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THE FACTORS AFFECTING FISHING EFFORT AND THEIR EFFECTS ON FISH CATCHES AT SELECTED LANDINGS ON LAKE VICTORIA

BY

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DECLARATION

I, MUHOOZI LEVI IVOR declare that this dissertation is my original work and has not been submitted for a degree in any other University.

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DEDICATION

This work is dedicated to my parents Gertrude and Eryezari Kayebire who sacrificed the little resources they had to enable me go through school. I recount the difficult times they went through to raise my school fees and respect their overwhelming support, encouragement and vision.

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LIST OF ABBREVIATIONS

ANOVA	=	Analysis of Variance
95%CL	=	95% Confidence Limits of the mean
CPUE	=	Catch Per Unit of Effort
EAFFRO	=	East Africa Fresh water Fisheries Research Organisation now Fisheries Research Institute (FIRI)
FAO	=	Food and Agricultural Organisation of the United Nations
TL	=	Total length
UNDP	=	United Nations Development Programme

ABSTRACT

In a fishery, the fish catch is partly determined by the type, number and size of fishing gear, the manpower on the fishing vessel and the fishing ground. In the Lake Victoria gill net fishery these fish catch attributes are dependent on the size and mode of propulsion of the fishing boat and the mode of operation of the gill nets. This study, conducted at six fish landing sites: Masese, Lingira, Bugonga, Kasenyi, Lambu and Kasensero on the Uganda sector of Lake Victoria, investigated how the size of fishing boats, mode of propulsion of fishing boats (motorised or manual), mode of operation of gill nets (active or passive) were related to the number of gill nets, number of boat crew, fishing grounds, the quantity and species composition of the fish catch and hence the income to the fishers.

There was significant increase in the overall mean number of gill nets per boats with increase in boats size (ANOVA test, $F_{6,499} = 124.1782$, $P<0.05$) from 20.9 $\pm$ 2.3 nets in 5.0-5.9 m long boats to 88.6 $\pm$ 11.8 nets in 11.0-11.9 m long boats. Bigger boats required more crew such that the number of crew increased with increase in boat size, from an average of 2 men in boats <8.0m to 3 men in large boats. The proportion of large gill net mesh sizes >127 mm (5 inch) also increased with increase in boat size from 40.4% in 5.0 - 5.9 m long boats to 100% in boats >10.0 m long. The majority of large boats $\geq$8.0 m long were motorised and fished in far offshore waters targeting Nile perch whereas nearly all boats <8.0 m long were manually powered and fished in inshore waters targeting both Nile perch and Nile tilapia. Boats operating gill nets actively fished very close to the shoreline targeting Nile tilapia. Nile perch contributed 97.7-100% of the catch in boats $\geq$8 m long whereas Nile tilapia and other fish species contributed 31.0- 59.9% in boats <8 m long. 73.6-89.0% of Nile perch caught by boats <8.0 m long were $\leq$50 cm TL whereas <17% of Nile perch in larger boats were $\leq$50 cm TL. The overall

mean fish catch rates increased significantly with increase in boat size (ANOVA test, $F_{6,513} = 15.0367$, $P<0.05$) from 12.6 $\pm$ 1.9 kg in 5.0-5.9 m long boats to 78.2 $\pm$ 16.4 kg in 11.0-11.9 m long boats. Actively fishing boats at Masese and Lingira carried about half the number of nets carried by passively fishing boats but there were no significant differences in the average mean total weights of fish landed by both categories of boats (ANOVA test $F_{1,181} = 3.8999$, $P<0.05$). Thus, active operation of the gill nets raised the catch rate per net twofold from 0.43 $\pm$ 0.11 kg in passively fishing boats to 0.96 $\pm$ 0.15 kg in actively fishing boats.

These observations indicate that full exploitation of the *L. niloticus* fishery of Lake Victoria up to offshore waters would require promotion of use of large motorised boats that use large numbers of large mesh sized nets and land desirable sizes of fish and putting restrictions on number of boats and/or mesh size of gill nets of manually powered boats that operate in inshore waters and land mainly immature fish. The management of the *O. niloticus* fishery should focus on discouraging the active operation of gill nets, reducing the number of boats operating in inshore waters and preventing further reduction of gill net mesh sizes.

CHAPTER ONE

BACKGROUND

Historical changes in the distribution of fishing effort on Lake Victoria and its effects on fish catch rates and catch composition.

The distribution of fishing effort in any fishery is influenced by the fish species composition; the population structure (size composition) of the fish available for harvesting; the morphometry and hydrological conditions of the lake; the facilities (e.g. boats and nets) that can be used in harvesting the fish stocks; the demand for fish imposed and the efficiency of the marketing structure. In turn, this distribution of fishing effort will affect composition and population structure of fish in the lake. Information on these factors is therefore required to guide exploitation and management decisions. The following text is a review of how these factors have influenced fishing effort in Lake Victoria since the beginning of the present century and how this affected the composition of fish species in the lake.

1.1 Description of Lake Victoria

Lake Victoria is the second largest lake in the world and is the largest fresh water body in the tropics lying across the equator (0°21'N - 3°0'S, 31°39' - 34°53'E) at an altitude of 1116 m above sea level. It is shared between Tanzania (51%), Uganda (43%) and Kenya (6%). Its greatest length and breadth are 400 and 320 km respectively; surface area is 68680 km^2; mean depth is 40 m and the deepest zone is 60-79 m. The lake's shoreline is extremely irregular and totals some 3300 km in length. There are a number of large islands (3.7% of the Lakes area), especially in the northern half, whose shorelines are as varied as those of the

mainland are. It has large expanses of open water, which during rough weather can be difficult to navigate especially by small boats.

1.2 The original fishery of Lake Victoria

At the beginning of the 20th Century the fish fauna of Lake Victoria was dominated by two indigenous tilapiine species *Oreochromis variabilis* Boulenger, 1906 and *Oreochromis esculentus* Graham, 1929 and about 300 species of haplochromines (Oijen et. al. 1981). There were only about 50 non-cichlid fish species in the lake (Lowe-McConnel, 1975).

The native fishery depended on few predominantly near-shore fish taxa. *O. esculentus* was the most important commercial species followed by *O. variabilis* (Graham 1929, Jackson 1971, Mann 1969, Ogutu-Ohwayo 1990a). Other important species included *Protopterus aethiopicus* Heckel, 1851 *Bagrus docmac* Forsskall, 1775 *Clarias gariepinus* Burchell, 1822 *Barbus* sp mormyrids and *Schilbe intermedius* Linnaeus, 1758. *Labeo victorianus* Boulenger, 1901 formed the most important commercial species in the affluent rivers of the lake's basin (Candwalladr, 1969). Haplochromine cichlids and *Rastrineobola argentea* Pellegrin, 1904 were abundant but because of their small size and low market value were not originally exploited on a large scale.

The major commercial species, the tilapiines, were abundant only in sheltered inshore waters of depth less than 18 m and a distance of about one kilometre from the shoreline whereas other cichlid and non-cichlid fish had a wider distribution (Graham 1929). These waters were easily accessible to traditional fishermen who used small fishing boats that varied from simple rafts to canoes of reed bundles and dugout canoes all propelled by hand and using simple locally made fishing gears that consisted of hooks and lines, harpoons and lances, non-return traps

basket traps and seines made of papyrus. Under conditions of a virgin fishery, excellent catches of fish were obtained which satisfied the geographically limited market of the subsistence requirements of people living near the lake. Fishing for mainly tilapiines was thus limited to inshore waters. Near-shore areas are also breeding grounds and fishing in these areas can be detrimental to the fishery.

The trend of the fishery over 1900 - 1970s was of increasing fishing intensity, expansion to more offshore waters and decreasing fish catch rates. Fishing started to intensify with the introduction of efficient cotton flux gill nets in 1905 (Worthington & Worthington 1933); improved communication like extension of the railway line to Kisumu in 1908 which facilitated the importation of modern fishing gear and supply of fish products to distant markets; the increased demand of fish due to development of urban centres and increasing human population around the lake (Graham 1929, Jackson 1971, Ogutu-Ohwayo 1990a).

The initial catch rates in 127 mm mesh size gill nets of about 45 m length ranged between 50 and 100 tilapia (*O. esculentus*) per net per night but by 1968, the catch rates had declined to 0.35 tilapia per net (Jackson 1971). The decline in fish catch rates prompted the first fisheries survey of Lake Victoria in 1927 (Graham 1929) after which a minimum gill net mesh size of 127 mm was recommended and imposed in 1931. By 1955, catch rates had fallen to such an extent that it became unprofitable to use 127 mm mesh size nets and some fishermen began using smaller meshes to catch un-exploited length ranges. From this time onwards the fishermen adopted the habit of shifting to smaller meshes whenever the catches in the larger meshes decreased. This made the 127 mm mesh regulation so difficult to enforce that it was repealed in Uganda and Tanzania in 1956 and in Kenya in 1961 (Jackson 1971). The removal of mesh size limit resulted in lack of uniform management policy for the whole lake. The subsequent trend of uncontrolled fishing effort and the continuously declining gill net mesh size led to the collapse

of the native tilapia fishery. During the 1950s the fishing pressure was further increased when synthetic fibre gill nets with a greater fish catching efficiency and a longer life span than the cotton flux gill nets were introduced in 1951 and communication on the lake were further improved with the introduction of the outboard engine in 1953 (Mann 1969).

1.3 A shift to smaller species fishery

While the catch rates of the larger species declined there was a gradual shift to the smaller, originally less preferred fish species particularly the Haplochromine cichlids and *R. argentea*. The need for changes in fishing strategy so that the harvest would quantitatively and qualitatively represent available stocks prompted the UNDP/FAO and EAFFRO lake-wide fish stock assessment survey of Lake Victoria 1969 to 1971. This survey showed that although many fish species were confined to the shallow inshore waters, there were considerable quantities of fish all over the lake and at all depths. The survey showed that 83 % of the demersal ichthyomass in the lake consisted of haplochromine cichlids with a potential yield of 200,000 metric tons which could be obtained from the relatively lightly fished deep water areas (depth > 20 m) and anticipated even higher yields because haplochromines whose catches had remained relatively low due to selective properties of the commercial fishing gears and the limitation of fishing to inshore waters which had deviated the commercial catches from the available biomass (Kudhongania & Cordone, 1974). Fishery yield from the lake could therefore be improved by developing appropriate technologies to fish over the entire lake.

In 1973 a small industrial trawl fishery was started in the Mwanza area of Lake Victoria using small trawlers (10 - 15 m long; 80-170 HP) and trawl nets with a 19 mm mesh size cod end (Witte & Oijen 1990). During the second half of the 1970s haplochromines were also increasingly becoming the target of artisanal fishermen

mainly using gill nets of mesh size 38 - 51 mm (Scalley 1975). Beach seines of 19 - 25 mm mesh size cod end and mosquito seines of 8 - 13 mm mesh size cod end were also in use especially in the Kavirondo gulf (Marten 1979). However, before the mechanisms of exploiting the haplochromine based fishery were fully developed rapid changes started to occur in the fishery due to impacts of an introduced predator, Nile perch.

1.4 Fish introductions

To enhance the fish production of Lake Victoria which had declined due to overfishing of the native fish stocks, four exotic tilapiine species, *Oreochromis niloticus* Linnaeus, 1758, *Oreochromis leucostictus* Trewavas, 1933, *Tilapia zilli* Gervais, 1848, and *Tilapia melanopleura,* Dumeril, 1959 were introduced into the lake in the early 1950s and the Nile perch, *Lates niloticus* Linnaeus, 1758 in the early 1960s (Kudhongania & Kitamwebwa 1995, Ogutu-Ohwayo 1990a). Since these introductions *O. niloticus* and *L. niloticus* have established themselves to the extent that they now dominate the fisheries of Lake Victoria. As a result of the Nile perch upsurge since the early 1980s, haplochromines have almost completely vanished in the sub-littoral and deep-water regions of the lake (HEST 1988, Ogutu-Ohwayo 1990a). The only native fish species that have remained abundant are *R. argentea* and only one haplochromine taxa, *Yssichromis* sp. in offshore waters. The tilapiine species, which were originally important, have virtually disappeared and the haplochromines that until 1970s dominated the fish fauna of the lake in both biomass and number of species are virtually absent from some parts of the lake (Ogutu-Ohwayo 1990a).

1.5 The new fishery of Lake Victoria.

The upsurge of the introduced fish species especially Nile perch has coincided with a phenomenal increase in total annual fish yield. For the Uganda sector of the lake, fish catches increased from 42,000 tons in 1970 to 120,000 tons in 1990 (Kudhongania & Kitamwebwa 1995), fishing effort increased from 3,200 fishing canoes in 1972 to 8000 canoes by 1990 (Okaronon 1994, Tumwebaze & Coenen 1991). The increase in exploitable fish stocks arising out of establishment of Nile perch has attracted major investments in the fishing industry transforming the fish markets from mainly local to broad sections of the East African region and overseas markets. Large scale commercial and overseas fish export ventures have been established around the lake in Uganda, Kenya and Tanzania (Reynolds et. al. 1995). The rapid expansion of the fish filleting capacity around the lake has increased significantly export earnings to the extent that in 1996/97 financial year fish exports were next to coffee in overall national exports in Uganda fetching US$ 41.37 million (Ministry of Planning and Economic Development, 1997).

The fishery of the Uganda sector of the lake is already showing symptoms of decline in annual yield from 132,000 tons in 1989 to 120,000 tons in 1991 and 103,000 tons in 1994 despite the increasing fishing effort (Okaronon 1994). Basing on the biology of *L. niloticus*, *O. niloticus* and *R. argentea* (Balirwa 1989, Fryer & Iles 1972, Ogutu-Ohwayo 1988, Wandera 1989) exploitation would be the main process to influence sustainability of increased catch levels of the three major commercial fish species in the future fishery of the lake. The lake continues to have unlimited entry for the number of fishermen and fishing gears and there is gradual expansion of the fishing industry fuelled by establishment of fish factories which can lead to over-fishing and collapse of the new fishery if there is no guidance of fishing effort.

The current fishing gears on the lake include gill nets, beach seines, cast nets, all with uncontrolled mesh sizes, and for *R. argentea* mosquito seine nets with similar lack of restriction although when the exotic species became established, most fishermen had switched to larger mesh size gill nets to catch *L. niloticus* and *O. niloticus* which grow to larger size than the native tilapiine species (Ogutu-Ohwayo 1990b). Fishing which was traditionally carried out almost exclusively in the waters near the shores using artisanal techniques is now spreading more offshore with fishermen targeting large Nile perch preferred by the fish processing industries (Orach-Meza 1992, Pitcher and Bundy 1994).

The changes in the fish community of Lake Victoria brought about by over-fishing and introduced fish species especially the Nile perch have resulted in the existing fishery where the native tilapiines (*O. esculentus* and O. *variabilis*) and the haplochromine cichlids have lost their commercial importance. Fishermen now concentrate more on Nile perch (*L. niloticus*), Nile tilapia (*O. niloticus*) and *R. argentea*.

1.6 Study Objectives

To contribute to the overall fishery objective of increased and sustainable fish production by generating information needed for regulating fishing effort on Lake Victoria; by determining the contribution of: -

(a) the size of fishing boats,

(b) the power of fishing boat (motorised or manual), and

(c) the mode of fishing (Active or passive)

to fishing effort in the gill net fishery of Lake Victoria.

The contributions of these factors to fishing effort were estimated by determining:

1. The quantities and mesh sizes of gill nets carried by fishing boats: -

   (a) of different sizes,

(b) motorised or manually powered,

(c) doing active or passive fishing.

2. The number of boat crew of fishing boats: -

(a) of different sizes,

(b) motorised or manually powered,

(c) doing active or passive fishing.

3. The fishing grounds of fishing boats: -

(a) of different sizes,

(b) motorised or manually powered,

(c) doing active or passive fishing.

4. The types, quantities and sizes of fish caught by fishing boats:-

(a) of different sizes,

(b) motorised or manually powered,

(c) doing active or passive fishing.

Hypotheses

1. There is no difference in the quantities and mesh size composition of gill net fleets carried by fishing boats: -

(a) of different sizes,

(b) motorised or manually powered,

(c) doing active or passive fishing.

2. There is no difference in the number of boat crew of fishing boats: -

(a) of different sizes,

(b) motorised or manually,

(c) doing active or passive fishing.

3. There is no difference in the fishing grounds of fishing boats: -

(a) of different sizes,

(b) motorised or manually powered,

(c) doing active or passive fishing.

4. There is no difference in the quantities, types and sizes of fish landed by fishing boats:-

(a) of different sizes,

(b) motorised or manually powered,

(b) doing active or passive fishing.

CHAPTER TWO

STUDY AREA, MATERIALS AND METHODS

2.1 Study Area

The study was conducted on six selected fish landing sites on Lake Victoria (Fig. 1). They represented the eastern, central and western parts on the Uganda sector of the lake. Two landings were selected in each part of the lake: Masese and Lingira in the eastern part; Kasenyi and Bugonga in the central part; and Kasensero and Lambu in the western part.

2.2 Description of the landings

(a) Lingira

This landing is located on an island and access is by water. It takes about 1 hour by motorised public transport boat from Jinja to Lingira. There is a large settlement for mainly the fishing community at the landing. The majority of fishing boats operating at the landing are involved in the *Rastrineobola* fishery and others in the gill net fishery for tilapiines and Nile perch.

(b) Masese

The landing is located on the mainland in Jinja Municipality. It is a major fish outlet to Jinja and other areas. It is in a town setting thus the fishing community is not resident at the landing. Fishing activities at the landing are dominated by gill netting.

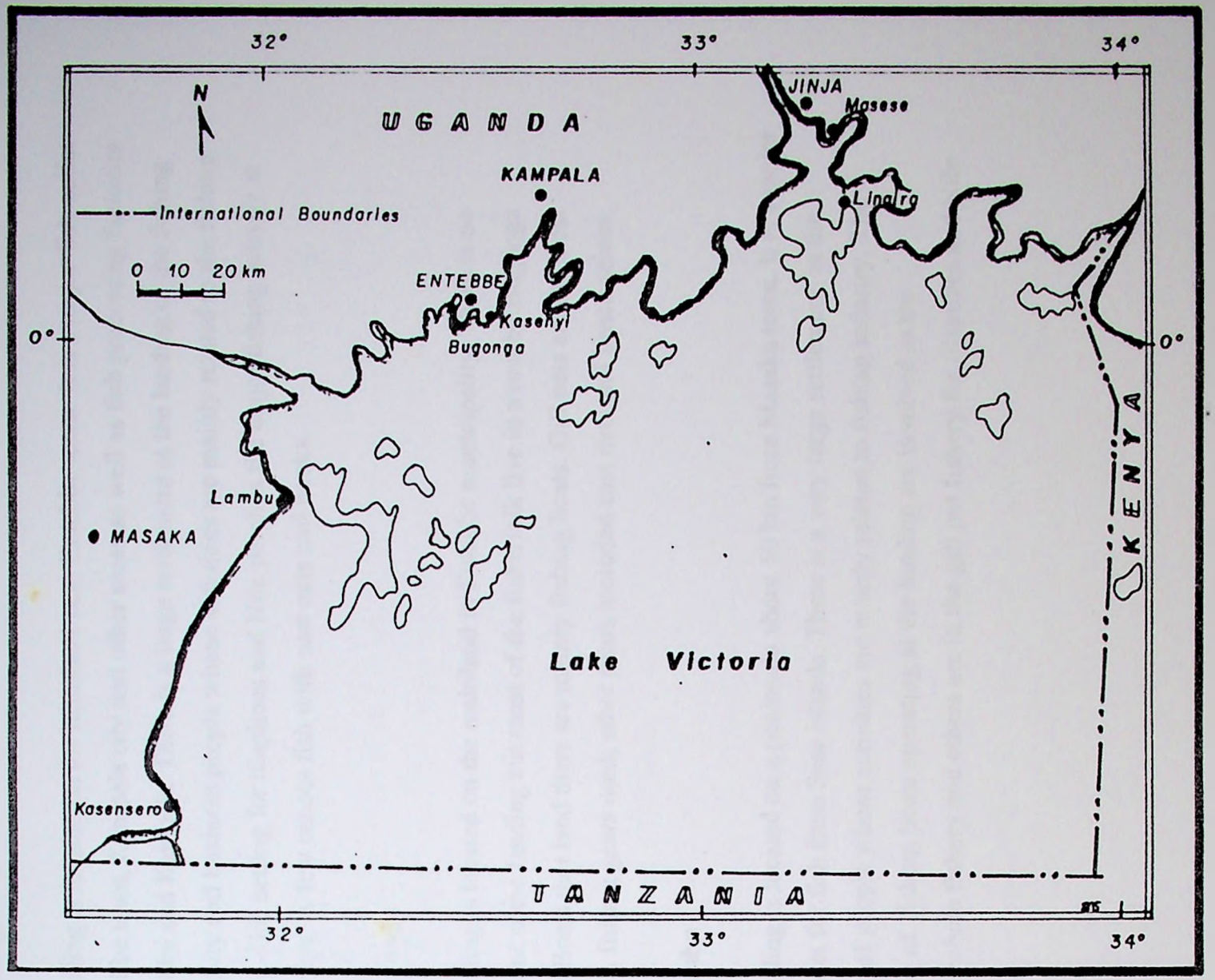


Fig. 1 Map of the northern portion of Lake Victoria showing the landings sampled.

(c) Kasenyi

The landing is located on the mainland near Entebbe town. It is a major fish outlet to Entebbe town, Kampala city and other areas as well as fish processing factories in Entebbe and Kampala. There is a large settlement at the landing of the fishing community and business people whose activities are mainly related to the fishing industry. Gill netting for tilapiines and Nile perch is the major fishing activity at the landing. A few canoes fish with cast nets and hooks.

(d) Bugonga

The landing is located on the mainland in Entebbe municipality. There is no settlement at the landing but most of the fisherfolk live in a nearby Bugonga village. Boats that land there are mainly fishing boats. Gill nets are the most common fishing gears used; other gears included cast nets and beach seines.

(e) Lambu

The landing is located on a peninsula about 50 km from Masaka town. It is a major fish outlet for fish from Sese islands. There is a very large settlement at the landing of people whose activities are mainly related to fishing industry. The majority of fishing boats operating at the landing are involved in the *Rastrineobola* fishery and others are in the gill net fishery for tilapiines and Nile perch.

Kasensero

e landing is located on the mainland about 2 km from the Tanzania/Uganda
rder. There is a large settlement at the landing of people whose activities are
inly related to the fishing industry. All the fish landed is from fishing boats.

Sample size

npling was on eight different days at each landing site between November 1996
l August 1997 covering 519 boat days: 46 boat days at Lambu, 95 boat days at
gonga, 87 boat days at Kasenyi, 105 boat days at Kasensero, 114 boat days at
sese and 72 boat days at Lingira (1 boat day = a sample unit of one fishing boat
ne day).

Materials and Methods

e basic sample unit was a fishing boat fishing with gill nets. There was a
dency of most fishing boats arriving at the landing beach in a short spell of time
l the fishers rushing to sell off their catch. Therefore, on every visit to each of
six landings, as many boats as time would allow were sampled randomly in the
er of their arrival at the landing beach at dawn without identifying those that
e sampled on the previous visit. Thus some boats may have been sampled on
eral visits whereas others may not have been sampled at all. For every boat
npled on each visit the following records were taken:

- The number of boat crew just before the boat landed.
- The Horse power of the engine for motorised boats.
- The fishing ground inshore or offshore by asking the boat's crew where they fished and the approximate distance from the shoreline. In cases where there

was clear view of where the boat set its nets the record was taken without asking the crew. Fishing grounds were categorised into two, inshore and offshore, according to the relative distance of the fishing grounds from the shoreline. Boats that set their nets in waters clearly viewed from the shoreline and returned to the landing after setting were considered to be fishing inshore while those that fished in waters far away from the landing site, stayed there overnight and returned at dawn were considered fishing offshore.

(d) The length of the boat measured to the nearest 0.1 m from the front tip to the rear end of the boat using a 15 m long rope marked at 0.1 m intervals.

(e) The stretched mesh size of gill nets in the boat's net fleet measured using a millimetre rule.

(f) The number of gill nets of each mesh size by physically counting the nets or asking the boat crew where it was not possible to count them.

Fish catches

(g) The number of fish of each species.

(h) The total weight of each fish species measured to the nearest 0.1 kg using a 50 kg Salter spring balance.

(i) The total length of individual fish measured to the nearest centimetre from the anterior extremity to the end of the tail fin using a measuring board with an anterior extremity of the fish put against a stop at the beginning of the measuring scale. Where it was not possible to measure the length of all fish in the boat, the catch was mixed and a sample of about 20 fish removed for length measurement.

5 Data analysis

5.1 The size of fishing boat

) In estimating the mean number of gill nets carried by boats of different sizes, fishing boats were grouped into 7 length ranges at 1 m interval. The mean number of gill nets per boat of each size range at the six landings and the overall mean number of gill nets per boat for all landings pooled were calculated. The 95% Confidence Limits (CL) of the mean were determined as follows:

$$95\%CL = (s/\sqrt{n}) \cdot t$$

here: $s/\sqrt{n} = S.E$

S.E = Standard error of the mean

s = standard deviation

n = number of observations

$t = t_{score}$ ($P<0.05$, two tailed test) at (n-1) df. (Fowler & Cohen, 1990)

One way ANOVA test for differences in means was carried out on log10 overall gill net counts. The gill net counts per boat were transformed to log10 before carrying out ANOVA when F_{max}-test ($F_{7,32} = 7.094$, $P<0.05$) showed that the variances of the mean gill net counts were not homogeneous in boats of different sizes. The F_{max}-test is a test for the homogeneity of variance where:

$$F_{max} = \frac{\text{largest sample variance}}{\text{smallest sample variance}}$$ (Fowler & Cohen, 1990)

(b) In the estimation of the mesh size composition of gill nets carried by boats of different sizes, the frequencies of the number of gill nets of different mesh sizes were tallied for fishing boats of different size ranges at the six landings pooled and percentage contribution by number of each gill net mesh size calculated.

(c) In the estimation of the number of crew in boats of different sizes, the frequencies of boats of each size range were tallied against boat crew number for

all boats at the six landings pooled. The percentages by number of boats of each size range with each number of crew were then calculated.

(d) In determining the percentages of boats of different sizes that fished inshore or offshore the frequencies of boats of each size range were tallied against the fishing ground, inshore or offshore for all the landings pooled. The percentages by number of boats of each size range that fished inshore and offshore were then calculated.

(e) In estimating the fish catches of boats of different sizes, the mean total weight of fish per boat (all species pooled) for each boat size range at each of the six landings and the overall mean total weight per boat for all landings pooled was calculated. The 95% Confidence limits of the mean were calculated as in 2.5.1 (a). One way ANOVA test for differences in means was carried out on log10 overall total fish weights in boats. The fish total weight per boat values were transformed to log10 before carrying out ANOVA when the F_{max}-test ($F_{7,32} = 23.761$, $P<0.05$) showed that their variances were not homogeneous.

(f) In estimation of the fish species composition of the catch of boats of different sizes, the overall mean total weight of *L. niloticus*, *O. niloticus* and other fish species pooled was determined for each of the 7 boat size ranges for all the six landings pooled. The percentage mean weight contribution of each fish species to the total catch of boats of different sizes was calculated.

(g) In the estimation of the sizes of fish landed by boats of different sizes, frequencies of total lengths for *L. niloticus* and *O. niloticus* landed by boats of different sizes were determined by tallying length of individual fish for each of the 7 boat size ranges at all the six landings pooled. The total lengths of fish were grouped in 5 cm classes and the number of fish in each length class used to

calculate the percentage contribution of the size group to the total number of fish landed by each boat size.

2.5.2 The mode of propulsion of boat

(a) In estimating the number of gill nets carried by motorised and manually powered boats, the mean number of gill nets per boat for motorised and manually powered fishing boats at Lambu, Bugonga and Kasenyi where both categories of boats operated was calculated and 95% Confidence limits of the mean determined as in 2.5.1(a) One way ANOVA test for differences in means was carried out on log10 gill net counts. The gill net counts per boat were transformed to log10 before carrying out ANOVA when F_{max}-test ($F_{2,82} = 3.210$, $P<0.05$) showed that the variances of the mean gill net counts were not homogeneous in motorised and manually powered boats.

(b) In estimating the number of crew of motorised and manually powered boats, frequencies of motorised and manually powered boats were tallied against boat crew number for all the six landings pooled. The percentages by number of boats with each number of crew were then calculated.

(c) In determining the fishing grounds of motorised and manually powered boats, frequencies of motorised and manually powered boats were tallied against the fishing ground, inshore or offshore for all the six landings pooled. The percentages by number of motorised and manually powered boats that fished inshore and offshore were then calculated.

(d) In estimation the fish catches of motorised and manually powered boats, the mean total weight of *L. niloticus*, *O. niloticus*, other fish species pooled and for all fish species combined was calculated for motorised and manually powered boats

at Lambu, Bugonga and Kasenyi. The 95% Confidence limits of the mean were determined as in 2.5.1(a). One way ANOVA test for differences in means was carried out on log10 overall total fish weights in boats. The weights of fish per boat values were transformed to log10 before ANOVA when the F_{max}-test ($F_{2,82}$ = 3.211, $P<0.05$) showed that the variances of the gill net counts were not homogeneous in motorised and manually powered boats.

2.5.3 The mode of operation of gill nets

(a) In estimating the number of gill nets carried by actively and passively fishing boats, the mean number of gill nets per boat for actively and passively fishing boats at Masese and Lingira where both modes of operation of gill nets were common was calculated. The 95% Confidence limits of the mean were determined as in 2.5.1(a). One way ANOVA test for differences in means was carried out on transformed (log10) gill net counts. The gill net counts were transformed to log10 when the F_{max}-test ($F_{2,40}$ = 4.885, $P<0.05$) showed that the variances of the gill net counts were not homogeneous in active and passive boats.

(b) In estimating the number of crew of boats fishing actively and passively, frequencies of boats fishing actively and passively were tallied against boat crew number for all landings except Kasensero. Only manually powered boats were considered at the five landings and Kasensero was left out because all boats sampled there were motorised. The percentages by number of boats with each number of crew were then calculated.

(d) In estimating the fish catches of actively and passively fishing boats, the mean total weight of *L. niloticus*, *O. niloticus*, other fish species pooled and overall for all fish species together was calculated for actively and passively fishing boats at Masese and Lingira where both modes of operation of gill nets

were common. The 95% Confidence limits of the mean were determined as in 2.5.1(a). One way ANOVA test for differences in means was carried out on overall total fish weights landed by actively and passively fishing boats. Variances of mean total fish weights were found to be homogeneous (F_{max}-test: $F_{2,40} = 1.008$, $P<0.05$).

The overall mean weight of fish caught per net per night was also calculated for actively and passively fishing boats at Masese and Lingira. The 95% Confidence limits of the mean were determined as in 2.5.1(a). Differences between the mean fish catch rates of gill nets of actively and passively fishing boats were tested by One way ANOVA on log10 weights of fish caught per net per night. The values of gill net fish catch rates were transformed to log10 before ANOVA test when the F_{max}-test ($F_{2,40} = 6.164$, $P<0.05$) showed that the variances of the mean weights of fish caught per net per night were not homogeneous.

CHAPTER THREE

RESULTS

3.1 The contribution of size of fishing boat to fishing effort

The lengths of all fishing boats sampled at the six fish landing sites were between 5 and 12 m (Figure 2 & Appendix 1). Boats using gill nets for fishing at Masese and Lingira in the eastern part of the lake were all below 8 m long. The size of gill netting fishing boats increased westwards with boats of length 5.0 - 9.9 m and 5.0 - 10.9 m recorded in the central part of the lake at Bugonga and Kasenyi respectively and the largest boats at Lambu (7.0-11.9 m long) and Kasensero (9.0-11.9 m long) in the western part of the lake.

3.1.1 Number of gill nets carried by fishing boats of different sizes

The mean numbers of gill nets carried by fishing boats of different sizes are given in Figure 3 and Appendix 2. The lowest mean number of gill nets per boat was recorded at Masese where boats carried 12.7$\pm$1.6 to 14.0$\pm$2.2 nets followed by Lingira, 16.9$\pm$3.8 to 18.7$\pm$2.7 nets. The mean number of nets per boat was more or less the same for boats of different sizes at Masese and Lingira. At Bugonga there was little change in mean number of gill nets carried by boats <8 m long but at Kasenyi fish landing site the mean number of nets per boat increased with increase in boat length for boats <8 m long. Similarly, larger boats at Lambu and Kasensero generally carried more nets. The overall mean number of gill nets per boat increased with increase in the size of fishing boats from 20.9 $\pm$ 2.3 nets in 5.0 - 5.9 m long boats to 88.6 $\pm$ 11.8 nets in 11.0 - 11.9 m long boats. One way ANOVA test (Appendix 3) on log10 gill net counts showed that the difference in the overall

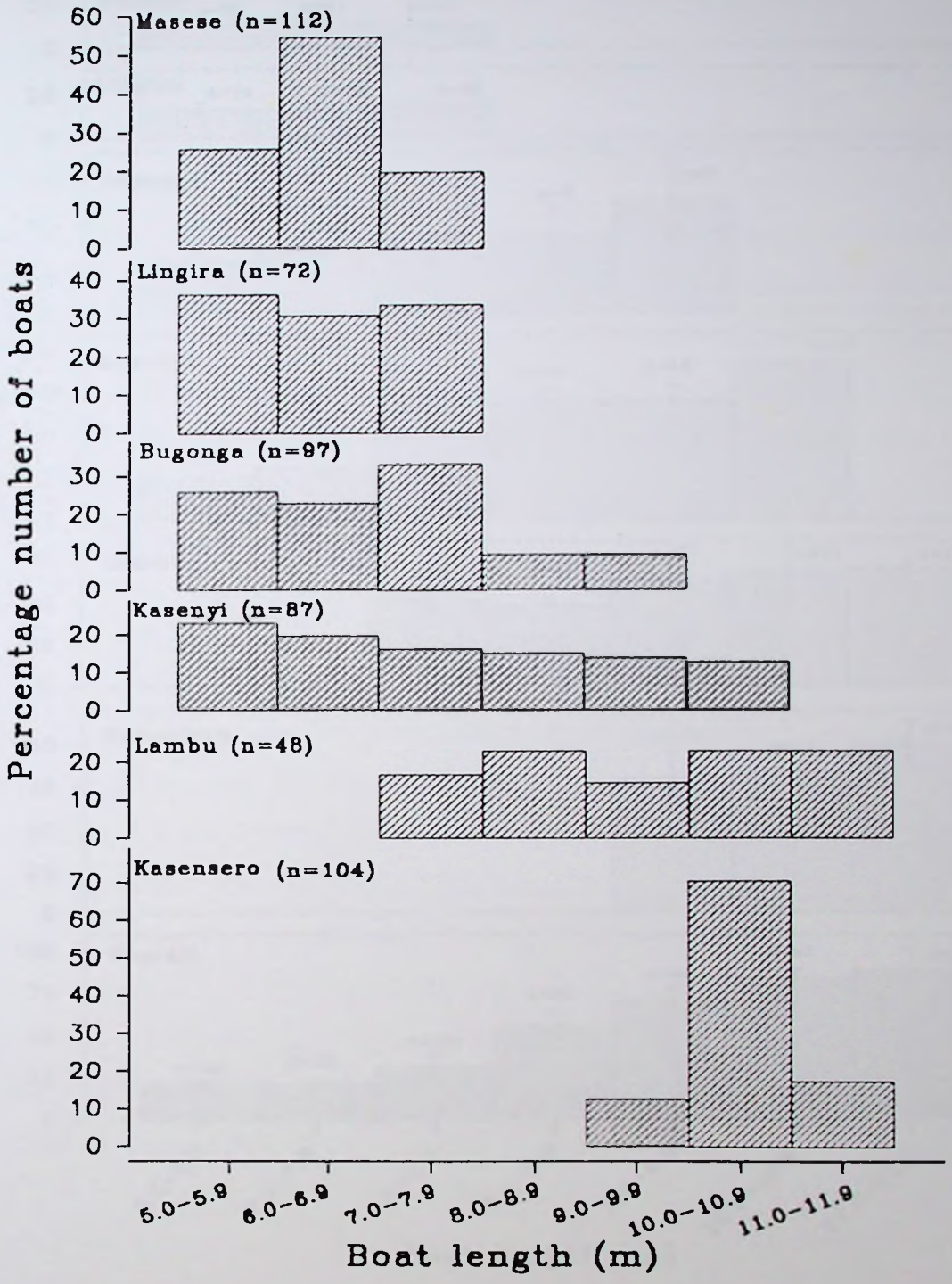


Fig. 2. Boat size distribution among boats fishing with gill nets sampled at the six landings.

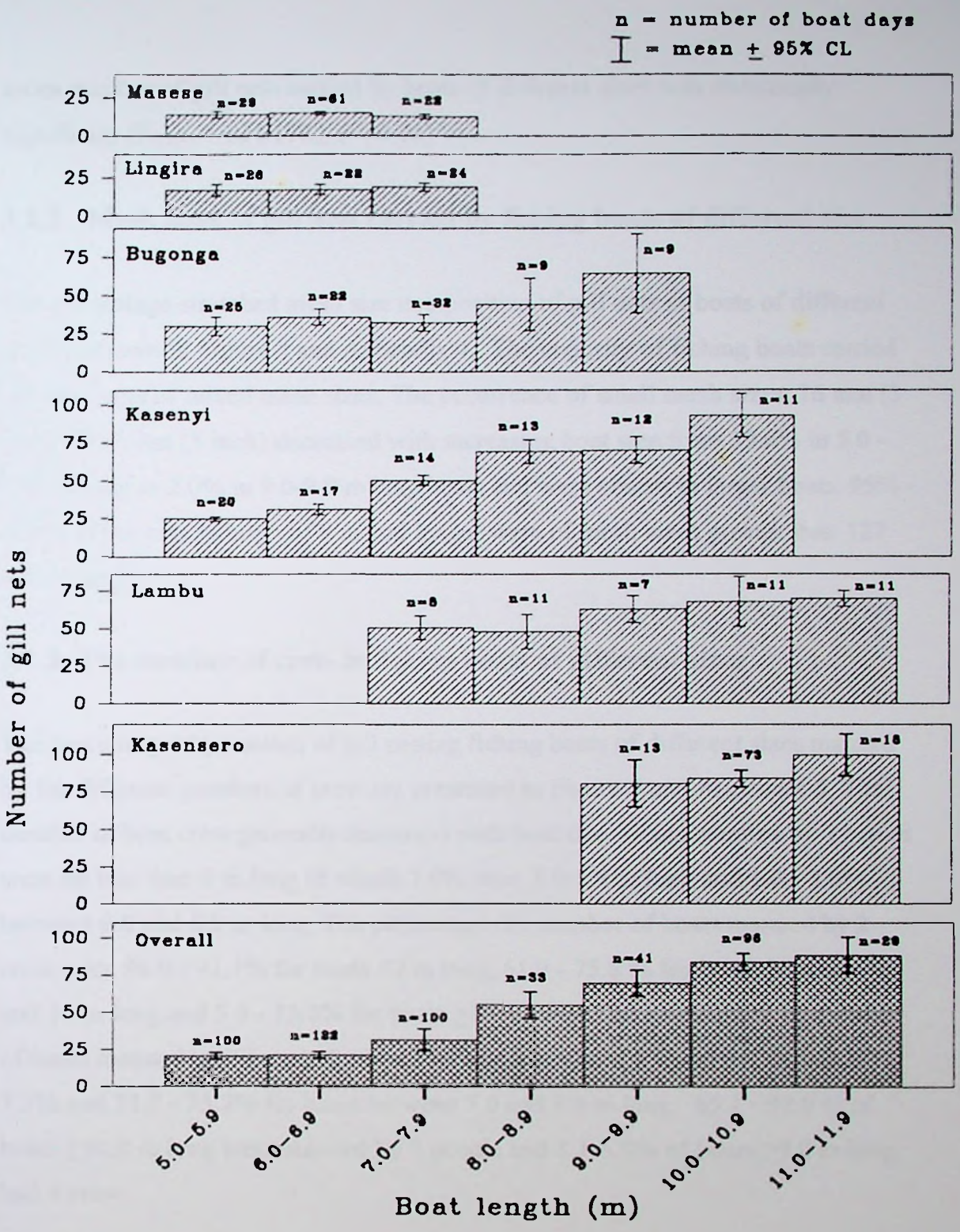


Figure 3. Mean number of gill nets carried by fishing boats of different sizes.

mean number of gill nets carried by boats of different sizes was statistically significant ($F_{6,499} = 124.1782$, $P < 0.05$)

3.1.2 Mesh sizes of gill nets carried by fishing boats of different size

The percentage stretched mesh size composition of gill nets in boats of different sizes is shown in Figure 4 and Appendix 4. The majority of fishing boats carried gill net fleets of mixed mesh sizes. The occurrence of small mesh sizes, 76 mm (3 inch) - 127 mm (5 inch) decreased with increasing boat size from 59.6% in 5.0 - 5.9 m boats to 2.0% in 9.0-9.9 m long boats and were absent in larger boats. 95% - 100% of the nets in boats of 8 m and longer were of mesh sizes greater than 127 mm (5 inch).

3.1.3 The number of crew in fishing boats of different sizes

The percentages by number of gill netting fishing boats of different sizes manned by the different numbers of crew are presented in Figure 5 and Appendix 5. The number of boat crew generally increased with boat size. Boats manned by 1 person were all less than 9 m long of which 7.0% were 5.0-5.9 m long and 1.0 - 3.0% between 6.0 and 8.9 m long. The percentages by number of boats manned by 2 crew were 88.0 - 91.1% for boats <7 m long, 61.9 - 75.8 % for boats between 7m and 10 m long and 3.6 - 13.8% for boats ≥10 m long. The percentages by number of boats manned by 3 people for boats of length between 5.0 and 6.9 m was 6.0 - 7.3% and 21.2 - 33.3% for boats between 7.0 and 9.9 m long. 85.1 - 92.8 % of boats ≥10.0 m long were manned by 3 people and 1.1-6.0% of boats ≥9.0 m long had 4 crew.

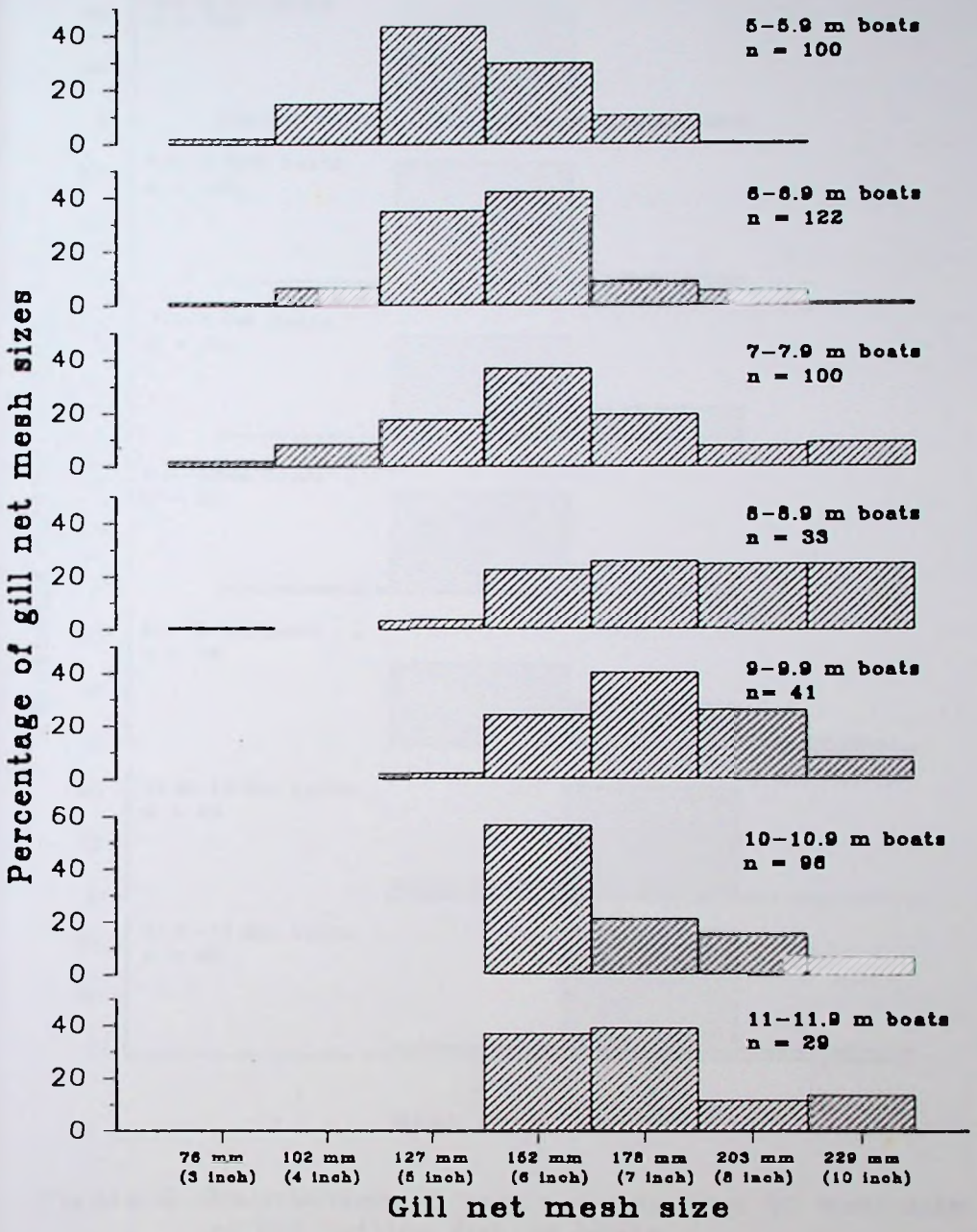


Figure 4. Mesh size composition of the gill net fleets of fishing boats of different sizes.

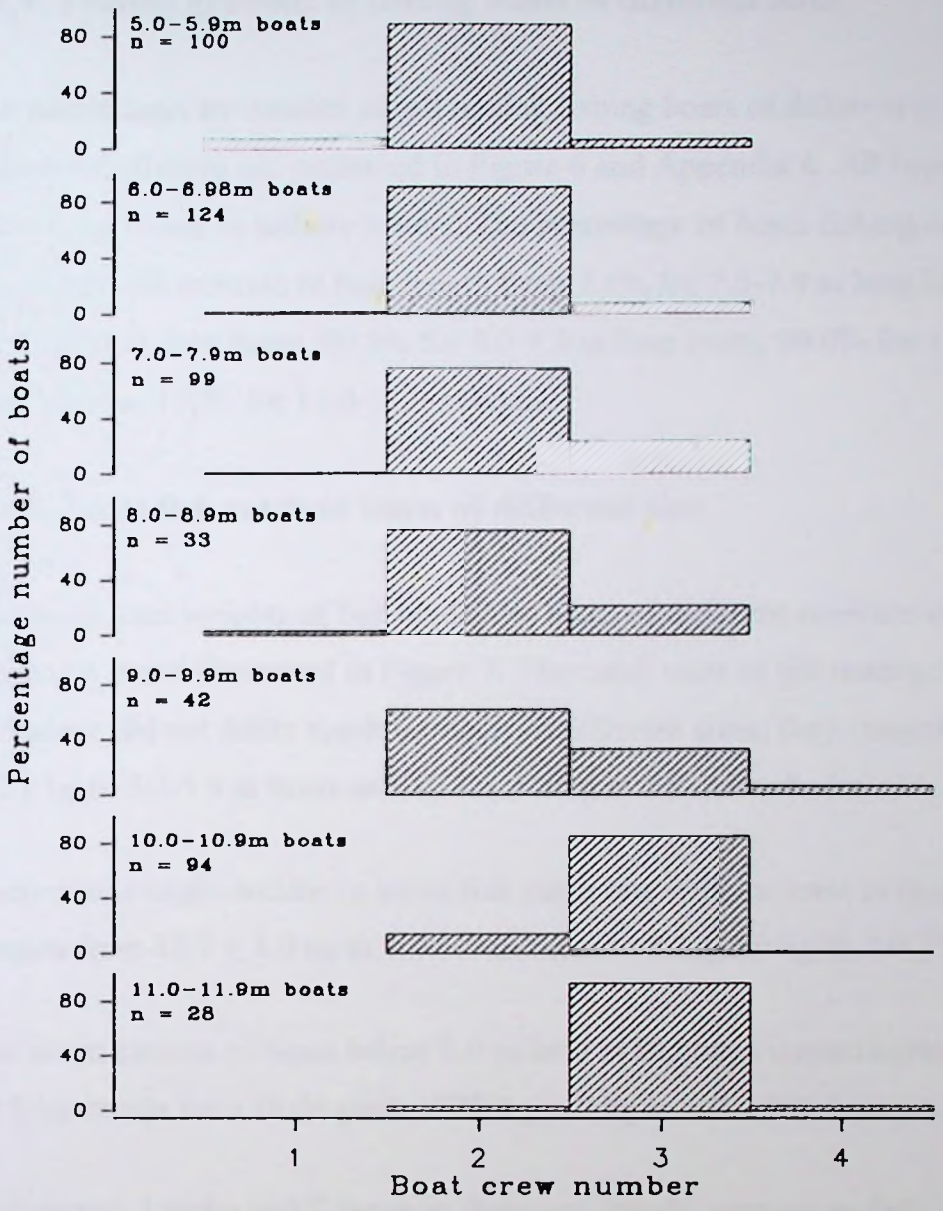


Figure 5. Distribution of boat crew number by boat size of gill netting fishing boats.

3.1.4 Fishing grounds of fishing boats of different sizes

The percentages by number of gill netting fishing boats of different sizes fishing inshore or offshore are presented in Figure 6 and Appendix 6. All boats less than 7.0 m long fished in inshore waters. The percentage of boats fishing offshore increased with increase in boat length from 7.1% for 7.0-7.9 m long boats, 60.6% for 8.0-8.9 m long boats, 90.5% for 9.0-9.9 m long boats, 99.0% for 10.0-10.9 m long boats to 100% for 11.0-11.9 m boats.

3.1.5 Total fish catch of boats of different size

The mean total weights of fish landed by boats of different sizes are shown in Appendix 7 and illustrated in Figure 7. The catch rates of gill netting fishing boats at Masese did not differ much for boats of different sizes; they ranged between 9.2 $\pm$ 2.2 kg in 5.0-5.9 m boats and 10.1 $\pm$ 4.3 kg in 7.0-7.9 m boats.

There was a slight decline in mean fish catch rate with increase in boat size at Lingira from 12.7 $\pm$ 3.0 kg in 5.0-5.9 m boats to 8.3 $\pm$ 3.0 kg in 7.0-7.9 m boats.

The mean catches of boats below 9.0 m long at Bugonga ranged between 18.8 and 22.0 kg except for a slight peak of 27.1 $\pm$ 6.0 kg in 6.0-6.9 m boats.

At Kasenyi, Lambu and Kasensero there was steady increase in fish catch rates with increase in boat size as follows: 9.69 $\pm$ 5.8 kg in 5.0-5.9 m boats to 56.0 $\pm$ 28.2 kg in 10.0-10.9 m boats at Kasenyi; 10.6 $\pm$ 7.8 kg in 7.0-7.9 m boats to 53.7 $\pm$ 19.1 kg in 11.0-11.9 m boats at Lambu and 51.6 $\pm$ 17.7kg in 9.0-9.9 m to 94.1 $\pm$ 22.1 kg in 11-11.9 m boats at Kasensero.

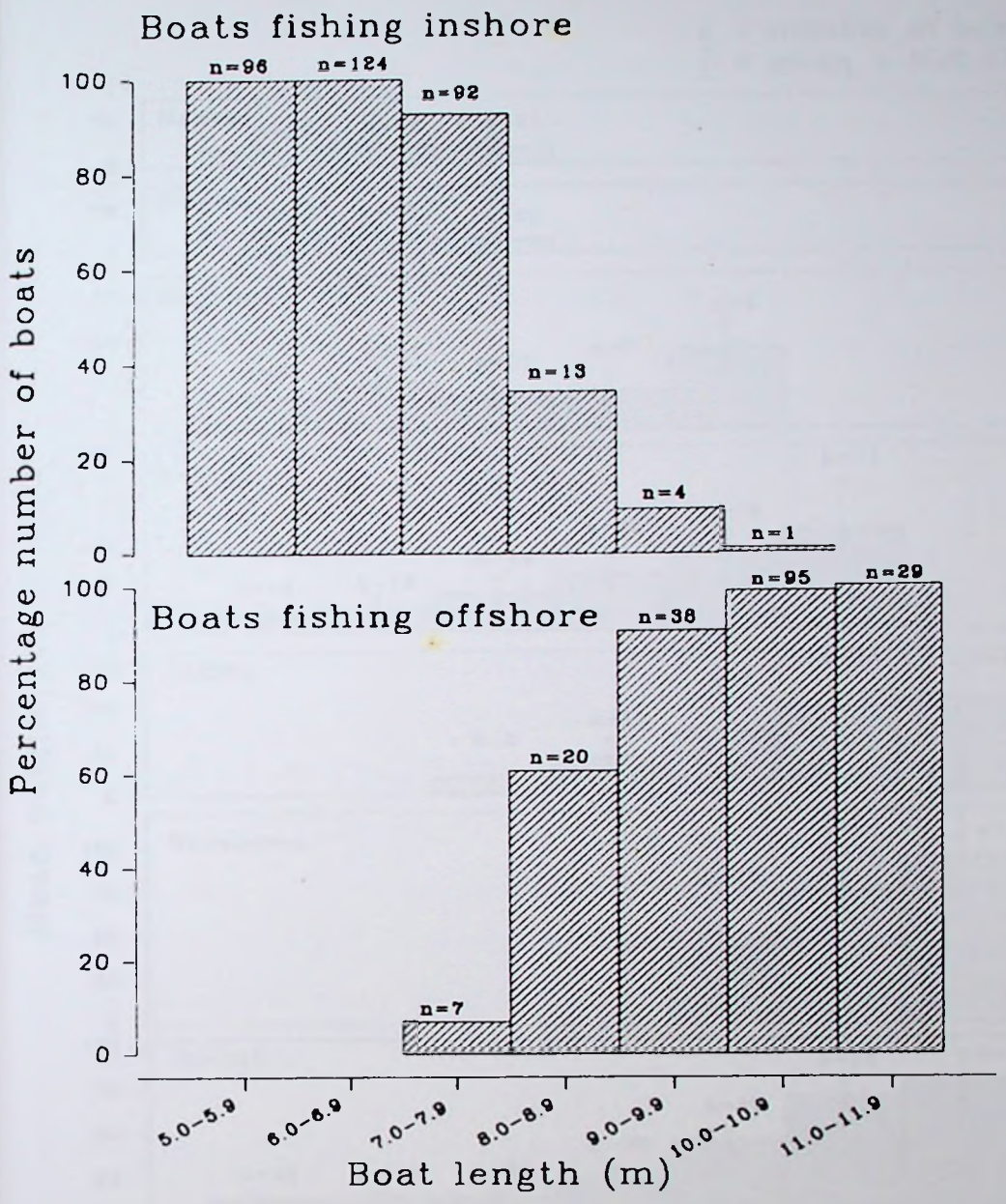


Figure 6 . Proportions of boats of different sizes fishing inshore and offshore.

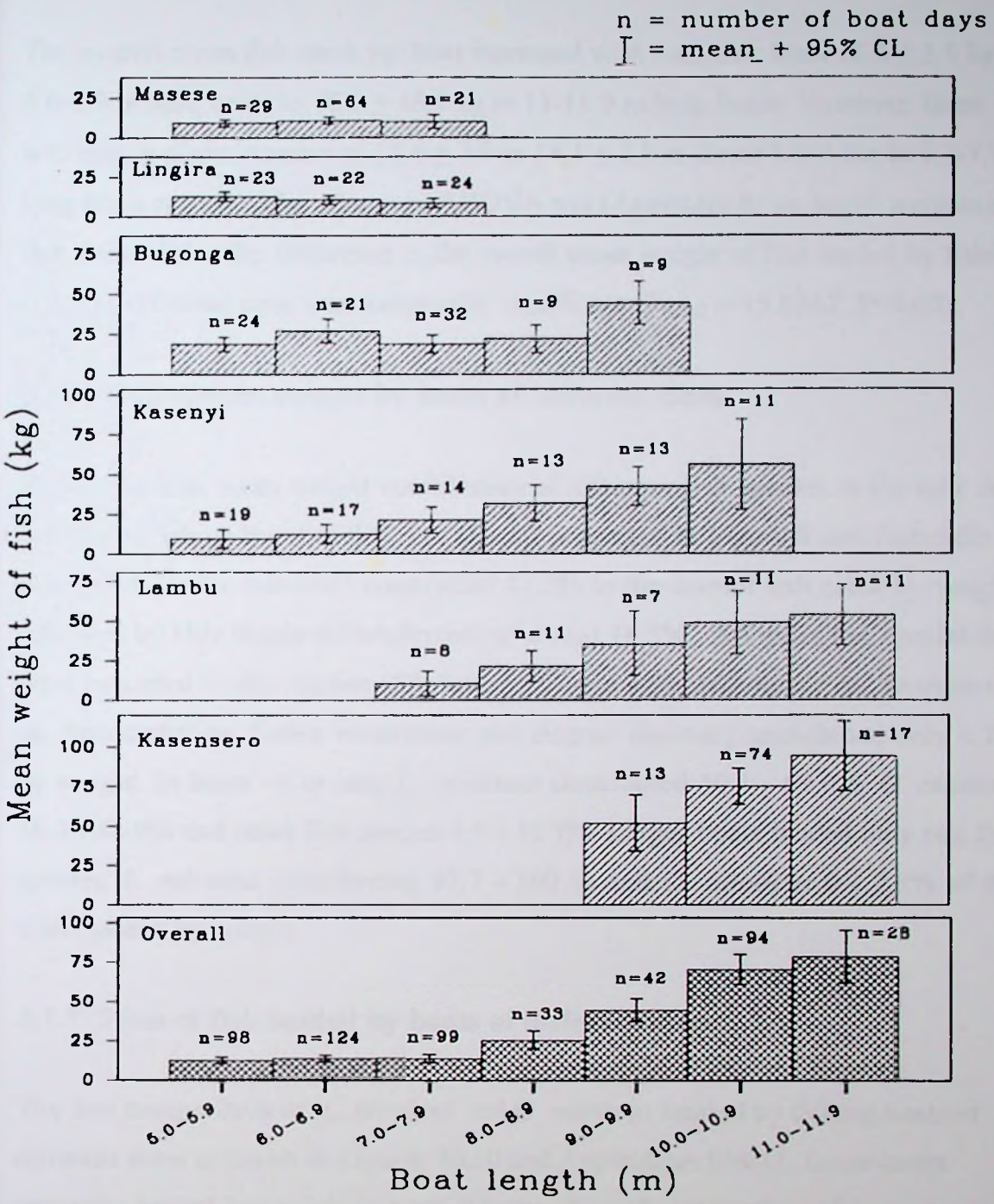


Figure 7. Mean Total weight of fish landed by fishing boats of different sizes.

The overall mean fish catch per boat increased with boat size from 12.6 ± 1.9 kg in 5.0-5.9 m long boats to 78.2 ± 16.4 kg in 11-11.9 m long boats. However, there was only a slight increase of 12.6 ± 1.9 to 14.1 ± 2.6 in boats 5.0-5.9m to 7.0-7.9m long boats respectively. One way ANOVA test (Appendix 8) on log10 weights of fish showed that the difference in the overall mean weight of fish landed by fishing boats of different sizes was statistically significant ($F_{6,513} = 15.0367$, $P<0.05$).

3.1.6 Fish species caught by boats of different sizes

The percentage mean weight contribution of different fish species to the total fish catches of fishing boats of different sizes is presented in Figure 8 and Appendix 9. Nile perch (*Lates niloticus*) contributed 81.3% to the overall fish catch by weight, followed by Nile tilapia (*Oreochromis niloticus*) 14.5%. All other fish species that were recorded in the catches (*Clarias* sp, *Tilapia zilli*, *Mormyrus* sp, *Protopterus* sp, *Synodontis* sp, *Labeo victorianus* and *Bagrus docmac*) contributed only 4.2% by weight. In boats <8 m long *L. niloticus* contributed 40.1 - 69.0%, *O. niloticus* 18.3 - 48.9% and other fish species 9.0 - 12.7%. Larger boats landed only two fish species, *L. niloticus* contributing 97.7 - 100 % and *O. niloticus* 0 - 2.3% of the total catches by weight.

3.1.7 Sizes of fish landed by boats of different sizes

The size composition of *L. niloticus* and *O. niloticus* landed by fishing boats of different sizes is shown in Figures 9&10 and Appendices10&11. Large boats generally landed larger fish than small boats. 83-95% by number of *L. niloticus* landed by boats 8.0 m and longer were greater than 50 cm total length whereas only 11-27 % of *L. niloticus* in boats less than 8.0m long were greater than 50 cm total length. Similarly, *O. niloticus* specimens landed by large fishing boats were

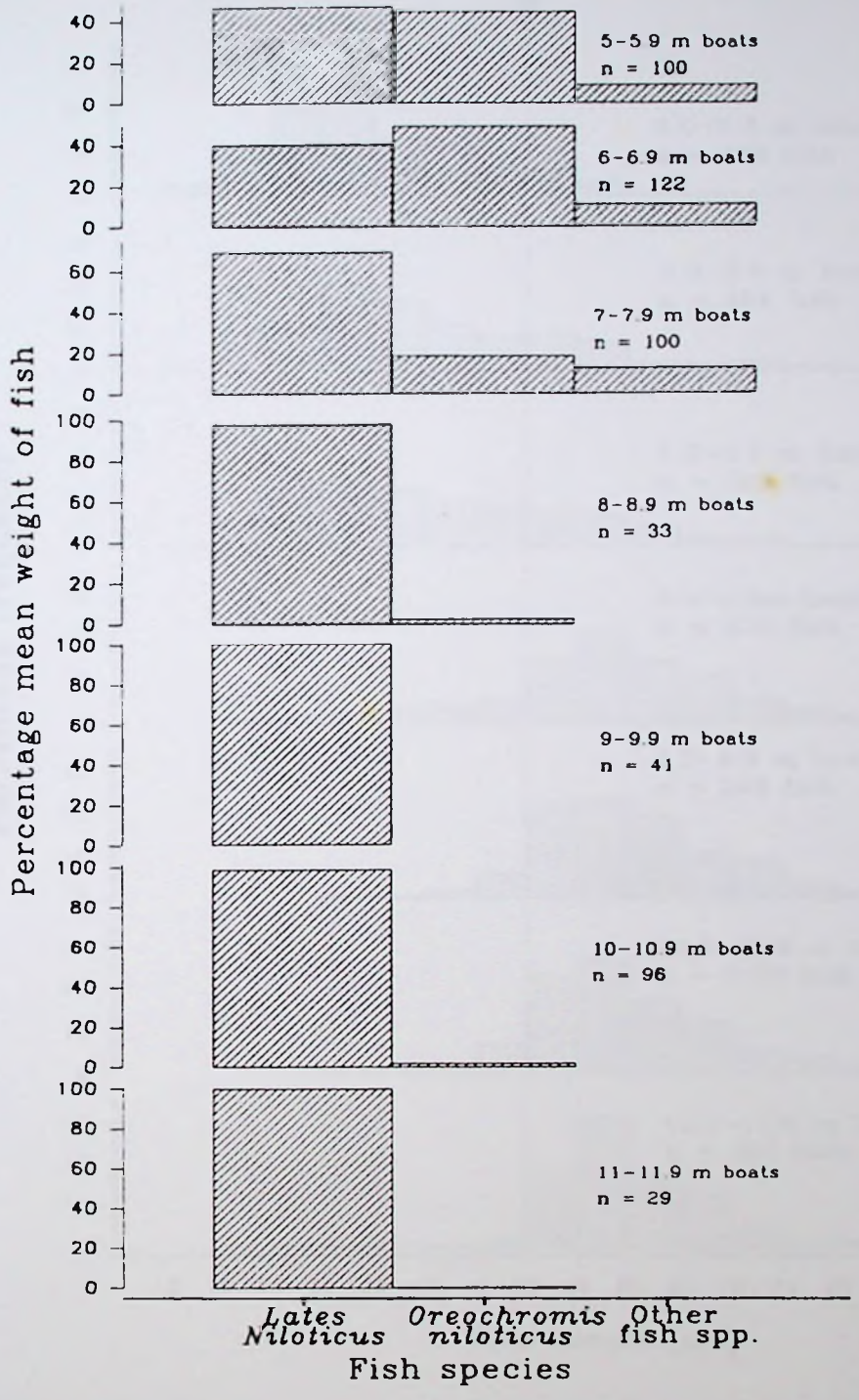


Figure 8. Percentage mean weight by species of fish landed by boats of different sizes.

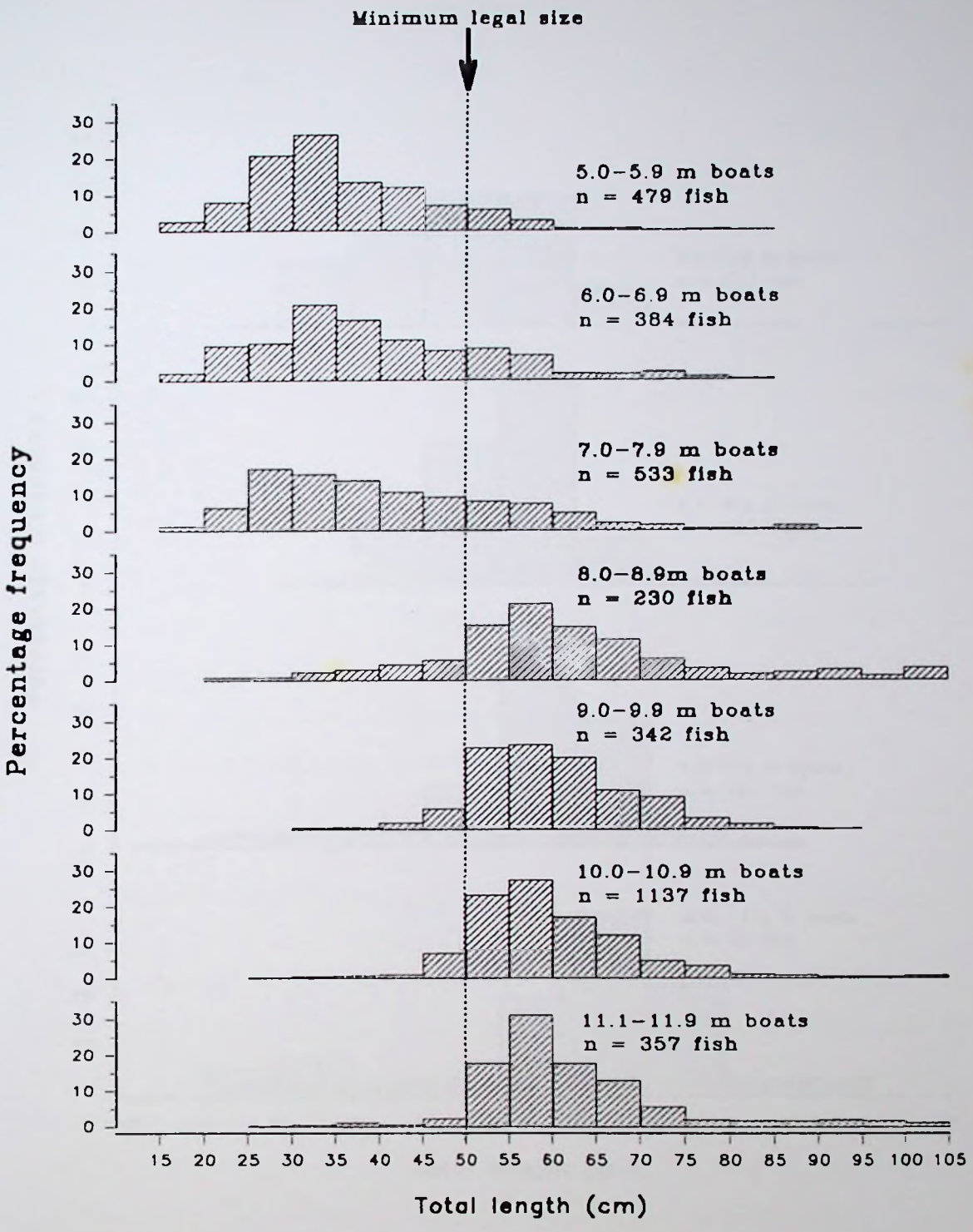


Figure 9. Length frequency distribution of Nile perch (*Lates niloticus*) landed by boats of different sizes.

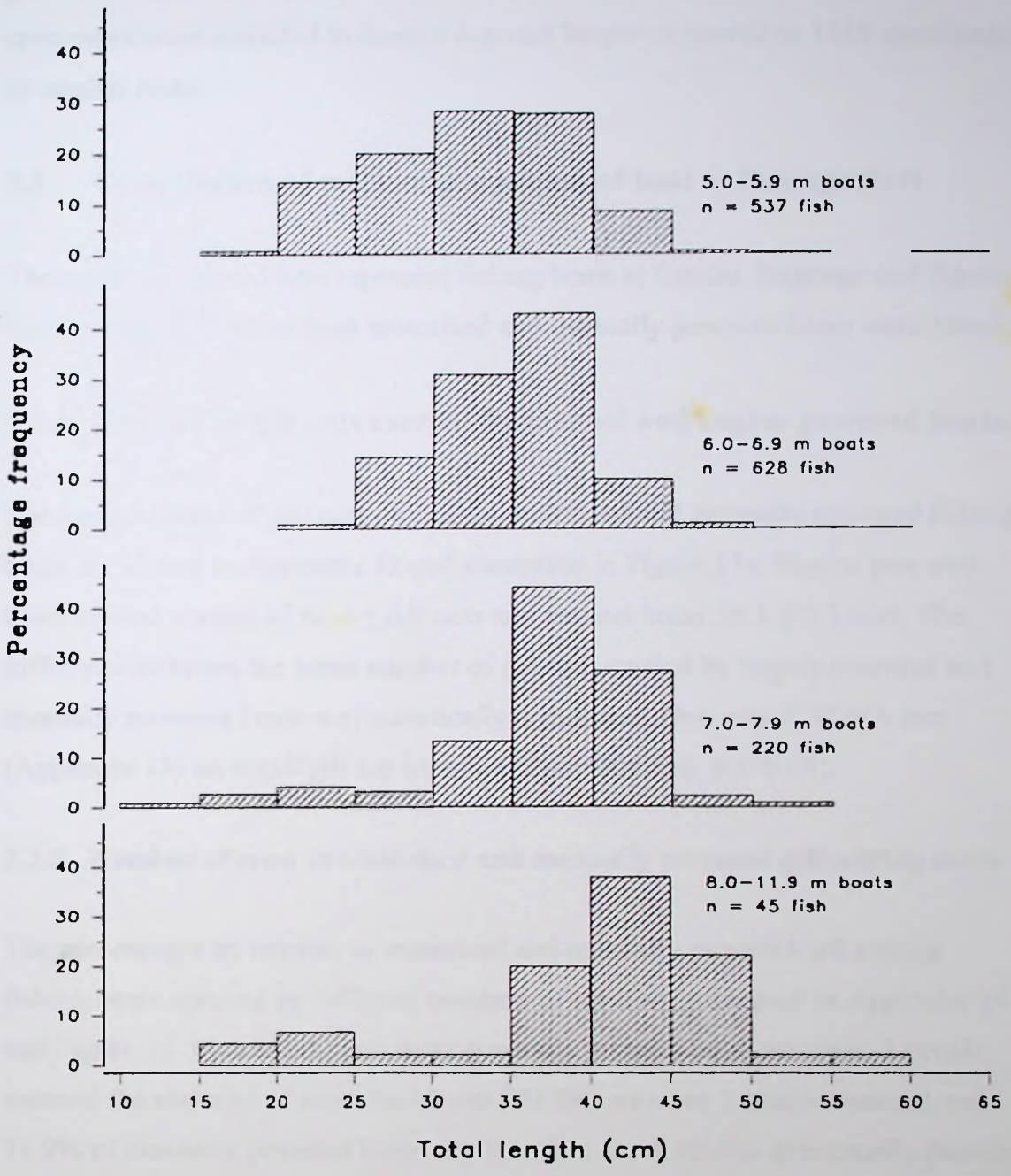


Figure.10 Length frequency distribution of Nile tilapia (*Oreochromis niloticus*) landed by fishing boats of different sizes.

generally larger than specimens landed by small fishing boats although only 45 specimens were recorded in boats 8.0 m and longer compared to 1385 specimens in smaller boats.

3.2 Contribution of mode of propulsion of boat to fishing effort

The results presented here represent fishing boats at Lambu, Bugonga and Kasenyi fish landing sites where both motorised and manually powered boats were found.

3.2.1 Number of gill nets carried by manual and engine powered boats.

The mean number of gill nets carried by motorised and manually powered fishing boats are shown in Appendix 12 and illustrated in Figure 11a. Engine powered boats carried a mean of 65.1 $\pm$ 6.0 nets and manual boats 35.1 $\pm$ 2.7 nets. The difference between the mean number of gill nets carried by engine powered and manually powered boats was statistically significant, One way ANOVA test (Appendix 13) on log10 gill net counts, ($F_{1,208}$= 101.198, $P < 0.05$).

3.2.2 Number of crew in motorised and manually powered gill netting boats

The percentages by number of motorised and manually powered gill netting fishing boats manned by different numbers of crew are presented in Appendix 14 and Figure 12. Motorised boats were generally manned by more crew. 3 people manned the majority of motorised boats (70.2%) whereas 3 people manned only 11.9% of manually powered boats. On the other hand, 85.6% of manually powered boats were manned 2 people as compared to 28.3% of motorised boats. 1 person manned 2.2% of the manually powered boats as compared none of the motorised boats. Gill netting fishing boats manned by 4 people were only 1.5% of the motorised boats and 0.3% of the manually powered boats.

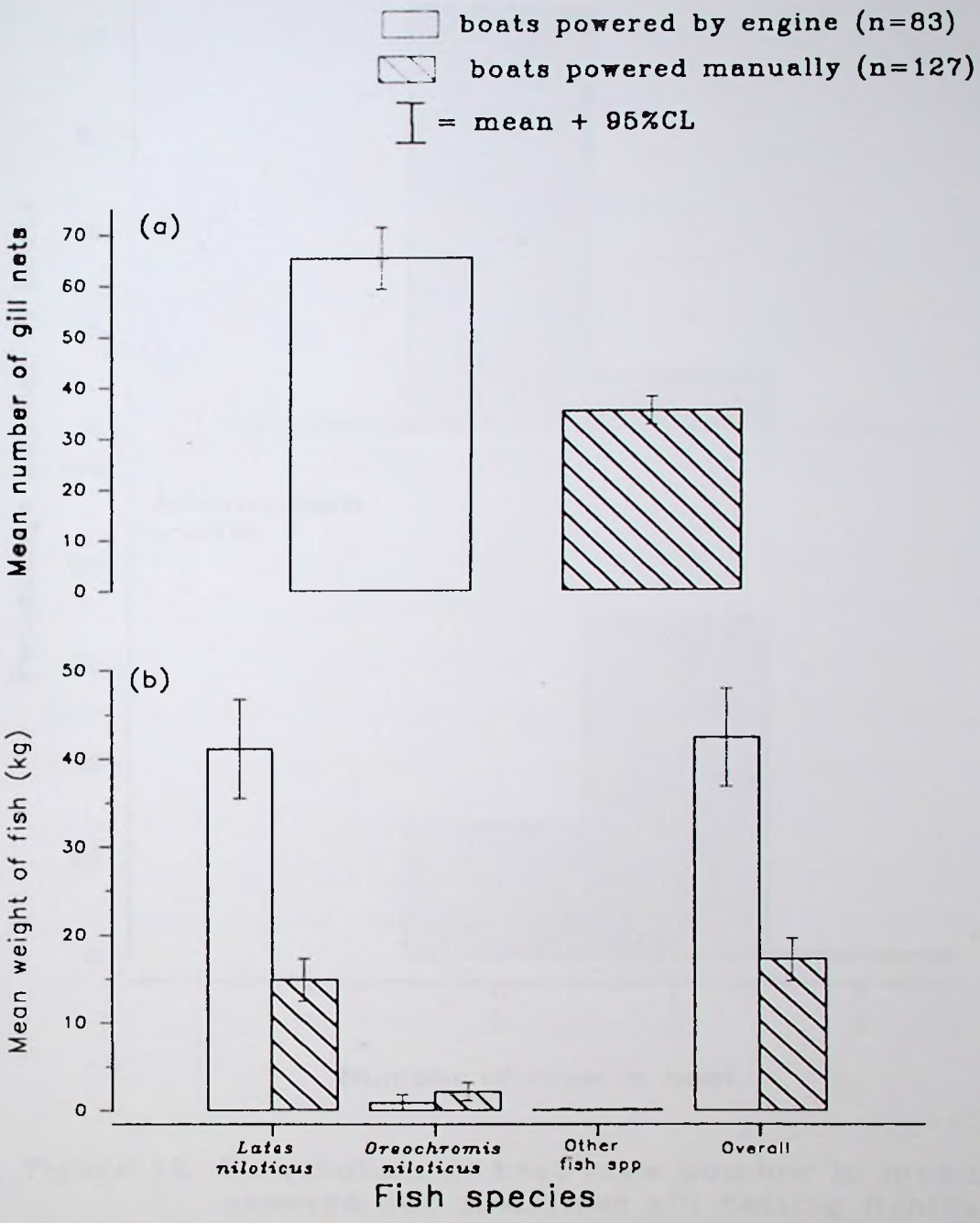


Figure 11. (a) Mean number of gill nets carried and (b) mean weight of fish landed by engine powered and manually powered boats at Lambu, Bugonga and Kasenyi fish landing sites.

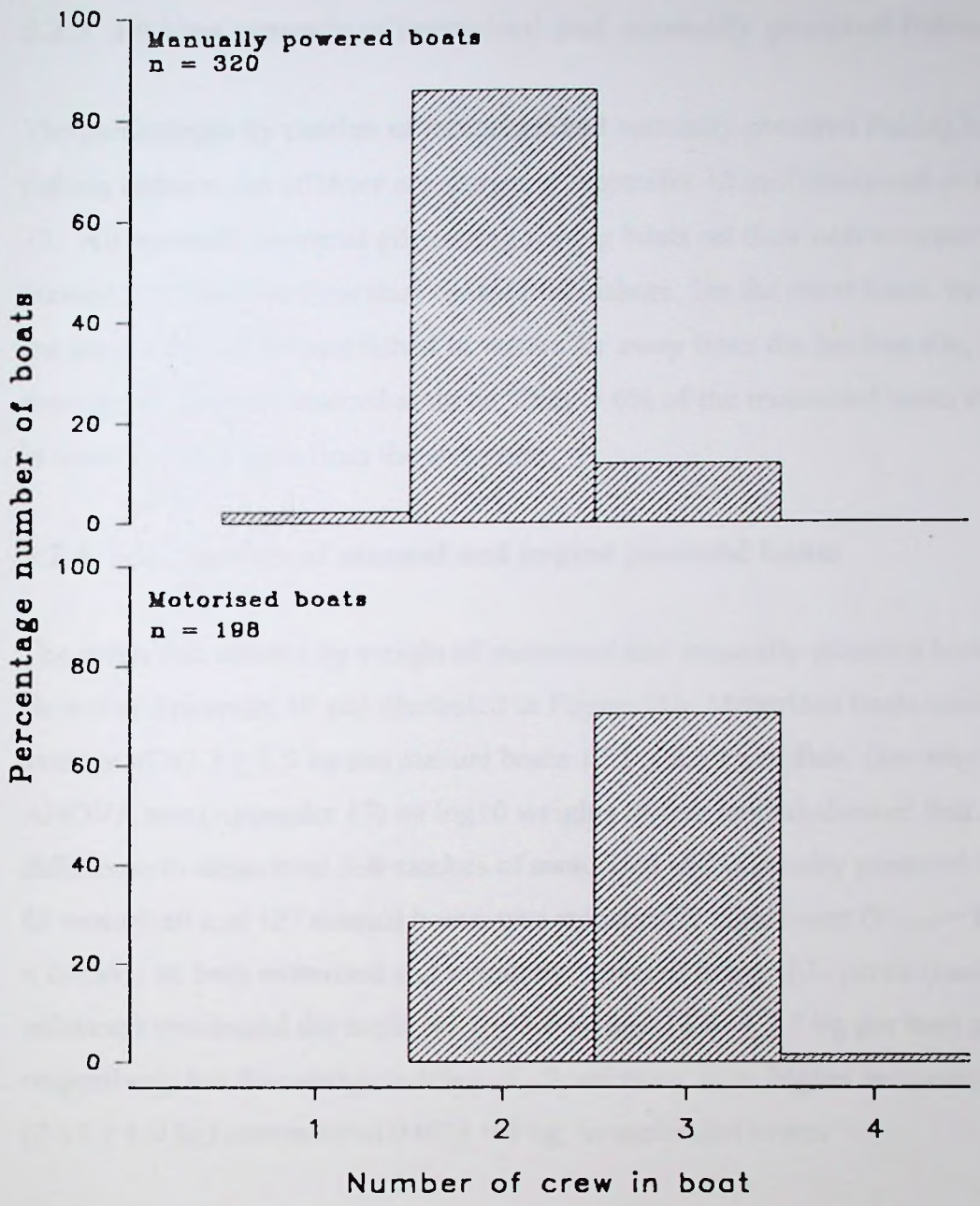


Figure 12. Distribution of boat crew number in manually powered and motorised gill netting fishing boats.

3.2.3 Fishing grounds of motorised and manually powered fishing boats.

The percentages by number of motorised and manually powered fishing boats fishing inshore and offshore are shown in Appendix 15 and illustrated in Figure 13. All manually powered gill netting fishing boats set their nets in waters clearly viewed from the shoreline thus considered inshore. On the other hand, 94.4% of the engine powered boats fished in waters far away from the landing site, stayed there overnight and returned at dawn. Only 5.6% of the motorised boats that fished in waters within sight from the shoreline.

3.2.4 Fish catches of manual and engine powered boats

The mean fish catches by weight of motorised and manually powered boats are shown in Appendix 16 and illustrated in Figure 11b. Motorised boats landed an average of 42.3 $\pm$ 5.5 kg and manual boats 17.1 $\pm$ 2.5 kg of fish. One way ANOVA test (Appendix 17) on log10 weights of fish landed showed that the difference in mean total fish catches of motorised and manually powered boats, n= 83 motorised and 127 manual boats, was statistically significant ($F_{1,208} = 86.98$, $P < 0.050$). In both motorised and manually powered boats Nile perch (*Lates niloticus*) dominated the catch, 41.1 $\pm$ 5.6 kg and 14.8 $\pm$ 2.5 kg per boat per night respectively but the average catches of *O. niloticus* were higher in manual boats (2.17 $\pm$ 1.0 kg) compared to 0.09 $\pm$ 0.9 kg in motorised boats.

3.3 Contribution of mode of operation of gill nets to fishing effort.

Data presented here is for fishing boats at Masese and Lingira fish landing sites where both active and passive modes of operation of gill nets were common. The common method of active fishing was by setting the gill net fleet at several sites in

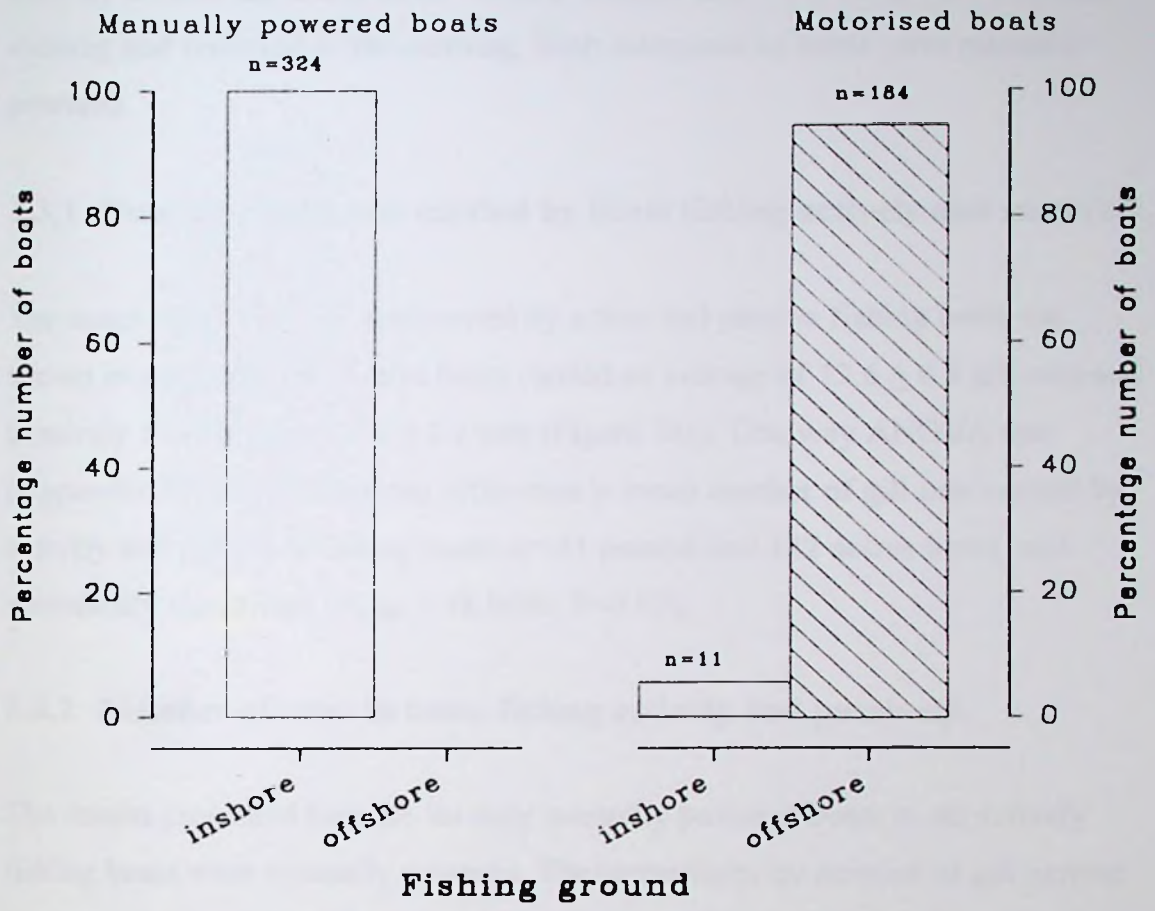


Figure 13. The percentages by number of manually powered and motorised gill netting boats fishing inshore and offshore.

one night and at each site beating water with a wooden hammer (locally known as *tycoon*) to scare the fish into the set nets. Passive nets were set at one site in the evening and retrieved in the morning. Both categories of boats were manually powered.

3.3.1 Number of gill nets carried by boats fishing actively and passively.

The mean number of gill nets carried by active and passive fishing boats are shown in Appendix 18. Active boats carried an average of 13.6 $\pm$ 0.9 gill nets and passively fishing boats 20.6 $\pm$ 2.1 nets (Figure 14a). One way ANOVA test (Appendix 19) showed that the difference in mean number of gill nets carried by actively and passively fishing boats, n= 41 passive and 142 active boats, was statistically significant ($F_{1,181} = 48.8809$, $P<0.05$).

3.3.2 Number of crew in boats fishing actively and passively.

The results presented here are for only manually powered boats as all actively fishing boats were manually powered. The percentages by number of gill netting boats fishing actively and passively manned by different numbers of crew are presented in Figure 15 and Appendix 20. All actively fishing boats were manned by 2 persons. The majority of passively fishing boats (75.3%) were manned by 2 people while 3.8% were manned by 1 person, 20.4% by 3 people and 0.5% by 4 people.

3.3.3 Fishing grounds of boats fishing actively and passively.

Gill nets of actively fishing boats were mainly set very close to the shoreline, in most cases within less than 300 m from the shoreline. The manually powered passively fishing boats set their nets in waters between the shoreline and about

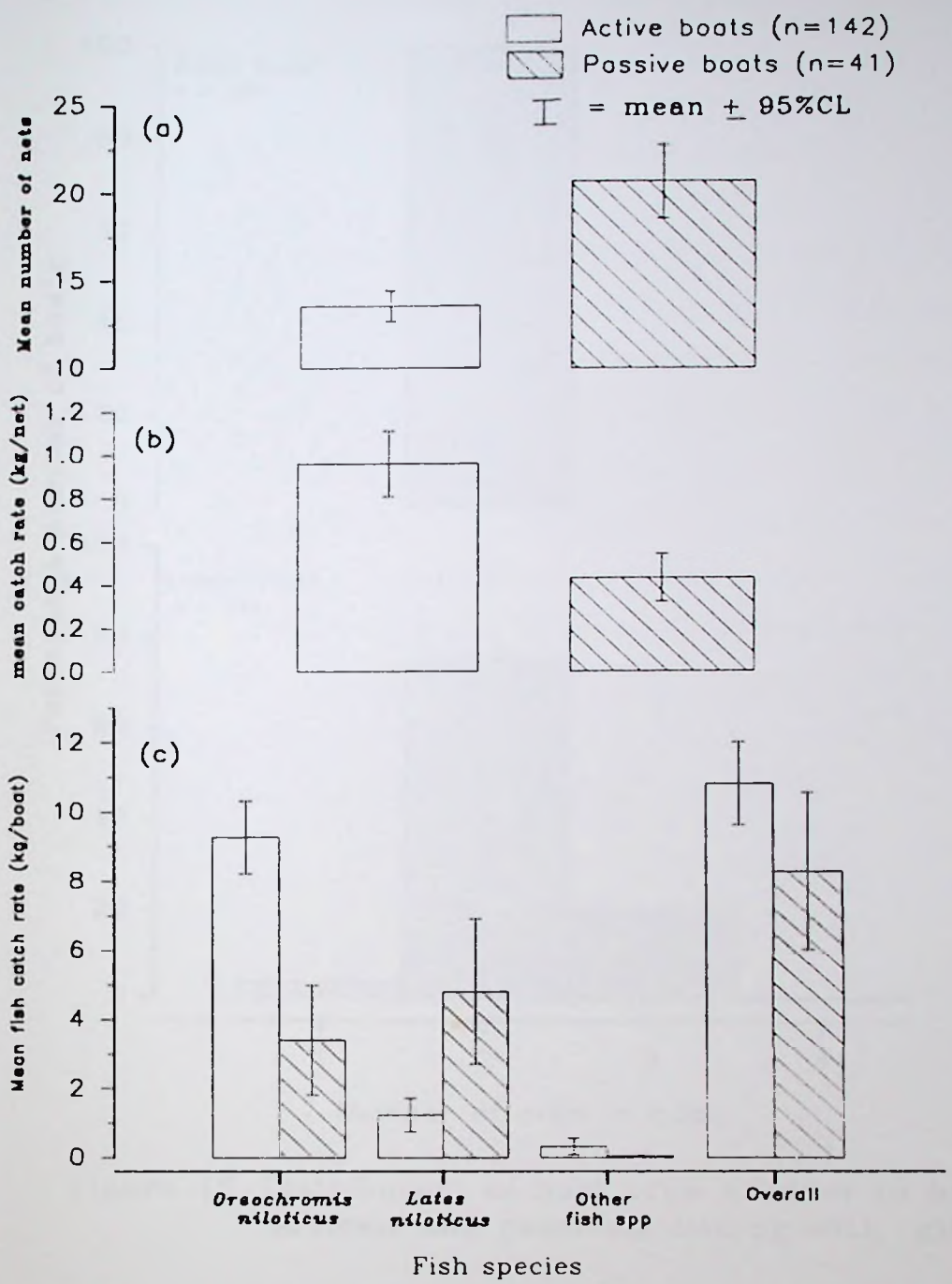


Figure 14. (a) mean number of nets carried, (b) mean fish catch rate per net and (c) mean fish catch rate per boat for Active and Passive fishing boats at Lingira and Masese fish landing sites.

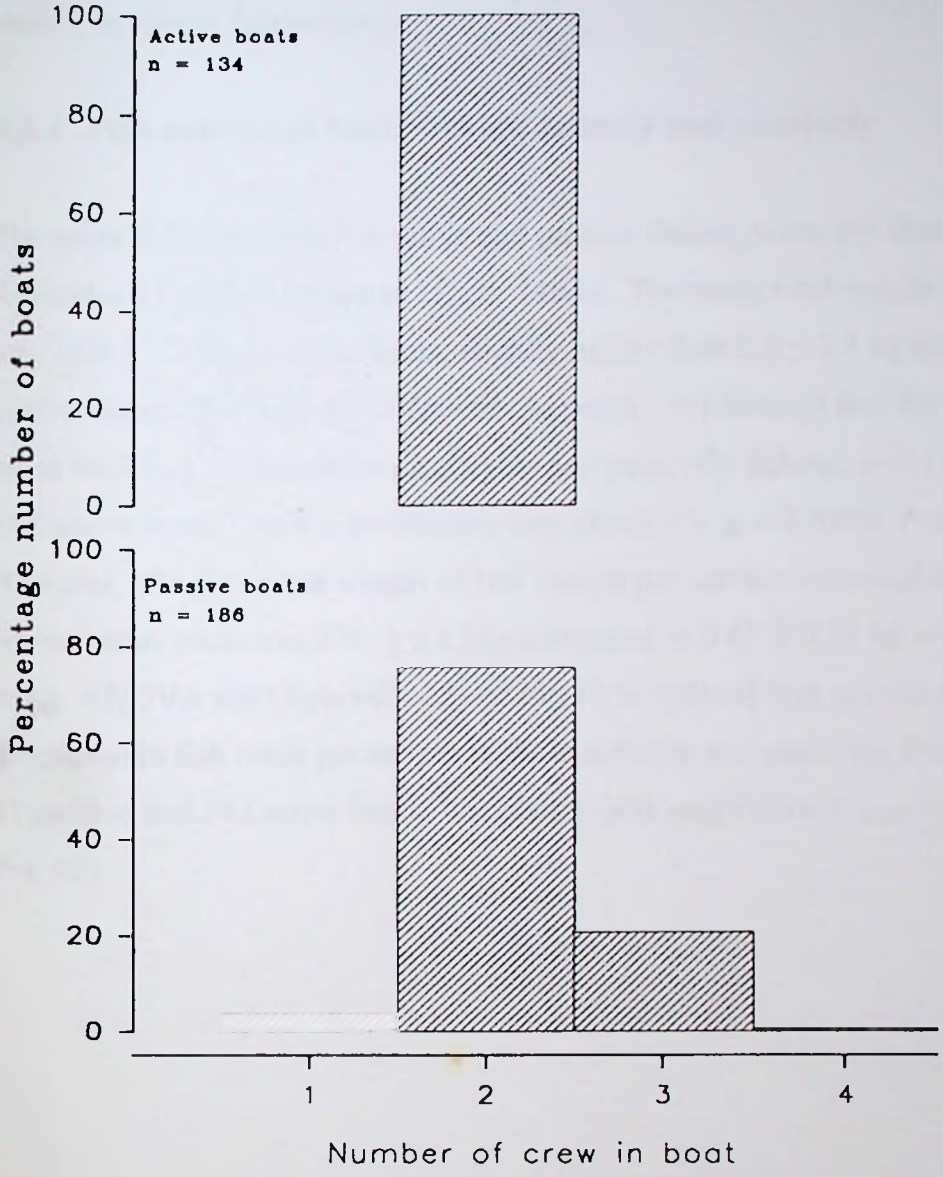


Figure 15. Distribution of boat crew number in boats actively and passively fishing with gill nets.

3 km away. Engine powered boats, which were all passively fishing set their nets mainly in waters further away.

3.3.4 Fish catches of boats fishing actively and passively.

The mean fish catch rates of active and passive fishing boats are shown in Appendix 21 and illustrated in Figure 14b&c. The mean total weight of fish landed was 10.8 $\pm$ 1.2 kg in active boats, slightly higher than 8.3 $\pm$ 2.3 kg recorded in passive boats. One way ANOVA test (Appendix 22) showed that the difference in mean total fish catches of boats actively and passively fishing, n= 41 passive and 142 active boats, was not statistically significant ($F_{1,181} = 3.8999$, $P<0.05$). However, a higher mean weight of fish caught per net was recorded in active boats whose mean catch was 0.96 $\pm$ 0.15 kg compared to 0.43 $\pm$ 0.11 kg in passive boats. ANOVA test (Appendix 23) on log 10 weights of fish per net showed that difference in fish catch per net per night in actively and passively fishing boats, n= 41 passive and 142 active boats, was statistically significant ($F_{1,181} = 20.4279$, $P<0.05$).

CHAPTER FOUR

DISCUSSION AND CONCLUSIONS

4.1 Discussion

The three factors contributing to fishing effort in Lake Victoria considered under the study (size of fishing boat, mode of propulsion of boat and mode of operation of gill nets) are inter-linked but the overriding factor seems to be size of a fishing boat. The size of a fishing boat strongly reflected its fishing characteristics in terms of number and mesh size composition of its gill net fleet, the number of crew, the fishing ground, the total fish catches, the fish species composition of the catch and the size composition of the fish caught.

Boats less than 7.0 m long which were only encountered at Masese, Lingira, Bugonga and Kasenyi carried a similar number of gill nets of similar mesh size composition, were predominantly manned by 2 crew, fished exclusively in inshore waters landed more or less the same overall mean total weights of fish of similar species composition (Fig 3, 4, 6 - 8&12). The fishing characteristics of 7.0-7.9 m long boats were intermediate between small and large boats. They carried more nets composed of bigger meshed nets, more boats were manned by 3 crew, a few boats (7.1%) fished in offshore waters but they landed more or less the same overall weight of fish as the smaller boats although their catch was dominated by Nile perch as in bigger boats. The size composition by Total Length (TL) of Nile perch landed by boats 5.0 - 7.9 m long was similar with a slight bias to bigger sizes with increase in boats size and the occurrence of larger Nile tilapia also increased with boat size among these boats (Fig 9&10). Larger fishing boats of 8.0 m and longer had similar gill net mesh size composition and fish species

composition but their overall mean number of gill nets, number of crew and mean weight of fish landed increased appreciably with increase in boat length. The percentage of boats fishing offshore also increased with increase in length of boat (Fig 3-8). The number of crew required per boat seems to be dependent on the number of gill nets the boat carries and the mode of operation of the gill nets. Larger boats carried more nets and could require more labour in setting and retrieval of the nets Larger boats also made better fish catches and could afford more labour costs (Fig 3&7).

These observations indicate a direct influence of the size of a fishing boat on the spatial distribution of its fishing operations, its target fish species and fish sizes. Small boats <7.0 m long and the majority of boats 7.0 - 7.9 m long boats were restricted to the inshore waters and used small gill net fleets composed of mainly small mesh sizes ≤127 mm (5 inch). Although they seemed to target Nile tilapia which contributed 44.2 - 48.9% by weight of the catches in 5.0 - 6.9 m long boats and 18.3% in 7.0 - 7.9 m long boats, they made substantial catches of Nile perch (Fig 8). All other fish species (*Clarias* sp, *Tilapia zilli*, *Mormyrus* sp, *Protopterus* sp, *Synodontis* sp, *Labeo victorianus* and *Bagrus docmac*) recorded in the catches were rare contributing <13% by weight in boats <8.0 m long and absent in larger boats. 77.6 - 89% of Nile perch in 5.0 - 6.9 m long boats and 73.6 % of Nile perch in 7.0 - 7.9 m long boats were ≤50 cm TL (Fig 9). Larger boats, 8.0 m and longer which fished mainly in offshore waters used gill net fleets composed of 95.7 - 100% gill nets >127 mm (5 inch) mesh size and >83% of their Nile perch catches were >50 cm TL. In Lake Victoria, 50% of male and female Nile perch mature at about 50 cm TL and 80 cm TL respectively (Hughes 1992, Ogutu-Ohwayo 1994). The sex ratios of the Nile perch population in the lake are male biased (Ogutu-Ohwayo 1994) therefore males dominate the catch and there may be little harm to the fishery by harvesting Nile perch >50 cm TL.

Nile tilapia catches were common in boats less than 8.0 m which fished in inshore waters (Fig 8&6). Nile tilapia (*O. niloticus*) in Lake Victoria is largely found inshore, thriving best in waters less than 10 m depth and restricted to waters less than 20 m depth (Kudhongania & Cordone 1974, Okaronon 1994), the habitat that was previously occupied by the indigenous tilapiines *O. esculentus* and *O. variabilis* (Graham 1929). 50% of male and female Nile tilapia in the lake are mature at about 18 cm and 24 cm TL respectively (Balirwa 1998). 93.6% by number of all the Nile tilapia recorded in the catches were above 25 cm TL, large enough to be part of the breeding stock. This size of Nile tilapia ($\geq$ 25 cm TL) is suitable for harvest with moderate fishing effort.

The contribution of the mode of propulsion of boat to fishing effort cannot be clearly separated from that of the size of the boat. All boats that fished offshore 7.1% of 7.0-7.9 m long boats, 60.6% of 8.0-8.9 m long boats, 90.5% of 9.0-9.9 m long boats, 99.0% of 10.-10.9 m long boats, and 100% of 11.0 - 11.9 m long boats (Fig 6) were motorised. Thus the proportion of boats powered by engine increased with boat size like all the other fishing characteristics. Only 5.6% of engine powered boats fished inshore (Fig 13) due to having inadequate amount of gear, unreliable engine, leakage or other such reasons that prevented them from going offshore. The use of an engine increases the mobility of the boat and its ability to go to rich, far, fishing grounds but also increases the costs of fishing. Generally, the possibility to use an engine seems to hinge on the ability to catch more fish in order to meet the costs involved, thus whereas motorised boats at Lambu, Bugonga and Kasenyi carried twice as many nets as the manually powered boats (Fig 11a), they landed about two and a half times the total weight of fish landed by manually powered boats (Fig 11b).

There was a sharp contrast between active and passive modes of operation of gill nets among the boats that fished in inshore waters at Masese and Lingira. Actively

fishing boats carried about a half the number of nets carried by passively fishing boats (Fig 14a) but landed slightly more mean total weight of fish than the latter (Fig 14c). The active techniques doubled the mean catch rate (Fig 14b) thus increasing the efficiency of the gill net twofold. Actively fishing boats operated within about 300 m from the shoreline whereas passively fishing boats operated in a wider area. The fish catches of actively fishing boats were composed of about 85.9% Nile tilapia, 11.1% Nile perch and 3.0% other fish species by weight compared to 41.0% Nile tilapia, 57.8% Nile perch and 0.6% other fish species in passively fishing boats (Fig 14c). This catch composition indicates that actively fishing boats targeted Nile tilapia whereas Nile perch was the main target of passively fishing boats.

Ecological implications of the observations

Predation by Nile perch and fishing are among the most important regulators of trophic dynamics in the Lake Victoria ecosystem. Therefore, stability of the lake's fishery largely depends on the nature of interaction between Nile perch and man, through fishing. Schindler et. al. (1998) using bioenergetic modelling show that the potential effects of Nile perch predation in the lake's food web are sensitive to the way in which fishing effort is allocated in the gill net fishery. They demonstrate that intensive harvest of juvenile Nile perch using small mesh size gill nets and beach seines would lead to recovery of haplochromines and other fish species preyed on by Nile perch. Recovery of haplochromines and increased fish species diversity has occurred in Napoleon gulf, Mwanza gulf, Winam gulf and other regions of Lake Victoria where fishing is locally intensive (Kitchell et. al., 1997). However, conserving the remnant species flock of haplochromines cannot be the primary goal but should depend on the success of the Nile perch because it would drastically reduce fishery yields and diminish economic benefits to the people who depend on the lake's fishery resources (Kitchell et al., 1997). Nile perch up to 50

cm TL in Lake Victoria feeds predominatly on invertebrates, especially, the prawns *Caridina nilotica* and dragonfly nymphs thus playing a beneficial role of converting invertebrates into a consumable commodity, fish (Ogutu-Ohwayo et al. 1996, Ogutu-Ohwayo 1994). It then shifts to a predominantly piscivorus diet comprising of *R. argentea*, juvenile Nile perch and Nile tilapia and haplochromines after about 50 cm TL, thus, destructive to biodiversity and economically wasteful.

Considering the enormous fecundity of Nile perch, its male biased sex ratio and the dependence of its juvenile on mainly invertebrate food (Ogutu-Ohwayo 1994), the 50 cm TL which corresponds with the size at which males start maturing is the right size for the onset of intense harvest of Nile perch using large mesh size gill nets. This would reduce the extent of its piscivory effects thereby fostering survival of its juveniles and its prey fish species as predicted by Kitchell, 1997. On the other hand, intense harvest of juveniles using small mesh gill nets and beach seines would diminish the productive potential of both predator and prey populations through recruitment overfishing. Schindler et al. 1998 predicted that maximum fish harvest and substantial reduction in Nile perch predation effects would result from minimum gill net mesh size restrictions between 152 mm (6 inch) and 254 mm (10 inch). Boats $\geq$8.0 m long used this gill net mesh size range that has both ecological and economic benefits (Fig 4). On the other hand boats $<$8.0 m long used gill net fleets with a large component of nets $<$152 mm mesh size and landed substantial quantities of juvenile Nile perch (Fig 9). If this phenomenon continues, it could be ecologically beneficial in the perspective of regaining the lake's biodiversity, but would be extremely wasteful economically. The Nile tilapia catches contained a good proportion of mature fish >25 cm TL but the popular method of fishing was the active operation of gill nets. This is

done close to the shoreline in the nursery grounds targeting the brood stock hence ecologically unsustainable.

In the interest of maintaining ecological balance and attaining increased sustainable fish production it is illegal in Uganda to fish on Lake Victoria with gill nets <127 mm (5 inch) mesh size and all forms of active fishing except light fishing for *R. argentea* are prohibited. It is also illegal to catch Nile perch <48 cm TL and Nile tilapia <25 cm TL which are caught in the smaller meshes. However, these regulations have never been fully implemented as these pratices continue. This calls for fresh management strategies to address the apparent long term ecological and economic consequences these practices may cause to the lake's fishery.

Socio-economic implications of the observations

Ecological considerations show that the total biomass of Nile perch will be reduced if fishing for juveniles depletes the population before growth allows accumulation of biomass by a cohort. Thus the fishing of juveniles will substantially diminish the total yields hence diminishing income to the fishers. Nile perch ≥2 kg (≥50 cm TL) is preferred by fish processing factories and fish mongers, it fetches a price 2-5 times higher than the price offered for an equivalent weight of smaller Nile perch. Thus price per fish would be much greater if the Nile perch were allowed to grow. Similarly for *O. niloticus*, adult tilapia commands the highest market price. Although fishers tend to exhibit a steep functional response to populations of fish and have a rapid commercial response, the majority of fishers on Lake Victoria cannot meet the costs required to fish in rich fishing grounds offshore. Successful fishing in offshore waters for large Nile perch requires a large number of nets of large mesh sizes which are more expensive than the small mesh size gill nets, a large boat, an outboard engine, fuel,

and a large number of crew (Fig 3-6). This is a heavy investment before one starts fishing for the desirable sizes of Nile perch that fetch a good price which ordinary fishers cannot afford. This implies that the undesirable fishing practices of the ordinary fishers using small boats <8.0m long will continue and intensify unless corrective measures with socio-economic considerations are put in place.

Management implications of the observations

Three distinct categories of fishing strategies could be recognised in the gill net fishery of Lake Victoria based on the two major commercial fish species the Nile perch (*L. niloticus*) and the Nile tilapia (*O. niloticus*):- (a) Large motorised fishing boats operating in far offshore waters targeting large Nile perch, (b) manually powered passively fishing boats operating in waters within about 3 km from the shoreline and targeting both Nile tilapia and Nile perch and (c) manually powered actively fishing boats operating in waters within about 300 m from the shoreline targeting Nile tilapia. Any management options to control the gill net fishery of Lake Victoria must consider this segregation in fishing practices in order to come up with a desirable impact.

The fishing practices of boats <8.0 m long whose Nile perch catches were composed of >73% fish ≤50 cm TL, have potential long term negative impacts on the Nile perch production in the lake through recruitment over-fishing. The catch of larger boats which was composed of <17 % of Nile perch ≤50 cm TL may comparatively have little harm to the potential production of Nile perch in the lake if the numbers of boats are controlled and they maintain use of large mesh size nets. The present threat to the tilapia fishery of Lake Victoria seems to be the open access to the resource and the increasing use of the gill net as an active method other than catching immature fish as is the case for Nile perch. The inputs required for one to start fishing inshore for tilapia, a small boat and few gill nets, are

affordable to many fishers, therefore with open access the number of boats fishing for tilapia will keep rising with time even when the catches decline. The use of active methods increases the efficiency of the gill net (Fig 14b) but it is difficult to assess effort and Catch Per Unit of Effort (CPUE) for management purposes because the size of catch does not necessarily depend on the abundance of fish in the lake. The size of the catch may be dependent on other factors like the number of hauls made which varies greatly depending on the catches and the skill of the fishers. Balirwa 1990 contends that as happened with the endemic tilapiines, a decline in CPUE with large meshed nets would lead to the use of smaller meshes while retaining the active operation of the gill nets. This premise may be true as nets of mesh sizes smaller than the legal minimum of 127 mm (5 inch) constituted 7.5 - 16.5 % of the number of gill nets carried by boats <8.0m long (Fig 4) and the practice of operating the gill net actively although illegal seemed to be popular among the fishers in the tilapia fishery.

Limitations of the study

1. The majority of fishing boats carried gill net fleets of mixed mesh sizes and the fish were removed from the nets before landing, therefore, it was not possible to determine the mesh size in which the individual fish landed were caught.
2. The duration of fishing was assumed to be uniform (one night) but in reality it changes with other factors like weather conditions, distance from the landing to the fishing ground, mode of operation of gill nets and the target fish species.
3. Fishing grounds were generalised as inshore or offshore according the relative distance from the landing to the fishing ground rather than according to depth, which could have been a better parameter.
4. The sampling did not take into account seasonal variations and lunar cycles, which may affect fish catches.

5. The sample size of only eight days at each landing due to funding constraints was small leading to small n - values.

Despite these limitations, the results of the study show clear trends that may guide fisheries management decisions on Lake Victoria thus achieving the general objective of the study.

4.2 Conclusions

The spatial distribution of fishing effort mainly depends on the size and power of a fishing boat. The larger the boat the more nets and crew it carries, the more fish it lands and the higher the income. The size and power of boat could, therefore, be an additional consideration when setting up management measures.

Large motorised boats ($\geq$8.0 m long) fish in offshore waters targeting large Nile perch >50 cm TL. Manually powered boats which are mainly <8.0 m long, fish in inshore waters targeting Nile tilapia and small Nile perch $\leq$50 cm TL. Manually powered boats that do active fishing with gill nets target Nile tilapia in inshore waters very close to the shoreline.

Thus, rational management of the *L. niloticus* fishery of Lake Victoria would require promotion of use of large motorised boats that land desirable sizes of fish and putting restrictions on the number of boats and/or mesh size of gill nets of manually powered boats that operate in inshore waters and land mainly immature fish. This would maximise both ecological and socio-economic benefits in the fishery.

The management of the *O. niloticus* fishery should focus on discouraging the active operation of gill nets, preventing increase in the number of boats operating in inshore waters and preventing further reduction of gill net mesh sizes.

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APPENDICES

Appendix 1. Percentage boat size distribution among boats fishing with gill nets sampled at the six landings. In brackets are the numbers of boat days.

	Boat length (m)						
Landing	5.0 - 5.9	6.0 - 6.9	7.0 - 7.9	8.0 - 8.9	9.0 - 9.9	10.0 - 10.9	11.0 - 11.9
Masese	25.9 (29)	54.5 (64)	19.6 (21)	--	--	--	--
Lingira	36.1 (26)	30.6 (22)	33.3 (24)	--	--	--	--
Bugonga	25.8 (25)	22.7 (22)	33.0 (32)	9.3 (9)	9.3 (9)	--	--
Kasenyi	23.0 (20)	19.5 (17)	16.1 (14)	14.9 (13)	13.8 (12)	12.6 (11)	--
Lambu	--	--	16.7 (8)	22.9 (11)	14.6 (7)	22.9 (11)	22.9 (11)
Kasensero	--	--	--	--	12.5 (13)	70.2 (73)	17.3 (18)

Appendix 2. Mean number (± 95%CL), of gill nets carried by fishing boats of different size.

Landing sites	Boat length (m)						
	5.0-5.9	6.0-6.9	7.0-7.9m	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9
Masese	14.0±2.2	14.9±1.2	12.7±1.6	--	--	--	--
Lingira	16.9±3.8	17.0±3.4	18.7±2.7	--	--	--	--
Bugonga	30.1±6.0	35.9±5.3	32.3±5.5	44.1±17.2	64.2±26.0	--	--
Kasenyi	25.3±2.9	31.6±7.4	50.6±7.2	69.5±18.4	70.3±27.4	93.1±26.0	--
Lambu	--	--	50.5±7.8	48.0±11.4	62.9±8.8	67.7±16.4	69.8±5.3
Kasensero	--	--	--	--	80.5±15.5	83.9±5.5	99.6±14.0
Overall	20.9±2.3	21.4±2.2	31.8±7.1	55.4±9.1	70.1±8.5	84.1±5.7	88.6±11.8

Appendix 3. ANOVA summary table for difference in mean number of gill nets carried by fishing boats of different sizes.

Source of Variation	SS	df	s^2	F
Between	39.76	6	6.62	124.1782
Within	26.63	499	0.05	
Total	66.39			

Appendix 4. Percentage gill net mesh size contribution to total number of gill nets in boats of different size.

Boat length (m)	Gill net mesh size (%)						
	76 mm (3 inch)	107 mm (4 inch)	127 mm (5 inch)	152 mm (6 inch)	178 mm (7 inch)	203 mm (8 inch)	254 mm (10 inch)
5.0-5.9	2.0	14.7	42.9	29.5	10.3	0.6	0.0
6.0-6.9	1.0	6.5	35.0	42.0	9.0	5.5	1.0
7.0-7.9	2.0	8.3	17.3	36.5	19.2	7.7	9.0
8.0-8.9	1.0	0.0	3.3	22.0	25.3	24.2	24.2
9.0-9.9	0.0	0.0	2.0	24.0	40.0	26.0	8.0
10.0-10.9	0.0	0.0	0.0	56.9	21.2	15.4	6.5
11.0-11.9	0.0	0.0	0.0	36.4	38.6	11.4	13.6

Appendix 5. Percentage number of gill netting fishing boats of different sizes manned by the different numbers of crew. In brackets are the numbers of boat days.

Number of rew	Boat length (m)						
	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9
1	7.0 (7)	1.6 (2)	1.0 (1)	3.0 (1)	--	--	--
2	88.0 (88)	91.1 (113)	75.8 (75)	75.8 (25)	61.9 (26)	13.8 (13)	3.6 (1)
3	6.0 (6.0)	7.3 (9)	23.2 (23)	21.2 (7)	33.3 (14)	85.1 (80)	92.8 (26)
4	--	--	--	--	6.0 (2)	1.1 (1)	3.6 (1)

Appendix 6. Percentage number of gill netting boats of different sizes fishing inshore and offshore. In brackets are the numbers of boat days.

Fishing ground	Boat length (m)						
	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9
Inshore	100 (96)	100 (124)	92.9 (92)	39.4 (13)	9.5 (4)	1.0 (1)	--
Offshore	--	--	7.1 (7)	60.6 (20)	90.5 (38)	99.0 (95)	100 (29)

Appendix 7. Mean total weight ± 95%CL of fish (kg) landed by boats of different sizes.

Landing sites	Boat length (m)						
	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9
Masese	9.2±2.2	10.8±2.1	10.1±4.3	--	--	--	--
Lingira	12.7±3.0	10.7±2.8	8.3±3.0	--	--	--	--
Bugonga	18.8±4.4	27.1±7.3	18.9±5.5	22.0±8.7	44.4±13.5	--	--
Kasenyi	9.69±5.8	12.7±6.0	21.4±8.2	32.0±11.3	42.3±12.0	56.0±28.2	--
Lambu	--	--	10.6±7.8	21.3±9.9	35.6±20.3	48.8±19.7	53.7±19.1
Kasensero	--	--	--	--	51.6±17.7	74.7±11.2	94.1±22.1
overall	12.6±1.9	13.8±2.1	14.1±2.6	25.7±5.7	44.5±7.2	70.1±9.5	78.2±16.4

Appendix 8. ANOVA summary table for difference in mean weight of fish landed by fishing boats of different sizes.

Source of Variation	SS	df	s^2	F
Between	895.1	6	149.2	15.0367
Within	59.5	513	9.9	
Total	954.6			

Appendix 9. Percentage mean weight contribution of different fish species to the total fish catches of boats of different sizes.

Boat length (m)	Fish species weight (%)		
	Lates niloticus	*Oreochromis niloticus*	Other fish species
5.0-5.9	46.8	44.2	9.0
6.0-6.9	40.1	48.9	11.0
7.0-7.9	69.0	18.3	12.7
8.0-8.9	97.7	2.3	0.0
9.0-9.9	100.0	0.0	0.0
10.0-10.9	98.3	1.7	0.0
11.0-11.9	99.5	0.5	0.0

Appendix 10. Percentage Length frequency distribution of *Lates niloticus* in boats of different sizes. In brackets are the numbers of fish measured.

Fish Total length (c m)	Boat length (m)						
	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9
16-20	2.7 (13)	2.1 (8)	1.3 (7)	--	--	--	--
21-25	7.9 (38)	9.4 (36)	6.4 (34)	0.9 (2)	--	--	--
26-30	20.5 (98)	10.1 (39)	17.0 (91)	0.9 (2)	--	0.3 (3)	0.3 (1)
31-35	26.1 (125)	20.6 (79)	15.5 (83)	2.2 (5)	0.6 (2)	0.5 (6)	0.6 (2)
36-40	13.2 (63)	16.4 (63)	13.7 (73)	3.0 (7)	0.6 (2)	0.7 (8)	1.1 (4)
41-45	11.7 (56)	10.9 (42)	10.5 (56)	4.3 (10)	1.8 (6)	0.9 (10)	0.6 (2)
46-50	6.9 (33)	8.1 (31)	9.2 (49)	5.6 (13)	5.7 (20)	6.9 (78)	2.2 (8)
51-55	5.7 (27)	8.6 (33)	8.0 (43)	15.1 (35)	22.5 (77)	22.9 (260)	17.9 (64)
56-60	2.9 (14)	6.8 (26)	7.4 (40)	21.1 (49)	23.4 (80)	27.1 (308)	31.1 (111)
61-65	0.8 (4)	1.8 (7)	4.9 (26)	14.7 (34)	19.9 (69)	16.9 (192)	17.6 (63)
66-70	0.8 (4)	1.6 (6)	2.1 (11)	11.2 (26)	10.8 (37)	12.1 (138)	12.9 (46)
71-75	0.2 (1)	2.3 (9)	1.5 (8)	6.0 (14)	9.1 (31)	4.9 (56)	5.6 (20)
76-80	0.4 (2)	1.0 (4)	0.6 (3)	3.4 (8)	3.2 (11)	3.5 (40)	2.0 (7)
81-85	0.2 (1)	0.3 (1)	0.4 (2)	1.7 (4)	1.5 (5)	1.1 (13)	1.7 (6)
86-90	--	--	1.3 (7)	2.2 (5)	0.6 (2)	0.8 (9)	1.7 (6)
91-95	--	--	0.2 (1)	3.0 (7)	0.3 (1)	0.4 (5)	2.0 (7)
96-100	--	--	--	1.3 (3)	--	0.4 (4)	1.7 (6)
>100	--	--	--	3.4 (8)	--	0.6 (7)	1.1 (4)

Appendix 11. Percentage Length frequency distribution of *Oreochromis niloticus* in boats of different sizes. In brackets are numbers of fish measured.

Fish total length (cm)	Boat length (m)			
	5.0-5.9	6.0-6.9	7.0-7.9	8.0-11.9
11-15	--	--	0.9 (2)	--
16-20	0.7 (4)	--	2.8 (6)	4.4 (2)
21-25	14.2 (76)	1.0 (6)	4.1 (9)	6.7 (3)
26-30	19.9 (107)	14.2 (89)	3.2 (7)	2.2 (1)
31-35	28.1 (151)	30.7 (193)	13.4 (29)	2.2 (1)
36-40	27.6 (148)	42.8 (269)	44.7 (97)	20.0 (9)
41-45	8.3 (45)	9.9 (62)	27.7 (60)	37.9 (17)
46-50	0.6 (3)	1.1 (7)	2.3 (5)	22.2 (10)
51-55	0.4 (2)	0.2 (1)	0.9 (2)	2.2 (1)
56-60	--	0.2 (1)	--	2.2 (1)
61-65	0.2 (1)	--	--	--

Appendix 12. Mean number (± 95%CL) of gill nets carried by manual and engine powered boats at Lambu, Bugonga and Kasenyi fish landing sites.

Landing site	manually powered boats	motorised boats
Lambu	48.6±6.2	66.0±8.6
Bugonga	33.6±3.7	51.4±11.3
Kasenyi	31.4±4.5	70.4±10.2
Overall	35.1±2.7	65.1±6.0

Appendix 13. ANOVA summary table for difference in mean number of gill nets carried by motorised and manually powered boats.

Source of Variation	SS	df	s^2	F
Between	4.031	1	4.031	101.198
Within	8.286	208	0.040	
Total	12.137			

Appendix 14. Percentage number of motorised and manually powered gill netting fishing boats manned by the different numbers of crew. In brackets are the numbers of boat days.

Number of crew	mode of propulsion of boat	
	motorised	manually powered
1	--	2.2 (7)
2	28.3 (56)	85.6 (274)
3	70.2 (139)	11.9 (38)
4	1.5 (3)	0.3 (1)

Appendix 15. Percentage number of motorised and manually powered boats fishing inshore and offshore. In brackets are the numbers of boat days

Fishing ground	mode of propulsion of boat	
	manually powered	motorised
Inshore	100.0 (324)	5.6 (11)
Offshore	--	94.4 (184)

Appendix 16. Mean fish catches by weight (kg) of motorised and manually powered boats at Lambu, Bugonga and Kasenyi fish landing sites.

Landing site	mean weight ± 95%CL of fish by species (kg)							
	L. niloticus		*O. niloticus*		Other species		Total	
	motorised	manual	motorised	manual	motorised	manual	motorised	manual
Lam bu	50.2 ± 9.1	11.9 ± 4.5	0.76 ± 1.0	0.42 ± 0.9	--	6.50 ± 1.1	50.9 ± 9.3	12.3 ± 4.7
Bugonga	30.4 ± 7.4	21.0 ± 3.5	0.07 ± 0.1	0.70 ± 0.6	--	0.10 ± 0.1	30.4 ± 7.5	21.8 ± 3.7
Kasenyi	39.8 ± 9.5	6.1 ± 3.1	1.40 ± 1.8	5.50 ± 2.8	0.18 ± 0.4	0.02 ± 0.02	41.6 ± 9.1	11.6 ± 3.5
Overall	41.1± 2.80	14.8 ± 2.46	0.92 ± 0.93	2.17 ± 1.03	0.09 ± 0.18	0.14 ± 0.16	42.3 ± 5.52	17.1 ± 2.48

Appendix 17. ANOVA summary table for difference in mean weight of fish landed by motorised and manually powered boats.

Source of Variation	SS	df	s^2	F
Between	10.36	1	10.36	86.98
Within	24.77	208	0.119	
Total	35.13			

Appendix 18. Mean number of gill nets carried by active and passive boats at Masese and Lingira fish landing sites.

Landing site	mean number ± 95%CL of gill nets per boat	
	Active boats	Passive boats
Masese	13.7 ± 0.9	17.3 ± 4.5
Lingira	13.2 ± 2.4	21.2 ± 2.4
Overall	13.6 ± 0.9	20.6 ± 2.11

Appendix 19. ANOVA summary table for difference in mean number of gill nets carried by actively and passively fishing boats.

Source of Variation	SS	df	s^2	F
Between	1570.16	1	1570.16	48.8809
Within	5846.24	181	32.12	
Total	74146.40			

Appendix 20. Percentage number of gill netting boats fishing actively and passively manned by the different numbers of crew. In brackets are the numbers of boat days.

Number if boat crew	mode of operation of gill nets	
	Active	Passive
1	--	3.8 (7)
2	100 (134)	75.3 (140)
3	--	20.4 (38)
4	--	0.5 (1)

Appendix 21. Mean fish catch rates of active and passive boats at Masese and Lingira fish landing sites

Landing Site	mean weight ± 95%CL of fish per boat (kg)								mean weight of fish caught per net (kg)	
	Active				Passive				Active	Passive
	O. niloticus	*L. niloticus*	Other fish spp	Total	*O. niloticus*	*L. niloticus*	Other species	Total	All species	All species
Masese	8.8±1.2	1.4±0.6	0.14±0.1	10.2±1.4	2.7±4.1	1.35±2.7	--	4.1±4.0	0.38±0.14	0.27±0.33
Lingira	10.8±2.0	0.8±0.5	0.86±0.9	12.4±2.2	3.5±1.8	5.4±2.4	0.05±0.08	9.0±2.5	1.33±0.41	0.45±0.12
Overall	9.27±1.1	1.2±0.5	0.32±0.2	10.8±1.2	3.4±1.6	4.8±2.1	0.05±0.06	8.3±2.3	0.96±0.15	0.43±0.11

Appendix 22. ANOVA summary table for difference in mean weight of fish landed by actively and passively fishing boats.

Source of Variation	SS	df	s^2	F
Between	201.85	1	201.85	3.8999
Within	9368.2	181	51.76	
Total	9570.05			

Appendix 23. ANOVA summary table for difference in mean weight of fish caught per net per night by actively and passively fishing boats.

Source of Variation	SS	df	s^2	F
Between	0.44	1	0.442	20.4279
Within	3.91	181	0.022	
Total	4.35			