stake nets (14.96 percent), gill nets (6.11 percent) and small size Chinese nets at 2.38 percent.

Return on capital investment was maximum for rectangular-mouthed stake nets at 215.77 percent followed by square mouthed units at 153.20 percent. The average return on capital was 9.81 percent, 46.64 percent and 116.47 percent for the small, medium and large categories of Chinese nets. Gill nets had an average return on capital of 87.12 percent.

Average return on turnover at 20.61 percent was maximum for large size Chinese nets followed by rectangular-mouthed stake nets with 16.95 percent, medium sized Chinese nets with 15.48 percent, square mouthed stake nets with 10.07 percent, gill nets with 4.89 percent and the lowest was for small sized Chinese nets with a return on turnover of only 2 percent.

Return on total cost was maximum for the large-sized Chinese net recording 26 percent. This was followed by the Type B stake nets at 20.44 percent, medium size Chinese net at 18.8 percent, Type A stake net at 12.45 percent, gill nets at 5.16 percent and small size Chinese nets at 2 percent.

The payback period was found to be the least for Type B stake nets (0.29 years). The highest payback period was for the Type A stake nets (1.82 years). The payback periods for small and medium Chinese nets were found to be almost the same at 1.21 and 1.22 years respectively, whereas for the large-size Chinese net it was only 0.55 years. The payback period for gill nets were found to be 0.35 years.

The break even point was maximum for large size Chinese nets at Rs. 53,345.06. It was least for small size Chinese nets at Rs. 15,001.33. The medium size Chinese nets had a break even point of Rs. 22,829.84. Break even points for Type A and B stake nets were worked out at Rs. 23,910.21 and Rs. 15,787.60 respectively. The gill nets recorded a break even point at Rs. 19,294.79.

TABLE 5.1 DETAILS OF SAMPLE.

Location	Number/Percentage	CHINESE NET				STAKE NET			GILL NET
		Small	Medium	Large	Total	Square	Rectangle	Total	Total
Krishnan Kotta	Units operated	—	24	—	24	36	26	62	28
	Units chosen	—	3	—	3	4	4	8	4
	Percentage of total	—	12.50	—	12.50	11.11	15.38	12.90	14.29
Chathanadu	Units operated	—	18	—	18	58	—	58	34
	Units chosen	—	3	—	3	6	—	6	4
	Percentage of total	—	16.67	—	16.67	10.34	—	10.34	11.76
Vypeen	Units operated	—	24	20	44	65	—	65	35
	Units chosen	—	3	3	6	10	—	10	4
	Percentage of total	—	12.50	15.00	13.64	15.38	—	15.38	11.43
Fort Cochin	Units operated	—	4	14	18	—	—	—	—
	Units chosen	—	2	3	5	—	—	—	—
	Percentage of total	—	50.00	21.43	27.78	—	—	—	—
Panangad	Units operated	8	26	—	34	22	20	42	31
	Units chosen	2	3	—	5	5	4	9	4
	Percentage of total	25.00	11.54	—	14.71	22.73	20.00	21.43	12.90
Arookutty	Units operated	5	32	—	37	52	14	66	14
	Units chosen	2	4	—	6	8	3	11	4
	Percentage of total	40.00	12.50	—	16.22	15.38	21.43	16.67	28.57
Vaikkom	Units operated	—	29	—	29	46	—	46	30
	Units chosen	—	3	—	3	5	—	5	4
	Percentage of total	—	10.34	—	10.34	10.87	—	10.87	13.33

TABLE 5.3 COSTS AND EARNINGS OF GILL NETS OPERATED AT DIFFERENT STATIONS (1986-88).

Item/Stations	K.Kotta	Chathanad	Vypeen	Panangad	Arookutti	Vaikkom	AVERAGE
Capital Investments							
Net	1350	1500	1600	1450	1500	1200	1433.333
TOTAL	1350	1500	1600	1450	1500	1200	1433.333
Variable costs							
Labour	19800	17600	22000	22000	22000	19800	20533.33
Maintenance	150	150	150	150	150	150	150
TOTAL	19950	17750	22150	22150	22150	19950	20683.33
Fixed Costs							
Rent for canoe	770	660	770	770	770	550	715
Interest							
On capital @ 12%	162	180	192	174	180	144	172
On Var.cost @ 12%	2394	2130	2658	2658	2658	2394	2482
Depriciation							
On net @ 15%	202.5	225	240	217.5	225	180	215
Insurance premium	150	150	150	150	150	150	150
Tax to the Govt.	10	10	10	10	10	10	10
TOTAL	3688.5	3355	4020	3979.5	3993	3428	3744
TOTAL COST	23638.5	21105	26170	26129.5	26143	23378	24427.33
EARNINGS	25033.17	22265.77	27766.37	27396.7807	27881.50	23845.56	25698.19
PROFIT	1394.671	1160.775	1596.37	1267.28075	1738.509	467.56	1270.861
Profitabilty ratios							
Return on turnover	5.571293	5.213270	5.749293	4.62565569	6.235349	1.960784	4.892607
Return on Capital	103.309	77.385	99.77312	87.3986724	115.9006	38.96333	87.12162
Return on Total cost	5.9	5.5	6.1	4.85	6.65	2	5.166666
Return on Variable cost	6.990834	6.539577	7.207088	5.72135778	7.848801	2.343659	6.108553
Payback period	0.325052	0.405868	0.341415	0.33589845	0.312401	0.376699	0.349556
Break Even Point	18164.81	16542.38	15874.19	20779.5016	19424.35	20983.52	19294.79

TABLE 5.5 AVERAGE PROFITABILITY RATIOS FOR THE DIFFERENT TYPES OF NETS.

	Chinese net			Stake net		Gill net
	Small	Medium	Large	Square	Rect.	
Return on variable cost	2.38	23.35	30.77	14.96	24.7	6.11
Return on Capital	9.81	46.64	116.47	153.2	215.77	87.12
Return on turnover	1.96	15.48	20.61	10.07	16.95	4.89
Return on Total cost	2	18.8	26	12.45	20.44	5.16
Payback period	1.21	1.22	0.55	1.82	0.29	0.35
Break Even Point	15001.33	22829.84	53345.06	23910.21	15787.6	19294.79

C H A P T E R – VI

RASCHEL KNOTLESS NETTING

6.1. Introduction

Knotless nets have been known for a long time and as the name implies are nets devoid of knots, the twines being joined at the mesh corners by an interlacing of the adjacent mesh bars. Introduction of chemical fibres for fishing brought the idea of welding or gluing synthetic fibres together to form netting. Stamping or molding finished net sheets have been unsuccessfully tried (Brandt, 1964).

The knotless net was invented in 1922 by the Nippon Seimo Co.Ltd. and was first introduced in the Japanese fishery (Nippon Seimo, 1959). This type of knotless netting is made of twines consisting of only two yarns. Meshes are formed by interlacing the yarns of two twines, once or several times. By increasing the number of interlacing of the twines at the joining points, the shape of the mesh may be changed from rhomboid to hexagonal. This method of making knotless netting is known as the Japanese twisted type, and the technique stimulated efforts elsewhere to develop production techniques for new types of knotless netting.

Consequent to these efforts, another type of knotless netting was introduced into fisheries around 1951. The manufacture of this type of netting was based on the Raschel technique popular in curtain - making for about a century and hence this type of knotless netting came to be known as Raschel knotless netting. This method has been developed in Germany in 1950 (Viswanathan, 1972), from where it spread quickly to other European countries and the U.S.A.

The bars of the meshes are built up by one or two knitted stitches made by looping of yarns referred to as looped threads (Damiani, 1964). Besides, additional loops for strengthening are provided by another set of yarns referred to as laid-in-threads or swing threads. In the most popular type of Raschel knotless netting, a thread is formed by three ends - two laid-in-threads and one looped, entwined together. The laid in threads are in an almost rectilinear position, while the looped threads follow a more complicated path. (Fig. 6.1)

The Raschel technique of knitting is done by special machines (Reichel, 1960). It not only makes the connections to form meshes but also knits the mesh bars. Therefore the Raschel machine operates quite differently from knotting machines, in that it produces, per unit time, not a certain number of connections but a certain area of netting which is not influenced by the mesh size (Brandt, 1964). There is no uniformity of opinion as yet regarding the mesh size above which the production of knotless Raschel nets are no more profitable. But, the output of Raschel machines increase with increasing strand size because the number of stitches per centimeter for building up the bar decreases with increasing strand sizes. This contradicts the widespread opinion that this technique is profitable only for the production of small-meshed netting. Apparently, the possibilities of the Raschel technique for producing heavy, large-meshed netting are gaining popularity in many countries.

The Raschel type knotless netting has characteristics of both the knotted as well as that of the Japanese twisted types and various combinations are possible depending on the choice of yarns used for looped and laid- in- threads and the method of interlacing of the threads (Nakamura, 1971). According to Damiani (1964), the more complex the structure of joints, the stronger and more durable they are, according to whether only the looped threads or also the laid-in-threads are entwined and depending upon the number of binding points. But a comparison of twine strength lost in the joints between knotted and Raschel knotless nettings was not possible due to the difference in the construction of the joints (Mugaas, 1964).

Advantages of knotless netting

Knotted netting has some principal disadvantages for fishing nets. An important factor is that knotting causes a significant decrease in the breaking strength (Klust, 1982). Another disadvantage is that the protruding knots are more susceptible to abrasion. In knotted netting a substantial proportion of the length of netting yarn goes into the knots, increasing the weight but not the useful area of the netting and this portion increases with decreasing mesh size and increasing diameter of the netting yarn.

Contrary to these unfavorable characteristics of knotted netting, the knotless netting claims many advantages. But the presence of at least two different construction techniques, twisting and Raschel, permit a wide range of modifications regarding the connections and twine, causing the advantages to vary quantitatively with each type of netting. The validity of these advantages also vary for different types of fishing gear.

All the essential advantages claimed by knotless variety are mainly due to the absence of knots. One significant advantage is that, since less twine is used to make the meshes for the same area, knotless netting would be lighter. This reduction in material used, greatly reduces the bulk, making it easier to handle the gear. In certain instances a saving of up to 50 percent by weight of material is noted. This in turn translates into a reduced production cost. Another important advantage is the low resistance offered by the knotless netting to the flow of water, making it possible to increase towing speed or the gear size.

The loss in strength, when knotted, is about 18 to 20 percent for natural fibres and 30 to 40 percent for synthetic fibres (Klust, 1982). But in knotless nets, as the fibres undergo practically no sharp bending, there is no reduction in strength and as a result, correspondingly lighter twine can be used.

Yet another benefit of avoiding knots is that since there is no tightening of knots, as in knotted nets, the meshes undergo no change and is almost 100 percent constant throughout its life (Nippon Seimo, 1959). The damage caused by abrasion of knots as a result of friction with the bottom of the operating area, against the boat's side or with other gear parts, can also be reduced in knotless nets.

The absence of interstices of knots considerably reduces the adherence of dirt and micro-organisms, so that knotless nets are much less fouled and need less washing. Other advantages such as causing relatively less damage to fish collected in the cod end, convenience and perfection in dyeing and quicker drying are also attributed to the knotless netting.

Specification of Raschel knotless netting

Even though the Raschel type knotless netting was introduced to fisheries during the early fifties, its production in India began only in 1964 (Lal, 1969) The properties and mode of specification of the Raschel type of knotless netting produced in India by four different production units have been studied in detail by Gopalan Nayar and Radhalakshmi (1981).

The popular 210 denier nylon multifilament yarn is used as looped as well as laid- in- threads. When used as looped threads, it is paired with either the same denier or heavier denier yarn laid-in-threads. Samples with 210 denier yarn as laid-in-threads and finer yarns as looped threads are also made. Use of finer denier yarns for looped threads is advantageous, since increase in weight by looping of yarns is reduced.

For specifying a knotless netting the quality numbers combined with dimensions of the netting are denoted. The first digit of the quality number expresses the first digit of the denier size of looped thread yarn, the second digit denotes the first digit of the denier size of laid-in-thread yarn and the last two digits, the size of mesh in mm (Gopalan Nayar and Radhalakshmi, 1981). In samples where more than one multifilament yarn was used for laid-in-thread, a third digit was incorporated before denoting the mesh size, to indicate the size of the second laid-in-thread yarn.

Raschel denier of the netting which is indicative of the weight is derived by adding the denier size of the laid-in-threads with four times that of the looped threads, since when looped threads stitch the bars, four times the length is utilized for the formation. A Raschel netting is economical by weight if the Raschel denier is nearer, equal to or is less than the resultant denier of the knotted equivalent. The sum total of the strength of laid-in-threads and looped threads gives the strength of Raschel netting. Laid-in-threads are in an almost linear position and hence the strength can be equated to the linear strength of the basic yarn. Looped threads follow a complicated path and hence there is a 25 percent reduction in strength by looping (Tani, 1964).

A recent development in the field of knotless netting has been the introduction of braided knotless netting. But it is yet to be introduced into fishing on an industrial scale. In this type, the bars are real braids consisting of three or four strands, which are braided together with the strands of the neighbouring bars, thus forming the joints. All threads run diagonally through the netting. It is possible that this type of knotless netting will prove superior to the other types of knotless netting (Klust, 1982).

6.2. Objectives

The acceptance of knotless webbing by the fishermen for the construction of different parts of the gear operated in the backwaters is an interesting phenomenon, since the introduction of this netting was done by the fishermen themselves and was not the result of any scientific study highlighting the advantages of this type of net for any specific gear or parts of a particular gear. Preliminary studies have shown that local fishermen have selected the knotless netting mostly in stake nets and Chinese nets where a large number of small sized meshes are required, especially in the codend region. Hence the preference for knotless netting could have been a labour saving measure. Advantages such as uniform mesh size, reduced bulk and cost benefits could have also helped in the change from the knotted to knotless netting.

Twines in knotted netting are supposed to be exchangeable if they have equal knot strength in wet condition. However, there are cases where, for special reasons in respect of certain fishing gear, other properties such as diameter, stiffness, visibility etc. have also been taken into consideration. But this well known practice of substituting twines in knotted netting cannot be applied to knotless Raschel netting because netting strength depends not only on the property of the twines, but also on the strength of the particular type of Raschel connection (Brandt, 1964). Hence the exchangeability of knotted and knotless netting, or of knotless nets made of different systems is based on the mesh strength, and an exchange is possible between netting of different constructions if the mesh strength in wet condition is more or less equal.

Therefore, it was the objective of this study to evaluate through basic studies, the properties of the Raschel Knotless netting used by the local fishermen, in order to ascertain whether the replacements made by them are actually advantageous in terms of mesh strength and reduction in material, affecting a lowering in the cost of fabrication of the gear.

6.3. Materials and method

The experiments were carried out in order to study the mesh strength in relation to different number of meshes in width and also with different mesh sizes, for Raschel knotless netting. The samples selected were similar to those employed by the local fishermen and had quality numbers 2 2 2 1 6, 2 2 2 2 0 and

2 2 2 2 4. A sample of knotted netting of 210x2x3 specification, which was replaced by the knotless netting was also tested for comparison. The length of panels were fixed at 200 mm and the number of meshes in width ranged from 1 to 4.

The tests were conducted in the ZWICK 1484 Universal Testing System and the procedure followed was a modification of the proposal for measuring netting strength cited by Brandt and Carrothers (1964). Strips of netting having 3, 4, 5 and 6 meshes in width were taken, so as to have an extra column of meshes at either sides and an extra row of meshes at the top and bottom. This was to avoid the effect of any knot loosening that might be caused if tension was applied to meshes at the edge. Instead of hooks mentioned in the proposal of Brandt and Carrothers (1964), pins, similar to those employed for mesh strength experiments by Wijngaarden (1959), were used in the present experiment for the attachment of the nettings.

To estimate the extent of reduction in material that can be achieved by substituting knotted netting with knotless, weights of knotted nettings, of specification 210x2x3 and dimensions of 100 x 100 meshes, were ascertained for mesh sizes 10, 14, 18, 22 and 26 mm. This was compared with the weights of knotless nettings of same dimensions and of quality numbers 2 2 2 1 0, 2 2 2 1 4, 2 2 2 1 8, 2 2 2 2 2 and 2 2 2 2 6, used to replace the knotted nettings.

Different methods are adopted for the calculation of the weight of netting. Radhalakshmi (1964) put forward a method for estimating the weight of netting based on the theory of Kawakami (1964) that the weight per unit length of a twine is proportional to the square of its diameter and that the length of twine required for knot is proportional to its diameter. Japanese workers Machii and Nose (1987 a, b) have developed equations for finding the weight in air of nylon netting. For the present study a more direct method suggested by Fridman (1986) was followed.

$$W_n(g) = L_t \cdot \text{Rtex} \cdot 10^{-3}$$

Where W_n is the weight of netting in grams

L_t is the total length in meters of yarn or twine used in a netting panel and

Rtex is the linear density of the final netting yarn or twine.

The total length in meters of yarn or twine (L_t) that goes into a netting panel, including that used in knots, was estimated from

$$L_t = E_y \cdot \left(\frac{A_f}{m_l} \right) \cdot 10^{-3}$$

Where E_y is the knot correction factor

A_f is the fictitious area of 'the netting panel and

m_l is the mesh length

In usual conditions, Fridman (1986) recommends an E_y

of 2.4 for knotted nettings and 2 for knotless nettings.

The fictitious area (A_f) is an unrealizable conceptual area of netting, when it is considered to be fully stretched in both horizontal and vertical directions simultaneously.

A_f is usually expressed as

$$A_f = \frac{A_n}{E_1 . E_2}$$

Where A_n is the actual working area of the netting panel and is the product of horizontal and vertical hung lengths.

E_1 and E_2 are the primary and secondary hanging coefficients respectively.

Rtex for the netting yarn in knotted netting was calculated from the runnage values, given in IS 4401 (1981) and for knotless netting the increase in length, by four times, of the looped thread due to looping and the length of laid-in-thread was also considered (Gopalan Nayar and Radhalakshmi, 1981).

6.4. Results and discussion

Kondo (1960) suggests that breaking strength of the netting is proportionate to the number of meshes on the width side and to the number of yarns in the netting yarn for a given yarn size and has no relation to mesh size and length. His experimental samples included cotton and synthetic knotted nettings. The applicability of his assumption was checked for the knotless netting in the present work. A comparison was also made with a representative knotted equivalent. Table 6.1 gives the strength of netting of different mesh sizes for Raschel knotless type and for the knotted sample. Even though there is no direct proportionality between the number of meshes on the width side and mesh strength, the relation was linear (Fig 6.2) with the formula

$$Y = a + bx$$

where Y is the strength of the netting
a and b are constants and
x is the number of meshes on the width side.

with a high correlation coefficient (Table 6.2). In the case of knotted netting also, the correlation between the number of meshes on the width side and mesh strength was linear as in the case of knotless, with a correlation coefficient of 0.9998.

To ascertain the influence of mesh size on mesh strength, the Chi-square statistic was applied (Fisher and Yates, 1957). A 3 x 4 contingency table was formed in which one attribute was the mesh size having the classification 16, 20 and 24 and the other attribute, strength, having four classes, 50-100, 100-150, 150-200 and 200-250. The Chi-square worked out to 1.473 having degrees of freedom six. This was not significant at 5 percent level indicating that mesh strength was independent of mesh size.

The knotted netting registered higher strength in all cases than the Raschel knotless nettings. But Brandt (1964) based on mesh strength studies with both knotted and knotless nettings of different constructions, has stated that in all cases, the mesh strength of Raschel knotless netting was higher than that of knotted nettings made of the same fibre material. The reason for the reduced strength registered by Raschel knotless netting used to replace the knotted netting by the local fishermen was due to the fact that the knotless netting was selected on the basis of total nominal denier of the knotted netting they replaced, rather than on its resultant equivalent. Hence to arrive at the knotless equivalent for knotted netting, the following steps are suggested after Gopalan Nayar and Radhalakshmi (1981).

To find the knotless equivalent for 210x2x3 knotted netting, first its resultant denier, which is the weight in grams of 9000 m of netting twine, was ascertained in the following manner.

Weight of 1 m of single yarn in the twisted form x Number of single yarns in the netting yarn x 9000 = 1450

The mesh strength of a 210x2x3 knotted netting sample was then experimentally determined and was found to be 8541 gf.

The Raschel denier (Rden) equivalent to obtain this strength was worked out using the equation.

$$Rden = 4X + Y$$

Where X is the denier of the looped thread and
Y is the denier of the laid-in-thread.

Since the knotted twine to be replaced had a resultant denier of 1450, the above equation becomes

$$4X + Y = 1450 \quad \ldots\ldots\ldots\ldots\ldots\ldots (6.1)$$

And the mesh strength of Raschel netting (Rms) was calculated using the equation

$$Rms = (t \times s_1 \times s_2 \times X) + (t \times s_2 \times Y)$$

Where t is the tenacity in g/denier of 210 denier multifilament yarn available in India (IS 4401 1981).

s_1 is the percentage of strength retained after looping and

s_2 is the percentage of strength retained after wetting.

Since the looped thread losses 25 percent strength due to looping and 20 percent by wetting and the laid-in-thread losses 20 percent strength by wetting, the above relationship becomes

$$\left[(6.5 \times \frac{75}{100} \times \frac{80}{100} \times X) + (6.5 \times \frac{80}{100} \times Y)\right] 2 = (3.9X + 5.2Y)\ 2$$

For obtaining equal strength as that of the knotted this should be equal to 8541 gf. Hence

$$(3.9\,X + 5.2\,Y)\ 2 = 8541\ \text{gf} \quad \ldots\ldots\ldots\ldots\ldots (6.2)$$

Subtracting equations (6.2) from (6.1), the value of X was found to be 193.5

Substituting the value of X in equation (6.1), the value of Y was found to be 676.15.

From the above it becomes evident that to make a substitution of knotted 210x2x3 netting with knotless netting, the denier for looped thread should be 193.5 and for laid-in-thread, the denier should be 676.15, which would have resulted in a total Raschel denier of 1450. However, in practice, the knotless netting of quality number 2 2 2, used for replacing knotted netting of 210x2x3 has as its looped thread a yarn of 210 denier and as laid-in-threads 2 yarns of 210 denier each, resulting in a total Raschel denier of only (4 x 210) + 420 = 1260. Hence the reduction in mesh strength in comparison with the knotted nettings.

Due to the above mentioned reason, it was found that on an average, knotless nettings of 2 2 2 quality number, recorded 25 percent lesser strength than nettings of knotted 210x2x3 specification. But this reduction in strength neither affected the performance nor the longevity of those parts in which knotless nettings were used in gears such as stake nets or Chinese nets. This was evidenced by the absence of any abnormally high incidence of breakage of these parts. It was, therefore, apparent that the strength of knotless webbings used for substitution was more or less sufficient for the respective parts.

The replacement also results in a saving of material. The weight of knotted and knotless webbings of standard dimensions was worked out for different mesh sizes and was also compared with the observed values (Fig. 6.3). To test the significance of the difference between the calculated and observed values, Students t-test was applied. The t values were 0.0468 and 0.0595 for 8 df in the case of knotted and knotless webbings respectively, indicating that the difference was not significant at 5 percent level. Irrespective of the mesh size, it was found that about 30 percent saving of material by weight could be achieved by replacing knotted with Raschel knotless netting (Table 6.3).

Considering all the above aspects, the substitution of knotted netting with knotless netting in certain gears operated in the backwaters can be said to be advantageous and a step in the positive direction.

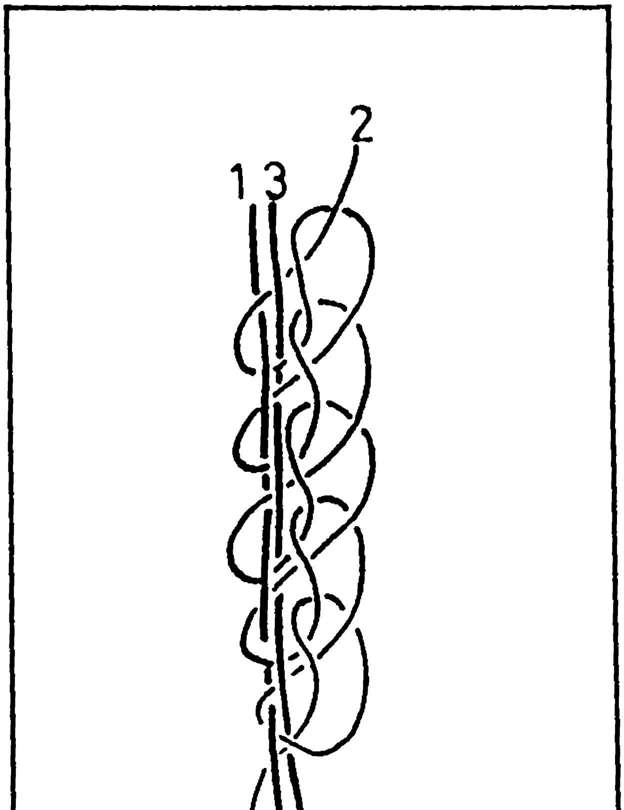


FIG. 6.1 LAID-IN-THREADS AND LOOPED THREADS FORMING A BAR IN RASCHEL KNOTLESS NETTING.
1 and 3 LAID-IN-THREADS
2 LOOPED THREAD

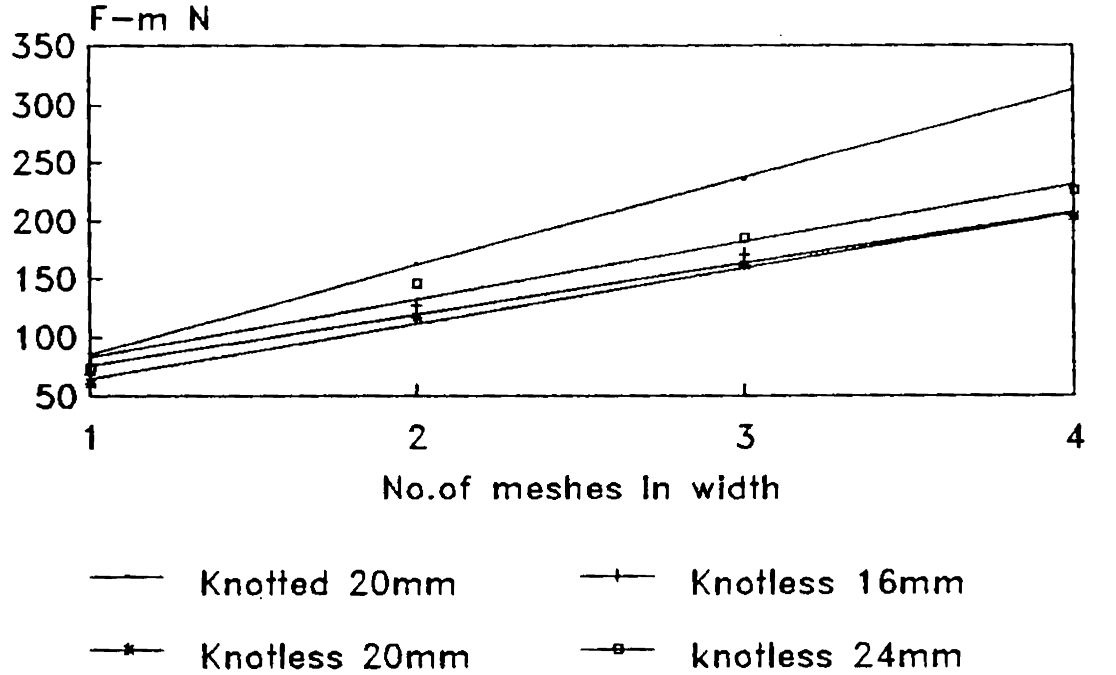


FIG. 6.2 RELATION BETWEEN THE NUMBER OF MESHES ON THE WIDTH SIDE AND MESH STRENGTH.

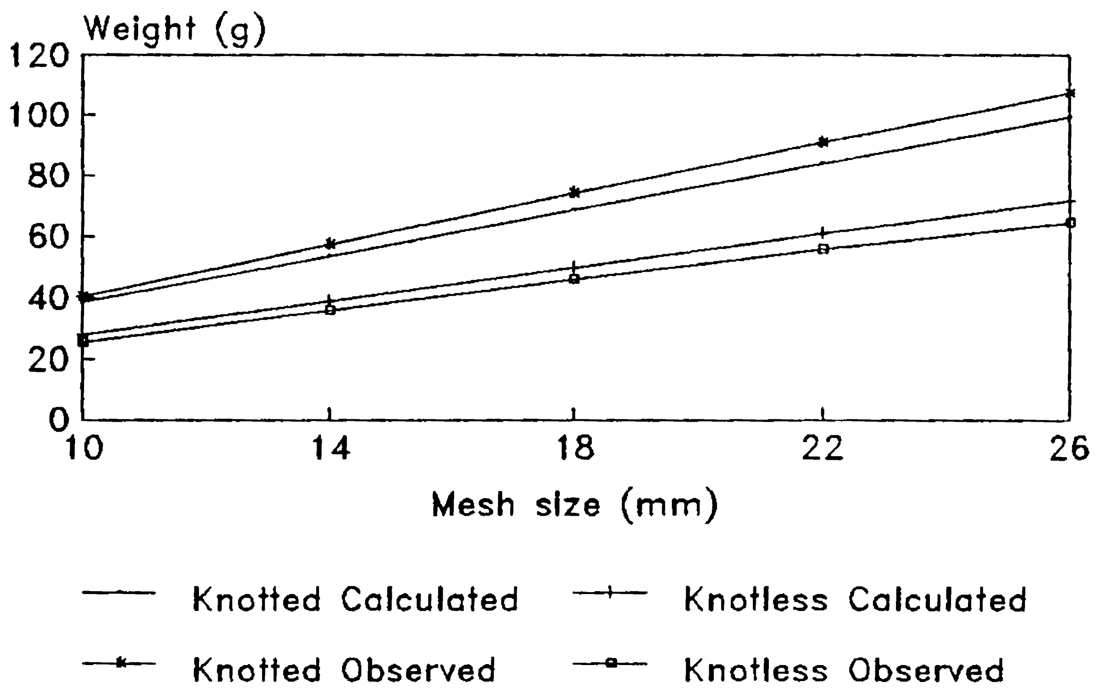


FIG. 6.3 COMPARISON OF THEORETICAL AND OBSERVED WEIGHT OF KNOTTED AND KNOTLESS NETTING.

TABLE 6.1 STRENGTH OF NETTINGS OF DIFFERENT MESH SIZES.

Type	Specification	Mesh size (mm)	Mesh strength of panels with different number of meshes in width			
			1	2	3	4
Knotless	22216	16	68.83	127.14	170.34	199.72
	22220	20	60.51	117.58	160.96	203.00
	22224	24	73.88	145.41	183.97	225.23
Knotted	210 x 2 x 3	20	85.41	161.74	234.82	313.81

TABLE 6.2 CORRELATION COEFFICIENT OF STRENGTH WITH NUMBER OF MESHES IN WIDTH.

Material	Nylon knotless			Nylon knotted
Specification	22216	22220	22224	210 x 2 x 3
Mesh Size	16	20	24	20
No. of meshes in width	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
Corr. Coeff.	0.989160	0.997121	0.9879	0.999775
df	2	2	2	2

TABLE 6.3 WEIGHT OF KNOTTED AND KNOTLESS NETTINGS OF DIMENSION 100x100 MESHES FOR DIFFERENT MESH SIZES.

Type	Specification	Mesh size (mm)	An (Sq.mm)	Af (Sq.mm)	Ey	Lt (m)	Rtex	Weight of netting (g) Calculated	Weight of netting (g) Observed
Knotted	210x2x3	10.00	433012.70	1000000	2.4	240.0	159.5	38.28	40.26
		14.00	848704.89	1960000	2.4	336.0	159.5	53.59	57.35
		18.00	1402961.15	3240000	2.4	432.0	159.5	68.90	74.40
		22.00	2095781.47	4840000	2.4	528.0	159.5	84.22	91.00
		26.00	2927165.85	6760000	2.4	624.0	159.5	99.53	107.50
Knotless	2 2 2	10.00	433012.70	1000000	2.0	200.0	138.6	27.72	25.25
		14.00	848704.89	1960000	2.0	280.0	138.6	38.81	35.75
		18.00	1402961.15	3240000	2.0	360.0	138.6	49.90	45.90
		22.00	2095781.47	4840000	2.0	440.0	138.6	60.98	55.80
		26.00	2927165.85	6760000	2.0	520.0	138.6	72.07	64.75

C H A P T E R – VII

SUMMARY AND CONCLUSION

The inland fishery sector is acquiring more significance in the light of stagnating output of the marine sector, coupled with decreased profitabilities and fast-rising fuel prices. But as the technological advances that proved successful in the marine sector cannot be applied to the inland fisheries directly, the challenge is to find low energy-intensive ways to upgrade and expand the catch capability of the artisanal fishing gears and methods. Despite its emerging importance, no detailed investigations have been carried out to improve the performance of these gears which have been evolved by the ingenuity of the fishermen themselves. Therefore, it was the aim of this work to study and describe in detail the design aspects, construction and operation of the more commercially important nets viz., stake nets, gill nets and Chinese nets operated in the Vembanad lake.

Chapter 1

The introductory chapter begins with a brief review of the evolution of fishing gear technology as an important branch of fishery science. The relevance and present status of fishing gear technology in the country is discussed. The prominence of the fishery sector in the economy of the state of Kerala and the contribution of backwaters has been stressed. These backwaters provide income to 41,600 active fishermen of 32,800 fishermen families with a total population of 1,97,200.

The Vembanad lake with an area of 256 sq.km forms the largest lake in Kerala and has all the characteristics of a typical tropical estuary and is reported as one of the most productive areas of the south-west coast of India. The rich and varied fishery resource of this lake is being exploited by a variety of fishing gears, methods and tactics, evolved over the centuries.

Attempts of various workers pertaining to the physico-chemical parameters, species diversity, total biomass, seasons, distribution and abundances of fishes, and fishing gears and methods of the Vembanad lake system were reviewed, identifying further research areas of importance that can lead to efficiency enhancement of these gears. In this context, it was noted that most of the previous works are devoted to fish and fisheries giving only a general description of the fishing gear and methods, and hence the relevance of the present study.

Chapter 2

The second chapter incorporates the classification, design, construction and operation of the stake nets operated in the Vembanad lake. Based on the shape of the mouth, two types, square-mouthed and rectangular-mouthed nets were identified. Though the latter type invariably had a greater perimeter, no relation was found between the periphery of the mouth and total length of the net in either types.

Three type of based systems associated with the stake net operation in the various centres and the method of fixing the stakes have been described.

Initial studies revealed the use of very small mesh sized as well as extra netting in the existing units. These factors contribute to a reduced rate of filtration, resulting in a lowering of the gear efficiency, and suggested possibilities for improvement in the design of these nets. Accordingly, on the basis of comparative drag calculations using a spread-sheet prepared specifically for this study in Lotus 1-2-3 programme, a new design was developed , by altering the mesh size, twine diameter and panel depth. Cutting ratios were employed to effect the taper. The calculated drag for the new design at 190.kgf was found to be 13 percent lower than that of the prototype, which had a drag of 219.442 kgf.

Based on the new design a net was fabricated and field tested, against the prototype. The measured drag was found to be 202.32 kgf as against 242.78 kgf of the prototype. The results of comparative fishing with the two nets were statistically analysed and it was found that the new net caught significantly higher catches at 5 percent level than the prototype.

Corollary to drag calculations, influence of mesh size, twine diameters and depth of panels and total drag of the net was studied. It was found that the mesh size of panels is inversely related to the total drag., but was not proportional, while increase in twine diameter of any panel was found to proportionately enhance the total drag. The effect of an increase in the depth of a panel was a lowering of the angle of attack and an increase in the twine surface area. These factors have a mutually antagonistic effect on total drag. Hence as long as the influence of a lower angle of attack offsets the influence of an increased twine area, the total drag was observed to fall.

Chapter 3

After a review of literature on gill nets, this chapter identifies ten type of gill nets operated in different parts of the lake and exhaustively describes their design, construction and operational details. The `Karimeen vala', a gill net specific for *Etroplus suratensis* a significant species of the lake which on an average provides 25 percent by weight to the total annual production of backwaters of Kerala, was taken for further studies with a view to determine the optimum mesh size, twine size and hanging coefficient, for the judicious exploitation of the optimum size group. The mesh selection factor `k´ was determined by length and girth frequency curves and was found to be 0.215, suggesting an optimum stretched mesh size of 73 mm.

The prototype net used polyamide netting yarn of 210Dx1x2 having a diameter of 0.37 mm. The calculated diameter of twine for the new net was found to be 0.34 mm. As this specification is not marketed, the same material used for the prototype was recommended.

Three nets of different hanging coefficient viz., 0.4, 0.5 and 0.6 was field-tested to assess comparative catch efficiency. The net with hanging coefficient of 0.4 was found to be superior followed by 0.5 and 0.6. Statistical analysis using ANOVA technique for number and weight of *Etroplus suratensis* caught also indicated the efficiency of unit with hanging coefficient of 0.4.

CHAPTER 4

The origin and evolution of Chinese nets and its introduction to our region has been briefly described. The Chinese nets operated in the Vembanad lake was classified into three size categories based on the net size, which is taken as the length of one side of the mouth of the net.

The design, construction and operation of the Chinese nets are described in detail with relevant illustration. Since any information regarding the basic process of designing is lacking, it was the aim of the present study to work out a few important relationships about the different parts of the net proper and its supporting structure.

Regression equations relating the depth of the operating area with net size, with the dimensions of individual panels that make up the net and with the various parts of the supporting structure have been worked out.

Chapter 5

The stake nets, gill nets and Chinese nets are operated on a commercial level and merits scrutiny regarding their economics of operation. Hence an economic assessment of the above mentioned three types of fishing gears operated at the various centres in the Vembanad lake, is made in this chapter.

Cost and earnings studies were made for the two types of stake nets, three size categories of Chinese nets and for the various types of gill nets.

Different profitability ratios, payback period and Break even point for each type have been worked out and averages are presented.

Average return on capital investment was maximum for rectangular-mouthed stake net (Type A) at 215.77 percent followed by square-mouthed stake nets (Type B) at 153.20 percent. Average return on variable cost, turnover and total cost were maximum for the larger size Chinese nets at 30.77 percent, 20.61 percent and 26 percent respectively.

The breakeven point was minimum for the small size Chinese nets at Rs. 15,000.00 while it was the maximum for large size Chinese nets at Rs. 53,345.00. The breakeven point for Type A and B stake nets worked out at Rs. 23,910.00 and 15,787.00 respectively.

Chapter 6

During the course of this study, it was observed that the local fishermen had replaced the knotted netting with knotless netting in some of the gears, especially in the codend region of the Chinese and stake nets, where a large number of small sized meshes were required.

To ascertain the advantages of Raschel knotless netting, over the knotted netting they replaced, basic studies were made on the properties of the Raschel knotless netting used by the local fishermen.

Experiments were carried out to study the mesh strength in relation to different number of meshes in width and also with different mesh size for Raschel knotless netting. A sample of knotted netting of 210x2x3 specification which was replaced by knotless netting was also tested for comparison. The test were conducted in the ZWICK 1484 Universal Testing System.

The test indicated that the mesh strength was independant of mesh size.

Contrary to the observations of Brandt (1964), the mesh strength of knotless netting was found to be lower than the knotted netting. This was because the substitution was not based on the resultant equivalent, but rather on the total nominal dinear. Suggestions to arrive at the correct knotless equivalent for knotted netting were also described.

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