COMPARISON OF CATCH EFFICIENCY AND SELECTIVITY OF ENTANGLING NETS: GILLNETS AND TRAMMELNETS IN LAKE KAINJI, NIGERIA.

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SEPTEMBER 2003.

COMPARISON OF CATCH EFFICIENCY AND SELECTIVITY OF ENTANGLING NETS: GILLNET AND TRAMMEL NET IN LAKE KAINJI

BY

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DEDICATION

To God the Almighty Father,

Jesus Christ my Saviour,

Holy Spirit my comforter

and

St. Anthony of Padua my intercessor.

DECLARATION

I hereby declare that this thesis titled "Comparison of catch efficiency and selectivity of entangling nets: Gillnets and Trammelnets in Kainji Lake" is an original work carried out by me and has not been reported any where by anybody to the best of my knowledge.

	13th Sept. 2003
A.B. ADIMULA	DATE

CERTIFICATION

This thesis titled "COMPARISON OF CATCH EFFICIENCY AND SELECTIVITY OF ENTANGLING NETS: GILLNETS AND TRAMMELS NETS, NIGERIA" was carried out by Augustine Babatunde Adimula of the Department of Fisheries and Wildlife, Federal University of Technology, Akure under the supervision of:

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ABSTRACT

The relative catch performance and selectivity of gillnets and trammel nets were investigated in 12 sampling stations on Lake Kainji, Nigeria.3 types of nets with dimensions 50m x 3m were constructed using 76mm and 178mm meshsizes for two type of gillnets, 76mm and 178mm meshsizes for the lint and armour nets of the trammelnets respectively. The stations, with a distance of about 1225m from each other were located at the lower basin of the lake. All the nets were randomly ganged together to form a fleet of nine nets each, and were set twice in each of the 12 stations which gave a total of 24 fishing operations. A total of 365 fish weighing 88.9kg and belonging to 16 different species were caught in all the nets. The trammel had the highest catch by number and weight constituting 60% and 69.22% of the total catch respectively with a relative species diversity index of .82. This was followed by 76mm gillnet which constituted 38.63% by number, 28.09% by weight, 0.69 relative species diversity index. The 178mm gillnet had the least percentage catch of 1.37% and 2.9% by number and weight respectively with 0.25 relative species diversity index. The master selectivity curves of the 76mm gillnets and trammelnets for the four most abundantly caught species (*Oreochromis niloticus, Citharinus citharus, Sarotherodon galilaeus and Synodontis membranaceous)* were bell-shaped. The minimum selection length for these species caught were the same for each net The trammel net had a wider selection range that skewed to right, a higher modal and median length indicating larger individual species being entangled in the net. The cost benefit analysis showed that the relative efficiency of the trammelnets was high enough to compensate for the extra cost incurred on them.

CHAPTER ONE

INTRODUCTION

Capture fisheries activities entail the use of fishing tools or implements, which are generally termed as fishing gears. Several types of fishing gears had been designed, fabricated, tried and possibly modified to suit a particular fishing ground or operation. Nedelec (1990) provided basic definition and classified these fishing gears into twelve categories by using the International Standard Statistical Classification of Fishing Gears (ISSCFG) method.

Entangling nets are categorised under ISSCFG No.07.0.0 with about nine different but slightly similar gears in the group (Appendix I). Gillnet (ISSCFG 07.1.0) and trammel net (ISSCFG 07.5.0) are two types of fishing gears that are exemplified in the entangling net category. The two gears are with unusually high degree of slackness caused by the low hanging ratio used in their rigging. On the basis of construction, Losanes *et al* (1992a) distinguished trammel net from gillnet by the presence of two sections of large-meshed nets (termed as the Armour nets) sandwiching a deeper small-meshed net (also called the Lint net). Using a hanging percentages of 50% (E = 0.5), for the lint net and 70% (E = 0.7) for the armour nets, the three nets are hung on a common float and sinker lines with the lint net forming an extra loose netting called (vertical slack) at the bottom. Gillnet on the other hand, is a single walled net hung on a float and sinker lines at the same hanging ratio with the lint net of a trammel net. The two nets can be passively or actively operated in the same way using the same effort, fishing ground and condition (Minns and Hurley, 1988; Fujimori *et al* 1996).

Entangling nets were reported to be widely in use by artisanal fisherfolks all over the world. These include tuna and shark fisheries in Sri Lanka (Ariyapala *et al*, 1997), rainbow trout and gizzard shad in Tokyo bay (Losanes *et al*, *op.cit.*). In USSR, Martosurboto (1989) reported trammel net to be a suitable substitute to trawl net in inland fishery.

Gillnet is observed to be highly selective, hence the use of an appropriate mesh size prevents the catch of juveniles and makes the catch of a desirable narrow size range of fish (Hamley, 1975; Petrakis and Stergiou, 1996). Hamley (1975) considered trammel net to be unselective and advocated it to be ban due to high entangling rate Recent work of Losanes *et al* (1992 a, b) however showed that trammel net has a high selection rate with a selectivity curve which skewed to the right was attributed to the wide selection range due to high ability of entangling large fish. Gillnet has gained popularity in artisanal fishery in Nigeria (Reed *et al,* 1967; Udolisa *et al,* 1994), unlike trammel net which usage remains rare and unknown in various fishing communities in Nigeria.

Lake Kainji is reported to have some 104 different types of fish species with a high Diversity Index of 0.91 when compared with other inland reservoirs in the country (Ita, 1993). The use of six different types of fishing gear as observed in Adimula and Fasakin (in press) for the over one hundred fish species makes gear fishery of the lake be less diversified. This may be one of reasons for the high concentration of fishing efforts on under-meshed nets

.1.1 Justification

In a recent checklist of the artisanal fishing gears of Lake Kainji, gillnets were identified to be the commonest gear used for fishing operation, followed by longlines, castnets, driftnets, seinenets and traps in that order (Mdaihli and Omorinkoba, 1999; Adimula and Fasakin in press). The absence of trammel net in the artisanal fishery of the lake showed that the gear might be alien to the fisherfolks of the lake. It was also observed that about 55% of gillnet fishery on the lake was concentrated on under-meshed nets (Meshsizes that are less than 76 mm according to Inland Fisheries Decree of 1992). This had resulted to indiscriminate exploitation of juvenile fishes in the lake.

Trammel net had been reported to be effective for fishing in lakes and rivers and also noted for its wider selection range (Losanes, 1996 b). This is due to the combination of different mesh sizes. Even though the trammel net is constructed with large mesh size, the combination of more than one netting of varying mesh sizes and hanging ratio tend to increase the entangling rate of the net leading to increase in catch.

In order to diversify fishing gear usage as well as encouraging the use of large mesh size nets, there is need to experiment on trammel net fishery and to compare its performance with that of gillnet which is known to be popular in the lake fishery.

1.2 Objectives

The objectives of this study therefore are to:

(a) Determine the catching rates of the entangling nets (gillnets & trammel nets) by comparing their relative efficiency as well as their Catch Per Unit Effort (CPUE).

(b) Compare the size of fish at capture, selection range and size selection of fish caught by the nets.

(c) Determine the proportion of fish caught in each mode of capture (enmeshing, wedging and gilling) for each given net type.

(d) Estimate status of spoilage of the fish caught by the nets at a given soak time.

(e) Carry out a benefit/cost analysis for each gear in a bid to determine profitability index.

CHAPTER TWO

LITERATURE REVIEW

2.0. Classification and Description of Entangling Nets

Using the International Standard Statistical Classification for Fishing Gear (ISSCFG) method, Nedelec (1990) classified entangling nets to ISSCFG No.07.0.0 category with some seven fishing gears listed in it. These include the conventional gillnet and tramelnet as shown in Appendix 1. Sainsbury (1986) described entangling nets as large rectangular wall of netting, attached to floatline and sinkerline, which are set across a water body to act as barrier to fish movement. YFJ (1994) described and grouped the mode of fishing of entangling nets into:

(a) Enmeshing:

This is when the fish body is made to push into the mesh and the tension of the netting chord (twines) held the body usually at the widest girth region and prevents the fish from passing through.

(b) Wedging:

When a part of the fish e.g. opercules or appendages are caught in the netting chord, and as the fish continues to thrashed around, the netting chord closes tightly around the opercules or appendages. This mode of capture is also termed as gilling - where gillnet is coined from. Appendix 2 is an YFJ (1994) illustration of mode of capture in relation to the body shape of fish.

(c) Entangling:

The whole body of the fish become entangled in a limply hanging mass of net.

Due to the extra vertical slack that is present in trammel net, Losanes (1992b) reported that the net catches more fish by entangling and enmeshing. Whereas the gillnet principal catching mode is observed to be by wedging. Since trammel net utilises more modes of capture, the net is theoretically expected to catch more fish, which some authors (Koike and Takeuchi, 1985; Losanes *et al* 1992 and Fujimori *et al* 1996) confirmed in their works.

2.1.Catch Efficiency of Entangling Nets

Losanes (1989) defined catch efficiency as the output of a gear, expressed in catch by weight or number, when all efforts are equal. It can also mean the ratio of fish caught to the number of encounter assuming the population of the stock is known.

When the class-size of the population of stock is known, Acosta (1994) refers to the gear efficiency as a defined or absolute standard which can be estimated using a model:

$$Q_i = C_i/N$$

where Ci is the catch of net i and N is the number of fish encountered or the size of the population that is subjected to fishing when effort is constant, q being the gear efficiency.

In water bodies such as lakes, large reservoirs and rivers where the size of the fish population is unknown, gear efficiency estimation is regarded to be a relative standard. Hence the model above ($Q_i = C_i/N$) may be difficult to apply when estimating the efficiency of fishing gear. In the determination of a relative standard efficiency of a fishing gear, Machiels *et al* (1994) compared two or more fishing gears used at the same time, same location, same conditions and equal fishing efforts. Thus, the relative efficiency of gear A to gear B in a water body of unknown population is expressed as a ratio using the model of Machiels *et al*,(1994).

$RE_A = Ci_A + Ci_B.\ K$ (Michiels *et al* 1994).

Where

RE_A is relative efficiency of gear A

Ci_A is the catch of gear A, of size class i,

Ci_B is the catch of gear B of size class i when both gears were subjected to equal fishing efforts K.

Samaranaya *et al* (1997) used a similar model to estimate the catch rates of drift tuna gillnets of varying hanging ratio in Sri Lankan waters.

2.2. Selection and selectivity curves of entangling nets

Hamley (1975) defined gear selection as a process that causes the probability of capture to vary with the characteristic of fish. The most common form of selection concerns the escape of fish from a gear such as the passing of a small fish through a bigger mesh size or the escape of a bigger fish because its head can not get stuck around smaller mesh of a net Stergiou *et al* (1994) described selectivity as a quantitative expression of selection and traditionally mean selection by size of fish or species of fish. Hamley (1975) also defined selectivity as a characteristic of the entire fishing operation, which is considered as any factor that causes the size composition of the catch to be different from that of the population. The exact definition is not a single process. These processes may be due to size or shape of fish (resulting to mesh size selectivity), or due to the t behaviour of fish toward the fishing gear or ground (species selection).

There are two approaches to selectivity determination as highlighted by Reis and Pawson (1992). These are:

(a) Estimating the proportion of fish captured and retained from the population.

(b) Estimating the proportion of fish captured and retained when it encountered net.

The first approach is commonly used presently.

Selectivity of entangling nets have received wide attention and many workers had propounded different models for selectivity estimation (Hamley, 1975; Karunasinghe and Wijeyaratne, 1991; Reis and Pawson,1992; Anon.1993; Fujimori *et al* 1996). Besides, Petrakis and Stergiou (1996) recognised two major experimental methods for the determination of selectivity parameters. These are:

(i) The indirect method in which selectivity parameters are estimated from catches taken by net of different mesh sizes.

(ii) The direct method in which the estimation of selectivity parameters is based on the proportion of fish caught from different size classes of a population with known length frequency distribution (Sparre *et al,* 1989).

Since the direct method again required a knowledge of the length frequency distribution of the population to be encountered, the method is best in experimental tanks and ponds where the proportion of fish sizes are known.

Studies on selectivity of gillnet on four species of fish in Greek waters, Petrakis and Stergiou (1996) used the Ishida indirect method based on Holt (1963) selection model:

$$Sij = Cij/Nij\ .E$$

Where

S is the selectivity of meshsize i for fish size j,

C is the catch,

N is the fish population and

E is the effort.

Since Nij is unknown in their studies, they compared the catch of two or more mesh sizes A and B (C_A and C_B) to give a representative of total population in the fishing ground, thus:

$$Sij\ (A)/Sij(B) = C_A/C_A + C_B$$

A more simplistic approach to selectivity studies of entangling nets is the model used in Fujimori *et al* (1996) based on same Ishida (1964) which is also direct approach method:

$$Sij\ (M : L) = Sij\ (KM : KL) \qquad \text{Where}$$

M = the meshsize,

L = length of fish, and

K = constant factor.

If the effort is constant for all the meshsizes, the model means that, for any meshsize, there is an equivalent proportional length of fish caught.

$$Cij = Sij\ (M : L).$$

Several models had also been used for selectivity curves. Losanes *et al* (1990) adopted the Kitahara (1968) method, which is a graphical method by using the fish length versus meshsize ratio to plot the selectivity curves for semi-trammel and trammel nets in Tokyo Bay.

In a more complex selectivity studies on recommended allowable harvest in the Lake Erie Yellow Perch (*Perca flavescens*) fishery, Madenjian and Ryan (1995) assessed the effect of gear selectivity on optimal fishing rate as determined by yield-per-recruit (YPR) analysis by the application of Beverton-Holt and Ricker Equilibrium Yield (REY).

Koike and Takeuchi (1982), Koike and Matuda (1988) reported a selectivity curve of trammel net to have a wider range and skewed to the right. They attributed the skewness and the wider selection range of trammel net to a higher capability of entangling large fish.

Losanes (1992a) noted that in a length frequency distribution of some species, there may be no catch at all some length classes. To estimate the ordinates for probability of capture, it is necessary for each size class to obtain a catch because a division of zero causes in the calculation. If the data is used for plotting selectivity curve, a narrow class can be obtained which may not give a clear picture of master selectivity curve.

Losanes (1992a) overcame this shortcoming by increasing the frequencies of occurrence of species in each length class by one (a form of data transformation). As probability of capture is an expression of the ratio of catch, such addition of one is observed to have no effect on the

shape of the curve and can still be plotted with satisfactory result (Petrakis and Stergou 1996).

2.3. Materials for entangling nets fabrication

The materials used for entangling nets fabrication particularly the netting material can affect the ability of the net to hold the fish caught (Hamley, 1975). In the past (pre-1940), natural fibres such as cotton, hemp or ramie were used for gillnet construction. Presently (post-1940), synthetic fibre mainly of multifilament nylon type (Polyamide, PA 6) had replaced the natural fibres. These fibres (Synthetic) are known to be more durable, with high tensile strength and a large elasticity ratio. These are pre-condition for proper enmeshing and entangling (Nomura, 1985). Recently, the introduction of monotwines (monofilament netting) proofed to be less visible to the fish due to its ability to blend with the water colour.

2.3.1. Some properties of synthetic netting materials

Losanes (1989) and Nomura (1991) listed some physical properties that a netting material must conformed to before it can be selected for entangling net fabrication.

(a) Twine elasticity

This referred to the degree of elongation of a twine. Synthetic fibres are known to have a high degree of elasticity that can be up to 35% of its original length for nylon material (PA6)). An increase in elasticity results to high enmeshing rate leading to the capture of larger fish and a wider selection range.

(b) Tensile Strength and flexibility of twine

Greater strength means more large individual fish are liable to capture without breaking the twine. Flexibility refers to the softness of twine which tend to influence the rate of entangling. The issue of higher tensile strength which is a function of twine thickness, that is, the higher the thickness the greater the strength and that of flexibility which is also a function of the twine thickness (lower the thickness the greater is the flexibility). These factors need to be considered on their own merits in relation to the size of fish to be captured before recommending the appropriate twine thickness for the construction.

(c) Colour/visibility of net

Some studies had been carried out on the effect of colour to efficiency of stationary nets (Fern et al 1986; Wardle et al 1991; Walsh and Hickney, 1993). The summary is that the colour, which has less contrast to the surrounding area, catch more fish because of its less visibility to fish. White nets are more efficient than dark ones in clear waters. Since different fish species react differently to net colour, choosing the proper colour will not only increase the efficiency of the net but also reduces the capture of unwanted species. Monofilament net is less visible in water hence, its relatively high efficiency. Visibility of netting depends mostly on the twine thickness, material and mesh size.

(d) Height/shape of net in water

This depends on the speed of current, size and shape of floats attached, surplus buoyancy and size of netting (Losanes, 1989). A higher netting height means more chances of blocking an in-coming fish. It is desirable that the area of net to intercept a fish is large enough.

2.4 Fish shape/behaviour in relation to selectivity

The shape of fish is known to have a great influence on the selectivity of the net and manner it is caught (wedging, enmeshing and entangling). YFT (1994) noted that fusiform and smooth-bodied fish such as trout (*Oncorhynchus mykiss*) or salmon (*Salmo trutta)* are mainly enmeshed. Tilapia and gizzard shad (*Konosirus punctatus*) have a slightly skewed selectivity curve while catfish is mostly caught by entangling with a skewed selectivity curve too (Losanes, 1989). Fish with long spines or appendages may give a skewed selectivity curve or a multi-modal curve. Appendix 2 gives the basic body shape of fish and the likely mode of capture (YFJ, 1994).

Fish behaviour towards the gear and fishing ground is another factor that can influence catch efficiency and selectivity. Even same species of fish are sometimes observed to respond differently depending on time interval and external stimuli (Dayaratine, 1988). Wardle (1983) observed the movement of rainbow trout to increase during sun rise and sun set. Gizzard shad (*Konosirus punctatus*) are mostly caught during the early morning (Losanes, 1992b), while sardines (*Amblygaster sardinella sirem*) during late afternoon (Dayaratne, 1988). Padilla and Trinidad (1995) observed the swimming speed and level of fish, which differ from species to species to affect the catchability of passive gears. Chopin and Arimoto (1995) noticed that visual sense of fish also affect the degree of a set net being encountered. Larger fish is reported to have a high degree of net avoidance because of a more developed visual receptor. Arimoto (1989) observed internal stimuli (i.e. hunger, mating and spawning) and external stimuli (e.g. temperature, pressure, effect of current and presence of predators) to alter the natural behaviour of fish and hence affect the catching process of the gear passive gears.

2.5 Effect of net slackness on the shape and catchability of entangling nets

Hanging of net is usually in such a way that some amount of slackness is created depending on the type of net that is being constructed (Gardner, 1986). Two types of net slackness (looseness) are associated with entangling nets (particularly trammel and semi-trammel nets).

(a) Horizontal Slack

This is the looseness created while hanging the net on head and footropes. Machiels *et al* (1994) illustrated two methods of horizontal net shortening known as hanging ratio (E value) and hang-in (S value). He defined hanging ratio as the ratio of the length of head-rope on which the net is mounted and the stretched length of the netting.

$$\text{Hanging ratio (E)} = \frac{\text{Length of head rope}}{\text{Stretched length of net webbing}}$$

The nearer the E value is to numerical number one, the higher is the tension created on the meshes, hence the lower is the rate of entangling.

Hang-in (S value) on the other hand is expressed as the amount of excess or loose webbing as a ratio of the total stretched length of webbing:

$$\text{Hang-in (S-value)} = \frac{\text{Excess Webbing}}{\text{Stretched length of net webbing}}$$

Again, the nearer the S value is to numerical umber one, the more is the looseness or slackness of the meshes.

Using an E value 0.45 for a gillnet, Machiels *et al* (1994) observed a higher catch of Pike perch *(Stizostedion luciperca)* and Bream (*Abramis brama*) in the Netherlands waters.

Fujimori *et al* (1996), mounting the lint and armour nets of trammel net at 0.5 and 0.3 S-value respectively reported to be ideal for the sea of Japan fishery. In Lake Kainji, artisanal fisherfolks hung their gillnets at 0.5 ± 0.08 E-value (Adimula, 1998).

(b) Vertical Slack

Vertical slack is usually associated with trammel net. Since the small-meshed lint net is deeper than that of the large-meshed armour nets, a vertical slack if formed on the lint net when hung on a common float and sinker lines. Vertical slack is therefore, the ratio of the deeper lint net to the depth of the armour net:

$$\text{Vertical Slack (V.S)} = \frac{\text{Depth of Lint Net}}{\text{Depth of Armour Net}}$$

The presence of vertical slack on a trammel net is reported to increase the efficiency as well as altering the shape of the selectivity curve (Losanes, et al. 1992a). Koike and Matuda (1988) while comparing the selectivity of trammel nets with different vertical slack to that of gillnet, observed a rightly skewed selectivity curve for the trammel nets. In their work, Losanes *et al* (1992a) also observed variation in the vertical slack of trammel net to influence the number of gizzard shad (*K. punctatus*) caught in Tokyo bay. The net with vertical slack ratio 1.5 obtained the highest catch, while the net with vertical 1.0 obtained the lowest catch.

2.6 The Effect of Soak Time and net saturation on the efficiency of entangling net.

Soak time, as defined in Losanes *et al* (1992 b) is the interval between the setting and hauling of a net particularly the passive nets. And this is identified to be one of the important factors that determine the catch efficiency of a fishing net. If the soak time is long i.e. one night or day setting, it is sometimes expressed as a unit of fishing effort in determining the Catch Per Unit of Effort (CPUE) of a series of nets. Minns and Hubart (1983) suggested the possibility of catch saturation for nets set with too long soak time. This means that the catch stopped increasing or remains constant after a long period of soak time. Koike and Takeuchi (1982) studied the maximum catch of gillnets for pond smelt fish (*Hypomesis transpacificus nipponnensis*) and found that the catch increased with increasing soak time over a period of their observation up to a point when the catch remain constant (point of saturation) even with further increment of soak time. Minns and Hubart (1983), Fjalling and Furst (1991) also observed that the efficiency of set nets decreases as fish accumulate in them. Eventually, the number of captured fish reaches a saturation point and does not increase further. Peterman and Steer (1981) indicated that the proportion of fish caught per unit effort relative to the population sizes varies inversely with overall fish abundance. This shows that saturation effects in entangling nets vary with the abundance of fish available to the fishing gear.

In his soak time experiments, Acosta (1994) showed that the catch rate of gillnet and trammelnets increased at the shortest soak time of 5 hours and decreased at the intermediate soak time of 10 hours. There was further increase in the catch rate at a longer soak time up to 15 hours after which there was an insignificant catch rate at 20 hours soak time and above. He also noticed a high proportion of dead fish and high degree of spoilage, which increased as the soak time increased.

These results conformed with that of Fjalling and Furst (1991) and Losanes *et al* (1992 b). It could be arguably stated that in order to improve catching rate of set entangling nets, they are either allowed to remain in water for a short soak time ($\leq$ 5 hours), thereafter, hauling can commence, or allowed to remain for a longer soak period ($\geq$ 10 to 15 hours). Beyond this limit, catch saturation may occur as well as higher proportion of dead fish and an increased degree of spoilage.

CHAPTER THREE

MATERIALS AND METHODS

3.0. The Study Area

Lake Kainji lies in the savannah zone of North-Western part of Nigeria and is bordered by Niger and Kebbi States (Fig. 1). Balogun and Ibeun (1995) gave a detailed description of the lake to show that it is located within latitude 9° 30' N - 10° 35' N and longitude 4°25' E - 4°4' E. It has a maximum length of 136 km and widest width of 24km with a maximum and mean depth of 60m and 11m respectively. With a surface area of 1270 km^2, the lake is presently the largest man-made lake in Nigeria and is capable of storing $15.6 \times 10^9 m^3$ of water at full capacity. The lake is divided into three main strata each of it representing a distinct ecological basin:

(i) The Upper Basin:

This is the area where the River Niger enters the lake. This basin is characterised by steep banks and a narrow channel. It forms about 10% of the lake surface area with an average depth of 8.0 m.

(ii) The Middle Basin:

This forms the largest portion of the lake consisting of about 70% of the surface area, with an average depth of 10.8 m. It is characterised by an extended flood plain, which is seasonally exposed during draw down period. Due to the poor clearing of this area prior to the lake the formation, there are lots of sub-merged stumps, which make utilisation of some fishing gears difficult.

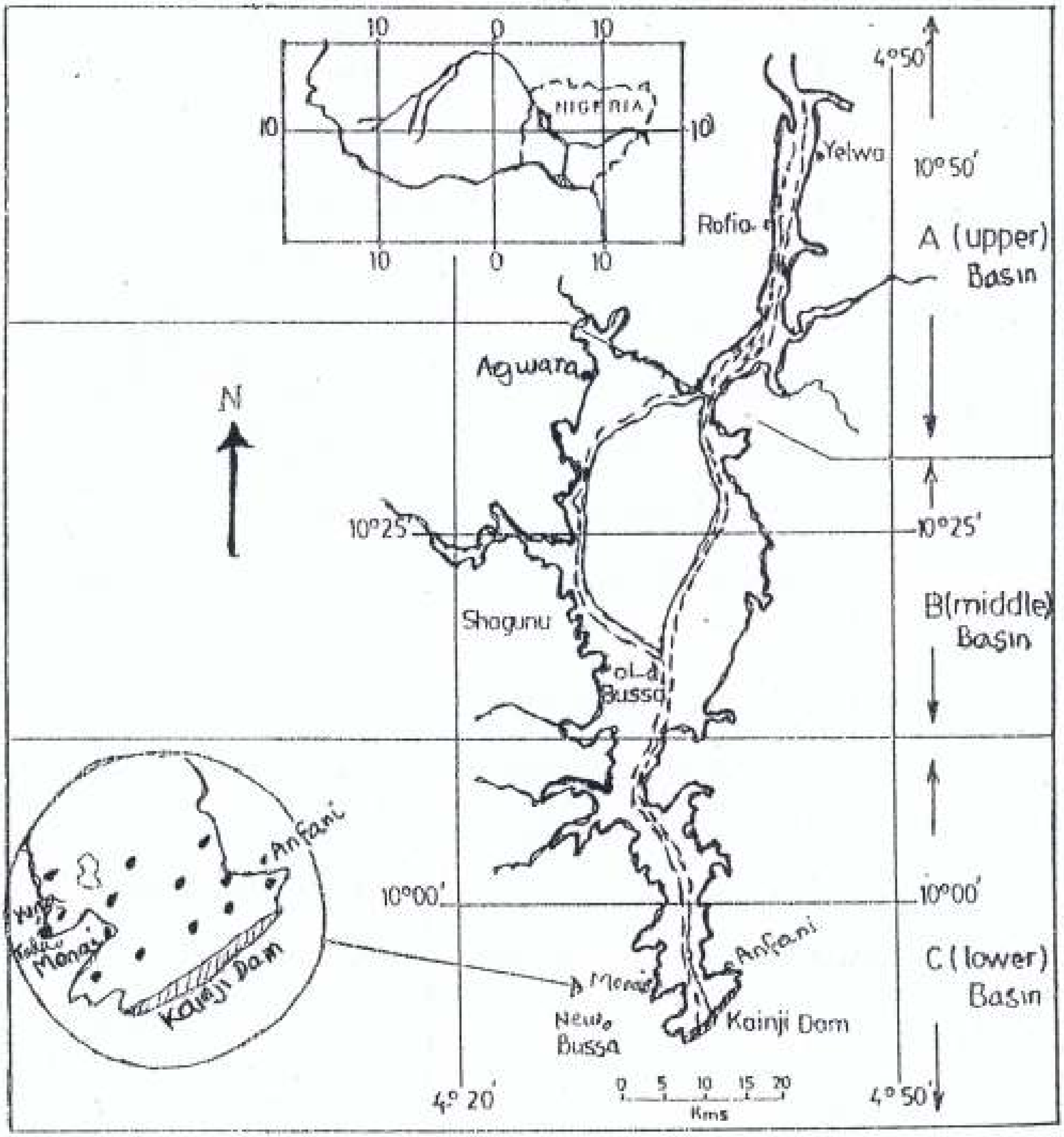


Figure 1. Map of Nigeria (Insert: Kainji Lake showing a blow up of the basin with the enlarged (in circle) sampling locations.

(iii). Lower Basin:

This is the deepest part of the lake with an average depth of 18.5 m. It is characterised by steep banks and covers about 20% of the lake surface area.

The study area (insert of Figure 1) is located in the lower basin of the lake which has some area been cleared of submerged stumps making the operation of the entangling nets easy.

3.2. Fisheries Resources of the Study Area

The periodic catch assessment survey of lake Kainji from 1994 to 1998 showed that *Citharinids, Synodontdis, Cichlids (Oreochromis, Sarotherodon &Tilapia) Bagrus, Lates and Alestes* were the dominant species caught in gillnet fishery (du Feu and Abiodun, 1998). Other less important species that present in the gillnet catches include *Labeo, Clarias, Distichodus* and *Chrysichthys.* Further breakdown of the catch data showed that these species were largely caught in gillnet fishing within the Lower Basin of the Lake where the study area is located.

3.2. Construction Material and Fabrication Method

Based on Nedelec (1990) design specification for entangling nets, a total number of nine nets each measuring 50 metre-rigged length and 3-metre depth were constructed in the College of Fisheries, New Bussa Net Loft. The basic design specifications and characteristics of the nets were presented in Table 1 and Figure 2 respectively. The nine nets were made of the following materials:

Table 1. The Design Specification of the entangling nets based on Nedelec (1990) ISSC FG Method

SECTION A: Elements of the Gears

Name of the Gear	76mm Meshsize Gillnet	178mm Meshsize Gillnet	Trammel	
			Lint	Armour
Head length Depth Fishing ground Vessel(s) Target fish No. of crews	50m 3m Pelagic zone 1 fishing boat Pelagic spp. 2	50m 3m Pelagic zone 1 fishing boat Pelagic spp. 2	50m 3.3m Pelagic zone 1 fishing boat Pelagic spp. 2	$50m^{x2}$ $3m^{x2}$ Pelagic zone 1 fishing boat Pelagic spp. 2

SECTION B: The Webbing

Name of the Gear	76mm Gillnet	178mm Gillnet	Trammel	
			Lint	Armour
Material types Colour Meshsize Twine size E value*[1] No. of mesh length*[2] No. of meshes depth*[3] Vertical slack*[4]	Nylon (PA) Multifilament White 7.6 cm $210^d/2$ (23 tex. x2) 0.5 1316 45 0	Nylon (PA) Multifilament White 17.8 cm $210^d/6$ (23 tex. x2) 0.7 402 38 0	Nylon (PA) Multifilament White 7.6 cm $210^d/2$ 0.5 1316 50 1.1	Nylon (PA) Multifilament White 17.8 cm $210^d/6$ (23 tex. x2) 0.7 402 38 0

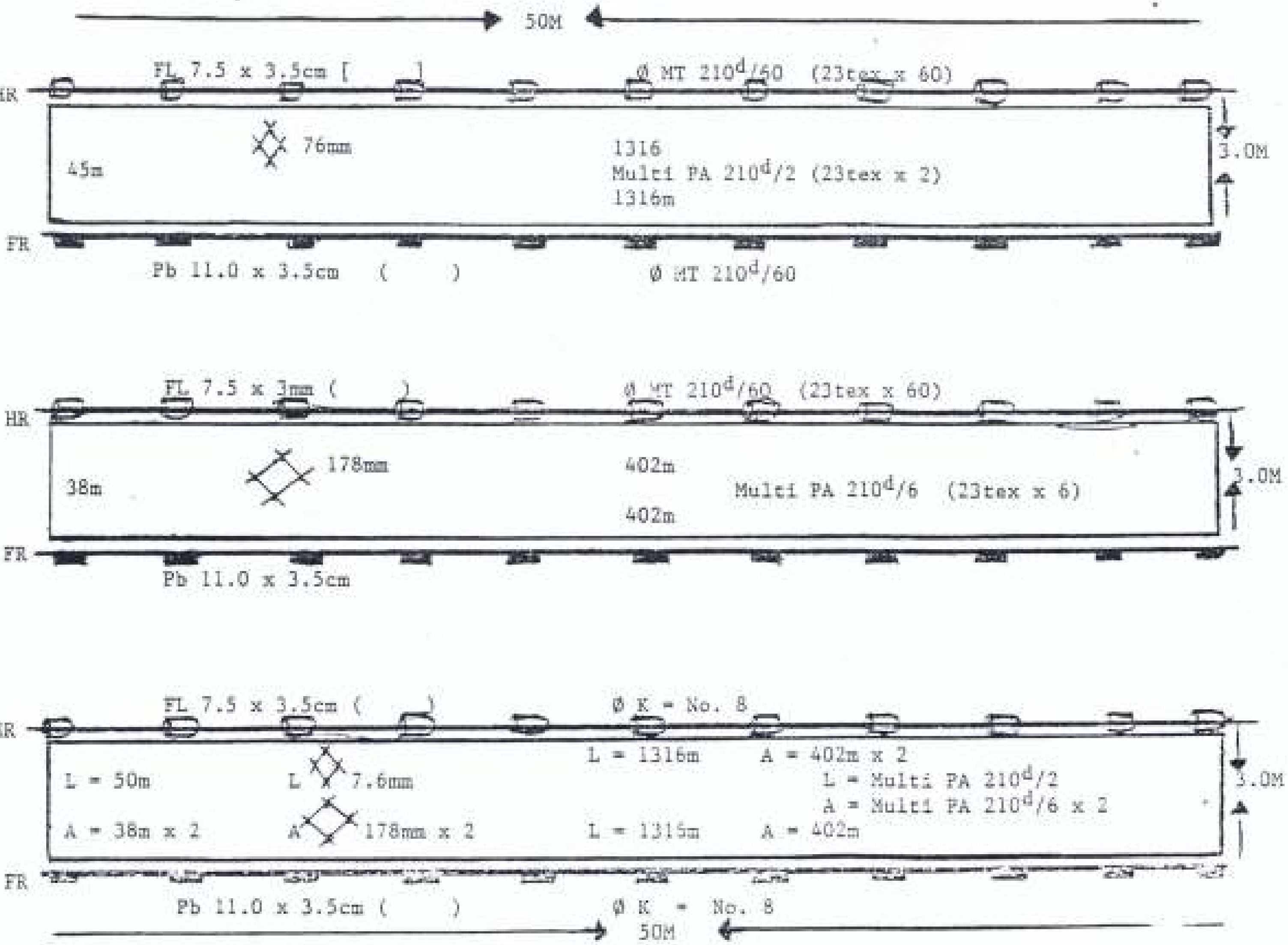
Table 1 (Contd.)

SECTION C: Lines and Ropes

	76mm Gillnet	178mm Gillnet	Trammel	
			Lint	Armour
Material type	Mounting twine	Mounting twine	Kuralon	Kuralon
Length (m)	50m	50m	50m	50m
Thickness/diameter	$210^{d}/60$	$210^{d}/60$	NO.8	NO.8
Twist direction	Z	Z	Z	Z

SECTION D: Accessories

	76mm Gillnet		178mm Gillnet		Trammel	
	Buoy	Sinker	Buoy	Sinker	Buoy	Sinker
Material type	Synthetic float	Flat lead	Synthetic float	Flat lead	Synthetic float	Flat lead
Weight	30 g	100 g	30 g	100 g	30 g	100 g
Spacing interval	5 m	5 m	5 m	5 m	5 m	5 m
Quantity used	11	11	11	11	11	11
Buoyancy*[5]/sinking power*[6]	-136g/F	10g/F	-136g/F	10g/F	-136g/F	10g/F
Dimension						



LEGEND		
FL	=	Synthetic float
Pb	=	Flat lead
MT	=	Mounting twine
Ø	=	Twine size/diameter
M	=	Length/depth in meter
m	=	Number of meshes
◇	=	Mesh
mm	=	Meshsize in millimeter
Multi	=	Multifilament fibre
PA	=	Polyamide nylon
L	=	Lint net
A	=	Armour net
cm	=	Dimension of Pb or FL in centimeter
K	=	Kuralon rope
HR	=	Head rope
FR	=	Foot rope

Figure 2: Design characteristics of the entangling nets
(a = 76mm gillnet; b = 178mm meshsize gillnets, C = Trammel net)

3.3.1. The Netting

(a). Three replicates of gillnets using white nylon (Polyamide - PA) multifilament netting of twine size $210^d/2$ (46 tex.) and mesh size 76 mm were used. The mesh size was taken to be the stretched length of a mesh from the mid point of one knot to that of a diagonally opposite one. The 76 mm meshsize was used because of the Fisheries Edicts that are applicable to the Lake (Niger and Kebbi States' Fisheries Edicts of 1985 and 1997 respectively). The edicts allowed the use of 76 mm as the minimum meshsize for gillnet fishery on the lake.

(b). Another three replicates of gillnet using the same material as in (a) above but different twine size and meshsize specification. The twine size and meshsize used were $210^d/6$ (138 tex) and 178 mm respectively.

(c). Three replicates of trammel nets were also constructed. The lint net had the same mesh size with that of 76mm gillnet while the amour nets have the same specifications with that of 178 mm meshsize gillnet. The two amour nets were made to sandwich the Lint while all the three nets were mounted on the same head rope and footrope.

3.3.2. Lines and Ropes

The same head-ropes and footropes were used for the nine nets made of Kuralon (Polyvinyl-alcohol, PVC) rope of thickness No.8. Eighteen pieces each corresponding to the rigged length of each net (50 m) were used as the head and foot ropes respectively

3.3.3 *Accessories*

Cylindrically shaped synthetic corks of dimension 70 mm x 30 mm and each weighing 30g were used as floats for all the net and were spaced at 5 metre interval. Total number of floats per net was 11 pieces.

Flat lead sheet was caught into pieces of dimension 150 mm x 30 mm each weighing 100 g and attached to the foot rope as sinkers with spacing interval corresponding to that of floats.

3.4. Horizontal and vertical slacks

A horizontal net slack (hanging ratio E) of 0.5 was used for hanging the 76 mm meshsize gillnets and the Lint net of the trammel nets, while the 178 mm meshsize gillnet and the Amour nets of the trammel nets were hung at 0.7 hanging ratio. These were achieved by using the appropriate models and co-efficient values as shown in Appendices 3 and 4.

A vertical slack was created in the Lint net of the trammel by making it deeper than the armour nets using a vertical slack ratio 1:1. This ratio was adopted in order to conform with the work of Losanes *et al* (1992) using ratio 1:1 vertical slack to have a significant influence on the rate of fish entangling by the trammel net. The depth of the lint net was thus 3.3 m while that of the armour nets was 3 m each post-hanging.

3.4. Experimental design

Using Petrokis and Stergiou (1996) method, the nine nets were ganged together randomly using randomised numbering technique to form a fleet of nine gangs of nets. The method was assumed to eliminate the possibility of net mesh leading a larger fish to the next net mesh of the size of the fish. Thus, all the nine nets were given equal opportunity of being encountered by the fish.

Twelve sampling stations were located at the southern-most basin (lower basin) of the lake between Monai/Tada/Yuna fishing villages at the western shore and Anfani village at the eastern shore as shown in Figure 1. Using a portable Global Positioning Satellite (GPS) model Navstar JLR-4110, the average distance of one station to another was about 1225 m (S.D ± 26 m). Each station was sampled twice giving a total of twenty four fishing operations. The first sampling period was from 5th to 28th June, Yr 2000 and the second sampling period was from the 17th July to 5th August, Yr 2000..

3.5. Soak Time of the Nets

Based on the result of Fjalling and Furst (1990), a total soak time of 15 hrs ± 0.244 was maintained. The setting time was usually between 5.10 p.m. to 6.10 p.m. and the hauling time was between 8.10 and 9.40 a.m. depending on the distance of the station to the landing site. It was assumed that there will be no net saturation within this soaking period. However, the state of fish caught was noted by using the following assessment parameters based on Acosta (1994).

1-Alive: This was when the state of fish was recognised by the opened and closed movement of the opercular or the struggling observations of the fish.

2-Dead: This was recognised when there was no movement of any of the fish appendages and trunk. The fish in any case would still be stiff (*rigor mortis* had not relaxed).

3-Spoilt: The degree of spoilage was based on the texture of the fish flesh and the odour emitted either from the gills or anal opening. As the fish become spoilt, the flesh turned soft (mushy) and offensive odour emitted from the fish body.

3.6. Net Recovery and Data Collection

The set nets were usually hauled the following morning. All the catches were carefully observed to determine the state of the catch. The catches were carefully removed as the nets were been hauled into the boat, separated according to the net that caught them and sorted into their respectively species/genus using fish identification keys prepared by Olaosebikan and Raji (1998) as taxonomic guide. With the aid of a designed net recovery form in Appendix 5, the following information was collected from each fish species.

(i) Scientific name of fish caught in each meshsize of gillnets and trammel nets.

(ii) Standard length (mm) of each fish. Total length measurement was not taken because some of the fish caudal fins were damaged probably due to struggling or during the process of removing the fish from the net meshes.

(iii) Weight of each fish (gm)

(iv) Mode of capture (A = enmeshed; B = wedged; and C = entangled).

(v) State of fish (1 = Alive; 2 = Dead and 3 = Spoilt).

(vi) Soak time (being the difference between the setting and hauling time)

3.7. Data Analysis

The twelve sampled stations constituted twelve experimental units. Since each station was located about 1225 metres from the next one, the assumption was that the experimental units were not homogenous. Therefore, each unit constituted a block so that the variation among the blocks was maximised while the variation within any particular block was minimised. The Experimental layout is shown in Table 2.

3.7.1. Test of Hypotheses

The following statistical hypotheses were assumed for the characteristics of the fish caught by each nets and their replicates.

(i) Null Hypothesis (H_O) of which there was no significant difference in the catches (relative efficiency) of the three types of entangling nets. The alternative hypothesis (H_A) if there was difference in the relative efficiency of the nets.

(ii) There was no significant difference in the size selectivity of fish caught in the three types of nets (H_O accepted). The alternative hypothesis (H_A accepted) of which there was significant difference in the size selectivity of fish caught by the three types of net.

(iii) There was no significant difference (H_O accepted) in the cost of construction of each net and the total weight of fish caught by the net The alternative hypothesis (H_A accepted) of there was significant difference in the cost of constructing each net and the total weight of fish caught.

Table 2. Experimental layout of the sampling stations in blocks (12 in number) each consisting of three replicates of the three types of nets (treatments) randomly assigned.

T = Trammel net; 3G = 76mm Gillnet, 7G = 178mm Gillnet; B = Block.

Entangling Nets (Treatments)									
B1	3G1	T2	2G2	7G1	T3	T1	7G3	7G2	3G3
B2	T2	7G3	7G1	3G2	3G1	T1	T3	3H3	7G2
B3	T3	7G1	7G2	T1	T2	3G3	7G3	3G1	3G2
B4	3G3	T2	T3	7G3	3G2	7G1	3G1	T1	7G2
B5	3G2	T1	T3	T2	3G1	7G3	7G2	3G3	7G1
B6	T1	T2	3G3	T3	7G1	7G2	3G1	7G3	3G3
B7	T3	3G1	3G3	3G2	7G1	T2	7G3	7G2	T1
B8	3G1	T3	T1	T1	7G3	7G2	3G2	7G1	3G3
B9	7G3	3G1	T2	3G2	T2	7G1	3G3	T1	7G3
B10	3G2	3G3	7G1	T1	3G2	7G2	T2	T3	7G3
B11	T3	7G2	T1	7G1	T2	3G2	3G3	7G3	3G1
B12	T1	T3	7G2	3G1	T2	3G2	3G3	7G3	7G1

(iii) The three hypotheses were tested using Analysis of variance (ANOVA). Since the experimental units were assumed to be heterogeneous and were grouped into blocks, the Randomised Complete Block Design (RCBD) was adopted using a linear statistical model

$$Yij = \mu + Bi + Tj + Eij$$

Where

Yij = Individual observation in ith treatment in the ith block.

μ = General mean

Bi = effect of the ith block

Tj = effect of the jth treatment

Eij = experimental error

The effects of the treatments and the blocks were fixed in the design

3.8.2. Follow-up Procedure

A post-mortem analysis was carried out for paired comparison of the three treatments since there was significant difference when tested at $p = 0.05$ level of significance. This was done using the Fisher's Least Significant Difference (LSD) method using a model

$$LSD = t(\alpha / 2, dfe) x \sqrt{\frac{2MSE}{r}}$$

where

t = tabulated student's t-value at a level of significance (x) 0.05

df = error degree of freedom (from ANOVA)

r = number of observation per treatment

3.7.3. Estimation of Relative Efficiency

The population and size structure of the fish stocks in the lake were unknown. The absolute standard method to determine the catch efficiency of the nets was not applicable. Rather, a relative standard method was adopted. This was determined by comparing the efficiency of a net with that of the other nets since they (the nets) were operated at the same, same location and equal effort. This method had been successfully used in the works of Losanes *et al* (1992b and Michiels *et al* (1994) using a model:

$$RE_a = \frac{Ci_a}{Ci_a + Ci_b + Ci_c} K$$

Where

RE_a = relative efficiency of gear A

Ci_a = Catch of gear A (Number).

Ci_b = Catch of gear B

Ci_c = Catch of gear C

K = equal fishing efforts for the gear

3.7.4. Estimation of Catch Per Unit Effort (CPUE)

In this experiment, Acosta's (1994) definition of catch per unit effort (CPUE) was adopted which was defined as catch (in gm) of a net, per the net length (in metre) per hour of fishing.

CPUE = Catch (gm)/m/hr.

The total length of the three replicates of each experimental treatment was 150m. For comparison of the CPUE of the experimental nets and that of the catch assessment data of the artisanal fisherfolks, the catch of each set of nets (76 mm, 178 mm and trammel nets) was projected to that of 1000 m length of net using 6.67 multiplying of 3.1 for the 76mm gillnet and trammel net, and 7.2 for 178mm gillnet. This was because a bundle of netting which the artisanal fisherfolks usually set was estimated to be 1000 m long (Ita, 199[illegible] Seisey and du Feu, 1999).

3.7.5. Estimation of Relative Species Diversity Index (RSDI)

The relative species diversity index for each type of entangling net was estimated using a slightly modified model of Ita (1993) as thus:

$$\text{RSDI} = \frac{\text{No. of Species Caught in a Net}}{\text{Total No. of Species Caught in all the Nets}}$$

3.7.6. Size Selection and Plotting of the Master Selectivity Curves

Using a class interval of 10 mm, a frequency distribution of the standard length of fish caught in each gear (where there were enough catch) was tabulated. The percentage occurrence in each length class mid-point for a species in each gear type was plotted in histogram graph.

A master selectivity curve was plotted for each species that had at least 20 catches per net type. This was done by the indirect method (Kitaharas method) which was successfully used by Losanes *et al* (1990, 1992) with slight modification in Samaranayaka *et al* (1997). The model (Kitahara, 1964) used was:

$$S_{ij} A\ (M: L) = S_{ij} B\ (M: L)\ K$$

where

S_{ij} A = Selectivity of net A

S_{ij} B = Selectivity of net B

M = Mesh size

L = Length of fish in a meshsize

K = Constant effort

Using the model above, the master selectivity curve was calculated by scaling the abscissas (x axis) in units of length/meshsize ratio and the ordinates (y axis) as the ratio of the catch of a given meshsize to the total catch of all the nets. In Samaranayaka *et al* (1977), the ratio of meshsize catch to total nets catch was maintained for the ordinate units.

However, the abscissas units were slightly modified by using the length class midpoints for a given fish in a given net. This modification was adopted in plotting the selectivity curves

for the four most abundant species caught during this experiment using the model below ordinate ratio which correspond to the probability of capture.

$$P(L_1) = e - \frac{(-L_1 - L_2)^2}{2S.D^2}$$

Where

P = Probability of capture

L_1 = at a given length class mid-point

L_2 = Median length mid-point

e- = Exponential value

$S.D^2$ = Variance.

The probability of capture, expressed as relative efficiency for each size class, was then superimposed by shifting them downwards or upwards graphically.

3.7.7. Capture modes of the entangling nets

The fish catching performance of each of the entangling nets grouped into enmeshed, entangled and wedged. The proportion of fish caught by a given capture mode was estimated using a ratio estimator (Cochran, 1977):

$$\frac{\sum_k Aik}{\sum_i \sum_k A.B.C.jk}$$

Where

r = proportion caught by the ith capture mode

Yik = number of fish caught by capture mode ABC in the kth stations

3.7.8 Spoilage status

This was categorised into three. The three categories (Alive, Dead and Spoilt) were put in a tabular form species by species for a given net type. The percentage of occurrence of all the species were pooled together and plotted against a given net type.

3.7.9 Benefit -Cost Analysis

The cost of producing a unit of the gear was estimated and the total fish caught and the market value was calculated. The data was used to determine the Fishing Profitability Index (FPI) using Kondo method as reported by Nomura (1991). This was expressed as:

Benefit - Cost Ratio (BCR):

$$BCR = \frac{\text{Cost of the Catch a net}}{\text{Cost of the Net}} \quad \text{............................... Eq. 1.}$$

Relative Productivity Index (RPI)

$$RPI = \frac{\text{BCR of Net A}}{\text{BCR of the 3 net}} \quad \text{.. Eq. 2.}$$

CHAPTER FOUR
RESULTS

4.1. General catch comparison

Table 3 showed that a total number of 365 fish were caught and all weighed 88.795 kg by all the nets during the 24 fishing operations. This fish belonged to 16 different species. Figure 3 showed the percentage occurrence of these species in all the nets pooled together. *Citharinus citharus, Oreochromis niloticus, Synodontis membranaceous* and *Sarotherodon galilaeus* were the four most abundant species caught in that order and they constituted about 81% of the total catch by number and 79.5% by weight.

The trammel net caught a total number of 219 fish belonging to 13 different species and weighing 61.472 kg. With a relative diversity index of 0.82, the net (Trammel net) had the highest number of fish caught both by number and by weight with 60.0% and 69.2% of the total catch of the 3 entangling nets respectively. Also, *C. citharus, O. niloticus, S. membranaceous* and *S. galilaeus* were the four most abundant species in that order with a percentage of occurrence of 79.9% and 79.4% respectively of the total catch of the net (trammelnet).

The 76 mm meshsize gillnet catch was next to that of trammel net with a total number of 141 fish weighing 24.94 kg and belonging to 11 different species with a diversity index of 0.69. This constituted about 38.6% and 28.1% by number and weight respectively of the total catch of the 3 entangling nets. Again, the 4 most abundant species occurred in this net (76 mm meshsize gillnet) but the order of abundance took the form of

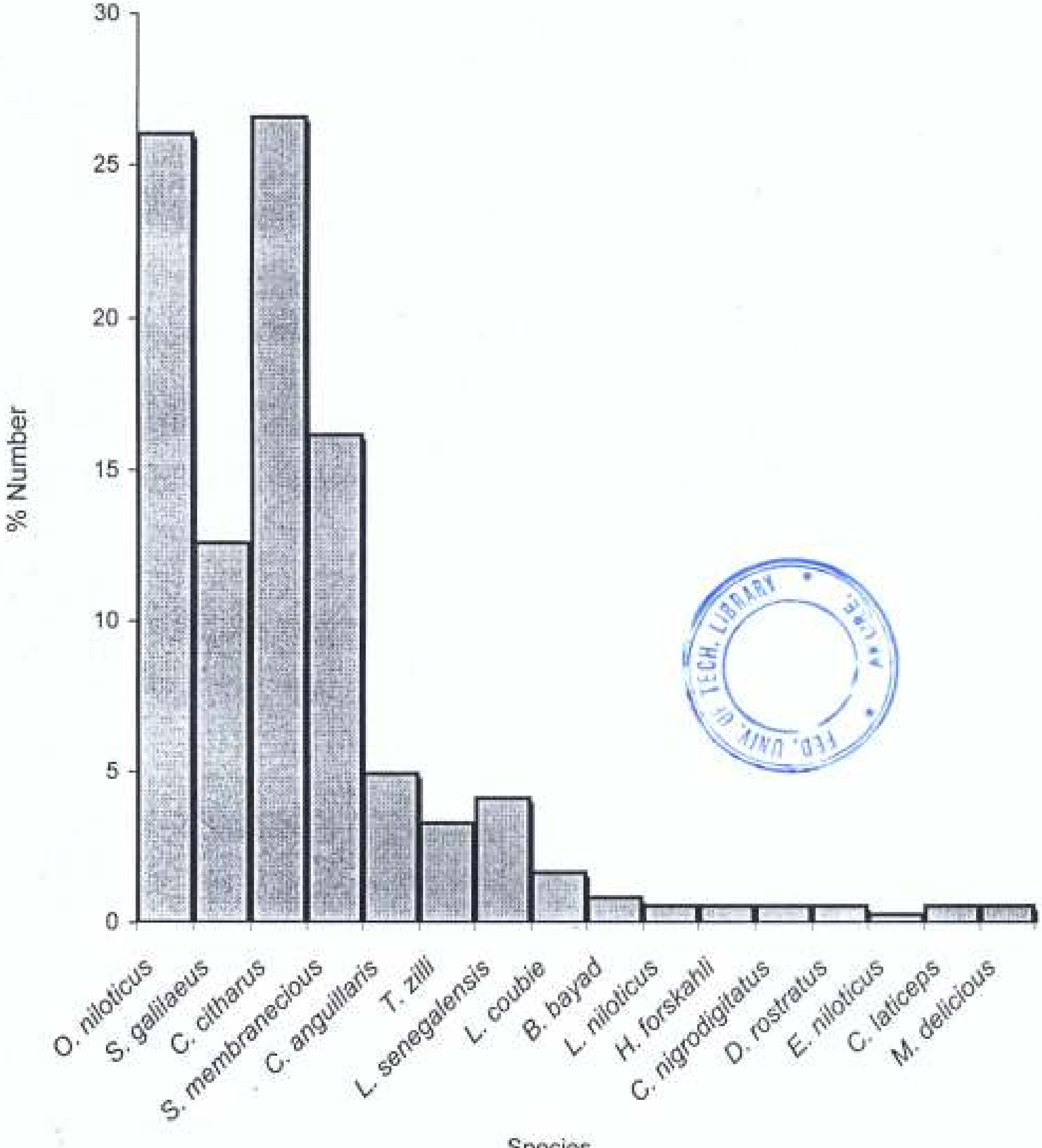


Fig. 3: Percentage Composition of species caught in all the nets.

Table 3. Summary of fish species caught in all the entangling nets during the experimental period

Family	Species	76mm Gill Net		178mm Gill Net		Trammel Net		Total	
		No	Wt (gm)	No	Wt (gm)	No	Wt (gm)	No	Wt (kg)
CICHLIDAE	*Oreochromis niloticus*	40	54565	-	-	55	10735	95	16.20
	Sarotherodon galilaeus	23	3100	-	-	23	4230	46	7.330
	Tilapia zillii	5	535	-	-	7	820	12	1.355
CITHARINIDAE	*Citharinus citharus*	39	7795	1	610	58	214550	98	29.850
DISTICHODONTIDAE	*Distichodus rastratus*	2	625	-	-	-	-	2	0.625
MOCHOKIDAE	*Synodontis membranaceous*	20	4905	-	-	39	12380	59	17.285
CLARIIDAE	*Clarias anguillaris*	4	930	-	-	14	5735	18	6.665
CIPRINIDAE	*Labeo senegalensis*	5	1015	-	-	10	2280	15	3.295
	Labeo coubie	1	220	1	380	4	1790	6	2.390
BAGRIDAE	*Bagrus bayad*	-	-	1	350	2	285	3	0.635
	Chrysichthys nigrodigitatus	-	-	-	-	2	450	2	0.450
	Clarotes laticeps	-	-	-	-	2	245	2	0.245
OTHERS	*Lates niloticus*	1	280			1	380	2	0.660
	Hydrocynus forskillii	-	-	-	-	2	750	2	0.750
	Eutropius niloticus	1	70	-	-	-	-	1	0.070
	Mormyrus delicious	-	-	2	1050	-	-	2	1.050
	Net Total	141	24.942	5	2.39	219	61.472	365	88.795
	Mean Weight (g)		176.9		478		280.7		243.5 g
	No. of Species	11		4		14			
	Relative Diversity Index	0.69		0.25		0.82			

O. niloticus, C. citharus, S. galilaeus and *S. membranaceous* respectively. The four most abundant species also dominated the catch of the 176 mm gillnet with 86.5% and 85.3% by number and weight respectively.

The 178 mm mesh size gillnet was the least both in number and weight of fish caught with 5 fish weighing 2.39 kg and belonging to 4 species. These were *Citharinus citharus*, *Labeo coubie, Bagrus bayad* and *Mormyrus delicious.* With a relative diversity index of 0.25, the catch of the net was only 1.37% and 2.69% by number and weight respectively of the pooled catches of the 3 entangling nets. Analysis of variance showed that there was significant difference in number and weight of the fish caught in the different entangling nets ($P < 0.05$). So also, was a significant difference between the 76 mm gillnets and 178 mm gillnets. Although the 178 mm gillnets caught the least number and weight of fish, but it had the highest mean weight of fish caught in the experimental nets which was 478 gm. This was followed by trammelnets with a mean weight of 280.7gm.The least mean weight of 176.9gm was from 76mm gillnet with 178gm mean weight.

4.1. Catch efficiency of the entangling nets

Figure 4 showed the overall Relative Efficiency Index in catching the various species encountered by the entangling nets. The trammel nets with ratio 0.6 was the most efficient gear, during the experimental period. Result of relative efficiency (species by species) showed that trammel was most efficient for capturing *C. citharus, O. niloticus, S. membranaceous* and *S. galilaeus* in that order. The 76 mm gillnet curve followed the same pattern but at a lesser degree while 178 mm gillnet did not give a useful information on which species it was efficient at catching.

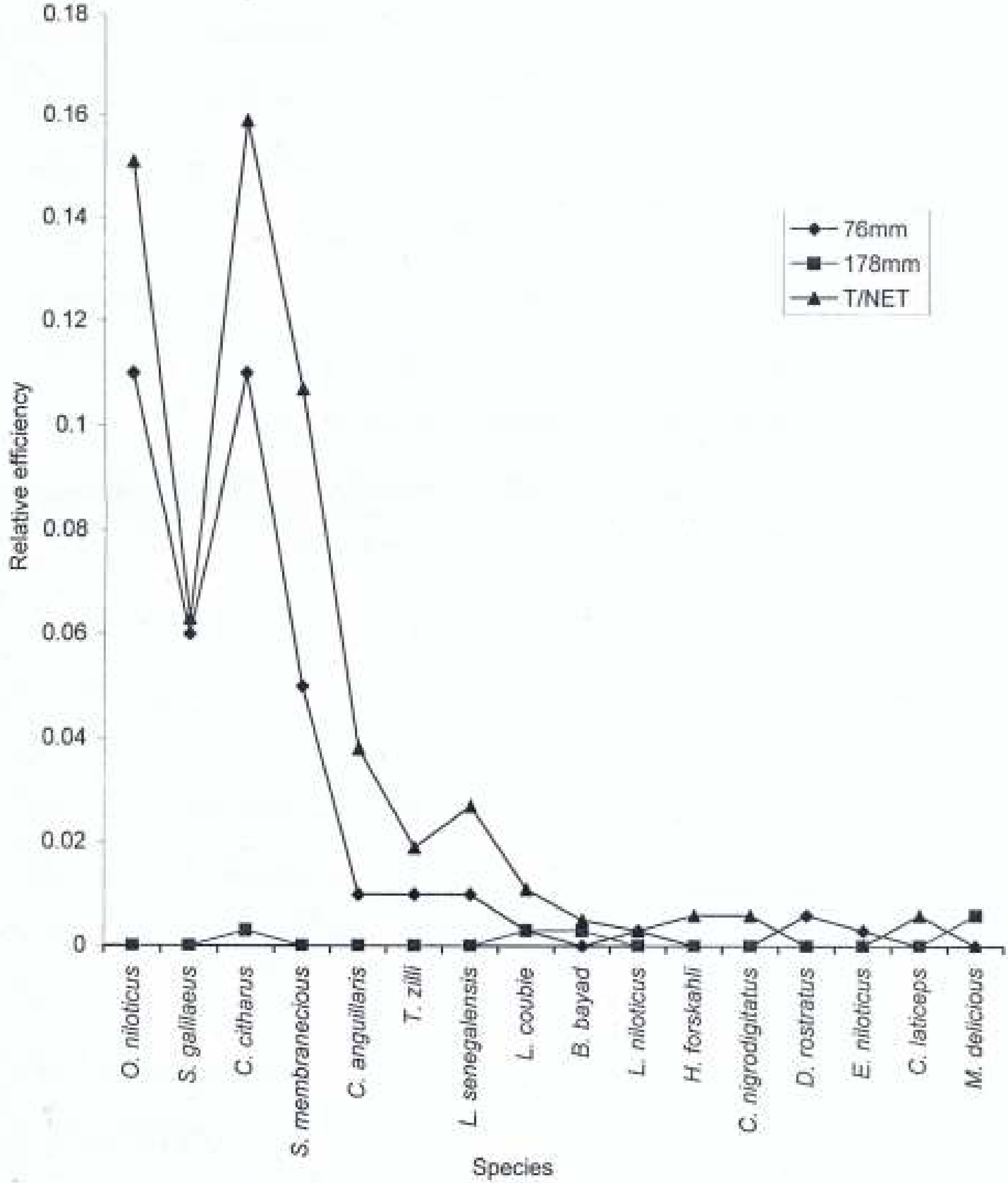


Fig.4: Relative effeciency of the entangling nets for capturing each species recorded during the period of study.

Table 4 showed that the total fishing hours for the 24 experimental fishing operations were 360.4 hours. This gave a mean of 15.02 hrs soak time for each fishing period (S.D. 0.24). This was used to estimate the CPUE for each net after the catch weight had been standardised. Table 5 showed that the trammel net had the highest CPUE of 7.95, followed by 76 mm gillnet with 3.23 and 178 mm gillnet had 0.72 as CPUE.

4.2 Size Class and Selection Range

Table 6 shows the length distribution of *O. niloticus, S. galilaeus, C. citharus* and *S. membranaceous* caught in the 76 mm gillnets and trammel nets with a length class interval of 10 mm. There was overlap in the minimum length class of fish caught by both 76 mm gillnet and trammel nets for the four dominating species. However variation in the maximum length class for the four species caught in net types differed. *O. niloticus* had 125 mm class mid-point for both 176 mm gillnet and trammels but 205 and 225 mm as maximum midpoints for 176 mm gillnets and trammel nets respectively. Some observation was made for the *S.galilaeus* minimum class mid-point but with shorter selection range of 115 to 195 for 76 mm gillnet and 115 to 215 for trammel net. The minimum class at capture for *C. citharinus* was at a higher mid-point of 155 for both net types. While the maximum class mid-point was at 245 mm and 275 mm 76 mm gill nets and trammel nets respectively, *S. membranaceous* had the lowest class mid-point of 75 mm for both net types. This ranged to a maximum of 175 mm for 76 mm gillnets and 235 mm for the trammel nets. It was generally observed that the 76 mm gillnet had a narrower length selection range than the trammel nets for all the four species analysed. Also, the wideness of selection

Table 4. **Summary of Soak Time for the entangling nets**

Station	Setting (p.m.)		Hauling (a.m.)		Soak Time		Total
	A	B	A	B	A Hr : Min	B Hr : Min	
1	5.40	5.30	8.35	8.30	14 : 55	15 : 00	29 : 55
2	5.15	5.20	8.20	8.40	15 : 05	15 : 20	30 : 25
3	5.15	5.30	8.10	9.00	14 : 55	15 : 30	30 : 25
4	5.10	5.40	8.15	8.50	15 : 05	25 : 10	30 : 15
5	5.25	5.20	8.30	8.40	15 : 15	15 : 20	30 : 35
6	5.35	5.10	8.30	9.40	14 : 55	14 : 30	29 : 25
7	5.38	6.00	9.10	8.30	15 : 32	14 : 30	30 : 02
8	5.30	6.15	9.00	8.40	15 : 30	14 : 25	29 : 55
9	5.36	6.10	8.30	8.40	14 : 54	14 : 30	29 : 24
0	5.30	5.20	8.40	8.30	15 : 10	15 : 10	30 : 20
11	3.20	5.40	8.40	8.30	15 : 20	14 : 50	30 : 10
12	5.30	6.20	8.20	8.25	14 : 40	15 : 05	29 : 45

Grand Total = 360 : 24
No. of Fishing Operations = 24
Mean Soaked Time = 15.02
Standard Deviation = 0.24

A = 1st Fishing trial
B = 2nd Fishing trial

Table 5 Estimation of CPUE for the entangling nets during the experimental period

Type of Net	A Total Catch	B Area of Nets (m^2)	C Area of a Bundle of Nets	D Multiplying Factors $^C/_B$	Mean Soak Time for Experimental Nets	CPUE of Exp. Nets/Hrs	CPUE of Exp. Nets/Day	CPUE* from CAS
76 mm Meshsize Gillnets	24.942	450	1390	3.1	15.43	0.215	3.23	3.5
178mm Meshsize Gillnets	2.39	450	3236	7.2	15.43	0.048	0.72	4.7
Trammel Nets.	61.472	450	Lint=1390 Armo=3236	3.1	15.43	0.529	7.95	N.A.

* = CPUE of artisanal 76 mm meshsize gillnets fishery of the lake. Data was extracted from Catch Assessment Survey from January 1995 to December 1998 (du Feu & Abiodun, 1999).

N.A. = No available data on the gear.

Table 6. Length distribution analysis for the four most abundant species.

Size Class (mm)	Length Class mid-point	*Oreochromis niloticus*			*Sarotherodon galilaeus*			*Citharinus citharus*			*Sarotherodon membranaceous*		
		GN	TR	Total	GN	TR	Total	GN	TR	Total	GN	TR	Total
70-79	75										1	1	2
80-89	85										2	3	5
90-99	95										0	1	1
100-109	105										0	1	1
110-119	115										1	1	2
120-129	125	2	2	4	3	1	4				10	3	13
130-139	135	7	5	12	6	0	6				2	3	4
140-149	145	27	6	23	1	2	3				1	10	11
150-159	155	5	5	10	4	6	10	1	1	2	1	3	4
160-169	165	3	2	5	6	3	9	4	0	4	2	4	6
170-179	175	1	2	3	0	3	3	0	0	0	1	2	3
180-188	185	3	16	19	2	3	5	6	1	7		2	2
190-199	195	1	8	9	1	1	2	15	4	19		1	1
200-209	205	1	7	8		0	0	6	5	11		0	0
210-219	215		1	1		1	2	4	4	8		1	1
220-229	225		1	1				1	6	7		2	2
230-239	235							1	14	15		1	1
240-249	245							1	7	8			
250-259	255								11	11			
260-269	265								1	1			
270-279	275								4	4			
		40	55	95	23	23	46	39	58	97	20	39	59

GN = 76 mm meshsize gillnet

TR = Trammel.

range for the trammel nets was towards a higher length class mid-point. This showed that the trammel nets caught more larger fish than the 76 mm gillnets. Hence, the higher mean weight of 280.7 g for trammel net and low mean weight of 176.9 g for 76 mm gillnets (Table 3).

Figure 5, 6, 7 and 8 show the optimal modal length for *O. niloticus, S. galilaeus, C. citharus* and *S. membranaceous* caught in the two net types respectively. Whereas the optimum modal length of *O. niloticus* caught in 76 mm gillnets was at 145 mm, in the trammel nets, it was at 185 mm class mid-point. It was also observed that the trammel nets had a minor modal length at 145 mm which corresponded to the optimal modal length of the gillnet (76 mm meshsize).

Figure 6 showed that *S. galilaeus* had optimal bimodal length at 135 mm and 165 mm in the gillnet (76 mm) catches. The trammel nets had optimum modal length at 155 mm and the Figure 6 also indicated high percentage of larger species (165 mm to 185 mm mid-point). The 76 mm gillnet had its optimal modal length at 195 mm for *C. citharus* while the modal length for the species in trammel net was at 235 mm. Though the trammel net length distribution had the widest selection range for this species than the rest, but the wideness tilted towards the mid-points that were lower than the optimal mid-point.

Size distribution to the different length class for *S. membranaceous* were similar for both 76 mm gillnets and the trammel nets. However, modal lengths for both type of nets were again different. While the modal length of 76 mm gillnet was 125 mm, that of the trammel net was at 145 mm. The selection range of *S. membranaceous* in the trammel net was the widest when compared with that of the other most abundant species.

Selectivity Curve

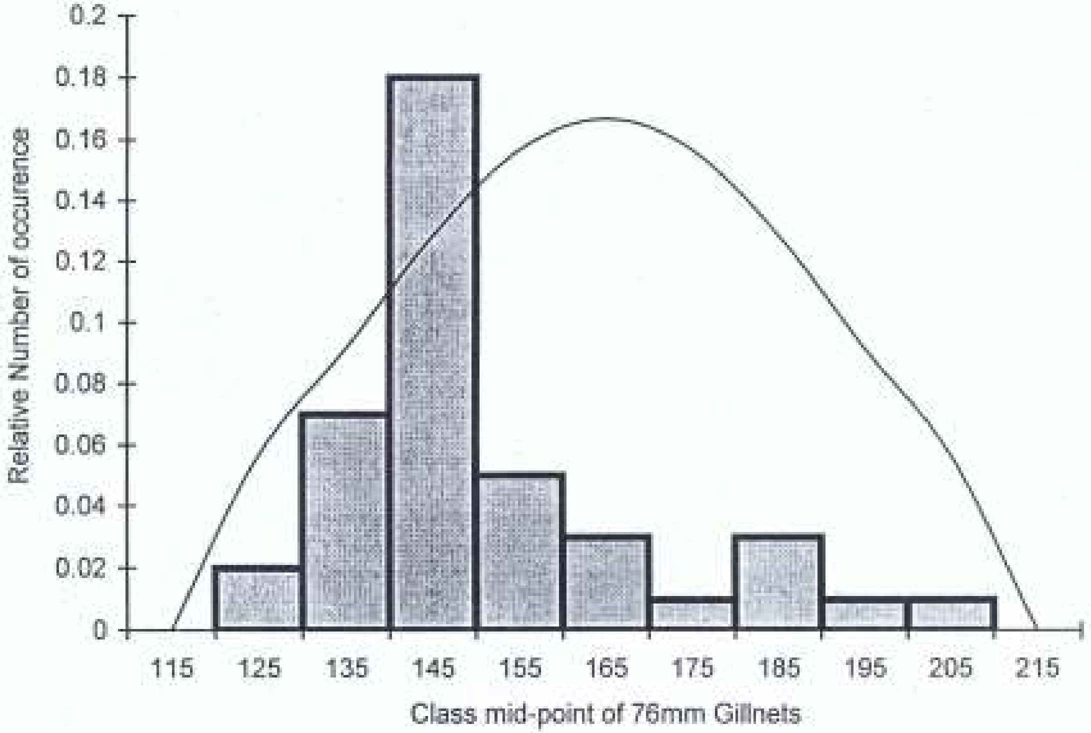
Figures 5, 6, 7 and 8 showed the master selectivity curves of gillnet and trammel fitted to logarithmic normal distribution models for *O. niloticus, S. galilaeus, C. citharus* and *S. membranaceous* respectively.

It was observed that while the optimum modal length *O. niloticus* was at 145 mm, the median length (μ) of the species caught in the 76 mm gillnet was at 165 mm. The optimum modal length being

Table 7. Estimated parameters for plotting the master selectivity curves of the four target species.

Species	Median Length (μ)	Modal length	Std. deviation (σ)	Selection range	Skewness (mode – median) / σ
O. niloticus					
GN	165	145	27.39	135-205	-0.73
TR	175	185	33.17	145-205	+0.30
S. galilaeus					
GN	160	135/165	24.5	135-185	
TR	170	155	30.28	140-210	
C. Citharus					
GN	200	195	30.28	170-230	-0.17
TR	215	235	38.94	175-255	+0.51
S. membranaceous					
GN	125	125	33.17	90-160	+0.0
TR	155	145	50.5	105-205	-0.20

GN = 76mm Mesh size gillnet
TR = Trammel net



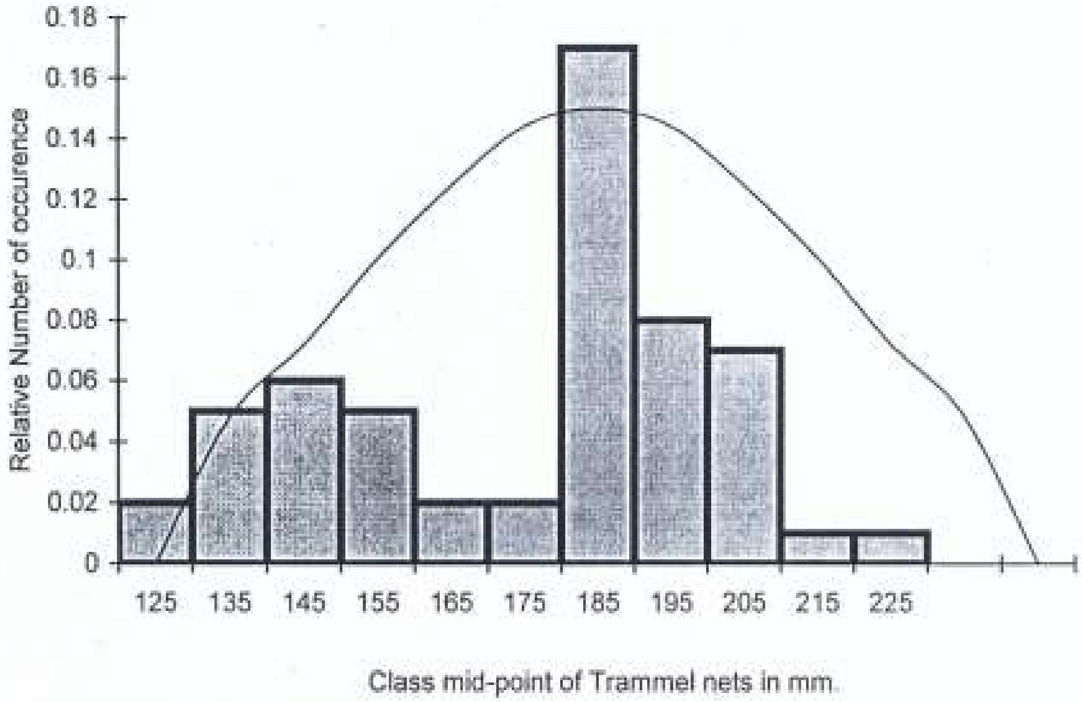
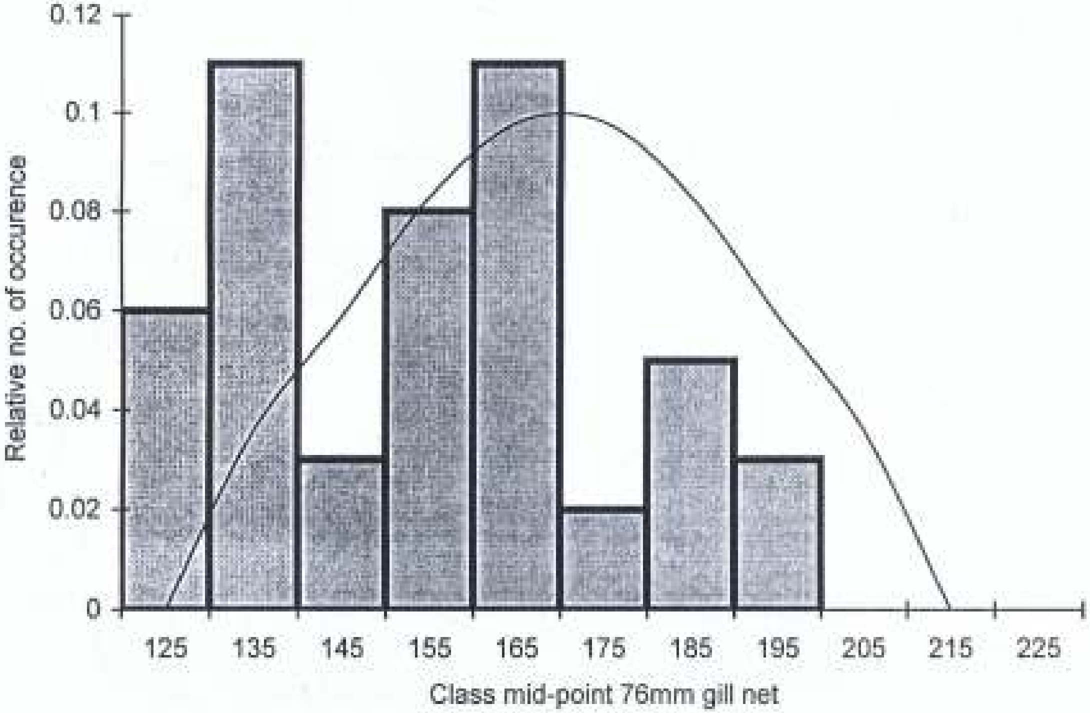


Fig. 5: Length distribution of *O. niloticus* in 76mm gillnet and Trammel net with selectivity curves fitted to a log of normal distribution.



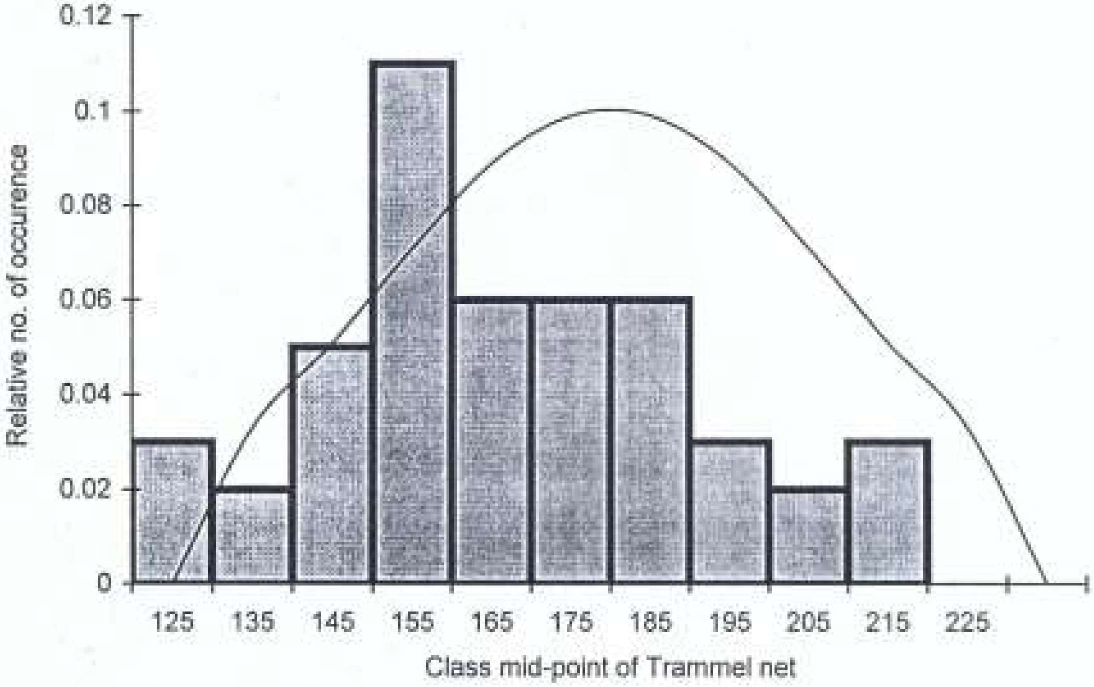
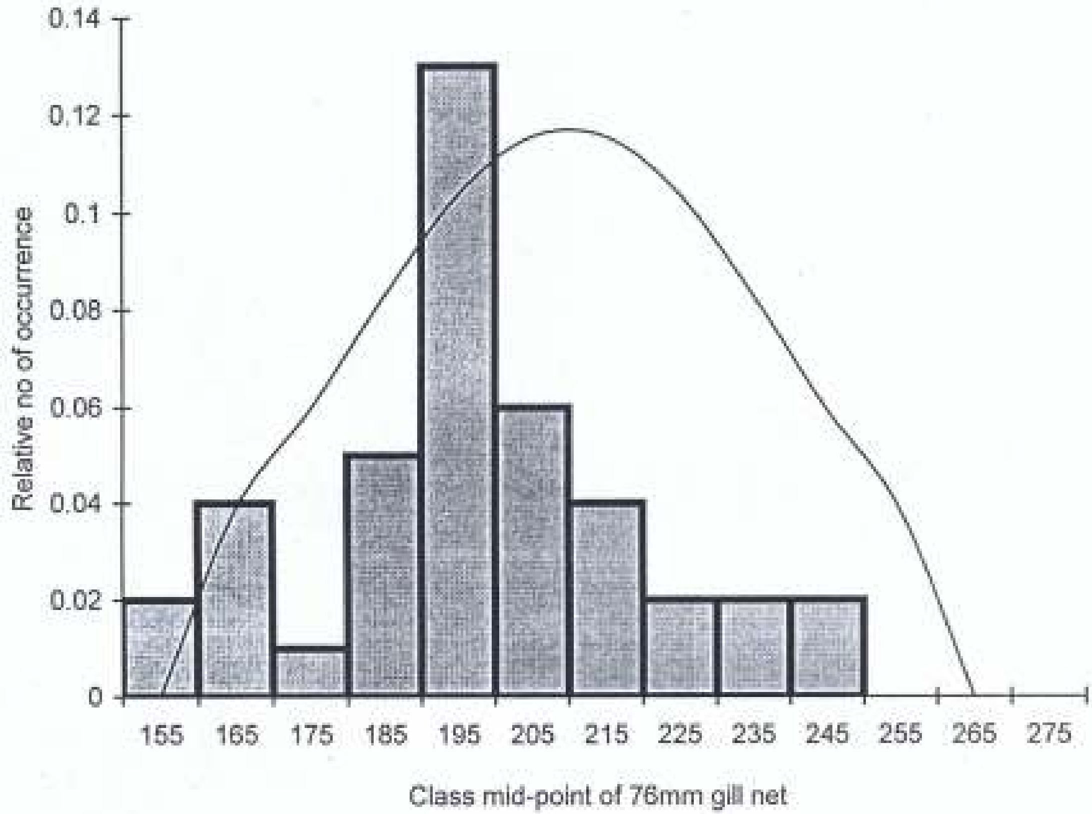


Fig. 6: Length distribution of *S. galilaeus* in 76mm gill net and Trammel net with selectivity curves fitted to a log of normal distribution.



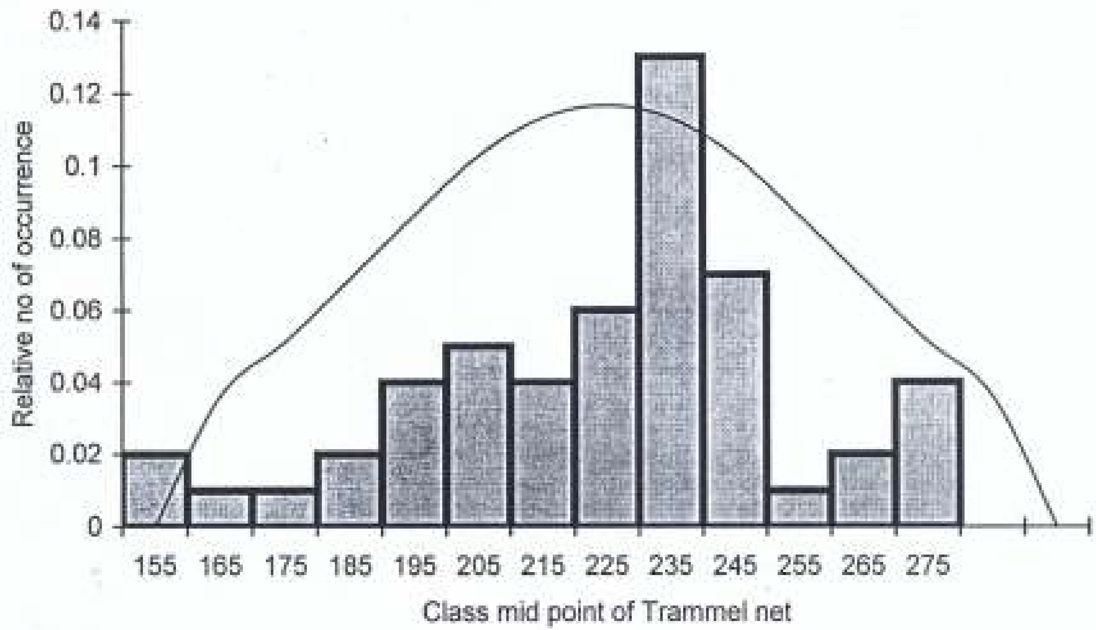
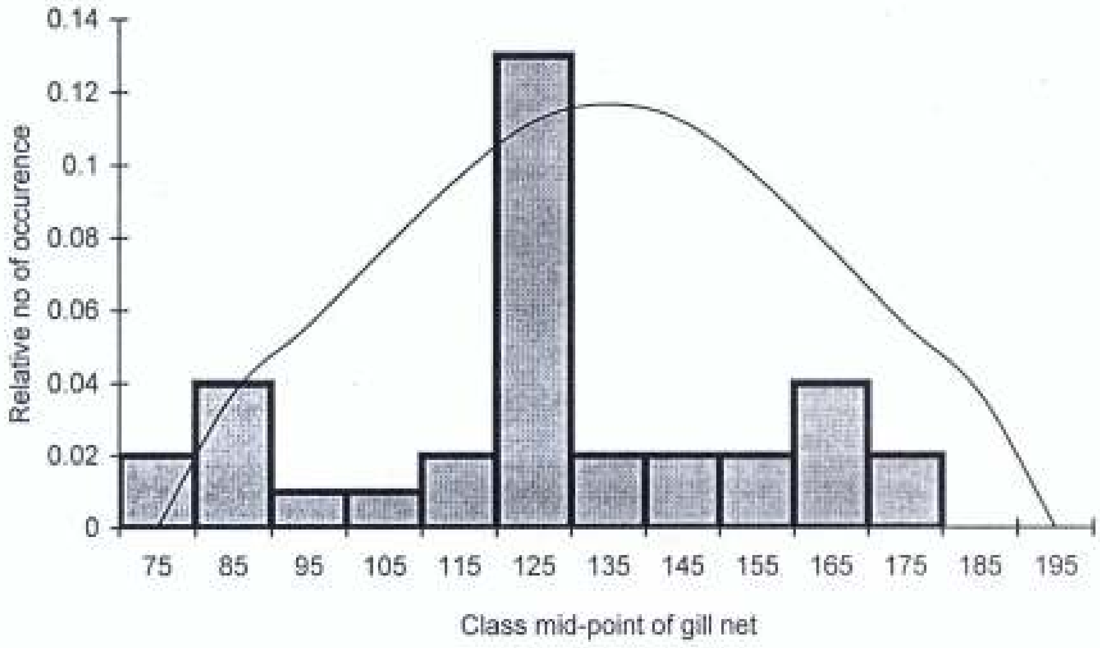


Fig. 7: Length distribution of *C. citharus* in 76mm gill net and Trammel net with selectivity curves fitted to a log of normal distribution.



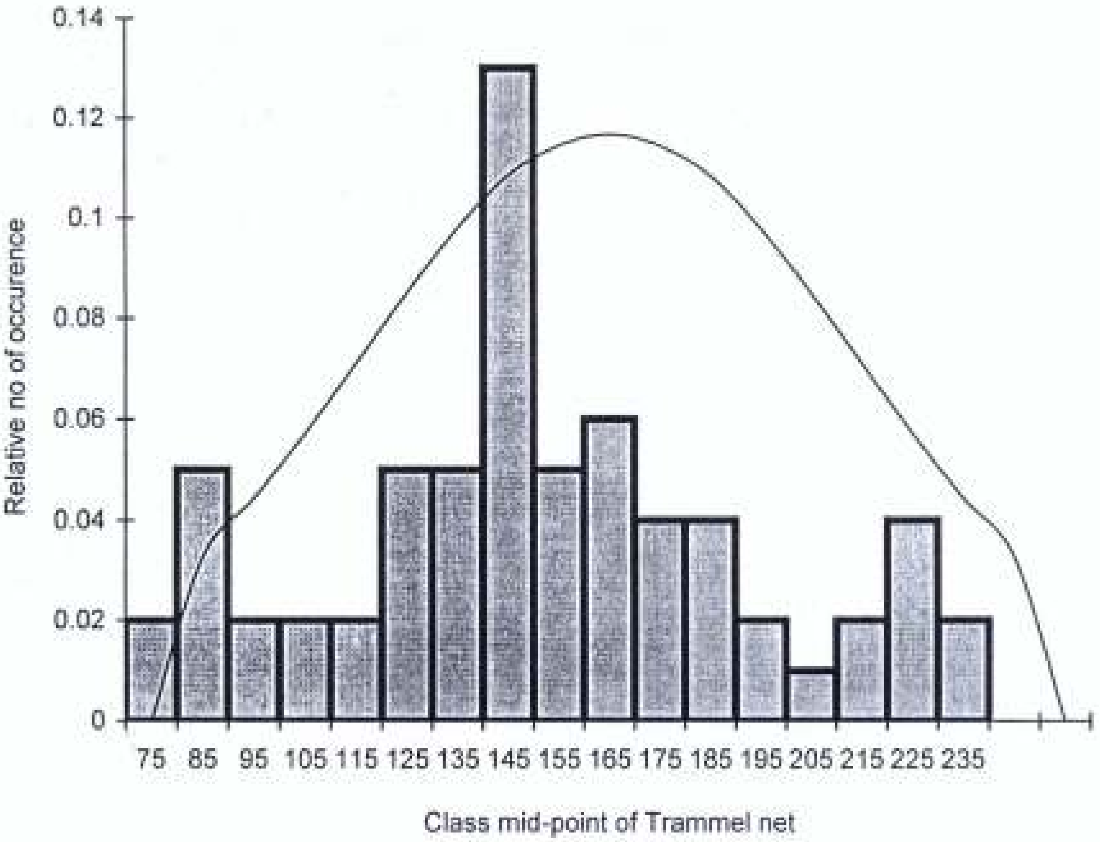


Fig. 8: Length of *S. membranaceous* in 76mm gill net and Trammel net with selectivity curves fitted to a log of normal distribution.

synonymous with the optimum probability of capture to the master curve being skewed to the left with a standard deviation (Õ) from the median length class of ± 22.6 mm. The median length of the species (*O. niloticus*) in the trammel net was at 175 mm but the optimum modal length was 185 mm. This caused the curve to skewed to the right with a pronounced long light tail (μ = 175.0 mm, Õ = ± 45 mm).

The median length of *S. galilaeus* (160 mm) fell in between the bimodal optimum length in the 76 mm gillnet catches (135 and 165mm) and standard deviation (Õ) was 20.5 cm which showed a lower selection range when compared with the *O. niloticus* in the net type. The high median length (μ = 170) of *S. galilaeus* in standard deviation (Õ = 52 mm). However, an optimum modal length of 155 mm eliminated the skewness of the curve to the right which also limited the extension of the right tail of the curve.

The master curve of the 76 mm gillnet to *C. citharus* followed the pattern of that of the *O. niloticus* but with a higher Õ value and optimum modal length. The latter was again at the left side of (195 mm) of the former (200 mm). This resulted to the curve being skewed to the left side without corresponding slipped left tail. The trammel net curve also skewed to the right with a long and gentle right tail, μ = 200, Õ = 62.52 m and optimum modal length = 235.

The master curves of the *S. membranaceous* in the 76 mm gillnet and trammel had the same bell shape but the selection range of the 76 mm gillnet was much narrower than that of the trammel net which was about the widest selection range in all the four species reported on.

4.4. Mode of capture of the entangling nets

Figure 9 shows that 21.9% of the pooled catches in 76 mm gillnets were enmeshed (gilled), followed by 11.2% entangled and 5.5% were wedged. Out of the 5 fish caught in the 178 mm gillnets, 4 were enmeshed and one entangled. The trammel net recorded 34% fish that were entangled. Enmeshed fish accounted for 19.2% and those that were wedged were 6.9%.

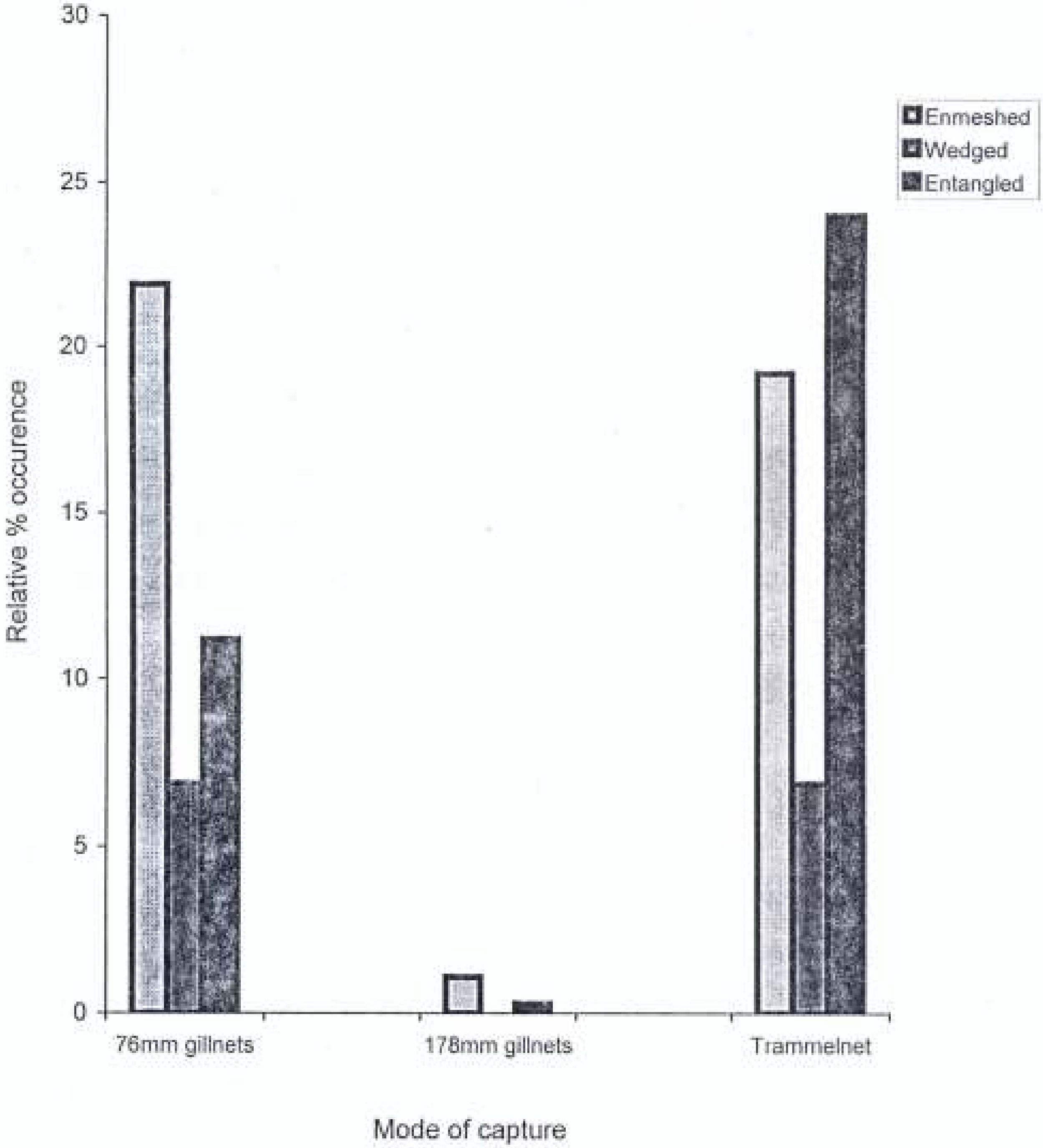


Fig. 9: Relative percentage of fish caught in a given mode of capture during the period of study.

Table 8 showed that in the 76 mm gillnet, the four most abundant species were mostly enmeshed (*O. niloticus* 60%, *S. galilaeus* 74% and *C. citharus* 59%) with the exception of *S. membranaceous* which was 40% enmeshed, 45% wedged and only 15% entangled. The trend changed in the trammel nets as shown in Table 8. The trammel nets entangled 55, 52% and 81% of *O. niloticus, S. galilaeus* and *C. citharus* respectively. Only 25% of the *S. membranaceous* was entangled while 41% and 33% of the species were wedged and enmeshed respectively.

The length composition of four principal fish caught (*O. niloticus, S. galilaeus and S. membranaceous*) was compared as shown in Figure 10a. There was no significant difference ($P > 0.05$) in the length range for the enmeshed and entangled fish caught in 76 mm meshsize. The modal peaks of *O. niloticus* and *S. galilaeus* that were enmeshed were at a lower length class mid-point - 145mm and 135 mm respectively; and the entangled *O. niloticus* modal length mid-point was at 185 mm. The mid-point modal peak for *C. citharus* was at 195 mm for both enmeshed and entangled fish.

In the trammel nets, there was a wider length range for *O. niloticus* that were entangled than those that were enmeshed. But the mid-point peaks for the two modes of capture were both at 185 mm (Figure 10b). Figure 10c showed that *C. citharus* enmeshed had a very narrow length range (from 215 to 245); whereas the length range of the fish caught by entangling was very wide from 155 mm to 175 mm with mid-point length peaks at 235 and 255 for enmeshed and entangled fish respectively. *S. membranaceous* had a wide but equal length range for the three modes of capture in figure 10d The range was from 75 mm 185mm.

4.5. Spoilage status of the fish caught

Table 10 showed condition of the fish after capture. Stages I and II (i.e. alive and dead respectively) were considered to be of good quality while stage III was considered as the spoilt stage. In general, out of a total of 365 fish caught, 143 were alive, 173 dead and 49 were spoilt. Data analysis showed the 39.2% and 47.4 that were alive and dead respectively were still in good condition. The spoilt fish accounted for only 13.4% of the total yield. Figure 11 was the relative percentage of occurrence of the fish in each state of

Table 8. Percentage mode of capture of the 76 mm and 178 mm meshsize gillnets during the experimental period.

Family	Species	Enmeshed (A)		Wedged (B)		Entangled (C)		Total
		No.	%	No	%	No	%	No.
CICHLIDAE	*Oreochromis niloticus*	24	60.0	1	2.5	15	37.5	40
	Sarotherodon galilaeus	17	73.9	2	8.7	4	17.4	23
	Tilapia zillii	4	80.0	1	20.0	-	-	5
CITHARINIDAE	*Citharinus citharus*	23	59.0	2	5.1	14	35.9	39
DISTICHODONTIDAE	*Distichodus rastratus*	-	-	2	100.0	-	-	2
MOCHOKIDAE	*Synodontis membranaceous*	8	40.0	9	45.0	3	15	20
CLARIIDAE	*Clarias anguillaris*	2	50.0	1	25.0	1	25.0	4
CIPRINIDAE	*Labeo senegalensis*	2	40.0	-	-	3	60.0	5
	Labeo coubie	-	-	-	-	1	100.0	1
BAGRIDAE	*Bagrus bayad*	-	-	-	-	--	-	-
	Chrysichthys nigrodigitatus	-	-	-	-	-	-	-
	Clarotes laticeps	-	-	-	-	-	-	-
OTHERS	*Lates niloticus*	-	-	1	100.0	-	-	1
	Hydrocynus forskhali	-	-	-	-	-	-	-
	Eutropius niloticus	-	-	1	100.0	-	-	1
	Mormyrus delicious	-	-	-	-	-	-	-
	Total	80	56.7	20	14.2	41	29.1	141
	178 mm Mesh size Gillnets							
	Citharinus citharus	1	100.0	-	-	-	-	1
	Labeo coubie	1	100.0	-	-	-	-	1
	Mormyrus delicious	2	100.0	-	-	-	-	2
	Bagrus bayad	-	-	-	-	1	100.0	1
	Total	4	80.0	-	-	1	20.0	5

76mm gillnet mode of capture in column A differ significantly from column B & C, but no significant difference between column B & C

Table 9. Percentage mode of capture of the trammel net during the experimental period.

Family	Fish Species	Enmeshed (A)		Wedged (B)		Entangled (C)		T
		No.	%	No	%	No	%	N
CICHLIDAE	*Oreochromis niloticus*	25	44.6	-	-	30	55.4	55
	Sarotherodon galilaeus	10	43.5	1	4.4	12	52.1	23
	Tilapia zillii	7	100.0	-	-	-	-	7
CITHARINIDAE	*Citharinus citharus*	11	19.0	-	-	48	81.0	59
DISTICHODONTIDAE	*Distichodus rastratus*	-	-	-	-	-	-	-
MOCHOKIDAE	*Synodontis membranaceous*	13	33.3	16	41.1	10	25.6	39
CLARIIDAE	*Clarias anguillaris*	1	7.1	5	35.7	8	57.1	14
CIPRINIDAE	*Labeo senegalensis*	1	10.0	-	-	9	90.0	10
	Labeo coubie	2	50.0	-	-	2	50.0	4
BAGRIDAE	*Bagrus bayad*	-	-	2	100.0	-	-	2
	Chrysichthys nigrodigitatus	-	-	2	100.0	-	-	2
	Clarotes laticeps	-	-	1	50.0	1	50.0	2
OTHERS	*Lates niloticus*	-	-	-	-	1	100.0	1
	Hydrocynus forskhali	-	-	-	-	2	100.0	2
	Eutropius niloticus	-	-	-	-	-	-	-
	Mormyrus delicious	-	-	-	-	-	-	-
	Total	70	32.0	25	11.4	124	56.6	219

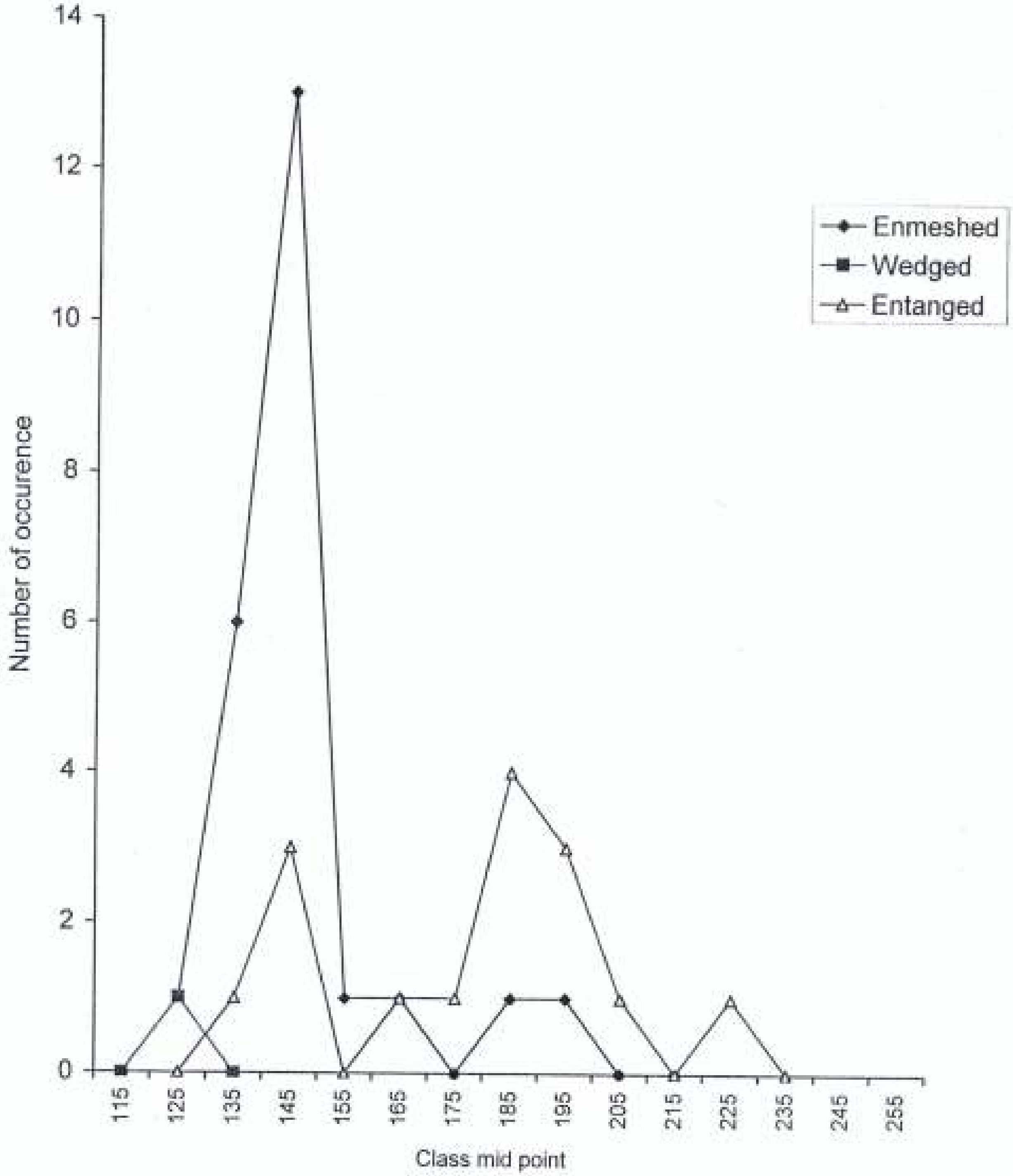


Fig. 10a: Length distribution by modes of capture for *O. niloticus* in 76mm gillnet.

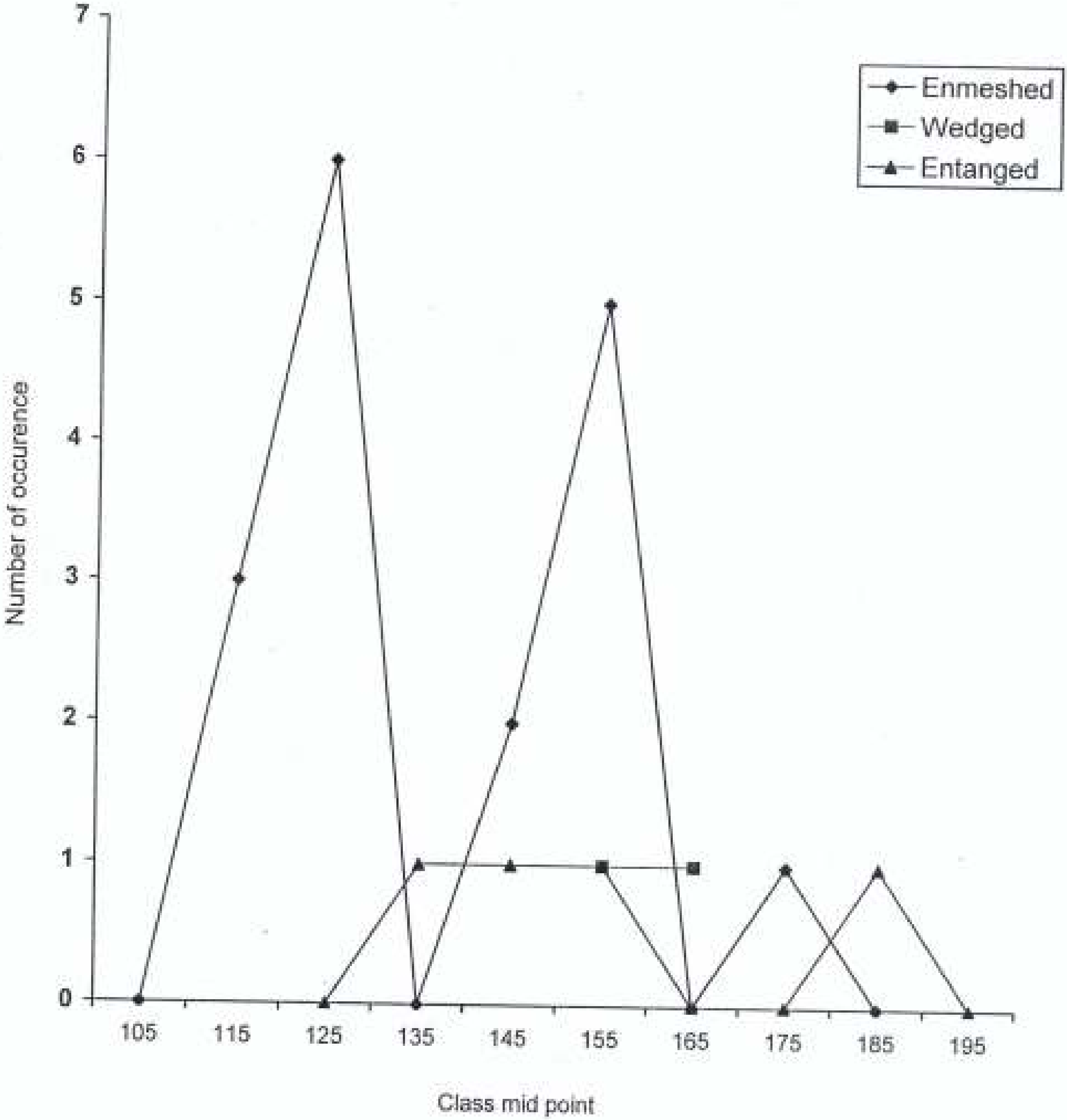


Fig. 10b: Length distribution by mode of capture for *S. galilaeus* in 76mm gillnet.

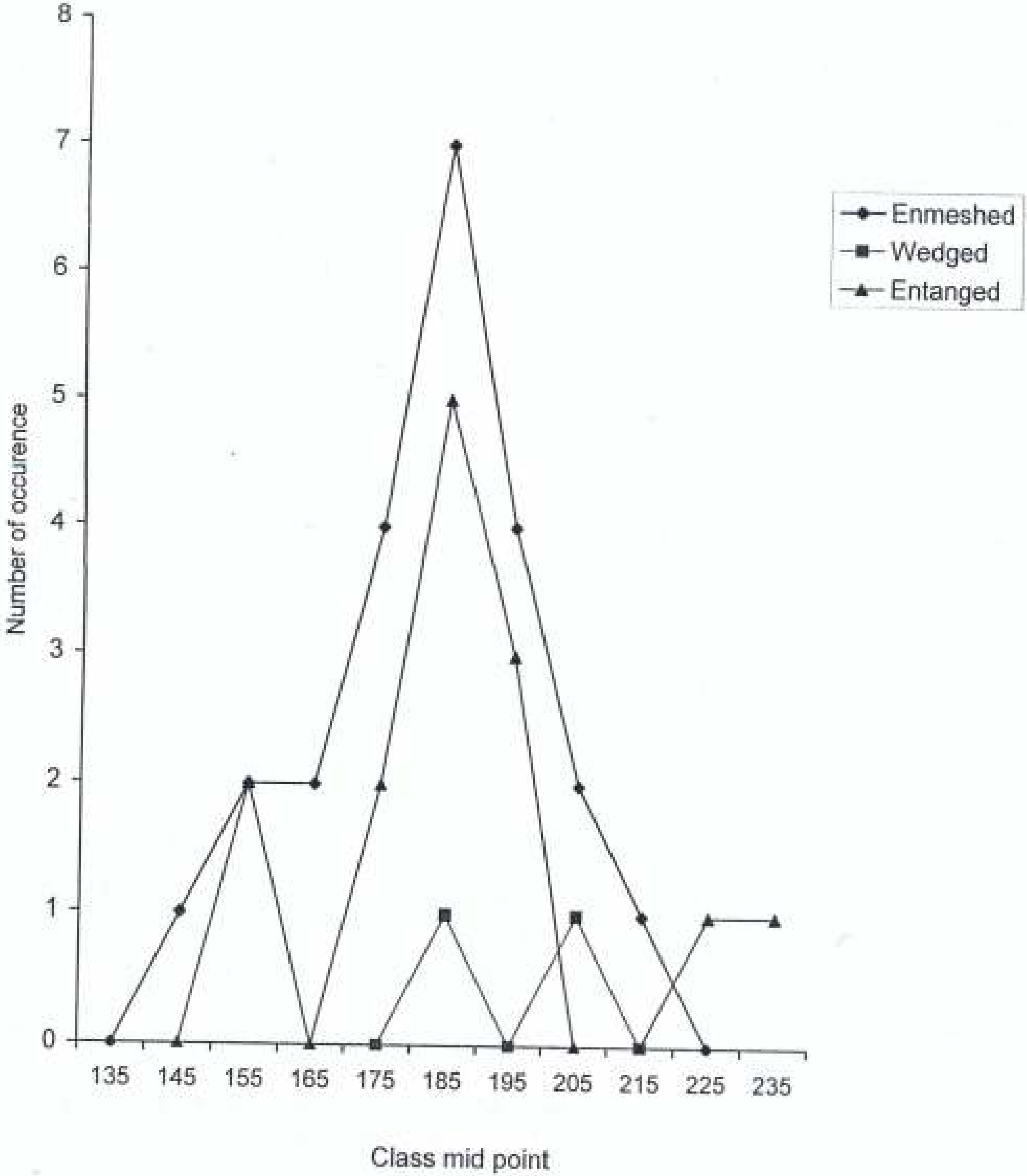


Fig. 10c: length distribution by mode of capture for *C. citharus* in 76mm gillnet.

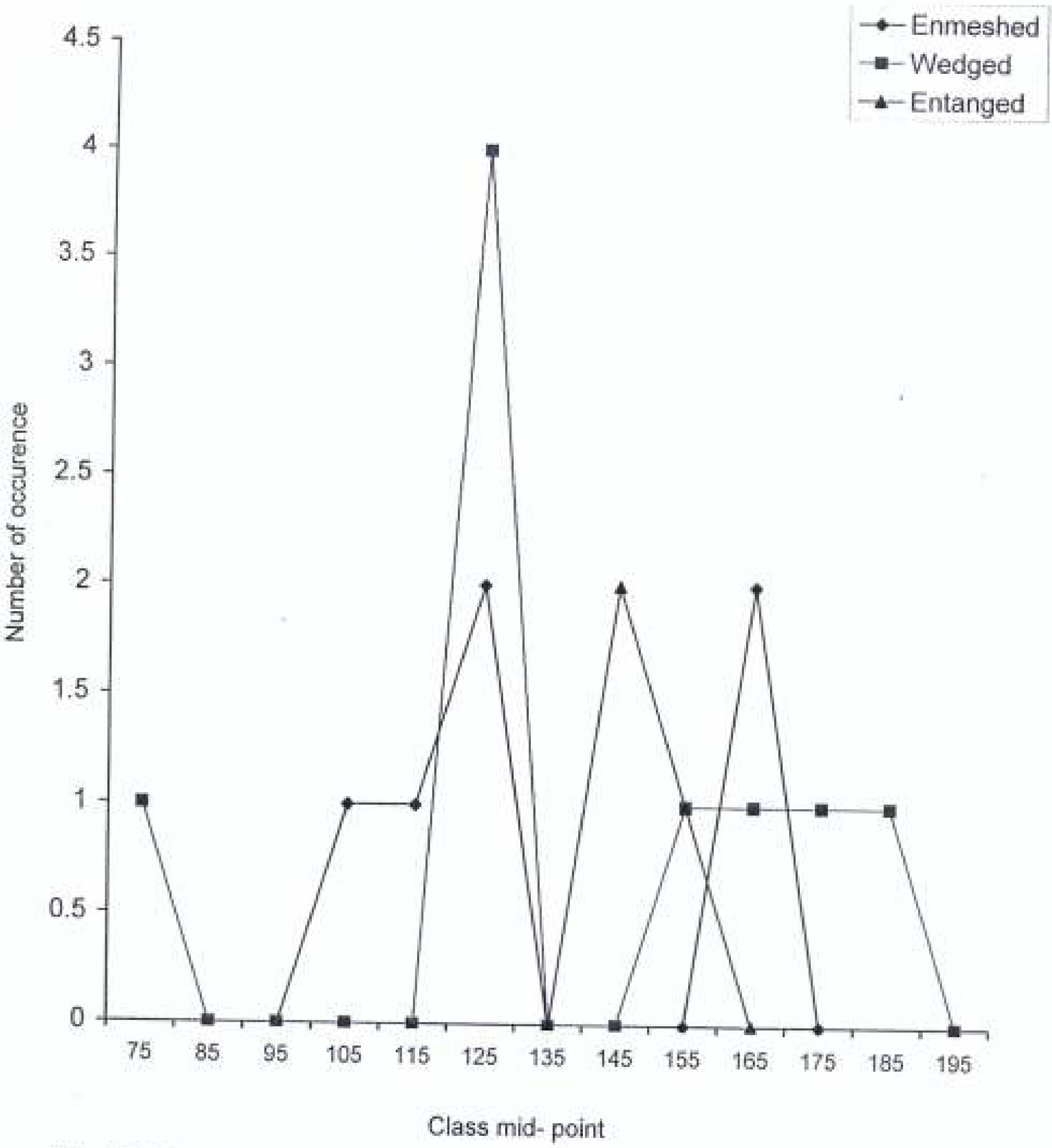


Fig. 10d: Length distribution by mode of capture for *S. membranecious* in 76mm gillnet.

spoilage for the types of net used. Occurrence of dead fish was slightly higher than those caught alive using 76 mm gillnets (17.3% to 14.8%) while the spoilt fish accounted for 6.9% of the total fish catch. Out of the five fish caught in with the 178 mm gillnet, four were dead and one spoilt, none was alive. In the trammel net catch however, the dead fish accounted for 29.2 % of the catch while live fish constituted 34.7% of the total catch. About 7% of the total fish caught by trammel net were found dead..

Table 10. Status of fish caught in all the nets pooled together.
I = Alive; II = Dead; III = Spoilt.

Species	76mm Gillnets				178mm Gillnets				Trammel Nets				GrandTotal		
	I	II	III	Total	I	II	III	Total	I	II	III	Total	I	II	III
Oreochromis niloticus	28	9	3	40	0	0	0	0	33	22	-	55	61	31	3
Sarotherodon galilaeus	6	12	5	23	0	0	0	0	9	12	2	23	15	24	7
Citharinus citharus	5	26	8	29	0	1	0	1	7	40	11	58	12	67	19
Synodontis membranaceous	10	10	0	20	0	0	0	0	27	12	0	39	37	22	0
Clarias anguillaris	03	2	2	4	0	0	0	0	5	9	0	14	5	11	2
Tilapia zillii	1	1	1	5	0	0	0	0	4	1	2	7	7	2	3
Labeo senegalensis	0	1	3	5	0	0	0	0	0	6	4	10	1	7	7
Labeo coubie	0	1	0	1	0	0	1	1	1	3	0	4	1	4	1
Bagrus bayad	0	0	0	0	0	1	0	1	0	1	1	2	0	2	1
Lates niloticus	0	0	1	1	0	0	0	0	0	0	1	1	0	0	2
Hydrocynus forskalii	0	0	0	0	0	0	0	0	0	0	2	2	0	0	2
Chrysichthys nigrodigitatus	0	0	0	0	0	0	0	0	2	0	0	2	2	0	0
Distichodus rostratus	0	1	1	2	0	0	0	0	0	0	0	0	0	1	1
Eutropius niloticus	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1
Clarotes laticeps	0	0	0	0	0	0	0	0	2	0	0	2	2	0	0
Mormyrus deliciosus	0	0	0	0	0	2	0	2	0	0	0	0	0	2	0
Total	54	63	25	141	0	4	1	5	90	106	23	219	143	173	49
% Relative Occurrence	14.8	17.3	6.9		0.0	1.1	0.3		24.7	29.04	6.3		39.2	47.4	13.4

No in column I & II of the 76mm gillnet and trammel net does not differ significantly, but both differ significantly from column III by LSD test

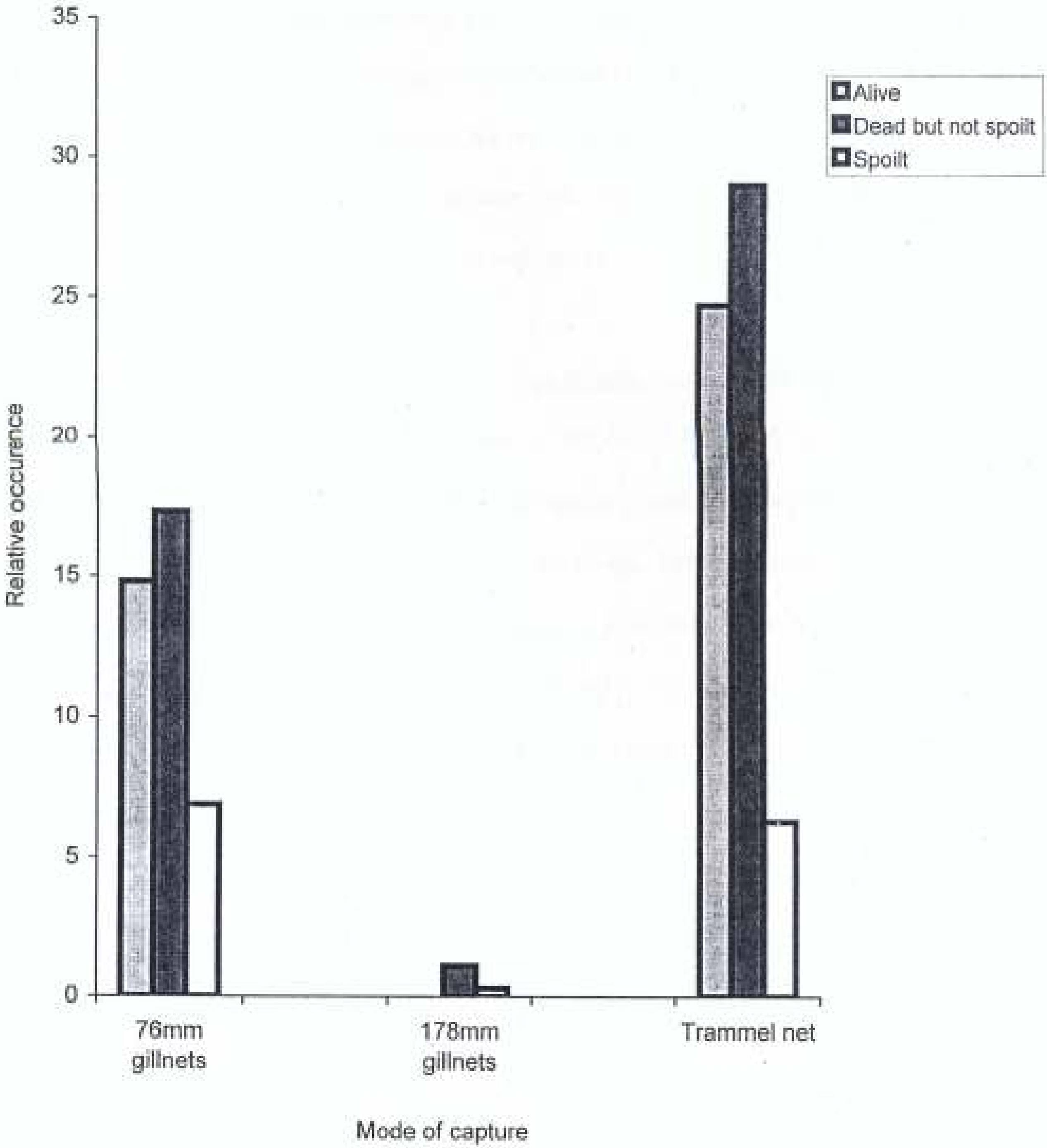


Fig. 11: Percentage of fish spoilage in the entangling net during the period of study.

Detailed analysis of Table 10 revealed that *C. citharus* had the highest number of spoilt fish of 19 (38.8%) out of 49. Eleven (11) of the spoilt *C. citharus* were from the trammel net while 8 came from 76 mm gillnet. All the *L. niloticus, H. forskhali, D. rostratus* and *E. niloticus* were already spoilt at the time the nets were hauled. Spoilage was not recorded in S. *membranaceous* and *C. nigrodigitatus.*

4.6. Cost Benefit Analysis

Table 11 shows the relative fishing profitability index estimated from the data available. While it was possible to estimate the number of fishing operations, a gillnet of a known twine size could do in a life span, it was not possible for trammel net because of its non-existence in the artisanal fishery of Lake Kainji. Hence, estimation of the relative profitability index of the trammel net was based on the life span of a 76 mm gillnet which was even less than that of 178 mm gillnet. Trammel net recorded the highest index of 0.48 followed by 76 mm gillnet being 0.45 and 178 mm gillnet had the least of 0.07.

Table 11 Estimation of Relative Fishing Profitability Index (RPI) for the entangling nets

S/No	Measurable Parameters	3 Fleets 76mm Gillnet	3 Fleets 178mm Gillnet
1	Cost of Construction (Materials only)	₦10,500.00	₦11,000.00
2	Estimated Weight of Fish/Unit operation $\frac{\text{(Total Wt of Fish)}}{\text{No. of operations}}$	1.04 kg	0.1 kg
3	Projected number of Operations in a life span* (22 Operations/Month)	25 x 15 = 330	22 x 24 = 528
4	Estimated Cost of Fish/kg (Data from local market survey)	₦130.00	₦130.00
5	Projected earning in life span (Items 2 x 3 x 4)	₦44,616.00	₦6,864.00
6	Benefit Cost Ratio (C.B.R.) $\frac{\text{(Item 5)}}{\text{Item 1}}$	4.25	0.62
7	Relative Profitability Index [$RPI = \frac{CBR_i}{\sum CBR}$ $\sum_{i-h} CBR = 4.25 + 0.39 + 4.57 = 9.38$	0.45	0.07

** The projection was based on that of gillnets used for artisanal fishery. Trammel net usage was nil and the period of experimentation was too short to determine the life span of the trammel net.*

CHAPTER FIVE

DISCUSSION

The species caught with experimental nets (76mm gillnets, 178mm gillnets and trammel nets) were similar to those reported for the artisanal gillnet fishery in the same stratum of the lake (du Feu and Abiodun, 1999). The four dominant species (*C. citharus, O. niloticus, S. membranaceous* and *S. galilaeus*) also followed similar trend in which synodontids, cichlids and characids were reported to dominate the artisanal gillnet catches of the lake, though with slight variations in order of abundance. This variation could be assumed to be due to the multi-fleets nature of the gillnets used in artisanal fishery catch statistics of the lake. This multi-fleet gillnets comprised of mesh sizes that ranged from 1" (25.5mm) to 7" (178mm). The smaller mesh sizes (< 76mm) of the artisanal gillnets caught smaller species such as *Alestes, Schilbe* and other Cichlids (e.g. *Hemichromis spp.*) in abundant, but these were eliminated in the experimental entangling nets whose mesh sizes were from 76mm and above.

When comparing the CPUE of the experimental nets with that of the artisanal fisherfolks' Catch Assessments Survey (CAS) of the Lake between January 1995 to December 1998, (Abiodun and du Feu 1999), it was observed that the CPUE of the 76mm gillnets in the experiment was 3.23 while that of the CAS was 3.5 (mean).The difference could be said to be minimal when we considered the fact this experiment was conducted for a period of twelve (12) weeks while fisherfolks CAS was for 48 months. There was no exiting data from the Lake *that the trammelnets CPUE could be* compared with due to the absence of the net (trammelnets) in the artisanal fisheries of the Lake.

The small difference between the species diversity index of the species caught in 76 mm gillnet and the trammel net (0.69 and 0.82 respectively) showed that both nets had similar species selection properties. Generally, the catches of passive gears (entangling nets inclusive) had always been an indication of fish activities (particularly their movement within the fishing ground where the gears were stationary set (Acosta, 1994). The effectiveness of the gear to select a particular species had been found to be a product of two probabilities:

(i) That of encountering of the gear by fish

(ii) That of retaining of caught fish by the gear.

In this study where the population of fish was unknown, the net encountering rate could not be determined. It thus followed that the retention rate of the nets was the factor useful in estimating the catch characteristics of the two nets. Therefore, slight and insignificant difference ($P < 0.5$) in the type of species retained (caught) in the gillnets and trammel nets was an indication of the similarity of both nets in species selection characteristics. This result agreed with that of Acosta (1994), though he noticed a significant difference in the total number of individual species caught.

The significantly high catching rate and relative efficiency (CPUE = 7.2; 0.6 efficiency) of the trammel net in this study was also observed in similar studies reported in Madenjian and Ryan (1975), Petrakis and Stergiou (1996) and Losanes *et al* (1997). Several factors that can positively influence the probability of capture of trammel nets were highlighted in Nomura (1991). Most importantly among these factors was however further observed by Losanes *et al* (1997).

In a flume tank experiment they observed that some meshes of the lint net formed pockets to the amour net meshes. These pockets they deduced, was created by the extra – looseness of the vertical slack of the lint net. This was the basis for the high entangling capability of trammel nets generally. This observation was also manifested in this study in which 56.6% of the trammel net catch was by entangling.

It was found that there was significant variation in the mean weight of fish caught in each net type. The 76 mm gillnet which caught more fish than the 178 mm gillnet had a lower mean weight (176.9 g) than the 178 mm gillnet (478 g). This indicated the ability of the larger mesh size net to retain large size fish. Ita (1998) and du Feu and Abiodun (1999) showed a trend in which the larger the meshsize of gillnet, the bigger the size of fish caught. Since bigger fish of the same species could be assumed to attain a more matured stage, concentration of fishing effort on small mesh sizes of gillnets would result to stock depletion due to over-fishing. The banning of small mesh sizes for the Lake's gillnet fishery was therefore, justifiable. It must be emphasized that Lake Kainji fisheries being a multi-species, had over 100 different fish species whose sizes ranged from <400 mm to >2000 mm for *Sierrathrissa leonensis (*Clupeids) and *Lates niloticus* (Centropomidae) respectively (Ita, 1993). The use of 76 mm as the minimum recommended mesh size for gillnet fishery on the lake would therefore, result to several species left unexploited. Hence the need for a greater diversification of the fishing gears of the lake as suggested by Adimula and Fasakin (in press).

Contrary to von Brandt (1984)'s belief that entangling nets, particularly trammel and semi-trammel nets had very low selectivity or out rightly unselective, the master selectivity curves for the four most widely caught species in this study showed that the trammel nets were as selective as the gillnets. The net had distinct minimum selection length for the four species which were similar to that of the gillnets. However, the trammel nets were found to have a wider selection range than the gillnets. Since the minimum selection length of the trammel nets was similar to that of the gillnets, the under selection range exhibited was an index of larger fish sizes being caught.

A similar observation was made in Madenjian & Ryan (1975) and Petrakis and Stergiou (1996) which they attributed to high entanglement of large fish species resulting to a high median length.

The occurrence of a minor modal length in the trammel nets length frequency histogram for *O. niloticus* could mean that the lint part of the trammel nets also had its own catch characteristic that could be distinctive. On the other hand, the bimodal optimal length of the 76mm gillnet in may be attributed to two cohorts of *S. galilaeus* existing during the experimental period. This assumption could be said to be true when the 76 mm gillnet result was compared with that of the trammel net. The equal probability of capture shown in three consecutive classes mid-point of the net (165mm, 175mm and 185mm) could have been due to the trammel (lint effect of the net, which distributed the catches of the cohorts that encountered it within several class mid-points.

The master curves of trammel and semi trammel nets were reported to be bell-shaped and tend to be skewed to the right for most species of fish (Losanes *et al* 1992a; Fujimori *et al* 1996). The curves which were described as being asymmetrical were similar to that of gillnets in shape (that is bell or gaussian shape) but differed in the sense that gillnets curves tend to be skewed to the left. This result of this study also followed that pattern of same extent except for the master curves of O. *niloticus* in which both (gillnets and trammel nets) skewed to the left. The reasons of this observation could not be adequately ascertained presently. This was because of the numerous *inter-playing factors, which was known to affect the selectivity curves and* skew ness of entangling nets. Out of the factors listed in Petrakis and Stergiou (1996) which include shape of fish, visibility of net, swimming speed and direction of net encountering; only the shape of the fish could be related to the skewness of the master curves in this study. Losanes *et al* (1992a) reported that the skew ness of the master curve to the right for rainbow trout (*Oncorhynchus mykiss*) in entangling nets was due to a greater proportion of large size fish being caught. Likewise, the skewing to the right of the trammel net master curves for *O. niloticus* and *C. citharus* could be due to a high proportion of large size of those species being caught during the experimental period. Although the laterally-compressed shape and noticeable girth formation of the two species could be arguably said to aid wedging process, but ability of trammel nets to combine entanglement with other capturing process might have contributed immensely to the curves skewing to the right.

The gillnets and trammel nets master curves skewing to the left for *S. galilaeus* showed that more of these species were caught below the median length which suggested that some selectivity factors other than the shape of the fish might have inter-played during the capturing process.

The shape of *S. membranaceous* might be the contributory factor to the trammel nets master curve skewed to the left. The spiny appendages of the species made it susceptible to wedging and further entangling even at quite a small size. The master curve being skewed to the left with an extra wide selection range (width of the trammel net curve) suggested that several species of small and large size *S. membranaceous* were caught together in the trammel net. This same observation was equally made by Losanes *et al* (1992a) in which an extra-wide selection range was noticed in the master curve of spiny goby and this was attributed to spiny appendages, which caused the fish (both small and large) to be highly susceptible to entanglement.

Comparison of the methods in which the fish were captured (enmeshing, wedging and gilling) by the entangling nets showed that the 76mm and 178mm gillnets caught fish mostly by enmeshing (56.7% and 80% respectively). Three of the most targeted species (*O. niloticus, S. galilaeus* and *C. citharus*) which had laterally compressed bodies and with noticeable girth region were mostly enmeshed (65% enmeshing) by the gillnets. On the other hand, wedging was more pronounced in the mode of capture for S. membranaceous, which was characterized with spiny appendages. The shape of these species could be said to have contributed to the mode of their capture in gillnet.

This was also confirmed in YFJ (1994), which pointed out, that enmeshing mostly caught compressed fish while spindle shape fish were caught by wedging. The trammel net caught fish by entangling (56.6%) and enmeshing (32%) while wedging was not pronounced except for the spiny species as demonstrated y S. membranaceous. The susceptibility of S. membranaceous to trammel net as has been demonstrated by the ability of the net to catch the fish by enmeshing, wedging and entangling may be of concern to the management of the stock. The length range of S. membranaceous in the three capture modes which were the same (from 75 mm to 185 mm) showed that whatever size of the fish that came in contact with trammel net, the probability of it being captured in any of the three modes was high. The ability of the net to effectively utilize the three modes of capture over a wider selection range could make the net to be indiscriminate in its selection process.

The observed spoilage of 13.4% recorded within a 15 hr soak time was higher than that recorded in Acosta (1984) in which 8% spoilage was obtained in a 10 – 15 hr soak time. The higher percentage recorded in this experiment could be due to the temperature variation in the location of the two study areas. While Lake Kainji is in the Tropic, Acosta (1984) work was in the Temperate Region. It needs to be emphasized however, that the 13.4% spoilage within the soak time was not high enough to affect the market value of the product.

The projected earning from the three types of nets and subsequent relative Profitability Index (RPI) showed that trammel net had the highest 0.48. No literature was available for comparison with other people work.

However, the RPI for trammel net was comparatively high enough to compensate for extra cost expended on the trammel net.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

The catching efficiency of entangling nets that was experimented on in Lake Kainji revealed that trammel net was more efficient in catch ability than that of 76mm gillnet and 178mm gillnet pooled together. Due to lack of adequate catch data for the 178mm, meaningful further analysis for selection mode of capture and spoilage studies could not be achieved for the meshsize.

Although there was a significant difference in the catch rates of the net types within the short fishing trials, however it may still be unwise to conclusively say that the use of trammel net should be encouraged in Nigerian inland waters. Further investigation on the efficiency of the nets over a longer period (for at least 2 seasons) should be carried out.

Suggested areas for further investigations include meshsize variations of the lint and armour panels of the trammel nets, hanging ratio variation, vertical slack and possibly the side of attack of the net. Construction cost of a trammel net which has three panels of netting is expected to be higher than that of a semi-trammel net which has two panels of netting (one lint and one armour).There is need to investigate the catching rate of the two nets (two walled and three walled trammel nets) in order to justify the extra expenses incurred on the three walled trammel net. The soak time is another area that deserved further work.

The investigation should be on the optimum soaking time for the highest catch, net saturation and rate of spoilage.

When all these information are known through further investigations, it will then be appropriate to recommend the use of trammel net or semi-trammel nets in Nigerian inland waters. One thing that was very certain was that trammel nets and gillnets almost had the same selection in terms of minimum length selection range, species selection and shape of the master curves.

The mode and width of trammel nets curves was higher and wider than that of gillnet due to the ability of the former to entangle larger fish species than the latter. That had been confirmed from different experiments including the one reported here.

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APPENDIX I: ISSCFG Category for Entangling Nets
(Extract from Nedelec, 1990)

Category/Name of Gear	Std. Abbreviation	ISSCFG No.
Entangling Nets		07. 0.0
(a) Set gillnets (Anchor)	GNS	07. 1.0
(b) Drift nets	GND	07. 2.0
(c) Encircling gillnets	GNL	07. 3.0
(d) Fixed gillnets (on stakes)	GNF	07. 4.0
(e) Trammel nets	GTR	07. 5.0
(f) Combined gill & trammel	GTN	07. 6.0
(g) Entangling net not specified	GEM	07. 7.0

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(d) Fixed gillnets (on stakes)	GNF	07. 4.0
(e) Trammel nets	GTR	07. 5.0
(f) Combined gill & trammel	GTN	07. 6.0
(g) Entangling net not specified	GEM	07. 7.0

Apendix 2 Mode of capture of entangling net based on body shape of fish (shaded area = is caught, blank area = is not caught).

Body shape / Ways the fish are caught	 Basic shape	 Sprindle shape	 Compressed shape
enmeshing			
wedging			
entangling			
Sample Species	Salmom, herring, sardine, Alestes, Lates, Labeo	Tuna, skipjack, billfishes, shark, Tilapia, Synodontis	Red sea bream, Citharinus, Distichodus

Body shape / Ways the fish are caught	 Depressed shape	 Elongated shape	 Crustaceans
enmeshing			
wedging			
entangling			
Sample species	flatfish, sole, lizard fish, Chrysichthys	Gymnarchus scabbard fish, sea eel, Clarias, clarotes	Spiny lobster, Gazami crab, crabs, kuruma prawn, mantis crab, etc.

Source: YFJ (1994)

APPENDIX 3: Models for Estimating Some Parameters in Table 1

*1. $$\text{E Value} = \frac{\text{Length of head rope}}{\text{Stretched length of netting}}$$

$$\text{or } \frac{\text{Length of head rope}}{\text{Mesh size x No. of meshes on head rope}}$$

*2. Number of meshes in the length of net after hanging

$$= \frac{\text{Length of net}}{\text{Mesh size x Co-efficient of horizontal shortening}}$$

*3. Number of meshes in the depth of net after hanging

$$= \frac{\text{Depth of net}}{\text{Mesh size x Co-efficient of vertical lift}}$$

*4. $$\text{Vertical slack} = \frac{\text{Depth of lint net}}{\text{Depth of Armour net}}$$

*5. Buoyancy of float = Weight of float – volume of float
or Wt. Of float (I – I/Specific gravity)

*6. Sinking power of lead = Volume of lead – Wt.
or Wt. (I/specific gravity – I).

Appendix 4: Estimated Horizontal and Vertical Lift Co-efficient of Net Hung at Varying Hanging Ratio *(After Gardner, 1986)*

Hanging Ratio E-Value	Hang-in S-Value	Horizontal Co-efficient (I – S)	Vertical Lift Co-eff. ($2S - S^2$)
1.0	0.0	1.0	0
.95	.05	0.95	0.31
.90	.10	0.90	0.44
.85	.15	0.85	0.53
.80	.20	0.80	0.60
.75	.25	0.75	0.66
.70	.30	0.70	0.71
.65	.35	0.65	0.76
.60	.40	0.60	0.80
.55	.45	0.55	0.84
.50	.50	0.50	0.87
.45	.55	0.45	0.89
.40	.60	0.40	0.92
.35	.65	0.35	0.94
.30	.70	0.30	0.95
.25	.75	0.25	0.97
.20	.80	0.20	0.98
.15	.85	0.15	0.99
.10	.90	0.10	0.995
.05	.95	0.05	0.999
.0	1.00	0.00	1.0

Appendix 5:

The Federal University of Technology, Akure

Department of Fisheries and Wildlife

Comparative Studies on Entangling Nets in Lake Kainji
Nets Recovery Form

Station:____________________ Date ____________________

Net ____________________ Mesh Size ____________________

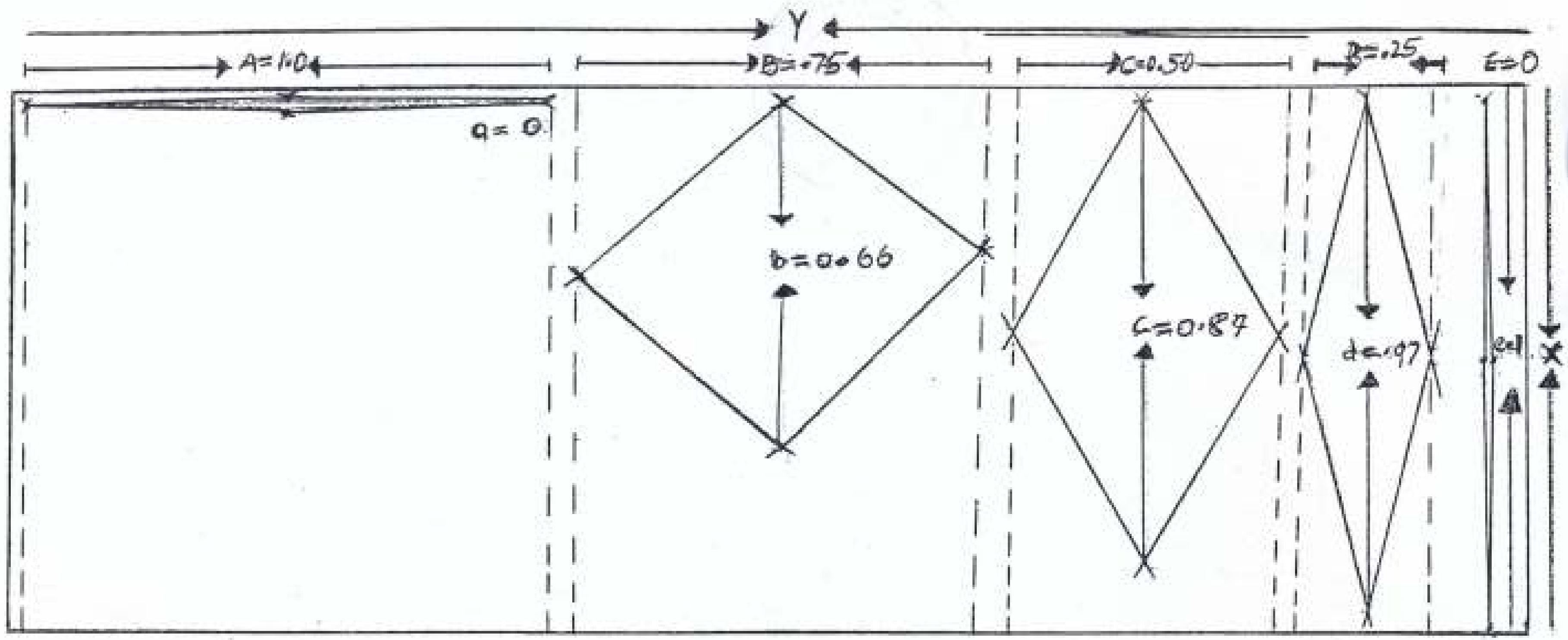
Setting Time ____________________ Hauling Time ____________________

S/No	Name of Fish	SL (mm)	Wt (gm)	Girth Length	Mode of Capture	State of Fish

Appendix 6: Estimation of Probability of Capture P(L) For Master Selectivity Curves

	O. niloticus		*S. galilaeus*		*C. citharus*		*S. membranaceus*	
Mid point	GN	TR	GN	TR	GN	TR	GN	TR
65							0	0
75							0.32	0.28
85							0.48	0.38
95							0.66	0.49
105							0.83	0.61
115	0	0.32	0.36	0			0.96	0.73
125	0.34	0.48	0.59	0.33			1.0	0.84
135	0.55	0.67	0.83	0.51			0.96	0.93
145	0.77	0.83	0.98	0.71	0	0	0.83	0.98
155	0.94	0.96	0.98	0.89	0.33	0.31	0.66	1.0
165	1.0	1.00	0.83	0.99	0.51	0.44	0.48	0.98
175	0.94	0.96	0.59	0.99	0.71	0.59	0.32	0.93
185	0.77	0.83	0.36	0.89	0.89	0.74	0	0.84
195	0.55	0.67	0	0.71	0.99	0.88		0.73
205	0.34	0.48		0.51	0.99	0.97		0.61
215	0	0.32		0.33	0.89	1.0		0.49
225		0		0	0.71	0.97		0.38
235					0.51	0.88		0.28
245					0.33	0.74		0
255					0	0.59		
265						0.44		
275						0.31		
285						0		
295								
SD	27.39	33.17	24.5	30.28	30.28	38.94	33.17	50.5
L_2	165	175	160	170	200	215	125	155

Appendix 7. Diagramatic representation of horizontal shortening and vertical lift of net mesh when hung at varying hanging ratio



Y = Horizontal length of mesh when hung at E   X = vertical lift co-efficient

A = 100% stretched length (E = 1.0)   a = 0

B = 75% stretched length (E = 0.75)   b = 0.66

C = 50% stretched length (E = 0.50)   c = 0.87

D = 25% stretched length (E = 0.25)   d = 0.97

E = 0% stretched length (E = 0)   e = 1.0