THE UNIVERSITY OF HULL

Exploitation and management of the artisanal fisheries in the Ugandan waters of Lake Victoria

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SUMMARY

The fisheries resources of Lake Victoria support the livelihoods to the lakeside rural communities and are vital to the economies of Kenya, Tanzania and Uganda, especially through fish exports. Management decisions to enable long-term sustainable exploitation of these fisheries require appropriate knowledge of the fishing effort and catch statistics, as these are pertinent for evaluating the fish stocks and future prospects of the fishery. Catch assessment programmes in the Ugandan part of the lake, which should provide this type of information, collapsed in the late 1980s. This study evaluated the current status of fishing effort and fish catches and their implications for the management of the fisheries in the Ugandan part of Lake Victoria. Historical trends in fishing effort and fish catches, total fishing effort in 1990 and 2000, and the current status of fish catch-effort, in the Ugandan part of the lake, were examined.

The findings revealed massive increases in all aspects of fishing effort over the last decade. Fishing boats approximately doubled, from 8000 to 15 462 boats, and gillnets almost quadrupled, from 84 977 to 294 529 nets, between 1990 and 2000. Gillnet mesh sizes declined from mainly 203 and 178 mm to ≤152 mm, and illegal gillnets <127 mm mesh size increased from 5 to 18.6%, between 1990 and 2000. Illegal gillnets constituted 53 and 23% of nets in parachute and paddled Sesse boats (small boats that operate in inshore areas) but only 1.9% in motorised boats. Other illegal gears, especially beach seines, operated inshore and indiscriminately catch juvenile fish, also increased considerably. These changes in fishing effort were coupled with declining catch per unit of effort and are considered indicators of a declining fishery, suggesting that the current fishing effort is not sustainable. The present exploitation rates and fishing mortalities of Nile perch (*Lates niloticus* L.) and Nile tilapia (*Oreochromis niloticus* L.) in the Ugandan waters were found to be excessive and require large reductions of fishing effort to achieve optimum yield. The use of illegal fishing gears and the overall fishing effort is highest in the eastern zone of the Ugandan waters, and in Kenyan waters at the regional level. Fishing strategies in the gillnet fishery, the predominant fishery for Nile perch and Nile tilapia, vary with boat type, suggesting that the regulation of fishing effort should be tailored to category of boat. Selection characteristics of the main fishing gears/methods in the Nile perch fishery suggested that fish above the minimum recommended 50 cm TL could be obtained from catches of drift gillnets with the minimum mesh size at 152 mm. The present long line fishery is largely non-selective and should be discouraged. Illegal, active fishing with gillnets and cast nets, which disrupt breeding of tilapiines inshore, prevail in the Nile tilapia fishery, and are indicative of overexploitation. The present fishing effort for *Rastrineobola argentea* in Ugandan waters approximates to the maximum sustainable yield, but is basically restricted inshore, where the 5-mm mesh size mosquito nets used catch mostly juveniles. Expansion of fishing effort without endangering sustainability in this fishery would probably be viable with reorientation of fishing to offshore stocks.

To reduce fishing mortality in the short term, in the Nile perch and Nile tilapia fisheries, immediate interventions should control the size of fish caught. This should be through enforcement of existing legislation on fishing gears that target the younger life stages of fish and regulating the size of Nile perch purchased by fish processing factories. In the long term, the quantities of fish processed by factories should be regulated by a quota system, consistent with the fishery production potential of the lake. Long lining should be discouraged pending further scientific investigations of hook selectivity characteristics. The minimum gillnet mesh size limit should be maintained at 127 mm in paddled boats but raised to 152 mm in motorised boats to reduce overall pressure on juvenile Nile perch and competition between the large-scale and small time operators, and promote social objectives of the fishery. Access to the fisheries should be limited because this is the overriding factor contributing to the present unsustainable status. Fisheries statistical data collection in Uganda (and Tanzania) should be revived and fisheries data, collection and reporting systems should be harmonised around the lake. The process of streamlining institutional mechanisms and legal instruments under which fishing communities will play important roles in fisheries management (co-management), should be accelerated. However, for any institutional arrangement to succeed in managing the fisheries of Lake Victoria, mechanisms for sustainable funding of fisheries activities should be established.

DEDICATION

... to my father, the late Eriazari Kayebire. His love for education always inspired me to aim higher. Senseless assailants murdered him in cold blood on 2 August 2002 while I was at the University of Hull writing up this thesis. He was prevented from sharing the joy of my completion of this study. May his soul rest in everlasting peace.

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CHAPTER ONE

1. GENERAL INTRODUCTION

1.1 Description of Lake Victoria

Lake Victoria in East Africa, with a surface area of approximately 68,500 km^2, is the largest lake in Africa and the second largest freshwater body in the world after Lake Superior in North America. The southern part (51% of the surface area) lies in Tanzania, the northern part (43%) in Uganda; and the north-eastern part (6%) in Kenya (Fig. 1.1).

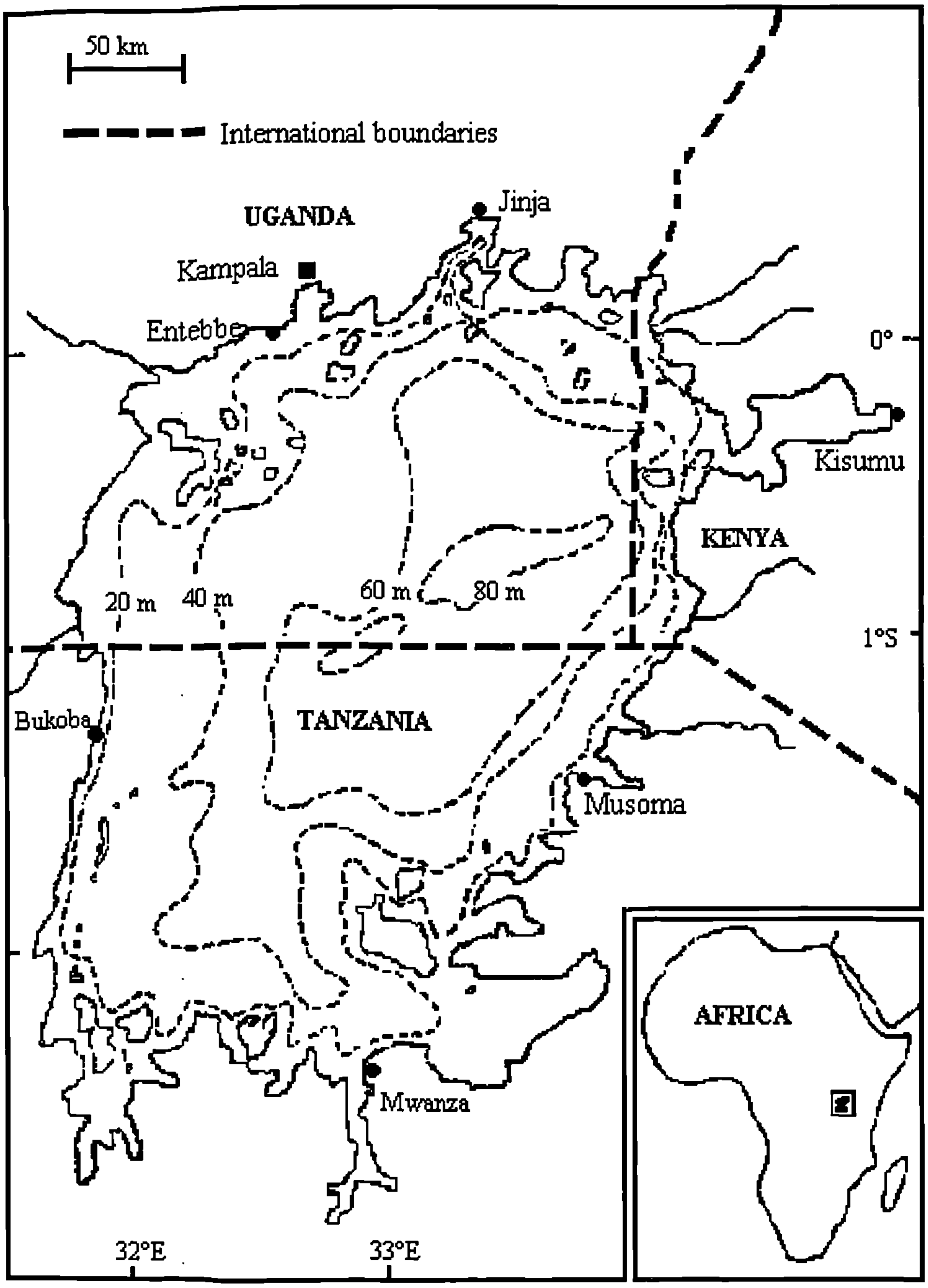


Figure 1.1 The location of Lake Victoria in Africa

A summary of the basic topographical features of the lake is presented in Table 1.1. The main input of water to the lake is rainfall and inflowing rivers and it has only one outlet, the Victoria Nile. But this accounts for part of the water loss, the remainder being evaporation.

Table 1.1 Morphometry, hydrological balance and geographical features of Lake Victoria

Characteristic	Measure
Position: Latitude	0° 20'N – 3° 00' S
Longitude	31° 39'E – 34° 53'E
Altitude (m above sea level)	1134
Catchment's area (km^2)	184000
Lake Basin area (km^2)	68500
Shore line length (km)	3440
Maximum length (km)	400
Maximum width (km)	240
Mean width (km)	172
Maximum depth (m)	84

Characteristic	Measure
Mean depth (m)	40
Volume (km^3)	2760
Inflow (km^3 $year^{-1}$)	20
Outflow (km^3 $year^{-1}$)	20
Precipitation (km^3 $year^{-1}$)	114
Annual lake level fluctuations (m)	0.4 -1.5
Maximum rise in Lake level (m)	2.4
Flushing time (years)	138
Residence time (years)	21

Sources (Hecky & Bugenyi, 1992; Spigel & Coulter, 1996; Balirwa, 1998)

1.2 Review of the development of the fisheries of Lake Victoria

Until the 1970s, the lake hosted a dynamic multi-species fishery in the form of tilapiine and haplochromine cichlids, but also with important subsidiary fisheries of more than 20 genera of non-cichlid fish, such as mormyrids, catfish, cyprinids and lungfish. The naturally occurring fish fauna was modified during the 1950s following the introduction of four non-indigenous tilapias (*Oreochromis niloticus* (Linnaeus, 1757), *Oreochromis leucostictus* (Trewavas, 1933), *Tilapia zillii* (Gervais, 1848) and *Tilapia rendalli* (Boulenger, 1896)), and was further altered around 1960 by the introduction of Nile perch (*Lates niloticus* (Linnaeus, 1758)). This resulted in the gradual development of the fisheries of Lake Victoria from the initial, purely subsistence fishing, to commercial-oriented fishing with adjustments to exploit the introduced fish species. Drastic changes in occurrence and distribution patterns happened amongst all fish taxa in Lake Victoria around the same time as the establishment of Nile perch in the lake (Tables 1.2). The Nile perch boom also coincided with changes in the trophic composition of the haplochromine cichlid assemblage, with strong reduction in numbers of species of piscivores, which were formerly dominant and apparent extinction of prawn eaters, whereas, other groups such as algae scrapers and insectivores were less affected (Seehausen, 1999).

Table 1.2 Occurrence of different fish taxa by depth ranges in bottom trawl catches in the pre-Nile perch boom era (• 1969-1971, (Kudhongania & Cordone, 1974)) and the post-Nile perch boom era (o 1993-1998 (Okaronon *et al.*, 1999)) (modified from Okaronon, *et al.*, 1999)

Species	Water depth (10-m intervals)												
	0-9	10-19	20-29	30-39	40-49	≥50		0-9	10-19	20-29	30-39	40-49	≥50
Afromastacembelus frenatus (Boulenger, 1901)	•	•	•	•									
Bagrus docmak (Forsskåll, 1775)	•	•	•	•	•	•		o	o				
Barbus altianalis (Boulenger, 1903)	•	•	•	•	•				o	o			
Other *Barbus* spp.								o	o	o	o	o	o
Brycynus spp.	•							o					
Clarias gariepinus (Burchell, 1822)	•	•	•	•	•	•		o	o				
Haplochromines	•	•	•	•	•	•		o	o	o	o	o	o
Gnathonemus longibarbis (Hilgendorf, 1888)	•	•	•										
Labeo victorianus (Gervais, 1848)	•	•	•						o				
Lates niloticus (Linnaeus, 1758)	•	•	•					o	o	o	o	o	o
Mormyrus kannume (Forsskåll, 1775)	•	•	•	•	•	•			o				
Oreochromis esculentus (Graham, 1929)	•	•	•	•									
Oreochromis leucostictus (Trewavas, 1933)	•	•						o	o				
Oreochromis niloticus (Linnaeus, 1758)	•	•						o	o	o			
Oreochromis variabilis (Boulenger, 1906)	•	•	•					o					
Protopterus aethiopicus (Heckel, 1851)	•	•	•	•	•	•		o	o				
Schilbe intermedius (Linnaeus, 1758)	•	•	•	•	•	•							
Synodontis afrofischeri (Hilgendorf, 1888)	•	•	•	•	•	•		o	o				
Synodontis victoriae (Boulenger, 1906)	•	•	•	•	•	•			o	o	o		
Tilapia zillii (Gervais, 1848)	•	•						o	o				
Xenoclarias eupogon (Norman, 1928)	•	•	•	•	•	•		o					

1.2.1 *Evolution of the fisheries of Lake Victoria*

The first fisheries of Lake Victoria by lakeside tribes were for subsistence purposes, using local materials for fishing such as seine nets of papyrus and reeds, basket traps, harpoons and hooks operated from simple rafts or dugout boats (Graham, 1929; Jackson, 1971). These initial fisheries were restricted to areas close to the shore and had little impact on fish stocks. Commercial fisheries started in Lake Victoria at the beginning of the 20th century when cotton flax gillnets were first introduced in 1905 into the Nyanza Gulf in Kenya. Gillnets were quickly adopted and the native methods of fishing soon died out except in a few remote areas (Jackson, 1971). The main target fish species of gillnets were two endemic tilapiine cichlids, *Oreochromis esculentus* (Graham, 1929) and *Oreochromis variabilis* (Boulenger, 1906), but catches of the large catfishes, mormyrids, *Protopterus aethiopicus* (Heckel, 1851), *Labeo victorianus* (Boulenger, 1901) and *Barbus* spp. were also important (Graham, 1929; Lowe-McConnell, 1997).

Following the introduction of gillnets fishing craft were also improved, the most important innovation being the dhow-type sailing rig, a propulsion method superior to paddling. These improvements in fishing craft and gears coincided with the development of railways that reached Kisumu on the shores of the lake in Kenya in 1908, and better roads, thus opening the way for fish to larger markets outside the immediate areas surrounding the lake. Demand for fish was also increased by development of urban centres and increasing human population around the lake. To satisfy the increasing demand for fishery products, fishing effort increased greatly.

Soon after the onset of commercial fishing, problems associated with all commercial fisheries began to be felt. As the years passed, the catches became smaller and the fishing boats had to ply waters further a field. The initial catch rates of tilapia in 1905, with five inch (127 mm) mesh size gillnets ranged from 50 to 100 fish in a single net about 50 m long (Worthington and Worthington, 1933). Twenty years later the catch rates in 127-mm mesh size gillnets had declined to about six fish per net and smaller mesh sizes, which had better catch rates, had been introduced, which suggested overfishing. The drastic decline in catch rates prompted the first fishery survey of Lake Victoria in 1927-8 (Graham, 1929). This survey confirmed that the stocks of *O. esculentus* were being over fished and recommended a minimum gillnet mesh size limit of 127 mm, which was imposed in 1931, but the entry of fishing boats into the fishery was not restricted. Fishing effort continued to increase as more boats entered the fishery along with the increase in human populations, and as new markets for fish became available due to improved transport to urban centres (Ogutu-Ohwayo, 1990a; Ogutu-Ohwayo *et al.,* 1997). Consequently, the catch per net continued to fall and fishers responded by ignoring the 127-mm gillnet mesh size limit, shifting to smaller illegal mesh sizes that gave better catches. The 127-mm minimum gillnet mesh size regulation became very difficult to enforce and was repealed in Uganda and Tanzania in 1956 and in Kenya in 1961, which also marked the end of uniform management for the fisheries of the lake (Ogutu-Ohwayo *et al.*, 1997).

Fishing pressure was further intensified by introduction of more efficient and long life span synthetic fibre gillnets in 1952 that eventually replaced cotton flax nets, and improved transportation on the lake through the introduction of outboard engines in 1953 (Jackson, 1971; Ogutu-Ohwayo *et al.*, 1997; Lowe-McConnell, 1997). The increase in efficiency of fishing operations by acquiring better fishing gears, improved transport on the lake, increase in total fishing effort and geographical extension of fishing operations maintained the fish yield from Lake Victoria, but against a continuous decrease in catch per unit of effort and mean size of fish caught; the catch per unit of effort fell to 0.35 tilapia per net by 1968 (Jackson, 1971).

Following the depletion of large sized fish species, fishers shifted to exploit the smaller species principally the haplochromines and *Rastrineobola argentea* (Pellegrin, 1904) (Ogutu-Ohwayo *et al.*, 1997). Very small mesh size nets of the size range 38 to 46 mm were introduced to harvest haplochromines and fine seine nets of 10 mm mesh size to exploit *R. argentea*. The seine nets were particularly problematic because they caught juveniles of the larger species and their dragging destroyed the breeding grounds of many cichlids in the littoral areas (Lowe-McConnell, 1956; Acere, 1988; Ogutu-Ohwayo et. al., 1997).

1.2.2 *Introduction of alien fish species into Lake Victoria*

In the 1950s, populations of the tilapiine cichlids, the principal species supporting the fishery, had decreased to very low levels following the intensification of the gillnet fishery (Fryer & Iles, 1972; Fryer, 1973). To boost tilapiine production, four alien species, *O. niloticus, O. leucostictus, T. zillii* and *T. rendalli* were introduced into the lake in the mid 1950s and early 1960s (Gee, 1964; Welcomme, 1966; 1968; 1988). The first two, *O. niloticus* and *O. leucostictus*, were introduced to supplement the stocks of the native tilapiines that had declined due to overfishing; *T. zillii* to feed on the abundant macrophytes, which were not being utilised by any other commercially-important species; whereas *T. rendalli* probably arrived accidentally in the lake from fish ponds (Gee, 1964).

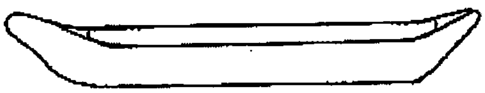
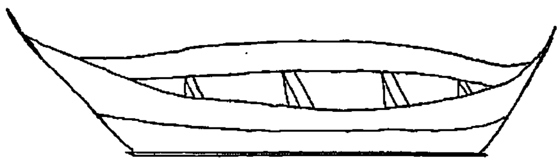
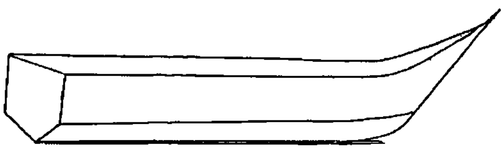
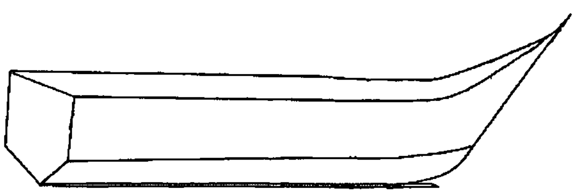
In addition to the tilapiines, a large piscivorous fish, Nile perch (*L. niloticus*), was also introduced into the lake during the late 1950s and early 1960s. The Nile perch was first unofficially introduced into the Ugandan part of Lake Victoria amidst unresolved controversy over the anticipated ecological and social consequences of such an introduction (Fryer, 1960; Jackson, 1960; Anderson, 1961). The debate on whether to introduce it ended prematurely when the first Nile perch was caught in the Ugandan part of the lake in May 1960 and the focus changed to studies of its biology in the new environment (Hamblyn, 1960; 1962; Gee, 1964; and Okedi, 1971). Further stocking was then carried out in 1962 by the Uganda Fisheries Department with fish from Lake Albert, and in 1963 by the Kenya Fisheries Department with fish from Lake Turkana (Gee, 1964).

1.2.3 *The fish community and fisheries of Lake Victoria after the introduction of alien fish species*

By 1970, the Nile perch had spread around the lake (Kudhongania & Cordone, 1974), but its numbers remained low until around 1978 when it started dominating the catches (Ogari, 1985). In the 1980s, population explosions of Nile perch occurred in all parts of the lake and the consequences of its effects on the lake's ecology and fisheries became more apparent (Acere, 1985; Ogutu-Ohwayo, 1990a; Witte *et al.*, 1992). Along with the massive increase in Nile perch catches, landings of all other species dropped, with the exception of *O. niloticus*, another introduced species and the native *R. argentea* (Acere, 1985; Goudswaard and Witte, 1985). In the present fisheries of Lake Victoria, different types/categories of fishing boats are also more or less specialised for exploitation of particular fisheries (Table 1.3)

Lake Victoria had a fish fauna that was dominated until recently by more than 300 species of haplochromine cichlids (Greenwood, 1974; Witte *et al.*, 1992). Approximately 200 haplochromine cichlid species vanished simultaneously with the rapid increase in population size of Nile perch in the 1980s. Some researchers (Acere, 1988; Harrison *et al.*, 1989), suggested the Nile perch was only partly to blame for the decline of the haplochromines, and the main cause was overfishing. Harrison *et al.* (1989) noted that in the inshore areas of the Nyanza Gulf where fishing was banned, haplochromine catches were considerably higher than in neighbouring areas where fishing was allowed. Other researchers (Witte *et al.*, 1992; Witte & Goudswaard, 1985; Seehausen *et al.*, 1997) agreed that fishing had had deleterious effects on the

Table 1.3 Sketches and description of the fishing characteristics of the present key fishing boat types/categories operating in the Ugandan part of Lake Victoria

Boat type/category	Description
1. Dugout boat 	▪ Curved out of a whole log of a tree. ▪ Common size, 4 to 5 m long ▪ Entirely propelled by paddle ▪ Operated exclusively in the littoral areas targeting Nile tilapia ▪ The main fishing gears used are gillnets and basket traps
2. Parachute 	▪ Constructed from several planks of timber ▪ Flat bottomed ▪ Common size, 4 to 5 m long ▪ Entirely propelled by paddle ▪ Operated exclusively in the littoral areas targeting Nile tilapia ▪ The main gears used are gillnets, cast nets and basket traps
3. Sesse pointed at both ends 	▪ Constructed from several planks of timber ▪ V-shaped bottom with a keel ▪ Common size, 6 to 10 m long ▪ Mainly propelled by paddle but a few have sails ▪ Operated in the littoral and sub-littoral areas, up to about 3 km from the shore ▪ Predominantly used in the *R. argentea* fishery with mosquito seines
4. Sesse flat at one end (Paddled) 	▪ Constructed from several planks of timber ▪ V-shaped bottom with a keel ▪ Common size, 5 to 8 m long ▪ Operated in the littoral and sub-littoral areas, up to about 3 km from the shore ▪ Largely unspecialised, i.e. used in the *R. argentea* with mosquito seines; in the Nile tilapia fishery with gillnets, cast nets and basket traps; and in the Nile perch fishery with gillnets, beach seines, long lines and hand lines
5. Sesse flat at one end (motorised) 	▪ Constructed from several planks of timber ▪ V-shaped bottom with a keel ▪ Common size, 7 to 12 m long ▪ Mainly target pelagic Nile perch in offshore waters with mid-water set drift gillnets and long lines

haplochromines but maintained that it was difficult to separate the effects of fishing and Nile perch predation. Environmental changes and overfishing played a role in the decline of the haplochromines but Nile perch was the likely key factor, especially in sub littoral (6-20m deep) and offshore (>20m) waters (Witte *et al.*, 1992). The proponents of the Nile perch introduction into the lake expected it to feed on the abundant haplochromines and convert them into a larger fish of greater commercial and recreational value (Anderson, 1961), and it appears to have done exactly that. By 1987, the contribution of haplochromines to the demersal ichthyomass had decreased from about 80% recorded between 1968 and 1971 (Kudhongania and Cordone, 1974) to less than 1% (Witte *et al.*, 1992).

Lake Victoria formerly supported important fisheries, based largely on herbivores and detritus feeders of the family Cichlidae. Fisheries based on such short food chains are ecologically the most efficient (Barel *et al.*, 1985). The food web of Lake Victoria, especially that of the sub littoral and deep waters changed considerably due to the increase in Nile perch and the disappearance of haplochromines (Litvoet & Witte, 1991). In contrast to the haplochromine zooplanktivores, the pelagic *R. argentea* increased strongly in numbers and biomass following the Nile perch explosion (Wanink, 1991). *Rastrineobola argentea* is considered r-selected compared with the more k-selected haplochromines, the latter being typically low fecundity organisms with extensive parental care (Goldschimidt & Witte, 1990). The difference in reproductive styles between the zooplanktivorous haplochromines and *R. argentea* was suggested to have caused the difference in ability to coexist with Nile perch (Bruton, 1990; Wanink, 1991). The freshwater shrimp, *Caridina nilotica* (Roux, 1833) and *R. argentea* became important prey of Nile perch after the decline of haplochromines (Ogutu-Ohwayo, 1990b). Besides *R. argentea*, the exotic Nile tilapia (*O. niloticus*) is the only other fish species that is flourishing in the presence of the Nile perch. Nile tilapia replaced the endemic tilapiines, mainly through competition and possibly hybridisation. These fish, particularly the young ones, live in the littoral and sub-littoral regions of the lake and have a minimal overlap with Nile perch (Lowe-McConnell, 1987; Welcomme, 1988;Ogutu-Ohwayo, 1990a). The two species also coexist in lakes Albert and Turkana. Man, through fishing, is currently the top predator of the Lake Victoria food web, and fisheries have the potential to alter further the community structure and dynamics of the lake (Schindler *et al.*, 1998).

1.2.4 *Recent ecological changes in Lake Victoria with impacts on fish species assemblage and fisheries of the lake*

In the recent past, Lake Victoria has undergone rapid eutrophication as a result of regional climate changes, increased nutrient inputs from the atmosphere and the catchment, reduction and reclamation of the buffer wetland zone and the colonisation by water hyacinth (Balirwa, 1995). Symptoms of eutrophication, e.g. algal blooms, anoxia and subsequent fish kills have been observed in various bays and near shore areas (Schneider & van Dijk, 1994). Primary production doubled, and algal biomass increased eight to ten-fold, accompanied by a shift in algal species composition from domination by diatoms characteristic of a mesotrophic system, to a eutrophic system dominated by blue green algae (Hecky, 1993; Mugidde, 1993). The increasing turbidity and deoxygenation, caused by the eutrophication, probably broke down the complexly balanced food web through a combination of demersal haplochromines displacement and increased invertebrate abundance (Hecky, 1993). In turn, the increased abundances of insect larvae and the atypid shrimp, *Caridina nilotica* (Witte *et al.,* 1992) probably favoured survival of juvenile Nile perch, which fed predominantly on invertebrates (Ogutu-Ohwayo, 1990b). Although the haplochromine community was trophically diverse it had limited ability to respond to a rapidly increasing food supply due to fertilisation of the lake by excess nutrients because haplochromines have a K-selected life history compared with the more r-selected invertebrates and Nile perch (Witte *et al.*, 1992; Hecky, 1993). The optical clarity of the waters of Lake Victoria also deteriorated with the increasing load of dissolved organic matter and suspended particles with the consequences of physiological inability of many haplochromines to find prey in the poor light environment but poor visibility had little effect on Nile perch which has enhanced vision, and the detritivorous invertebrates that do not require light to find food (Seehausen *et al.*, 2003).

1.2.5 *The new fisheries of Lake Victoria*

The fisheries of lake have undergone drastic changes in its recent history. They changed radically from a focus on native species before 1970 to dominance in catches of Nile perch, introduced tilapiines, and the native pelagic cyprinid *R. argentea* (Ogutu-Ohwayo, 1990a). Following the increase in the Nile perch stock in the lake, an important artisanal fishery developed. The total fishery yield increased considerably, during the 1980s and supported a prosperous industry based largely on gillnet fishing for Nile perch and Nile tilapia (Greboval, 1990). In the 1960s, the fisheries sustained a production of around 100,000 t year^{-1} but since the late 1970s when Nile perch started appearing in the catches, total catches increased 4-5 fold, to approximately 400,000 t in the second half of the 1980s, making Lake Victoria the largest freshwater fishery in the world (Reynolds & Greboval, 1988; Greboval, 1990; Reynolds *et al.,* 1995). Thus from the fishery point of view, the Nile perch could be considered successful (Barel *et al.*, 1985). However, the present fisheries are much simpler than before, being dominated by only three species: the Nile perch, Nile tilapia and *R. argentea.* Also, the lake ecosystem is still changing; therefore, it is not clear whether this harvest is sustainable. For example, in Lake Kyoga, where Nile perch became established first, the total landings, and Nile perch landings in particular, have declined considerably since the extremely high catches in the 1970s (Ogutu-Ohwayo, 1990a). A survey carried out in Lake Kyoga in 1985 at nine important fish landing sites gave proportions of the different species as 78.5% for Nile tilapia 16.7% for Nile perch and 4.8% other species, whereas earlier in the 1970s, the two species contributed almost equally to the total landings (Ogutu-Ohwayo, 1990a). What is most worrying for Lake Victoria, is that the mean size of the individual fish caught from the lake has been declining steadily, even during the 1980s when Nile perch catches were increasing, following the explosive increase in Nile perch stocks (Laggis, 1992). Fishers are switching to progressively smaller meshes in gillnets and juvenile Nile perch are increasingly exploited by beach seine fisheries in many areas (Kitchell *et al.*, 1997). In recent years, there has been a resurgence of the cichlid populations as fishing pressure on Nile perch intensified and predation on them decreased (Witte *et al.,* 2000). The bioenergetics model for Lake Victoria (Kitchell *et al.*, 1997) had indeed predicted the recovery of haplochromines with increasing exploitation of Nile perch. The recovering haplochromines are dominated by zooplanktivores, which might also cause a decline in the *R. argentea* population through competition for food as the latter had increased substantially after the decline of the haplochromine cichlids in the 1980s (Wanink, 1999; Wanink & Witte, 2000; Witte *et al.*, 2000). This scenario suggests that the continued abundance of fish resources in the lake should not be taken for granted.

1.2.6 *Trends of fishing effort and fishery production*

In the Ugandan part of the lake the numbers of fishing boats remained fairly stable from 1970 to 1988, increasing modestly by only 827 boats from 2643 to 3470, but in the following years they increased tremendously to 8000 in 1990 and 15,462 in 2000 (Fig. 1.2).

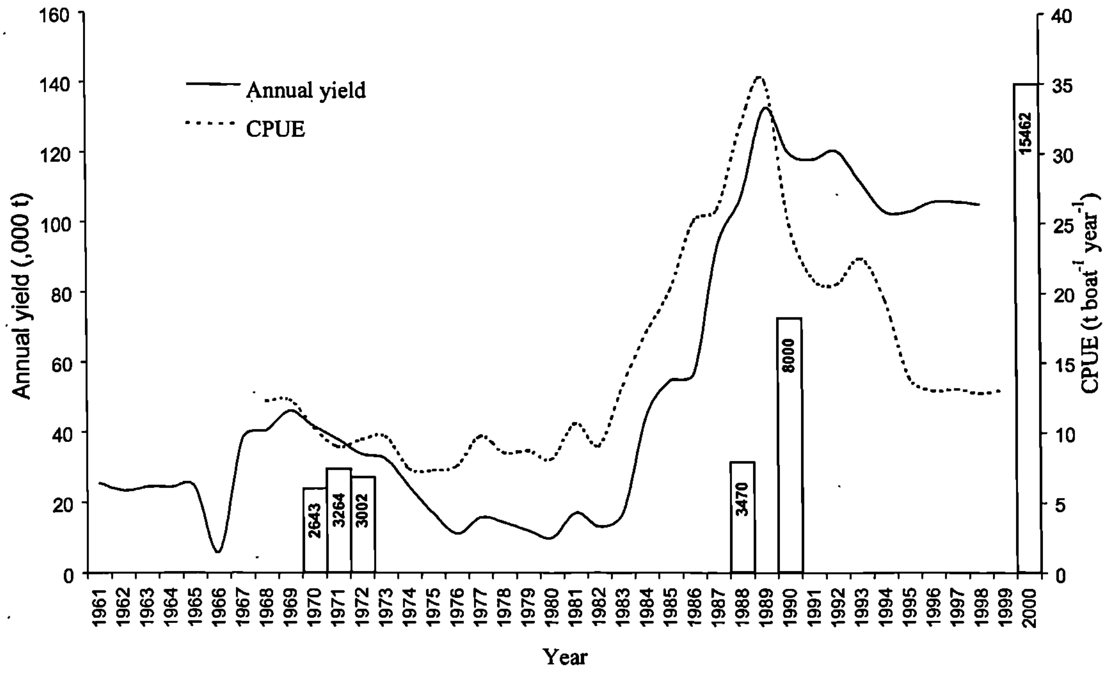


Figure 1.2 The estimated number of fishing boats (bars, number of boats inside the bars), and estimated annual fish yield in the Ugandan part of Lake Victoria (source UFRD records); estimated catch per unit of effort (CPUE) for the whole Lake (source: Asila, 2001a) from 1961 to 2000.

Total fish catches were low between 1961 and 1983 with a peak between 1967 and 1971 and the lowest catch between1973 and 1982. From 1983 to 1989 total fish, catches rose from 17,000 to 132,400 t but declined to a lower level of 103,000 t in 1994, which was somewhat stable up to 1998. The catch per unit of effort (CPUE) followed a similar trend, being fairly stable between 1968 and 1983, rising to a peak in 1989 and falling steadily thereafter with exception of a slight peak in 1993. The initial incentive to increase effort from 3470 boats in 1988 to 8000 boats in 1990 was undoubtedly the response to the improved catches of the introduced Nile perch and Nile tilapia but in the following decade, effort continued to rise against the declining CPUE. In the 1980s, most fishers switched to large gillnet mesh sizes to harvest the large sized fish (Ogutu-Ohwayo, 1990a), but this was short lived. The declines in gillnet mesh sizes is demonstrated indirectly by the declines of the modal length of Nile perch catches in the Tanzanian part of the lake, from 70-80 cm TL in 1988 (Litvoet & Mkumbo, 1990) to 50-60 cm TL in 1992 and 40-50 cm TL in 1994, the size sustained until the end of the 1990s (Mkumbo *et al.*, 2002).

The total annual fish landings in the three riparian states of Lake Victoria (Fig.1.3) more or less stabilised over the 1990s after the maximum achieved around 1990, but started rising again at the end of the 1990s.

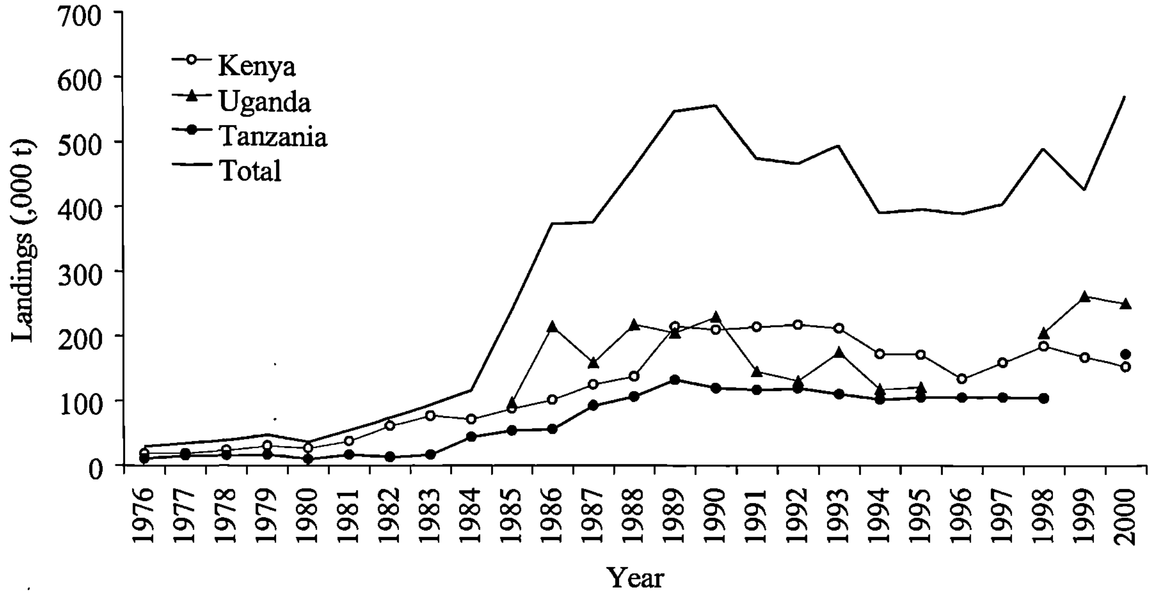


Figure 1.3 Trends in total landings of fish (t) in the riparian countries of Lake Victoria. Sources: Reynolds and Greboval 1988 and unpublished Fisheries Departments' statistics.

Since the late 1980s, catch assessment has been inconsistent in the Ugandan waters of Lake Victoria and to some extent in the Tanzanian part of the lake, as revealed by data gaps (Fig. 1.4). Notwithstanding the weaknesses in fisheries statistics in Tanzania and Uganda where data of contribution of different fish species to the total catches are fragmentary, some trends are discernible. In all the three countries sharing the lake, the contribution of Nile perch dropped and remained at low levels since 1994, despite increasing fishing effort. The apparent increase in total catches from around 1997 is therefore arising from the increasing contribution of *R. argentea*, tilapias and other species. However, poor catch assessment data prevent any conclusive evaluation of trends in recent years.

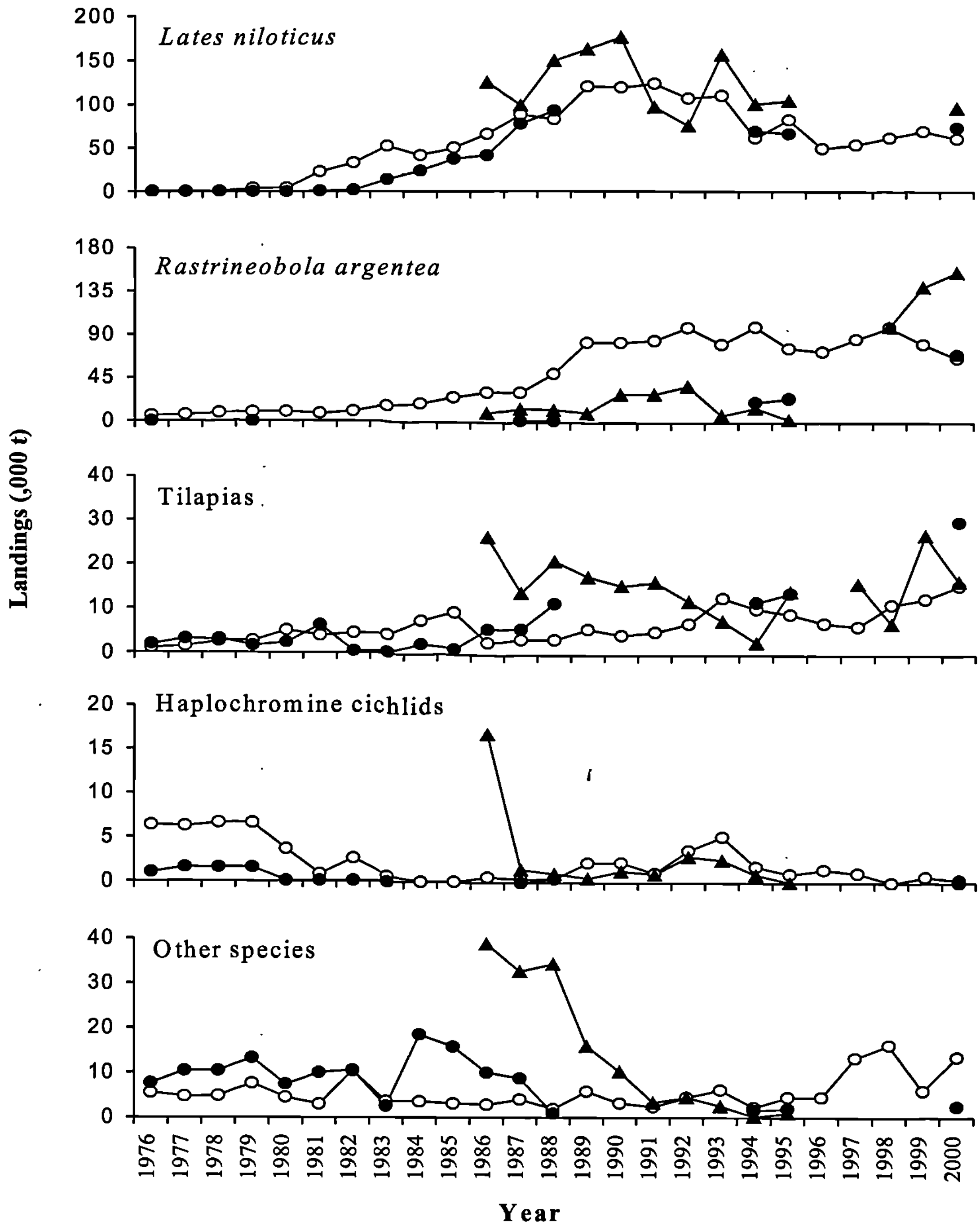


Figure 1.4 Trends in landings of major fish species groups in the riparian countries of Lake Victoria (○ Kenya; ▲ Tanzania; ●Uganda). Sources: Reynolds & Greboval, 1988 and unpublished Fisheries Departments' statistics.

1.3 Objectives of the study

The evaluation of fish stocks and fishing prospects requires good understanding of the fishing effort, notably the number of fishing boats and fishing gears of different kinds, how they are being used, and changes in fishing activities over time; and knowledge of how much and what kinds of fish are being caught in the fishery. As noted above

(Fig.1.4), the catch assessment programmes in the Ugandan part of the lake have been inadequate to provide reliable estimates of this information and its systematic update broke down around 1988.

The overall objective of this study was to evaluate the current status of fishing effort and fish catches and their implications for the management of the fisheries in the Ugandan part of Lake Victoria. The following specific objectives were pursued:

1. To evaluate fully the fishing capacity of the artisanal and commercial sub-sectors of the fishing industry whereby recognition was given to the understanding of the magnitude, composition and patterns of fishing effort.
2. To assess the yield of the major commercial fish species and trends in fish catches and provide estimates of annual fish yield to underpin management decision-making.
3. To provide management options for the fisheries of Lake Victoria to resolve the following questions:

- Is the level of exploitation of the major commercial fish species excessively high?
- What are the major factors contributing to the present exploitation level?
- How can the fishery be managed on a sustainable basis?

1.4 Structure of the thesis

1. **Chapter One** reviews the development of the fisheries of Lake Victoria that lead to this study.
2. **Chapter Two** describes the study area and provides the materials and methods used.
3. **Chapter Three** examines the current magnitude and distribution of fishing effort in the Ugandan part of Lake Victoria and shows its changes over the last ten years. It also elaborates the current spatial distribution of fishing characteristics in the Ugandan part of the lake and the regional disposition of fishing effort amongst the three riparian countries.
4. **Chapter Four** identifies the major factors that characterise fishing effort in the Ugandan part of Lake Victoria and relates them to fish catch rates and catch composition. It provides spatial and temporal patterns of fish catch rates and identifies the aspects that need intervention by management. The total annual catches in the Ugandan part of the lake are also estimated.
5. **Chapter Five** describes the population characteristics and exploitation levels of the three most important commercial fish species, Nile perch, Nile tilapia and *R. argentea*

in the Ugandan part of Lake Victoria, and provides annual yield estimates for these species.

6. **Chapter Six** integrates the outputs of the above chapters in a discussion of management initiatives that ought to be undertaken to ensure long-term sustainable fisheries in Lake Victoria.

CHAPTER TWO

2. GENERAL MATERIALS AND METHODS

2.1 Introduction

The materials and methods are presented in three parts. The first part (section 2.2) contains the procedures followed in the collection of total fishing effort data in the two most recent frame surveys in the Ugandan part of Lake Victoria in 1990 and 2000 and the adjustments made to these data to make them comparable. The 2000 frame survey was carried out in conjunction with this research programme. The author participated in the design, implementation and analysis of data from the Ugandan part of the lake of the 2000 Frame survey. He also re-analysed the 1990 Frame survey data for comparison with those of the 2000 Frame survey. The results of this section are presented in Chapter Three. The second part (section 2.3) describes the procedures followed in field data collection and subsequent data analysis of the current study and the results are presented in Chapter Four. The third part (section 2.4) shows how the population dynamics of the major commercial fish species (Nile perch, Nile tilapia and *R. argentea*) presented in Chapter Five were derived.

2.2 Frame survey procedures and methodology

2.2.1 *The 1990 frame survey (Tumwebaze & Coenen, 1991)*

Questionnaires A1 and A2 (Appendix 2.1) incorporating numerous questions on socio-economic factors of the fishing industry were designed in early 1989, and tested on Lake Victoria in early 1990. The Ugandan part of Lake Victoria was divided into 5 operational regions: Masaka, Sesse, Entebbe, Jinja, and Tororo (Fig. 2.1). The survey teams in each of the five regions consisted of two fisheries field staff and the Regional Fisheries Officer (RFO). Regional surveys were co-ordinated by staff from the Fisheries Department headquarters. The survey teams were trained for two days (16-17 August 1990) on conducting the surveys using the questionnaires. Each survey team was equipped with a boat, an outboard motor, fuel, binoculars, frame survey forms and topographic maps of scale 1:50,000. The survey teams used a powered boat to move along the shoreline locating fish landing sites with the help of binoculars. At each landing fishers, or other respondents, were interviewed. Landings were each given a code number that was used on the topographic map. Forms A1, for the landing characteristics, and A2, for each individual fishing boat, were filled in for every landing. Due to time constraints or because some boats were not present at the time of the survey, boat cards (i.e. form A2) were sometimes left behind with the fisheries field

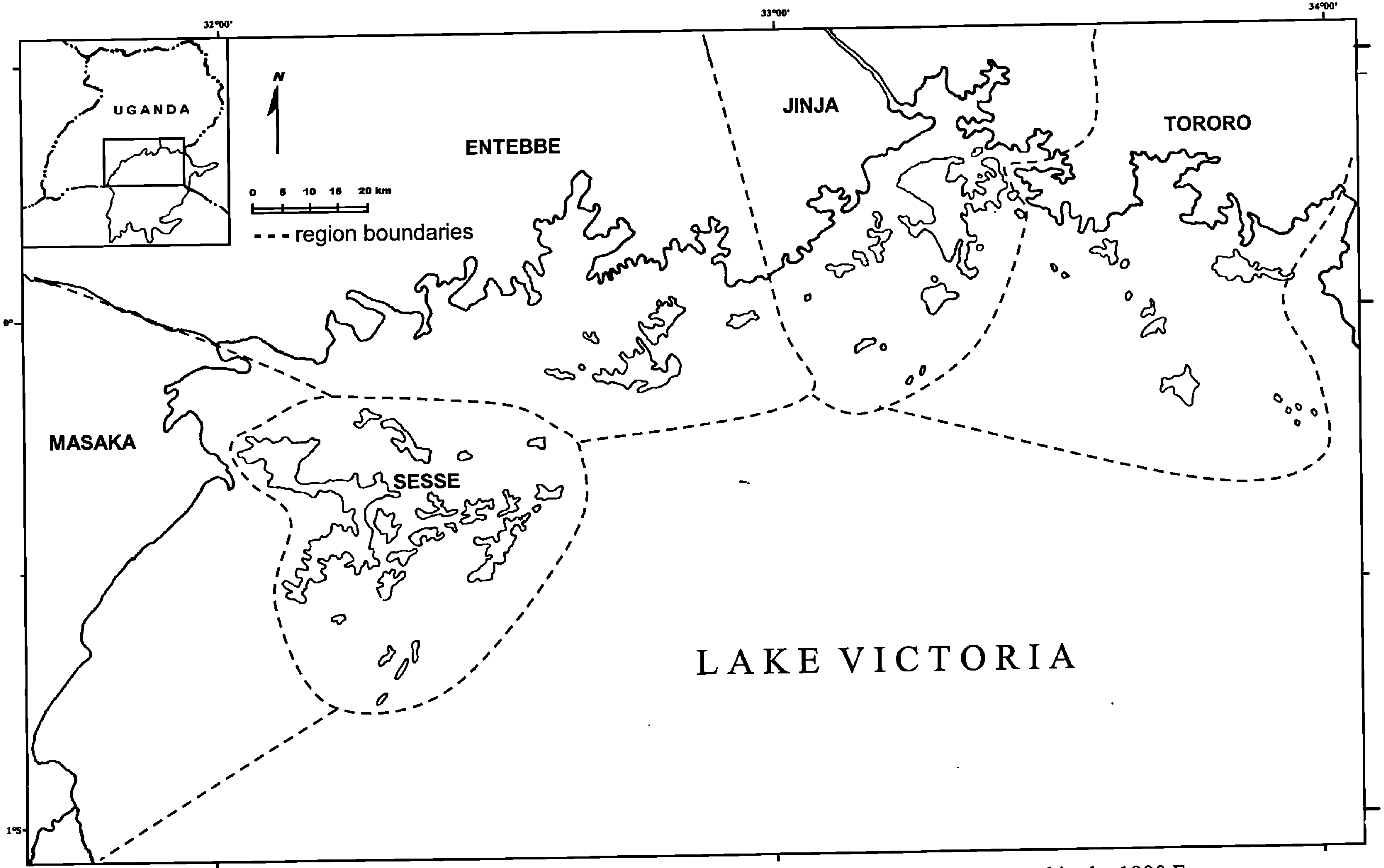


Figure 2.1 Map of the Ugandan part of Lake Victoria showing approximated boundaries of regions used in the 1990 Frame survey.

staff to be filled in and returned to the RFO and Fisheries Headquarters later. At most landings that were no resident fisheries staff, the team had to fill in all boat cards. Difficulties were thus encountered obtaining details of fishing gear and other characteristics of boats that were away or whose owners were absent.

2.2.2 *The 2000 frame survey*

The process of this frame survey started with the formation of a regional taskforce composed of at least one fisheries research and one fisheries management person from each of the three countries that share the lake, i.e. Kenya, Tanzania and Uganda. The author represented the Fisheries Resources Research Institute (FIRRI) in Uganda, on this taskforce. The taskforce developed harmonised frame survey questionnaires and procedures. Two questionnaire forms, Sheets 1 and 2 (Appendix 2.2) were developed. The inputs of the author at this stage were fundamental in categorising boats and classifying fishing gears in Sheet 2, according to those that were already being used in this research programme as these were acknowledged as the best available information. Sheet 1 recorded the following information:

(i) the date of survey of a landing beach, name of recorder, status of respondent, and administrative location of the landing beach, i.e. district, sub-county/division, parish/location and the name of landing;

(ii) a summary of the number of boats on the landing beach categorised as follows: derelict craft, transport craft (non fishing), fishing craft with outboard engine, fishing craft with inboard engine, fishing craft using paddles only, fishing craft using sails and the total number of craft on the beach;

(iii) an inventory of some basic beach facilities: (a) Presence or absence of fish handling facilities at the beach, i.e. *Banda* (fish shade), cold room, pontoon/jetty, and a fish store; and (b) Presence or absence of net repair and boat repair facilities;

(iv) access to an all weather road and electricity supply;

(v) status of fisheries department staffing;

(vi) nearest fish market; and

(vii) whether fishers use the landing for more than 5 months in a year.

Sheet 2 recorded details on each fishing craft and the fishing gears it was using:

(i) the craft type, i.e. Sesse flat at one end, Sesse pointed at both ends; parachute (flat bottom planked boat) and any other type would be specified;

(ii) length of the boat in metres;

(iii) mode of propulsion, i.e. inboard motor, outboard motor, paddles or sails;

(iv) the number of crew that normally go on the boat on its fishing trips; and

(v) the type and number of fishing gear(s) used: (a) for gillnets, the number of gillnets of each mesh size; (b) number of hooks for long lines and hand lines; and (c) number of gear units for beach seines, cast nets, traps or mosquito seines.

The design of these questionnaires aimed at making them simple to fill in and more focused to the major variables that determine fishing effort, as compared with those of earlier Frame surveys, e.g. those used in 1990 (Appendix 2.1).

The frame survey was organised according to the existing administrative structures, i.e. in Uganda: National level, district level and sub-counties. Implementation started by training 40 supervisors (16-17 March 2000), including ten district fisheries officers - one from each district around the lake and thirty sub-county fisheries officers. Survey forms were given to the supervisors upon completion of training. At sub-county level, the supervisors recruited enumerators from the fishing communities, assembled them at the sub-county headquarters two days before commencement of the survey, trained them on data recording and handed them questionnaires ready to start enumeration. Overall, 200 enumerators were deployed in the Uganda part of the lake, distributed proportionally to estimates of boats and landing sites in each sub-county presented by sub-county officers during the supervisor training. Each enumerator was allocated 1-4 landing sites depending on their size.

The aims and objectives of the frame survey exercise and the survey dates were widely publicised through radio announcements and posters pinned at landing sites. Beach community leaders were also sensitised through Fisheries Department field staff to explain the purpose of the frame survey to their fishing communities. These publicity and sensitisation efforts coupled with use of enumerators that were locally known to a large section of fishing communities reduced suspicion of the exercise to the extent that no lack of co-operation was reported.

The enumeration process

District and sub-county supervisors were given funds for transport to enable them to co-ordinate frame survey activities both on land and water. Each enumerator covered the landing sites assigned to him or her on foot. The enumerators filled in Sheet 1 by interviewing an elder, a leader, or a small group of people with good knowledge of the landing site. They moved along the beach making successive entries for fishing boats on Sheet 2. They were required to examine the fishing gears used by each boat, especially mesh sizes of gillnets before recording them. The records of numbers of some fishing gears that are difficult to count, e.g. gillnets and hooks on long lines, depended on the answer given by the respondent: the boat crew, the boat owner or a third person. However, as most of the enumerators were recruited from those fishing communities, they were expected to be familiar with fishing gears, thus able to make good judgement of the quantity given by the respondent. The details of fishing gears deployed at the fishing grounds and fishing boats that were absent from the landing site on a fishing trip at the time of enumeration also depended on estimates given by the respondents.

Length of fishing boats was estimated by any of three ways:

(a) using a rope (10 to 15 m long) with knots tied at 1-m intervals, stretched from the tip to the posterior end of the boat;
(b) making long steps alongside the boat from one end to the other, each step being equivalent to one metre; or
(c) approximate conversion from feet to metres, by dividing the length in feet by a factor of three, as most boat owners and fishers know the length of their boats in feet.

Enumerators returned completed forms to sub-county supervisors who scrutinised, compiled and passed them on to district supervisors. The district supervisors also scrutinised and compiled district returns and forwarded them to the Fisheries Department at the national level.

2.2.3 *Frame survey data analysis*

The 1990 frame survey data were adjusted for omissions, lost boat cards and to distinguish between different types of fishing boats to make them comparable with the 2000 data.

Omission of parachute boats in 1990 survey forms

The survey forms in 1990 provided for five categories of boats: (i) Sesse planked; (ii) dugout; (iii) fibreglass; (iv) trawler; and (v) other. Parachute boats (i.e. flat bottom planked boats) that are a common and unique type of boat used mainly in inshore waters were not given a code while fibreglass boats and trawlers that are rare were categorised. Some recorders coded parachutes as dugout boats but appended a comment that the boat was a parachute while on most of the boat cards indicating dugout boat there was no comment appended. Other recorders may have coded parachutes as Sesse planked boats but no evidence was apparent when scrutinising the available boat cards.

A negligible number of dugout boats operate on the lake, e.g. only 269 (1.7%) boats in the 2000 frame survey were dugouts. A total of 2242 (28%) dugout boats were reported in 1990, a figure that compares well with the 34% contributed by parachutes among fishing boats recorded in 2000. Dugout boats are very durable and many should have been detected in 2000 if they existed in 1990. As a result of the failure to separate parachute and dugout boats in the 1990 data, the two categories of boats are grouped to compare the two surveys.

Distinguishing between boat categories and adjustment for lost boat cards of 1990

Unfortunately data collected in the 1990 frame survey were never fully analysed. The only available document about the survey is the preliminary report (Tumwebaze & Coenen, 1991) compiled immediately after the survey outlining the frame survey methodology and procedures, and giving a summary of the major outputs. The report gives the total numbers of transport and fishing boats by region but does not distinguish between dugout, planked and powered boats that were transport or fishing boats (Table 2.1). The category of planked boats also included both motorised and paddled boats. This information is necessary for comparing the fishing factors then and in 2000.

Table 2.1 Totals of selected variables for the five regions in the Uganda part of Lake Victoria (as in the report on frame survey 1990)

Region	Landings	Active boats	Transport boats	Fishing boats	Dugout boats	Planked boats	Powered boats
Jinja	188	2512	222	2290	408	2104	257
Entebbe	243	2782	255	2527	703	2079	472
Tororo	68	1502	105	1397	623	879	181
Sesse	182	1172	62	1110	123	1049	246
Masaka	34	706	30	676	385	321	94
Total	715	8674	674	8000	2242	6432	1250

The total of 8000 fishing boats reported was obtained from records of fishing boats on frame survey form A1 whereas the boat cards for individual fishing boats were never analysed. During the course of the current study 7115 boat cards of the 1990 frame survey (form A2), providing details of fishing gears and other boat characteristics of individual fishing boats, were obtained from the Fisheries Department archives and analysed. These data provided the opportunity to determine the relative proportions of fishing boats by the three main categories: dugout/parachute, paddled Sesse and motorised Sesse (Table 2.2).

Table 2.2 Numbers of boats from available boat cards (15 fibreglass boats, 4 trawlers and 1 other are excluded)

Region	Dugout/Parachute	Paddled Sesse	Motorised Sesse	Total
Jinja	168	1363	247	1778
Entebbe	513	1574	122	2209
Tororo	665	646	107	1418
Sesse	89	745	200	1034
Masaka	365	215	76	656
Total	1800	4543	752	7095

However, the 7115 boat cards analysed were fewer than 8000, the total number of fishing boats reported for 1990. The loss by 872 boats was attributed to two factors. Some boat cards that were left behind with fisheries field staff during the survey to be filled in and forwarded to fisheries headquarters later were never returned, and some boat cards could have been misplaced during storage.

The number of fishing boats was raised from 7095 to 8000 by a representative proportion to account for the boat cards presumed to have been lost, assuming that the total of 8000 fishing boats was the correct figure for 1990 (Table 2.3). This procedure was necessary for estimating numbers of fishing boats by region and boat category in 1990 for comparison with 2000 frame survey data.

The total numbers of fishing gears were raised through the same proportion for each of the three categories of boats. The estimate relied on 7095 records obtained from actual records of available boat cards, ignoring the rare boat categories (15 fibreglass boats, 4 trawlers and 1 unclassified) that were also missing in the summary table for 1990. The boundaries between regions in 1990 did not follow clear-cut administrative boundaries, in some cases different parts of one sub-county (the basic administrative unit) occurred under different regions. One example is Malongo sub-county in Mayuge district (formally Iganga district), part of which was in Jinja region and another part in Tororo region in the 1990 survey. The whole sub-county was completely placed in Tororo region for comparison of both surveys.

Table 2.3 Numbers of boats raised by the same proportion from 7095 to 8000, the total number of fishing boats reported in 1990

Region	Dugout/Parachute	Sesse paddle	Sesse powered	**Total**
Jinja	189	1537	279	2005
Entebbe	578	1775	138	2491
Tororo	750	728	121	1599
Sesse	100	840	226	1166
Masaka	412	242	86	740
Total	2030	5122	848	8000

It was not possible to allot data to regions by names of landing sites because some names had changed, some landing sites no longer existed, while others were new. The sub-counties were preferred because their names and boundaries had not changed between 1990 and 2000. The boundaries used for comparison of the 1990 and 2000 frame surveys were therefore estimated by following the sub-county boundaries (Fig. 2.1). Landing sites were thus allotted to the existing sub-counties. This could have caused variation in numbers of boats reported per region in 1990 (Tables 2.1-2.3), but the variables compared occurred within the same boundaries for both surveys.

2.3 The current (Year 2000) catch effort study at selected fish landing sites

2.3.1 *Study area*

The study was carried out at 25 selected fish landing sites in the Ugandan part of Lake Victoria (Fig. 2.2). The landing sites were selected in zones 1, 2 and 3 in the western, central and eastern areas of the Ugandan part lake respectively. The three zones were being followed by other ongoing fisheries studies on this part of the lake and were adopted for this study to compare results. Selecting landing sites in the three zones was also expected to spread sampling in all regions of the lake. Nine landing sites were selected in zone 1, i.e. Kachanga, Lambu, Kaboga, Nakatiba, Kananansi, Kyagalanyi, Buda, Buturume and Dembe; six in zone 2, i.e. Bugonga, Kasenyi, Lwanjaba, Kasali, Kimi and Sasa; and ten in zone 3, i.e. Masese, Lingira, Zinga, Namone, Lukale, Kachanga, Kijaka, Kiko and Lwazi (Fig. 2.2).

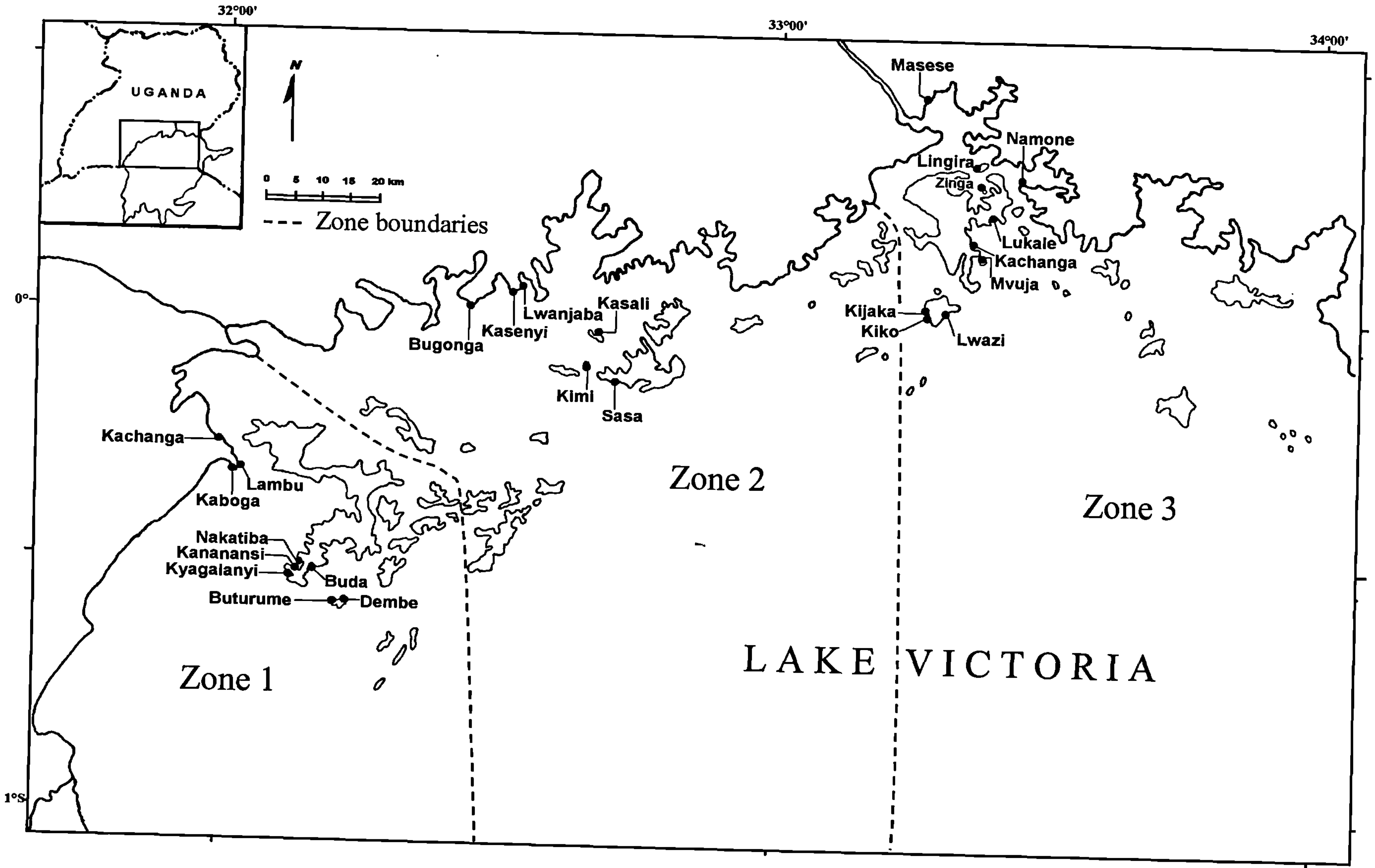


Figure 2.2 Map of the Ugandan part of Lake Victoria showing the fish landing sites sampled

2.3.2 *Selection of fish landing sites*

Standard methods of selecting landing sites for sampling in catch assessment

In large fisheries with scattered fish landing sites like those of Lake Victoria, collection of catch and effort data should adopt sub-sampling procedures that attempt to provide a representative sample or samples for determining the total population statistics by proportion (Bazigos, 1974). The procedure is dependent on the sub sample(s) being representative of the whole fishery, a situation that is complicated by variability in many parameters associated with the fishery. The prominent sources of such variability in inland fisheries are listed below, from Cowx (1993):

(i) Occurrence of multiple fish species stocks in the same water body;

(ii) variability in fishing methods and fisheries;

(iii) settlements of fishing communities along the water body;

(iv) variations in types and sizes of fishing gears;

(v) variations in types of fishing vessels;

(vi) variations in the type of mechanisation/propulsion of the fishing vessels;

(vii) variations in the fishing methods and times,

(viii) variation in landing times and places; and

(ix) diversity in fishing skills.

Most of these difficulties are taken care of by adopting stratified sampling procedures. The basic rules of stratified sampling (Sparre & Venema, 1998) are that the sample size per stratum, $n(j)$, should be large when:

(i) the stratum is large (if $N(j)$ is large);

(ii) the standard deviation $s(j)$ is large; and

(iii) for financial reasons, sampling is inexpensive.

The first two conditions are expressed as:

$$n(j) \quad \text{proportional to } N(j) \cdot s(j) \qquad \text{(equation 2.1)}$$

$$\text{or} \quad n(j) = n \cdot \frac{N(j) \cdot s(j)}{\sum_{j=1}^{m} N(j) \cdot s(j)} \qquad \text{(equation 2.2)}$$

where n is the total sample size of strata $1...m$. This formula is called the "*optimum stratified sampling equation*" (or *Neyman allocation*).

The cost of taking a sample will differ from stratum to stratum and it is necessary to consider the cost of sampling when designing a sampling scheme.

If $c(j)$ is the cost of taking a sample unit in stratum j and C_o is the additional fixed cost of the whole sampling programme, then the total cost, C, for m strata becomes:

$$C = C_o + \sum_{j=1}^{m} c(j) \cdot n(j) \qquad \text{(equation 2.3)}$$

For an optimum allocation, the sample size should be proportional to $1/\sqrt{c(j)}$.

An optimum use of the available resources is achieved when the sample size is proportional to

$N(j) \cdot s(j) / \sqrt{c(j)}$, or if

$$n(j) = n \cdot \frac{N(j) \cdot s(j) / \sqrt{c(j)}}{\sum_{j=1}^{m} N(j) \cdot s(j) / \sqrt{c(j)}} \qquad \text{(equation 2.4)}$$

where n is the total sample size of strata $1 \ldots m$.

If the total budget available is C and the fixed cost is C_o the total number of sample units in all strata is given by (equation 2.5):

$$n = (C - C_o) \cdot \frac{\sum_{j=1}^{m} N(j) \cdot s(j) / \sqrt{c(j)}}{\sum_{j=1}^{m} N(j) \cdot s(j) \cdot \sqrt{c(j)}} \qquad \text{(equation 2.5)}$$

and the number of units sampled in stratum j is given in (equation 2.6):

$$n(j) = (C - C_o) \cdot \frac{N(j) \cdot s(j) / \sqrt{c(j)}}{\sum_{j=1}^{m} N(j) \cdot s(j) \cdot \sqrt{c(j)}} \qquad \text{(equation 2.6)}$$

Before these elaborate procedures for designing a random stratified sampling programme can be adopted, a considerable amount of information about the fishery is required. Unfortunately, before the start of this study in September 1999 there were no recent baseline data to show the fishery characteristics of existing fish landing sites in the Ugandan part of Lake Victoria. The last frame survey providing such information was in 1990 and many changes had taken place in the fisheries since. Additionally, data collected in 1990 had never been fully analysed and could not be readily used for designing a sampling programme.

Random stratified sampling designs are also suitable where the personnel recording data are stationed at the fish landing sites and unlimited resources are available. The latter was not the case in this study and a team of three people comprising the author, a field assistant and a coxswain was all that was available. Consequently, a compromise situation was required. In this study, one survey team moved from one landing site to another, therefore, it was desirable to have a systematic approach in the limited time and resources available. This precluded the use of random sampling because of the large number of sampling sites that would have to be sampled. The procedure given below was followed in attempting to define the most appropriate parameters of fishing effort to allocate sampling effort accordingly.

Procedure followed in selecting landing sites for sampling in this study

1. In each zone, a transect from the mainland out into the islands further offshore was marked on a map of the lake. On these transects, areas from which landing sites would be selected to represent fishing in the major ecological zones, from shallow inshore waters to deep offshore waters, were marked.
2. On the first field trip in each zone all landing sites in each marked area were visited and landing sites to be sampled regularly were selected. The criteria for selection of particular landing sites were: (a) where landing sites were specialised for one of the major commercial fisheries, i.e. Nile perch, Nile tilapia or *R. argentea*, at least one landing site was selected for each species; (b) landing sites with a variety of boat and fishing gear types were preferred to those with uniform boat types and/or gear types, because the former would provide opportunity of sampling fish catches of a wide range of fishing gears and methods in the limited time and space of coverage of this study.
3. Surveys in each zone were limited to 10 days, using a small boat powered by 15 horsepower outboard motor. A maximum of nine landing sites could be sampled within this period. The survey team camped at two landing sites in zone 1 (Lambu and Kyagalanyi); two in zone 2 (Kasenyi and Kimi); and three in zone 3 (Namoni, Lukale and Kijaka). Fishing boats start landing from as early as 0600 hrs, thus the rest of the landing sites had to be selected within reasonable distance from the camp requiring travelling for not more than one hour. The survey could not be extended further offshore because the boats and outboard motor available were insufficient to withstand bad weather often associated with those areas.
4. Ideally nine landing sites were to be sampled in each zone, however, an extra one, i.e. Masese, was sampled in Zone 3. This landing site was sampled outside the normal survey time. In zone 2, only six landing sites were sampled, but two of these required more time: (a) Kasenyi, has two-in-one landing sites about 200 m apart. The main landing is predominantly used by boats with outboard motor operating legal gillnet mesh sizes targeting Nile perch, while the auxiliary landing site is mainly used by

smaller paddled boats, that target both Nile tilapia and Nile perch operating gillnets of both legal and illegal mesh sizes. Therefore, obtaining a representative sample of fish catches at this landing required a minimum of two days to sample both landing places. (b) Another landing site, Kimi, located on a small island had a multiplicity of fishing activities providing an opportunity of data on fish catches of a variety of fishing gears and methods. These included beach seining, long lining, hand lining, mosquito seines for *R. argentea*, and gillnetting by both large motorised boats and small paddled boats. Full coverage of this variety of fishing gears and methods required a minimum of 2 days of sampling.

2.3.3 *Fishery characteristics of the selected fish landing sites*

The description of landing sites below indicates the general composition of fishing boats and gears in use at these landing sites at the time they were selected for regular sampling. Fluctuations in numbers of boats and changes in fishing gears used were common in later visits to these landing sites, partly due to the frequent migrations of fishers with their craft, a common phenomenon in Lake Victoria, but the fisheries targeted remained more or less the same.

Zone 1

1. **Kachanga,** Nile tilapia is the major fishery of this landing site but there is also beach-seining activity targeting small Nile perch. A total of 24 active fishing boats were present, of which 17 were operating gillnets for Nile tilapia and 7 boats operating beach seines

2. **Lambu** This is the leading landing site of the *R. argentea* fishery in the western part of the lake. The majority of fishing boats, 26 motorised and 52 paddled, operated mosquito seines targeting *R. argentea.* Other subsidiary fisheries included 16 parachute boats operating either gillnets or cast nets targeting Nile tilapia; 12 paddled, and 4 motorised boats operating gillnets targeting Nile perch.

3. **Kaboga** This landing site is located close to Lambu above, but amidst the bush and is used exclusively for illegal fishing. The catch is landed and sold off by 0600 hrs, before full daylight. The entire 24 parachute boats that were landing there operated illegal gillnets of 76 to 102 mm mesh sizes targeting small Nile tilapia.

4. **Nakatiba** on the southwestern end of Sesse islands had 28 boats, 12 of which were motorised, all operating gillnets and targeting Nile perch.

5. **Kananansi** in the same bay as Nakatiba had 13 motorised boats, all operating gillnets

targeting Nile perch but the gillnets operated by boats at this landing were of large mesh sizes, ≥ 152 mm, compared with Nakatiba where smaller mesh sizes, 127 to 138 mm, were predominant.

6. Kyagalanyi had 21 boats of which 11 paddled boats targeted small Nile perch using small mesh size gillnets nets and 4 motorised boats operated gillnets targeting large Nile perch. Two parachute boats were operating gillnets for Nile tilapia and four other boats operated hand lines for Nile perch.

7. Buda had 21 boats, 18 paddled Sesse boats operating mosquito seines for *R. argentea* and 3 parachute boats operating gillnets targeting Nile tilapia.

8. Buturume had 18 fishing boats of which two were motorised and 12 paddled operating gillnets targeting Nile perch and the remaining four operated mosquito seines targeting *R. argentea.*

9. Dembe had nine paddled Sesse boats, all operating gillnets targeting Nile perch.

Zone 2

1. Bugonga had 22 boats of which 14 operated gillnets of 76 to 102 mm mesh size targeting small Nile perch. Five other boats operated beach seines, two operated long lines for Nile perch and one boat cast netted for Nile tilapia.

2. Kasenyi had two landing places about 200 m apart. Both landing places had a total of 60 fishing boats comprising 30 motorised boats operating gillnets for Nile perch, 22 paddled boats operating gillnets targeting both Nile perch and Nile tilapia, six boats operating long lines for Nile perch and two boats operating cast nets for Nile tilapia.

3. Lwanjaba had 12 boats, seven operating mosquito seines for *R. argentea* and five boats operating gillnets for Nile tilapia.

4. Kimi had 77 fishing boats with a variety of fishing strategies. Boats targeting large Nile perch included 19 motorised operating gillnets, 12 operating long lines and six operating hand lines. Sixteen boats operated mosquito seines for *R. argentea* while 24 other paddled boats were not specialised, operating gillnets, cast nets and beach seines.

5. Kasali had 19 fishing boats, five motorised and five paddled gillnetting boats targeting large Nile perch, eight paddled gillnetting targeting either small Nile perch or Nile tilapia, one boat operating a cast net for Nile tilapia.

6. Sasa had 16 fishing boats, eight motorised and three paddled gillnetting boats targeting large Nile perch and five boats operating small mesh size gillnets targeting small Nile perch.

Zone 3

1. Masese had a total of 42 fishing boats, 38 gillnetting and four operating cast nets, all targeting Nile tilapia.

2. Lingira had 32 fishing boats, 27 operating mosquito seines for *R. argentea*, three beach seining for Nile perch; one cast nets and one gillnets for Nile tilapia.

3. Zinga had 43 fishing boats, 32 operating gillnets and 11 basket traps, all targeting Nile tilapia.

4. Namoni had 107 fishing boats comprising of five motorised gillnetting boats targeting Nile perch, 48 parachute and 29 paddled Sesse gillnetting for Nile tilapia; 15 operating cast nets for Nile tilapia, eight beach seining for small Nile perch; and two boats operating mosquito seines for *R. argentea.*

5. Lukale had 32 fishing boats comprising 14 operating mosquito seines for *R. argentea*, 10 gillnetting and six operating cast nets for Nile tilapia; and two operating beach seines for small Nile perch.

6. Kachanga, had a total of 20 fishing boats, 10 gillnetting and eight operating cast nets, targeting Nile tilapia. Two other boats operated 102 mm mesh size nets targeting small Nile perch.

7. Mvuja had a total of 38 active fishing boats including eight motorised and 13 sailed, operating gillnets targeting large Nile perch; 12 paddled gillnetting boats targeting small Nile perch; three boats with long lines for Nile perch and two with cast nets for Nile tilapia.

8. Kijaka had 16 fishing boats comprising seven motorised and nine paddled Sesse boats, all using gillnets for Nile perch. Five of the paddled boats used small mesh size gillnets for small Nile perch.

9. Kiko had 11 fishing boats, eight operating mosquito seines for *R. argentea* and three boats operated gillnets for Tilapia.

10. Lwazi had 22 boats, nine of them motorised and ten paddled, operating gillnets targeting Nile perch. Three other boats operated beach seines targeting small Nile perch.

The above statistics are based on starting status but they changed over the study period, i.e. the boat numbers were not static.

2.3.4 *Sampling*

Sampling was carried out quarterly in each zone from September 1999 to June 2001, beginning with zone 3 in the east, followed by zone 2 and then zone 1. The construction of survey boats for use in zones 1 and 2 was delayed, therefore, surveys started in zone 3 where a boat was readily available. This order of sampling was maintained throughout the study. Each landing was visited at least once every three months, spreading the sampling over the four major seasons in the year, two dry and two wet seasons. Dry weather prevails in the first and third quarters of the year, i.e. in January to February and between June and September; and the wet weather prevails in the second and fourth quarters of the year with peak rainfall in April – May (long rains) and in November-December (short rains) (Spigel & Coulter, 1996). Due to other unavoidable responsibilities of the author, sampling was not possible in May, therefore, the quarterly sampling scale over that period covers four months instead of three, i.e. March-June 2000.

At the landing site the basic sampling unit was a fishing boat. Boats were categorised according to type, mode of propulsion, gear type and target fish species. Each category of boats was sampled on landings where more than one category occurred.

Selection of boats for sampling

From previous experience, fishers often became impatient and reluctant to co-operate if asked to wait for their boats to be sampled before they could dispose off their catch. To minimise the waiting time of fishers, and to maintain random selection of boats, the following general procedures were followed in this study.

1. On landing sites with up to ten active fishing boats, all boats were sampled.
2. On landings with between 10 and 20 active fishing boats, if boats landed over a wide time frame, they were all sampled but if many landed simultaneously, every second boat to arrive was sampled.
3. On landings sites with more than 20 active boats the second or third boat to arrive, depending on how fast they followed each other, was sampled. In these circumstances, a person from that landing would be used to keep asking fishers in the selected boats to wait for measurements of their catch and to monitor any attempt to tamper with the catch. The approach to fishers was always friendly and they often restrained anybody attempting to remove fish before measurements were complete.

The nature of boat landing activity varied between landing sites and different fisheries within one landing site. It was also influenced by other factors like weather conditions and the size of the catch. Therefore the sampling strategy was always adjusted to suit the prevailing conditions. The actual number of boats sampled was also influenced by other factors like the amount of the catch to be measured per boat and weather conditions, e.g. many boats would be sampled in a short time when the catches were poor and vice versa. Bad weather, e.g. heavy rain, would disrupt or slow down sampling.

The above criteria mainly applied to boats operating gillnets and those fishing for *R. argentea* that landed at dawn. Boats operating other gears had different landing patterns.

1. Boats operating hooks on long lines and hand lines fished during daytime and had no specific time of landing, varying from around 1800 hrs until late in the night. Due to the time of landing, data collection on these boats was only possible at the landing sites where the survey team resided.
2. Boats operating cast nets fished during daylight, more particularly in the evening hours. They were difficult to sample because they had neither a specific landing time nor a particular landing area on the beach. Most of their catch was consumed in the landing village; thus, the catch was removed and taken around the village for sale immediately after landing. Due to these difficulties, it was only possible to sample boats at the landing sites where the survey team resided.
3. Boats operating beach seines fished both during day light and at night. Fishers were fully aware that this is an illegal gear and were very sensitive to the presence of the survey team despite assurances that they would not be reported. In most cases they stopped fishing or hid the catch. The few boats that were sampled were mostly those found on surprise visits.

The beach seines referred to in this study are the type used to target Nile perch. There is wide use of beach-drawn mosquito seines to catch bait fish (especially haplochromines) for long lining and hand lining. This bait fishery with mosquito seines operated as beach seines is also important with regard to non-target fish species, e.g. juvenile Nile perch and Nile tilapia and some species of haplochromines which are not used for bait. Despite the importance of this fishery, it was not investigated because: (i) the time and place of collection of bait were unpredictable, and (ii) handling of the bait would increase mortality and lead to conflict with fishers.

In this study no attempt was made to measure the duration of actual operation of fishing gears, e.g. the soak time of gillnets. This was because fishing duration is very variable depending on factors like weather condition and skill of fishers. It would be very difficult to validate the estimate of the fishers if they were asked the time they spent fishing. It was therefore assumed that the duration of fishing was uniform amongst similar boats using similar gear and targeting the same fisheries when calculating the catch per unit of effort.

Boat and gear characteristics

The information below, describing the fishing characteristics of fishing boats and fishing gears, was recorded at the fish-landing site.

1. The total number of fishing boats at the landing and the number of boats that fished on the day of sampling by boat type, mode of propulsion and type of gear used.

2. The type of boat and mode of propulsion of every boat that was sampled.

3. The type(s), size(s) and quantities of gear(s) carried by every sampled boat and the mode of operation of these gears, e.g. active, stationary or drifting.

(a) For gears made out of netting material, e.g. gillnets, the 'stretched' mesh size was measured. The field measurements of gillnet mesh sizes were done in Imperial "inches" and later converted to millimetres. This was because standard sizes of gillnets are graded in inches and when in use changes in elasticity cause differences between sizes of meshes of the same net, thus, when measured on the inch scale the original mesh size could be more easily determined.

(b) Counting of the number of gillnets and hooks on long lines were impractical, therefore, the estimate of their numbers depended on the response from the fishers operating them. A second opinion was sought from the owner or other experienced fishers at the landing if the first respondent was judged to be inaccurate.

Boats operating mid-water set drift gillnets had large numbers of nets piled in big heaps making it difficult to approximate the numbers of nets they contained. However, for drift gillnet settings, a fixed number of large floats are used per gillnet, thus the numbers of these floats in the boat were a good indicator of the approximate number of gillnets involved. The numbers of these floats were therefore used to judge the accuracy of the numbers indicated by the respondent.

Measurements of fish catches

The fish catches were sorted and counted by species, and fish of each species was weighed separately, to the nearest 0.1 kg, in a fish basket using a 25 or 50-kg spring balance, adjusted for the weight of the basket. Small fish landed in small quantities were weighed to the nearest 0.01 kg in light polythene bags using a 0.5, 1 or 2-kg spring balance, where appropriate. The number and total weight of each species was recorded.

The total length (TL), the greatest length of the fish from the anterior most extremity (mouth closed) to the end of tail fin (Lagler, 1978), was measured to the nearest cm below on a centimetre scale measuring board for *L. niloticus* and *O. niloticus*, the major commercial species. The lengths of all fish specimens of the two species in the catch were measured except where numerous small fish were landed, e.g. in beach seine and small mesh size gillnet catches. In the later case, the catch was mixed and a random sample of about 100 fish removed for length measurement.

Sampling of *R. argentea* catches

The catches of *R. argentea* are offloaded from the boat using a tin or basin. Three tins/basins of the catch were weighed in a basket and the mean weight of one tin/basin calculated. The total weight of the catch of a boat was estimated by multiplying the mean weight of one tin/basin by the number of tins/basins landed by the boat. A sample of one mug was scooped from each boat at random for measurement of length. Samples from all boats were mixed in a basin from which a sub-sample was removed and preserved in 5% formalin solution for examination in the laboratory.

Laboratory examination of *R. argentea* samples

Samples were washed and soaked overnight in water to remove excess formalin. Each sample was thoroughly mixed and then a handful (approximately 200 fish) of sub-sample taken randomly for measurement of length. Standard length (SL) measured to the nearest millimetre (mm) was preferred to fork length or total length because tails were frequently damaged. Standard length involves a measurement from the most anterior extremity (mouth closed) to the insertion of the median tail fin rays (Lagler, 1978).

Sex and maturity of *R. argentea*

A handful sub-sample was taken randomly from each sample and all fish specimens ≥25 mm SL dissected to establish the sex and maturity. More random specimens of the 1-mm length classes that were underrepresented in the sub-sample were taken to raise the minimum number of dissected fish per length class to ten, where possible. More specimens were also taken in the length classes where the specimens dissected contained very few or none of one of the two sexes. It was difficult to distinguish between sexes in fish < 25 mm SL, and all were found to be immature. Maturity was based on subjective examination of the status of the gonads. The specimens were grouped into seven maturity stages (Table 2.4) by modifying the generalised classifications of maturity stages in fishes of Kesteven (1960) and Nikolsky (1963), as quoted by Lagler (1978), to suite this species. The sex and maturity of *R. argentea* was established by close examination of the gonads using a dissecting microscope (magnification range 6.5x to 50x). The gonads of both the males and females lie on either side of the ventral cavity, and can be removed by careful dissection. The ovaries of females are flat in immature or the resting stages and eggs were easily discernible when mature and/or breeding (Table 2.4). The males have tubular testes, which are thin and small when immature, and smooth and plump when filled with milt, but often the surface is rugged when breeding.

Sex and maturity of Nile perch and Nile tilapia

It was impractical to obtain samples for determining the maturity stages of Nile perch and Nile tilapia during the surveys of this study because it would require purchase of the specimens from the fishers. This would be costly, and the cost would not be justified because parallel studies (Bottom trawling surveys) under the Lake Victoria Fisheries Research Project (LVFRP) would provide this information at no additional cost. Information on maturity status for the two fish species was therefore based on samples analysed during the LVFRP bottom trawling surveys. During these surveys, the state of maturity (gonad state) was assessed and classified into seven stages according to the classification in Lagler (1978), modified to apply to Nile perch and Nile tilapia.

Table 2.4 Criteria used to classify fish into maturity stages, modified from generalised classifications of maturity stages in fishes of Kesteven (1960) and Nikolsky (1963) in Lagler (1978) to apply to *R. argentea*

Stage	Description	Descriptive name	Maturity level
1	Very small sexual organs close to the vertebral column. Both testes and ovaries transparent. Tests threadlike, length about three quarters of the ventral cavity. Ovaries wider than testes and length half or less than half of the ventral cavity.	Virgin	Immature
2	Testes small, translucent, white-grey. Ovaries translucent or opaque and single eggs can be seen with magnifying glass. Length of testes and ovaries as in stage 1.	Maturing virgin	Immature
3	Testes opaque, flat with smooth surface. Ovaries opaque and eggs embedded in interstitial tissue visible to the naked eye with a whitish granular appearance. Ovaries occupy about half of the ventral cavity but testes remain small.	Developing or Resting	Maturing
4	Testes white-grey, thick, round and surface smooth. Eggs completely round, some already translucent and ripe. Ovaries filling ventral cavity.	Developing or resting	Mature – not breeding
5	Testes white-grey, thick, round and surface slightly rugged. Most eggs translucent with few opaque eggs remaining in ovary.	Gravid	Mature - breeding
6	Testes white-grey, thick, round, and surface heavily rugged, rupturing easily. All eggs are fully translucent, with no opaque eggs left. Eggs are easy to separate with little interstitial tissue binding them together.	Spawning	Mature - breeding
7	Testes and ovaries appear deflated, the ovaries containing few left over eggs and testes with some residual sperm, in a state of re-absorption).	Spent	Mature - spent
3	Ovary / testes return to resting at stage 3.	Recovering or resting	Mature – not breeding

2.3.5 *Data analysis*

Fish catch rates

Mean fish catch rates were estimated quarterly and by zone for the boats operating gillnets targeting Nile perch and Nile tilapia, and those operating mosquito seines targeting *R. argentea*, which were encountered in all zones in every survey. For other fishing gears, which were irregularly encountered, catches were pooled across zones. Mean quarterly catch rates were plotted to illustrate seasonal trends. Gillnetting boats were grouped into three categories with similar fishing characteristics, i.e. parachute, paddled Sesse and motorised/sailed to illustrate their specialisations and impacts on the fishery. Differences in mean quarterly catch rates within each zone were tested with One-way ANOVA and those between zones were tested with multiple comparison Univariate Analysis of Variance tests.

Throughout the thesis, all estimates of confidence intervals of the mean and Error bars in charts represented 95% confidence limits.

Length-frequency distribution

Length frequency distributions of Nile perch and Nile tilapia were plotted to illustrate the size composition of the catch under different fishing attributes like boat type, fishing gear and mode of operation of the gear. They were also to show seasonal variations that could be related to recruitment patterns. Length frequency distributions of *R. argentea* were plotted to illustrate spatial and temporal distribution of fish sizes in the catch.

Estimation of annual catches

Mean quarterly catch rates were raised to total catches by zone and boat category in the case of the gillnet fishery or gear type for boats using other fishing gears, using the fraction of boats fishing daily, the number of days in a quarter and the total number of boats recorded in the 2000 Frame Survey as raising factors (equation 2.7)

$$C_{iqbz} = c_{iqbz} \cdot f_{qbz} \cdot T_{bz} \cdot d \qquad \text{(equation 2.7)}$$

where:

C_{iqbz} is the estimated total catch of fish species 'i' in quarter 'q' by boat category 'b' in zone 'z'; c_{iqbz} is the estimated mean catch per boat per day of fish species 'i' in quarter 'q' by boat category 'b' in zone 'z'; f_{qbz} is the proportion of fishing boats of category 'b' fishing daily in zone 'z' in quarter 'q'; T_{bz} is the total number of fishing boats of category 'b' in zone 'z' counted in the 2000 Frame Survey; and d is the total number of days in one quarter.

The annual total catches for the year 2000 were then estimated as (equation 2.8):

$$Y_i = \sum_{q=1}^{4}\left\{\sum_{z=1}^{3}\left(\sum_{b=1}^{n} C_{iqbz}\right)\right\} \qquad \text{(equation 2.8)}$$

where Y_i is the estimated annual catch of fish species '*i*' by boat categories (*b*= *1...n*), in zones (*z* = *1...3*), and quarters (*q* = *1...4*).

Sex and maturity analysis

The length at first maturity (LM_{50}) was estimated according to Beverton and Holt (1957), by examining the proportion of mature fish (stages four to seven) in each 1-mm length class, for *R. argentea* and 1-cm length classes for both Nile perch and Nile tilapia. The LM_{50} was determined by *SOLVER*, an *MS Excel Sub routine*, which fits a sigmoid curve though a data set ranging from zero mature fish to all mature fish. LM_{50} is the point on the curve where 50% of the fish are mature. This parameter gives an insight into the length of the fish that are mature in the different zones, and comparisons between the zones can therefore be made.

2.4 Population dynamics of the major commercial fish species

Analyses of population dynamics were carried out for only three fish species: Nile perch, Nile tilapia and *R. argentea,* which are the major commercial fish species in Lake Victoria. Although data were collected for 21 months, between, September 1999 and June 2001, the analyses of population dynamics were restricted to 12 months covering the year 2000 because of complications caused by variable recruitment times. Population parameters of Nile perch and Nile tilapia were estimated using only gillnet catches because they are the main fishing gear for the two fish species and their selectivity characteristics were known (Asila, 2001b). In the case of *R. argentea,* samples collected from the catches of 5 mm mesh size mosquito seines were used for the analysis. The mesh size of mosquito seines in use was uniform at all the sampled landing sites. The selectivity characteristics of these mosquito seines were not known but they were assumed to be a non-selective gear as they caught a wide range of *R. argentea* sizes, thus, the length frequency data of *R. argentea* were used in the population dynamics analyses without any adjustments for selectivity.

2.4.1 *Adjustment for gillnet selectivity*

The length frequency data obtained from the gillnet fishery were adjusted to remove the bias caused by selectivity (Gayanilo and Pauly, 1997). Selectivity factors for Nile perch and Nile tilapia catches of multi-filament gillnets operated in Lake Victoria, were obtained from an independent study (Asila, 2001b). These selectivity factors covered the gillnet mesh size range 25.4 – 203 mm, and were determined according to the Baranov and Holt model, originally developed by Baranov (1914), subsequently improved by Holt (1963) and described in Gayanilo and Pauly (1997).

The adjustments for gillnet selectivity were done on a monthly basis. Most fishing boats used gillnets of different mesh sizes and it was impractical to identify the mesh sizes in which the fish specimens measured were caught. Therefore, in each month, the common selectivity factors of all the gillnet mesh sizes encountered were estimated following the model for multiple mesh sizes (Sparre & Venema, 1998).

For n mesh sizes, $n-1$ estimates of the intercept a and slope b were obtained from Asila (2001b).

$$[a_1, b_1], [a_2, b_2], \ldots, [a_{n-1}, b_{n-1}]$$

corresponding to mesh sizes:

$$[m_1, m_2], [m_2, m_3], \ldots, [m_{n-1}, m_n]$$

A regression analysis, forcing the line through the origin $y_i = b \cdot x_i$, with $y_i = -2 \cdot a_i / b_i$ as the dependent variable and $x_i = m_i + m_{i+1}$ as independent variable was performed, and the slope b became the selection factor SF for that range of gillnet mesh sizes (equation 2.9).

$$-2 \cdot a_i / b_i = SF(m_i + m_{i+1}), \quad i = 1, 2, \ldots, n-1$$

or $$b = \sum x_i y_i / \sum x_i^2$$

$$\therefore \quad SF = \frac{-2\sum_{i=1}^{n-1}(m_i + m_{i+1}) \cdot (a_i / b_i)}{\sum_{i=1}^{n-1}(m_i + m_{i+1})^2} \qquad \text{(Equation 2.9)}$$

The observed catches at each length were adjusted for the gillnet selectivity according to equation 2.10:

$$C'_i = C_i \cdot SF_i(m_1, m_2 \ldots m_n) \qquad \text{(equation 2.10)}$$

where C'_i is the adjusted catch in numbers for fish of length (i); C_i is the observed catch in numbers for fish of length (i) and SF_i ($m_1, m_2 \ldots m_n$) is the common selectivity factor for fish of length (i) caught in gillnet fleets composed of mesh sizes $m_1, m_2 \ldots m_n$.

2.4.2 *Estimation of growth parameters*

To estimate growth parameters, the von Bertalanffy growth equation was applied. This expresses the length (*L*) as a function of age of the fish (*t*) in the form (equation 2.11)

$$L_t = L\infty\left[1 - e^{(-K(t-t_0))}\right] \qquad \text{(equation 2.11)}$$

where, $L\infty$ is the asymptotic length, i.e. the mean length the fish in a population or stock would reach if they were to grow indefinitely; *K* is the curvature rate of the von Bertalanffy growth function (VBGF), i.e. the rate of dimension time^{-1} at which $L\infty$ is approached and t_o is the age of the fish at zero length.

The asymptotic length ($L\infty$) and growth constant (*K*) were estimated by the ELEFAN I (electronic-frequency analysis) routine of the FiSAT (FAO_ICLARM Stock Assessment Tools) package (Gayanilo & Pauly, 1997).

The growth performance index 'Munro's phi prime' (ϕ ') (Munro & Pauly, 1983; Pauly & Munro, 1984) was estimated using equation 2.12.

$$\phi' = \log K + 2\log L\infty \qquad \text{(equation 2.12)}$$

2.4.3 *Mortality parameters and exploitation level*

Total mortality (*Z*) was estimated using the linearised length converted catch curve method as provided in the FiSAT package (Gayanilo & Pauly, 1997), with the von Bertalanffy growth parameters as input data. This model is discussed in Pauly (1983; 1984). The catch curve, with the slope (–*Z*), was obtained by plotting the natural logarithms of the numbers of fish surviving by length (equation 2.13).

$$\ln\left(F_{(L1-L2)} / \Delta t\right) = c - Zt_{(L1+L2)} / 2 \qquad \text{or}$$

$$\ln(F / \Delta t) = c - Zt \qquad \text{(equation 2.13)}$$

where, *F*, is the number of individuals in each age class, *t*, is the relative age and, *c*, is a constant. The value of Δt is the time taken for the species to grow through a particular length class.

The natural mortality (*M*) was estimated using Pauly's empirical formula (equation 2.14) based on the growth parameters ($L\infty$ and *K*) and annual mean water temperature, T=25°C (The thermal environment of Lake Victoria is nearly constant, with temperature changing within the 24°C to 26°C range throughout the year (Hecky *et al.*, 1994; Kitchell *et al.*, 1997)).

$$\ln M = -0.0152 - 0.279 \cdot \ln L_\infty + 0.6543 \cdot \ln K + 0.463 \cdot \ln T \quad \text{(equation 2.14)}$$

The fishing mortality F was estimated as the difference between Z and M (equation 2.15)

$$F = Z\text{-}M \qquad \text{(equation 2.15)}$$

The exploitation level, E was estimated from the values of F and Z, (equation 2.16)

$$E = F/Z \qquad \text{(equation 2.16)}$$

2.4.4 *Estimation of the mean size at first capture (L_c)*

Probabilities of capture were derived from the ascending arm of the length converted catch curve. This method, in FiSAT, consists of extrapolating the right, descending left side of a catch curve such that fish that ought to have been caught, had it not been for selection and incomplete recruitment, are added to the curve, with the ratio of expected numbers to those that are actually caught being used to estimate probabilities of capture.

2.4.5 *Recruitment pattern*

The recruitment pulses to the fishery were identified using restructured monthly length frequencies in FiSAT, following Moreau and Cuende, (1991). This routine of FiSAT reconstructs the recruitment pulses from a time series of length frequency data to determine the number of recruitment pulses per year and the relative strength of each pulse.

2.4.6 *Virtual population analysis (VPA)*

The length-structured virtual population analysis (VPA) was used to reconstruct fish population structure by length to estimate the population size, fishing mortality, and total annual catches. The following were the inputs: (i) catch in numbers representing the total annual catch; (ii) *'a' and 'b'* from the length-weight relationship; (iii) natural mortality *M*; (iv) terminal fishing effort F_t; and (v) the von Bertalanffy growth parameters, $L\infty$ and *K*. Three parameters for input into VPA, i.e. *M*, $L\infty$ and *K*, were estimated above.

(1) The monthly catch at length data for input into the predictive models was raised to represent total annual catches (equation 2.17).

$$C_i = \sum_{m=Jan}^{Dec} (\frac{c_{im}}{b_m} \cdot f_m \cdot d_m \cdot b_t) \quad \text{(equation 2.17)}$$

Where C_i is estimated annual catch by number of fish of length i; c_{im} is the number of fish of length i recorded in month m; b_m is the number of fishing boats sampled in month m; f_m is the proportion of fishing boats active in month m; d_m is the number of days in the month m; and b_t is the total number of fishing boats recorded in the Frame Survey.

The catches were raised separately for each of the gears used to target either of the two species, i.e. gillnets, long lines, hand lines and beach seine for Nile perch, and gillnets, cast nets, traps and beach seines for Nile tilapia. Also for gillnets, the total number of boats from the Frame Survey data that were used as the raising factor for either of the two fish species, was only that of the boat categories targeting the fish species. In the case of Nile perch, all categories of Sesse boats using gillnets, i.e. paddled, motorised and sailed, were considered and all parachute boats were excluded. In the case of Nile tilapia, the paddled Sesse boats less than 7m in length, with gillnets mesh sizes not exceeding 152 mm and all parachute boats using gillnets were considered. In Lake Victoria, gillnetting boats less than 7 m are used to target both Nile tilapia and Nile perch but bigger boats target only Nile perch (Muhoozi, 1998; Muhoozi & Ogutu-Ohwayo, 1999); also, gillnet mesh sizes larger than 152 mm are very rare in boats that target tilapia (see Chapter 4). These limits were used to estimate, from Frame Survey data, the number of paddled Sesse boats that could be targeting Nile tilapia because these boats are not specialised to fisheries of a particular species.

(2) The values of the length-weight parameters *'a'* and *'b'* were obtained from the regression of the natural logarithms of length and weight pairs of 3923 Nile perch specimens in the size range 10 to 112 cm TL, and 2888 Nile tilapia specimens in the size range 10 to 63 cm TL, using the linearised form of equation 2.18. These specimens were caught in bottom trawl surveys in the Uganda part of the lake in 2000.

$$W = aL^b \quad \text{(equation 2.18)}$$

i.e. $\ln W = \ln a + b \ln L$

where W is weight in grams, a is the y-axis intercept, b is the slope of the regression line and L is total length (cm).

(3) The terminal fishing effort, F_t, was estimated iteratively in FiSAT.

2.4.7 *Yield per recruit analysis*

The relative yield-per-recruit model with knife-edge selection was used. This model is based on the Beverton and Holt model of 1966, modified by Pauly and Soriano (1986). The inputs of the knife-edge model in FiSAT were: $Lc/L\infty$ ratio and M/K. The relative yield per recruit (Y'/R) was computed from equation 2.19:

$$Y'/R = EU^{m}(1-(3U/(1+m)) + (3U^{2}/(1+2m)) - U^{3}/(1+3m) \qquad \text{(equation 2.19)}$$

where: $U = 1 - (L_c/ L\infty)$

$m = (1\text{-}E) / (M/K) = (K/Z)$

$E = F/Z$

The relative biomass per recruit (B'/R) was estimated from equation 2.20:

$$B'/R = (Y'/R)/F \qquad \text{(equation 2.20)}$$

The model produces plots of Y'/R vs E (=F/Z) and B'/R vs E, from which E_{max} (exploitation rate that produces maximum yield), $E_{0.1}$ (exploitation rate at which marginal increase of Y'/R is $1/10^{th}$ of its value at E=0) and $E_{0.5}$ (value of E under which the stock has been reduced to 50% of its unexploited biomass) are also estimated.

2.4.8 *Thompson and Bell*

Yield, stock biomass and value of catch were predicted for various levels of fishing effort, using the length converted Thompson and Bell analysis. The output from the Virtual population Analysis, fishing mortality at length and catches at length were used as input data. Additional inputs were parameters of length weight relationship and average price of fish per kilogram by length groups.

The sum of the yields $\left(Y = \sum Y_i\right)$ was computed from equation 2.21:

$$Y_i = C_i \cdot \overline{w_i} \qquad \text{(equation 2.21)}$$

where the mean body weight

$$\overline{w_i} = \left(\frac{1}{L_{i+1} - L_i}\right) \cdot \left(\frac{a}{b+1}\right) \cdot \left(L_{i+1}{}^{b+1} \cdot L_i{}^{b+1}\right)$$

where a and b are the coefficients of the length-weight relationship and L_i and L_{i+1} are the lower and upper limits of the length class, respectively; also

$$C_i = (N_i - N_{i+1})(F_i / (M + F_i))$$

where the predicted population (N_i) is given by

$N_{i+1} = N_i \cdot EXP(-(M + F_i) \cdot \Delta t_i)$, and

$$\Delta t_i = (1/K) \cdot \ln((L_\infty - L_i)/(L_\infty - L_{i+1}))$$

The biomass was computed from equation 2.22:

$$B_i = ((N_i - N_{i+1})/(M + F_i)) \cdot \Delta t \cdot \overline{w_i} \qquad \text{(equation 2.22)}$$

and the value(V_i) was computed by equation 2.23:

$$V_i = Y_i \cdot v_i \qquad \text{(equation 2.23)}$$

where v_i is the unit value for class i. The model produced plots of yields, values and biomass estimates for a range of f-factors.

CHAPTER THREE

3. THE STATUS OF FISHING EFFORT IN THE UGANDAN PART OF LAKE VICTORIA

3.1 Introduction

To date, six frame surveys have been carried out in the Ugandan part of Lake Victoria. The first three surveys were conducted in the early 1970s: in 1970 by the Wild Life Services Ltd (Wild Life Services Ltd., 1970), in 1971 by EAFFRO/FAO (Wetherall, 1972), and in 1972 by the Fisheries Department (Dhatemwa & Walker, 1972). The latter two were aerial counts of fishing crafts and fish landing sites. The following numbers of fishing boats were reported for the Ugandan part of Lake Victoria: 2643 in 1970, 3264 in 1971 and 3002 in 1972. From then up to 1988, baseline information concerning fishing effort was partly updated using time series and monthly annual reports from the Fisheries Department regional offices (Nyeko & Acere, 1990). In 1988 the Planning Department of the Ministry of Agriculture Animal Industry and Fisheries (MAAIF) carried out a nationwide fisheries survey, including Lake Victoria. This survey estimated a total of 3470 fishing boats on the Ugandan part of the lake. However, there were serious doubts about the design, methodology used and operational aspects of the 1988 frame survey. Okaronon & Kamanyi (1990) considered the results of this frame survey unreliable and recommended another frame survey because the number of operating boats was believed to have been grossly underestimated.

A comprehensive frame survey was carried out by the FAO funded project for fisheries statistics and information system (UGA/87/007), in close collaboration with the Fisheries Department from 3 September to 20 December 1990. This survey covered the whole Uganda part of the lake, taking a full record of the major fishing factors. The initial plan was to carry out the survey within a period not exceeding 21 days to minimise errors arising from the fast changing dynamics in the fishery. However, due to operational problems that required sharing of facilities, it was conducted in phases and lasted almost 4 months. Gross errors of omission and duplication could have occurred, although it is reported that maximum care was taken to avoid them (Tumwebaze & Coenen, 1991). Despite the long duration, the exercise was thorough, taking record of landings with only one fishing boat.

The most recent frame survey was carried out from 22 – 25 March 2000. The 2000 Frame Survey was unique in its planning and execution. It was planned at the regional level and carried out at the same time over the whole lake. It was funded by two regional projects on the lake, i.e. the Lake Victoria Environment Management Project (LVEMP) and the Lake Victoria Fisheries Research Project (LVFRP), and co-ordinated by the Lake Victoria Fisheries Organisation (LVFO). A regional task force composed of both fisheries management and fisheries research personnel from each of the three riparian countries, Kenya, Tanzania and Uganda, developed uniform frame survey questionnaires, harmonised work plans and budgets in a series of regional meetings. The 2000 Frame Survey took the community approach by deploying large numbers of community-based enumerators to minimise the duration of the exercise to a maximum of 4 days. Data obtained in the Lake Victoria 2000-frame survey provided the most current and complete information on the magnitude and distribution of fishing effort on the lake.

The last two surveys, in 1990 and 2000, seem to be the most comprehensive with complete coverage of lake shoreline, both on the mainland and the numerous islands. In addition to the counts of landing sites and fishing crafts, they made a total inventory of fishing boat characteristics, i.e. boat type, size and mode of propulsion, number of crew, and composition of fishing gear. The two surveys therefore stand alone, at two points of time in the recent past, to show the status of fishing effort. Although the two surveys had differences in duration, composition of enumerators and questionnaire design, their results are generally comparable.

This chapter estimates the current magnitude and distribution of fishing effort in the Ugandan part of Lake Victoria and how it has changed between 1990 and 2000. It shows changes in the qualitative characteristics of fishing effort that occurred between 1990 and 2000 in different regions of the Ugandan part of the lake, which include: (i) composition of fishing boats; (ii) composition of fishing gears; and (iii) the number of gear units per boat. Finally, the chapter elaborates the current spatial distribution of fishing characteristics in the Ugandan part of the lake both by types of fishing boats and types of fishing gears as well as the regional disposition of fishing effort between the three riparian countries.

3.2 Comparison of fishing factors between 1990 and 2000

3.2.1 *Spatial changes in numbers of fishing boats*

The overall total number of the main three categories of fishing boats increased from 8000 in 1990 to 15 462 in 2000. Going by region as of the 1990 Frame Survey, the largest increase in number of boats was in the eastern region of Tororo from 1598 to 3739 boats, an increase of 134.0%. Second to Tororo was the Sesse region - 1166 to 2453 boats (110.4%), followed by Jinja region - 2005 to 3882 boats (93.6%), and Masaka region - 740 to 1296 boats (75.1%). The Entebbe region had the least increase of 64.3% from 2491 to 4092 boats. Regional differences are evident for particular categories of boats (Fig. 3.1).

Parachute/dugout boats

The Jinja region had the highest increase in number of parachute/dugout boats from 189 to 1169 boats, an increase of 518.5%. Next was the Sesse region from 100 to 467 boats, a 367% increase, followed by Tororo from 749 to 1860 boats (148.3%). In the Entebbe region these boats increased by 131.5% from 578 to1338 boats while Masaka region had the least increase of 88.6% from 412 to 777 boats. Overall, parachute/dugout-fishing boats increased by a factor of 176.4% from 2030 boats in 1990 to 5611 in 2000.

Paddled Sesse boats

The highest increase in number of Sesse paddled boats was in the Sesse region from 840 to1530 boats, an increase of 82.1% followed by a 40% increase from 1537 to 2155 boats in the Jinja region, 34.4% (1775 - 2386 boats) in the Entebbe region and 12.5% (728 - 819 boats) in the Tororo region. The number of Sesse paddled boats remained the same in the Masaka region. Overall, paddled Sesse boats increased by a factor of 39.2% from 5122 boats in 1990 to 7132 boats in 2000.

Motorised Sesse boats

In the eastern zone of Tororo the number of motorised Sesse boats increased by 291.7% from 121 boats in 1990 to 474 boats in 2000. Masaka region followed with a 197.8% increase from 86 to 256 boats, Entebbe region by 146.4% from 138 to 340 boats, then Sesse region from 226 to 449 boats (98.6%), and lastly Jinja region from 279 to 480 boats (72.0%). Overall, motorised boats increased by 135.7% from 849 boats in 1990 to 1999 boats in 2000.

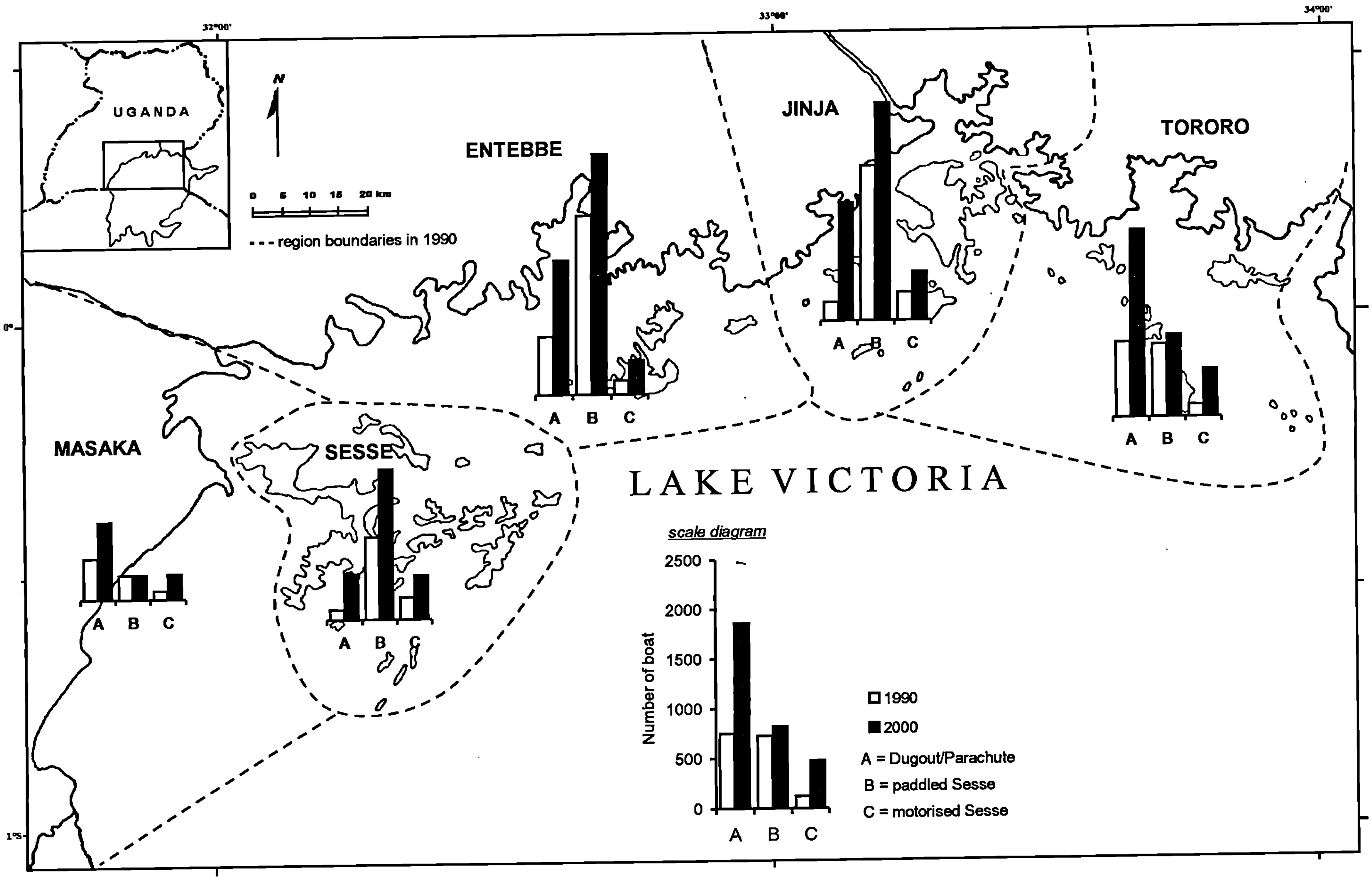


Figure 3.1 Map of the Ugandan part of Lake Victoria showing regional changes in numbers of the major categories of fishing boats between 1990 and 2000.

3.2.2 *Spatial changes in fishing gears*

The changes that occurred in the distribution of fishing gear types between 1990 and 2000, by major boat type categories, are shown in Figure 3.2. The numbers of boats shown may not match the total numbers of boats reported for the two frame surveys for two reasons: (i) in some records of fishing boats, the gears used were not identified; and (ii) some boats used more than one type of fishing gear.

Parachute/dugout boats

The majority, 80 - 98%, of the 2030 parachute/dugout fishing boats in 1990 used gillnets. Although gillnets remained the major fishing gear for these boats, diversification to use of other fishing gears, to different extents in different regions was noted in 2000.

The smallest decrease in use of gillnets was in the Masaka region from 95.3% in 1990 to 83.7% boats in 2000 but the number of parachute/dugout boats using gillnets increased from 391 to 603. In this region the second most important gear of these boats were traps, which rose from 0.5% (2 boats) in 1990 to 10.5% (75 boats) in 2000. The next moderate decrease in proportion of boats using gillnets was in the Entebbe region from 97.5% in 1990 to 78.9% in 2000, but parachute/dugout boats using gillnets increased from 568 to 950. The Sesse region followed with a decrease from 95.6% to 71.9% of boats using gillnets but the actual number of boats increasing from 97 to 343. Cast nets were the second important fishing gear in use in the Sesse region while traps came second in the Entebbe region. The two regions in the eastern part of the lake, Jinja and Tororo, had the lowest proportion of parachute/dugout boats using gillnets in 2000 i.e. 48.0% and 58% respectively. However, the number of these boats using gillnets had increased tremendously from 162 to 609 boats in Jinja and 627 to 1162 boats in Tororo. In the Jinja region the use of cast nets rose from 1.5% in 1990 to 23.5% in 2000 representing 3 and 298 boats respectively. A wider diversity of fishing gears replaced use of gillnets in the Tororo region, with more prominent change in use of cast nets from 0.4% (3 boats) to 10% (199 boats) and hand lines 1.3% (10 boats) to 8.5% (170 boats).

Overall among parachute/dugout boats, the use of gillnets declined from 88.0% of boats in 1990 to 64.6% in 2000, but the number of these boats using gillnets increased from 1457 to 3667, an 152% increase.

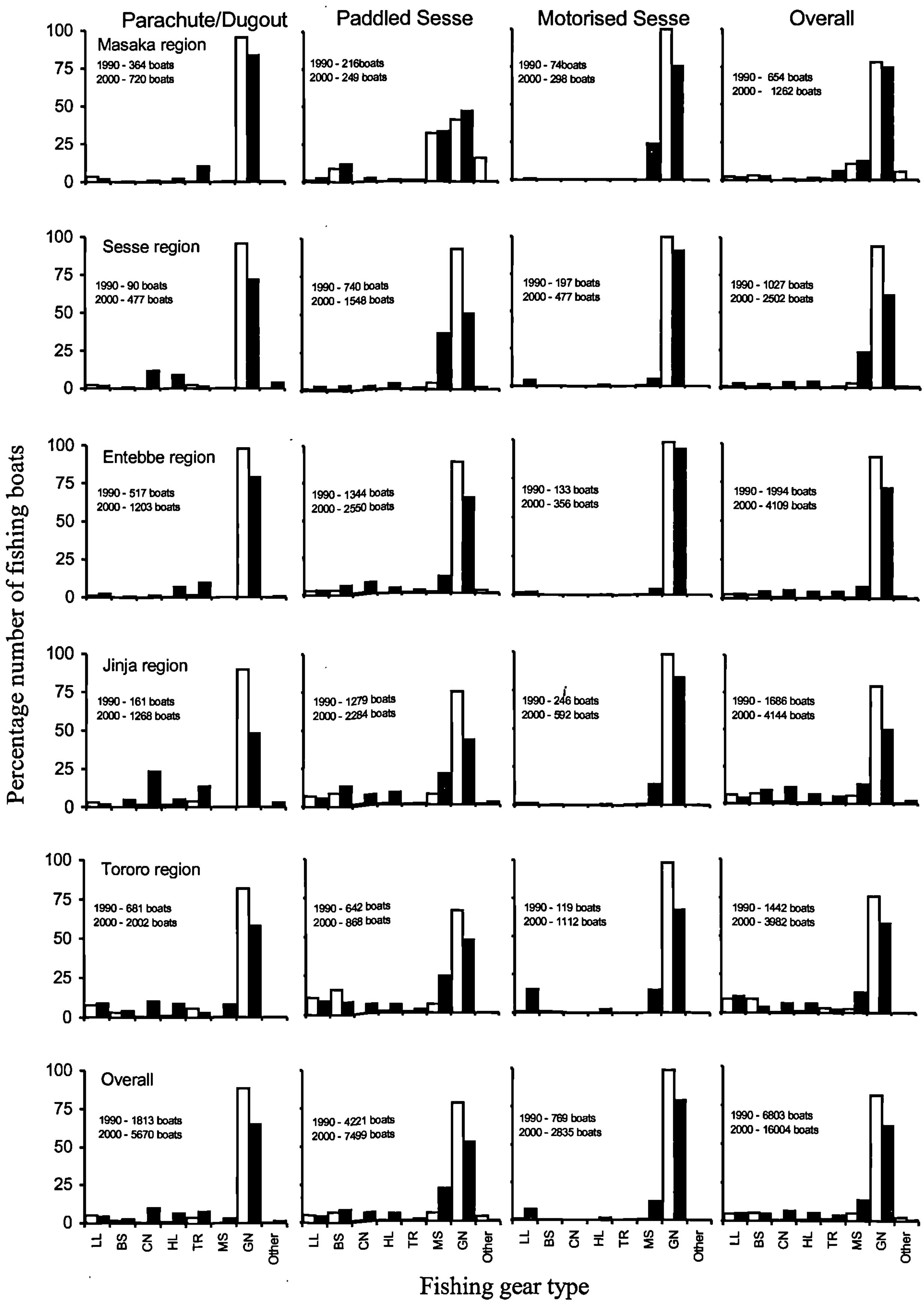


Figure 3.2 Distribution of fishing gear type by boat category in five regions of the Ugandan part of Lake Victoria in 1990 (clear bars) and 2000 (shaded bars), LL=long line, BS=beach seine, CN=cast net, HL=hand line, TR=traps, MS=mosquito seine and GN=gillnet.

Prominent among the gears substituting gillnets were cast nets (0.4 to 10.1%), traps (3.8 to 7.6%) and hand lines (0.9 to 6.6%). The number of parachute/dugouts using cast nets increased from 7 in 1990 to 575 in 2000, traps from 63 to 431 boats and hand lines from 16 to 375 boats.

Paddled Sesse boats

Fishing gear use among paddled Sesse boats in the Masaka region between 1990 and 2000 showed a unique pattern from those in the rest of the lake. The number of boats remained fairly stable and the proportion of boats using each of the prominent fishing gears (gillnets, mosquito seines, and beach seines) increased slightly, using up the category of other unclassified gears that was absent in 2000.

In the Sesse region, the decrease in proportion of boats using gillnets, from 92.4 to 49.7%, was mainly taken up by use of mosquito seines that increased from 4.1 to 37.1 %. Paddled Sesse boats' using gillnets in this region was stable (771 to 770 boats) while those using mosquito seines increased from 34 to 572 over the ten-year period.

In the Entebbe region the decrease in use of gillnets from 88.2 to 64.2% was mainly taken up by mosquito seines (1.0-11.6%), cast nets (1.4-7.8%) and beach seines (3.3-6.7%). However, boats using each of these gears increased in number: gillnetting boats increased from 1337 to 1637, mosquito seines from 15 to 296 boats, cast nets from 21 to 201 boats and beach seines from 51 to 171 boats.

In the Jinja region, use of gillnets dropped from 74.3 to 42.6% of boats while use of mosquito nets increased from 6.8 to 20.3%. The numbers of paddled Sesse boats using gillnets decreased from 1071 to 974 while those using mosquito seines increased from 98 to 464. The proportion of boats operating long lines also decreased from 7.0 to 5.6%, but with a small increase in the number of boats using the gear from 100 to 128 boats. Proportions of boats using the rest of the gears increased, particularly beach seines from 8.8 to 13.7%, with the actual boat numbers increasing from 126 to 312, and cast nets from 1.5 to 6.9% (21 to 158 boats). The Tororo region had a similar pattern to Jinja except that the proportion of paddled Sesse boats using beach seines decreased from 16.2 to 7.9% and their number also decreased from 117 to 69 boats.

Overall among paddled Sesse boats, the use of gillnets declined from 77.6% of boats in

1990 to 52.0% in 2000, but the number of boats using gillnets increased from 3692 to 3901, a 6% increase. Prominent among the gears substituting gillnets were mosquito nets (5.6 to 21.6%), cast nets (0.9 to 6.0%) and hand lines (0.5 to 5.2%). Paddled Sesse boats using mosquito seines increased from 265 to 1618, cast nets from 44 to 451 boats and hand lines 24 to 388 boats. The proportion of beach seining boats increased slightly from 6.8 to 8.4% but in real terms, the increase in number of boats operating the gear was large, from 324 to 570 boats.

Motorised Sesse boats

These boats were almost exclusively gill-netters in 1990, but there was a shift to other gears, mainly mosquito seines and long lines, by 2000. The largest proportion of motorised boats using mosquito seines (23.8% - 74 boats) was in the Masaka region, followed by Tororo, (14.8% - 165 boats) and Jinja (13.7% - 81 boats). In addition to mosquito seines, the Tororo region had 15.2% (169 boats) of motorised boats operating in the long line fishery. The Sesse and Entebbe regions had the lowest decline in the proportion of motorised boats using gillnets, from 99.5 to 90.4% and 98.5 to 94.1% respectively. Overall, the proportion of motorised boats using gillnets declined from 98.6% in 1990 to 78.7% in 2000, whereas those using mosquito seines increased from 0.4 to 12.4%, long lines 0.9 to 7.2% and hand lines 0.5 to 1.3%.

Overall regional differences in fishing gear composition

The least changes in overall composition of fishing gears between 1990 and 2000 were in the Masaka region in the western part of the lake, whereas the widest changes occurred in the Jinja and Tororo regions, in the eastern part of the lake. The proportion of boats using gillnets in 2000 was highest in the Masaka region at 74.6% of 1262 boats followed by Entebbe (71.1% of 4109 boats), Sesse (61.7% of 2502 boats), Tororo (58.1% of 3982 boats), and lowest in the Jinja region (50.1% of 4144 boats). The proportions of boats using cast nets and beach seines were highest in the Jinja region at 11.0% and 9.1% of 4144 boats respectively. The lake wide status for the Uganda part of Lake Victoria shows an overall decline in the proportion of boats using gillnets from 81.2% of all boats in 1990 to 61.4% in 2000, but the number of gillnetting boats increased from 5921 to 9800. The proportion of boats operating beach seines also declined slightly from 5.0 to 4.6%, while their number increased from 348 to 730. The percentage and numbers of boats using the rest of the gears also increased:

- mosquito seines from 4.7% to 13.4% (269 to 2130 boats);

- cast nets from 0.5% to 6.4% (51 to 1026 boats);
- hand lines from 0.6% to 5.0% (39 to 799 boats);
- traps from 1.1% to 3.4% (83 to 547 boats); and
- long lines from 4.7% to 5.0% (329 to 793 boats).

3.2.3 *Changes in the gillnet mesh size composition*

A shift from large gillnet mesh sizes in 1990 to utilisation of smaller mesh sizes in 2000 was evident in all three main boat categories (Fig. 3.3). This was coupled with tremendous increases in the total numbers of gillnets used: from 8235 to 43 359 nets in parachute/dugout boats, 34 536 to 116 078 in paddled Sesse boats and 42 207 to 135 092 nets in motorised and sailed boats. Overall, the number of gillnets increased about 3.5 times, from 84 978 nets in 1990 to 294 529 nets in 2000.

Parachute/dugout boats

Amongst parachute/dugout boats, 127 mm, the recommended minimum mesh size, was the most commonly used constituting 28.0% of total number of gillnets in 1990 and 28.4% in 2000. However, mesh sizes larger than 127 mm, declined from 43.8% in 1990 to 18.4% in 2000 and consequently, the use of illegal gillnet mesh sizes smaller than 127mm increased from 28.1% of nets (2317 nets) in 1990 to 53.3% (23 091 nets) in 2000, an almost 10 fold increase.

Paddled Sesse boats

Amongst the paddled Sesse boats, the most prominent gillnet mesh sizes used in 1990 were 178 mm and 203 mm constituting 36.0% and 34.9% respectively, of the total number of gillnets used by these boats. In 2000, gillnet mesh size composition was dominated by 127 mm and 152 mm, contributing 27.1% and 31.2% respectively of all nets used. Mesh sizes larger than 152 mm contributed only 12.8% of gillnet fleets of these boats in 2000 compared with 72.2% in 1990, their total number declining from 24 931 to 14 810 nets. The use of illegal mesh sizes smaller than 127mm rose from 2.2% in 1990 to 22.5% in 2000, but this represented a tremendous increase in total number of nets from 751 to 26 100.

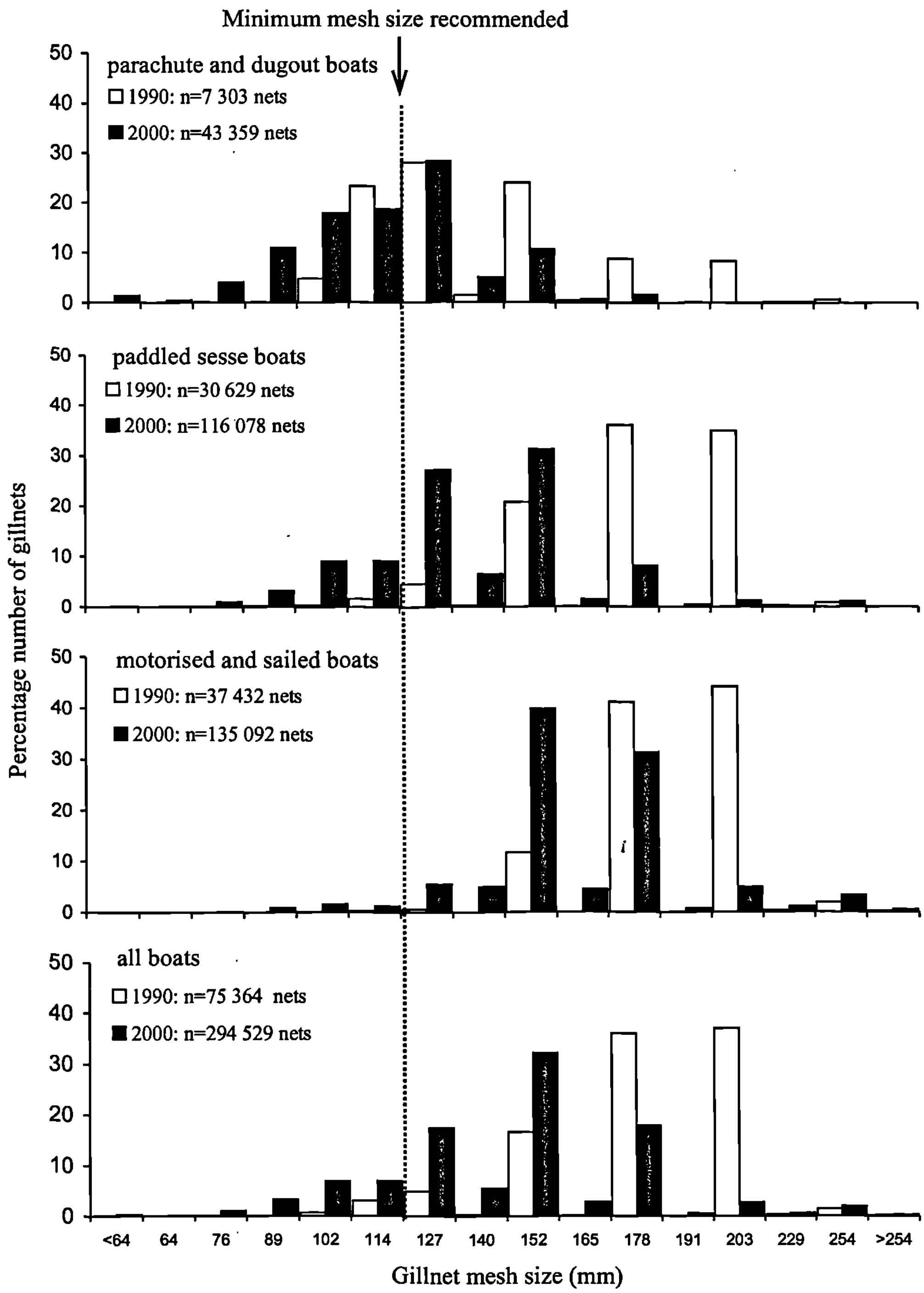


Figure 3.3 Mesh size composition of gillnets used by different categories of boats in the Ugandan part of Lake Victoria in 1990 and 2000.

Motorised Sesse boats

The motorised Sesse boats consistently used the largest mesh sizes of all boat categories in 1990 and 2000. However, the use 203-mm mesh size declined drastically from 44.2% in 1990 to 4.8% in 2000, with the actual number of nets decreasing from 16 543 to 6516 respectively. On the other hand, the use of 152-mm mesh size nets increased from 11.6% in 1990 to 39.9% in 2000, with an enormous increase in the number of nets from 4334 to 53 856 respectively.

Although the 178-mm mesh size nets remained important in the gillnet fleets of these boats, their proportional contribution decreased from 41.2% to 31.4% but their actual numbers increased from 15 408 to 42 360 nets. Gillnet mesh sizes smaller than 152 mm were virtually absent in 1990, but contributed 14.1% (19 092 nets) in 2000 of which 3.7% (5063 nets) were illegal, i.e. below the 127-mm minimum mesh size recommended.

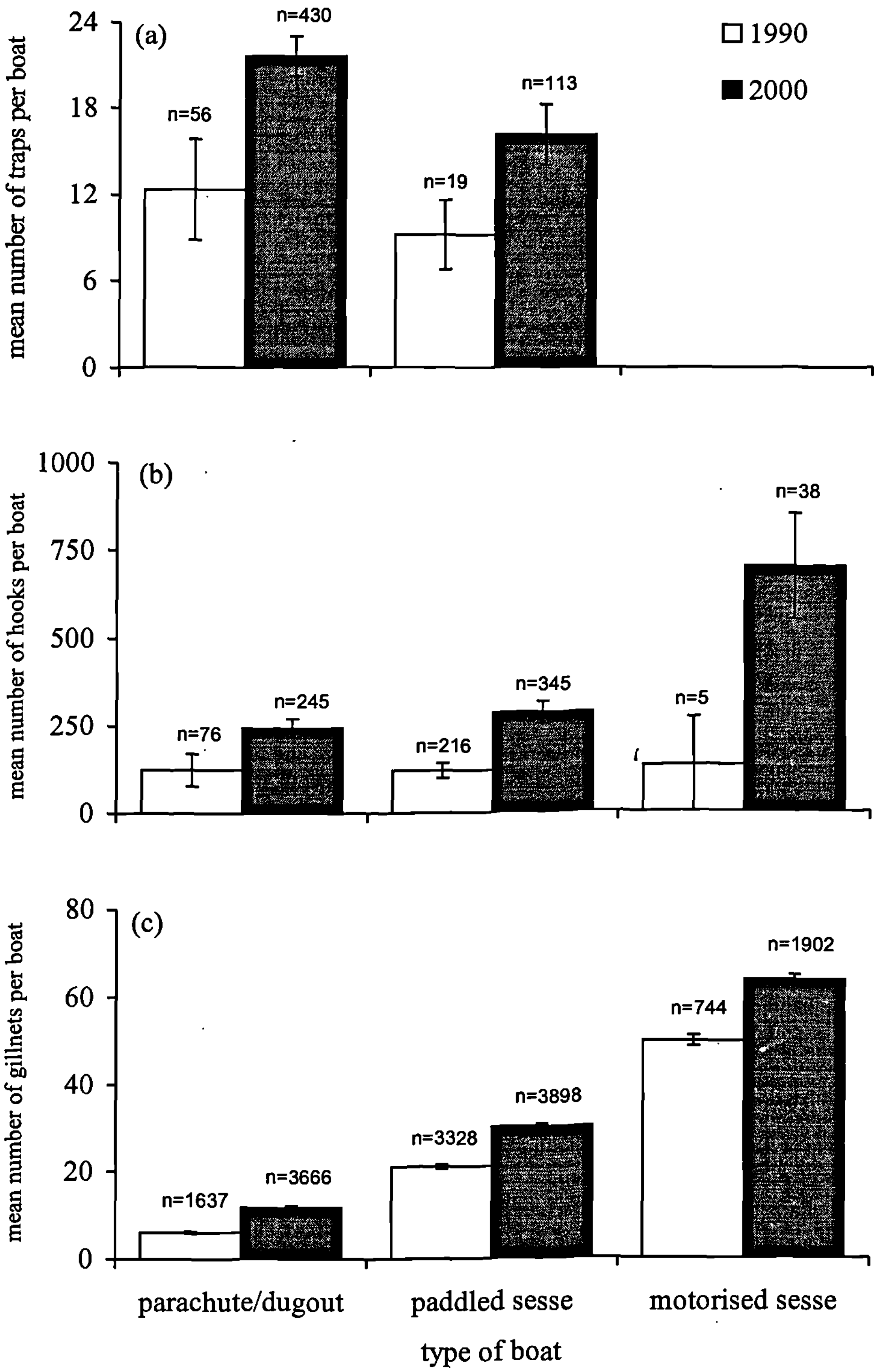
The overall use of illegal gillnets <127 mm increased from 3.7% (3164 nets) in 1990 to 18.4% (54 254 nets) in 2000. The use of 127-152 mm mesh size gillnets increased from 21.6% (18 384 nets) to 55.1% (162 181 nets) while meshes sizes >152 mm reduced from 74.6% to 26.5%, but with an increase in the number of these nets from 63 439 to 78 094 nets.

3.2.4 *Changes in the number(s) of fishing gear units per boat*

One unit of fishing gear is used per boat at any one time for beach seines, cast nets and mosquito seines. For hand lines, several hooks are used per boat, depending on the number crew, but the total number of hooks rarely exceeds ten. Therefore, among the major fishing gears used on Lake Victoria, the number of gear units per boat only varies widely for traps, long lines and gillnets. The numbers of gear units per boat increased between 1990 and 2000 for all the latter three fishing gears (Fig. 3.4).

The mean number of traps per boat rose from 12 $\pm$ 4 in 1990 to 22 $\pm$ 1 in 2000 in parachute/dugout boats, and 9 $\pm$ 2 to 16 $\pm$ 2 in paddled Sesse boats. None of the motorised boats used traps. Similarly, the mean number of hooks used on long lining boats increased from 122 $\pm$ 46 in 1990 to 243 $\pm$ 27 in 2000 in parachute/dugout boats, from 119 $\pm$ 21 to 284 $\pm$ 32 in paddled Sesse boats and 131 $\pm$ 138 to 701 $\pm$ 151 in motorised Sesse boats. The mean number of gillnets per boat in all the three main categories of fishing boats also increased between 1990 and 2000: on parachute/dugout boats from 6 $\pm$ 0 to 12 $\pm$ 1 nets, on paddled Sesse boats from 21 $\pm$ 1 to 30 $\pm$ 1 nets and on motorised Sesse boats from 50 $\pm$ 1 to 64 $\pm$ 1 nets.

Figure 3.4 Mean number of (a) traps (b) hooks on long lines and (c) gillnets per boat in



the three main categories of boats in the Uganda part of Lake Victoria in 1990 and 2000 (n=number of boats that used the gear and Error bars = 95%CL).

3.3 The current distribution of fishing characteristics - 2000 frame survey

3.3.1 *Spatial distribution of fishing boats*

Fishing boats were generally few and dispersed in the western and central areas of the Uganda part of Lake Victoria compared with the eastern part where they were quite aggregated (Fig. 3.5).

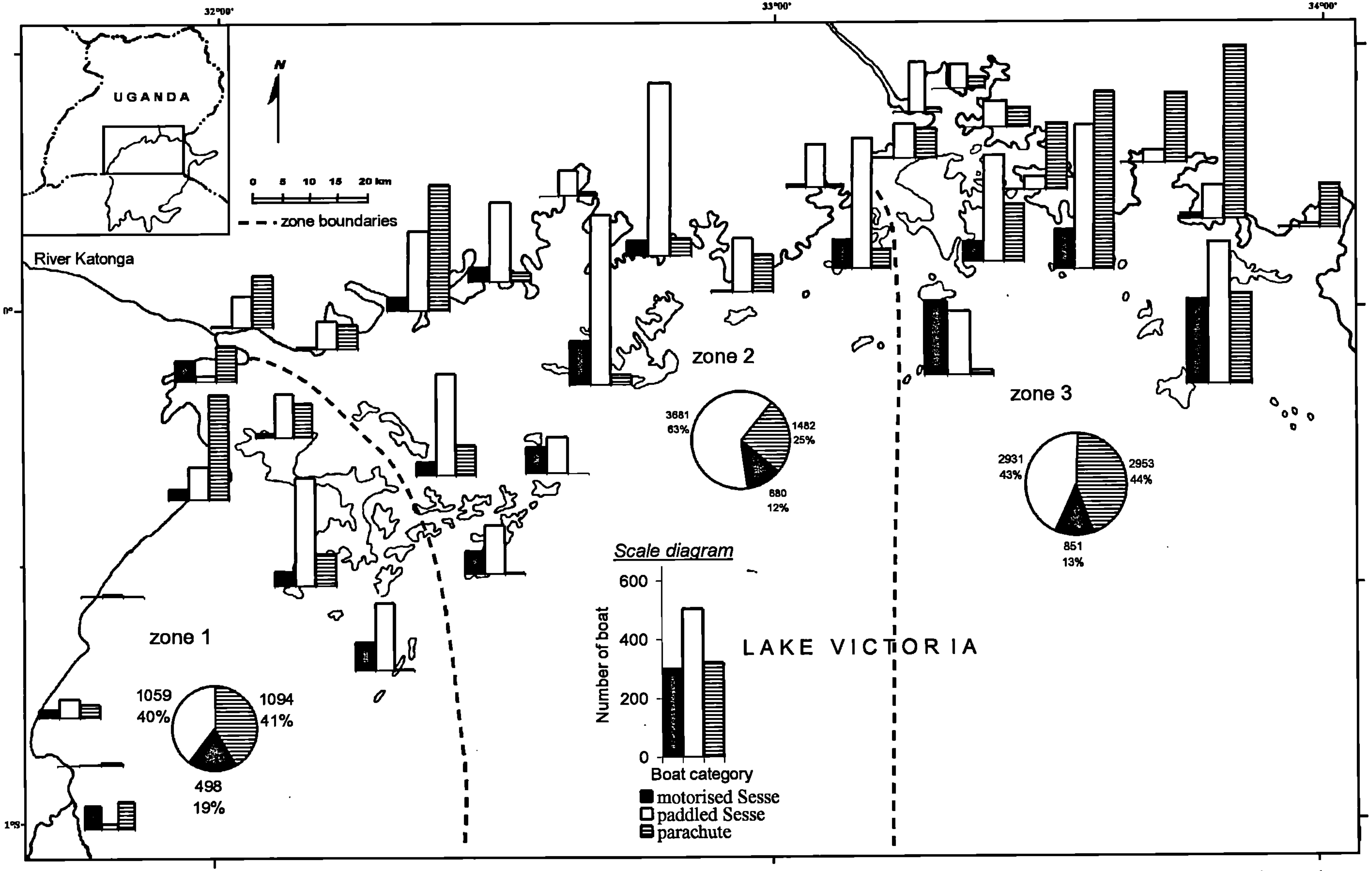


Figure 3.5 Map of the Ugandan part of Lake Victoria showing the spatial distribution of the three major categories of fishing boats. Bar charts show numbers of boats plotted against approximate location of sub-counties (not shown) where they occurred. Pie charts show proportions of boats by zones (Zones 1-3 are demarcations followed in recent fisheries research surveys).

Parachute boats were more prominent along the eastern and northwest shorelines but rare in the central areas and islands. They contributed 44% (2953 boats) of the total number of boats in zone 3 in the east, 41% (1094 boats) in zone 1 in the west and only 25% (1482 boats) in zone 2 – the central area.

Paddled Sesse boats were the dominant fishing craft in zone 2, where they contributed 63% (3681 boats) of the total number of fishing boats. They constituted 40% (1059 boats) and 43% (2931 boats) in zones 1 and 3, respectively.

Zone 1 had the highest proportion of motorised boats at 19% of the total number of fishing boats, followed by zone 3 (13%) and zone 2 (12%). However, the highest number of motorised boats was in zone 3 (851 boats), showing strong presence in the island areas, followed by zone 2 (680 boats) and zone 1 (498 boats).

3.3.2 *Spatial distribution of fishing gears*

Gillnets

Generally, fewer gillnets were used along the mainland shoreline compared with the islands, especially in zone 3 (Fig. 3.6). The 127-178 mm mesh size gillnets were the most common throughout the lake, constituting 79% in zones 1 and 2, i.e. 55 394 and 82 472 gillnets, respectively, and 70% (83 812 nets) of gillnets used in zone 3. Next in importance were the mesh sizes less that 127 mm which showed a stronger presence in the eastern part of the lake, although they were common throughout the lake. They constituted 17% (11 617 nets) of gillnets in zone 1, 16% (16 300 nets) in zone 2 and 22% (26 282 nets) in zone 3. Gillnet mesh sizes greater than 178 mm were quite rare, showing relatively high occurrence south of Buvuma islands in the east, Kome islands in the central part and the southwestern part of the lake. They constituted 4% (2492 nets) of gillnets used in zone 1, 5% (4843 nets) in zone 2 and 8% (10 187 nets) in zone 3.

Other gears excluding gillnets

Diversification to use of various fishing gears, excluding gillnets, increased from the western part of the lake eastwards (Fig. 3.7). Mosquito seines were the most important fishing gear used by non-gillnetting boats throughout the lake but the proportions of boats using this gear declined in importance eastwards from 66% in zone 1, to 40% in zone 2 and 32% in zone 3.

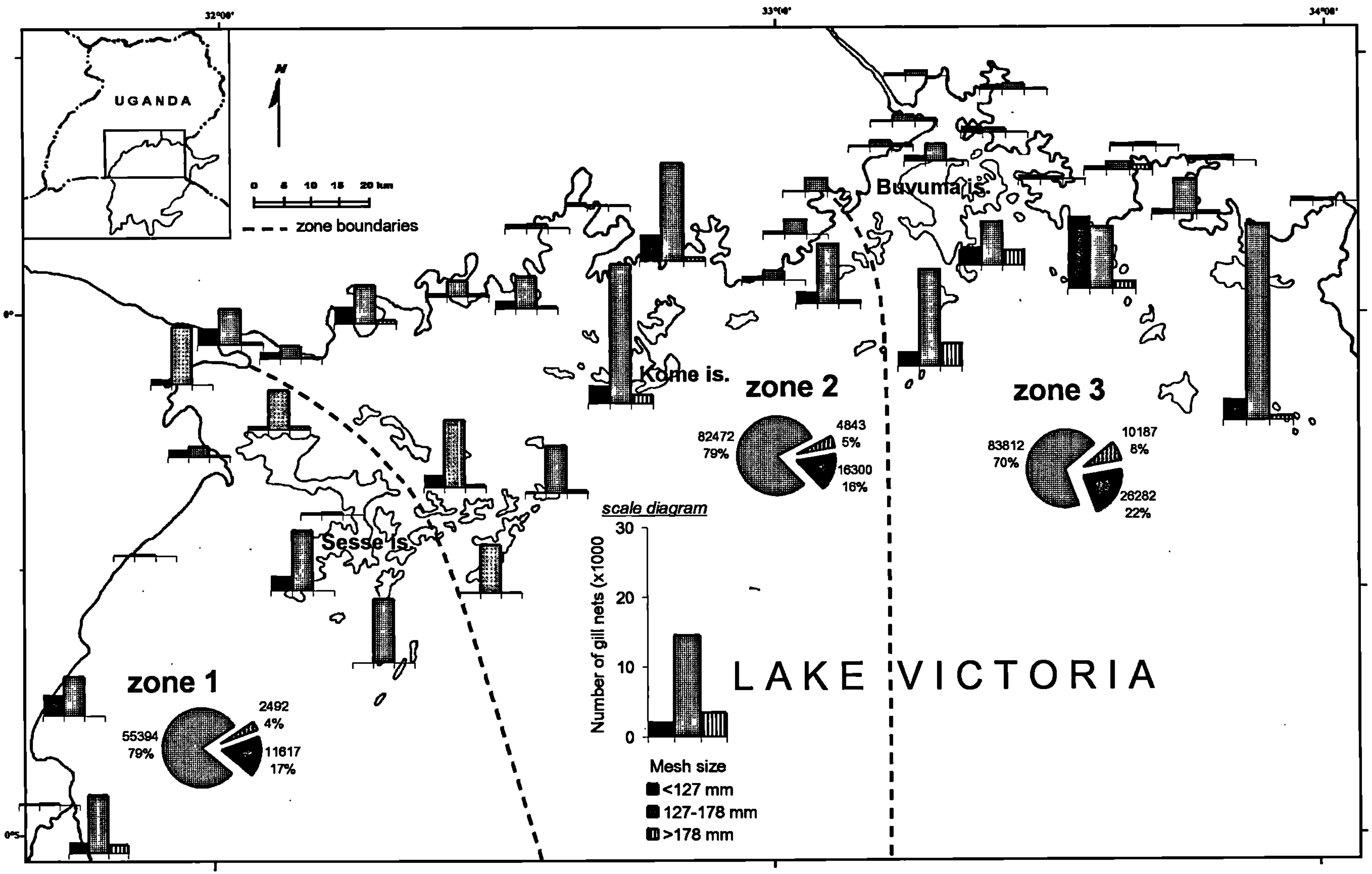


Figure 3.6 Map of the Ugandan part of Lake Victoria showing the spatial distribution of gillnet by mesh size ranges. Bar charts show numbers of gillnets plotted against approximate location of sub-counties (not shown) where they occurred. Pie charts show proportions of mesh size ranges by zones (zones 1-3 are demarcations followed in recent fisheries research surveys).

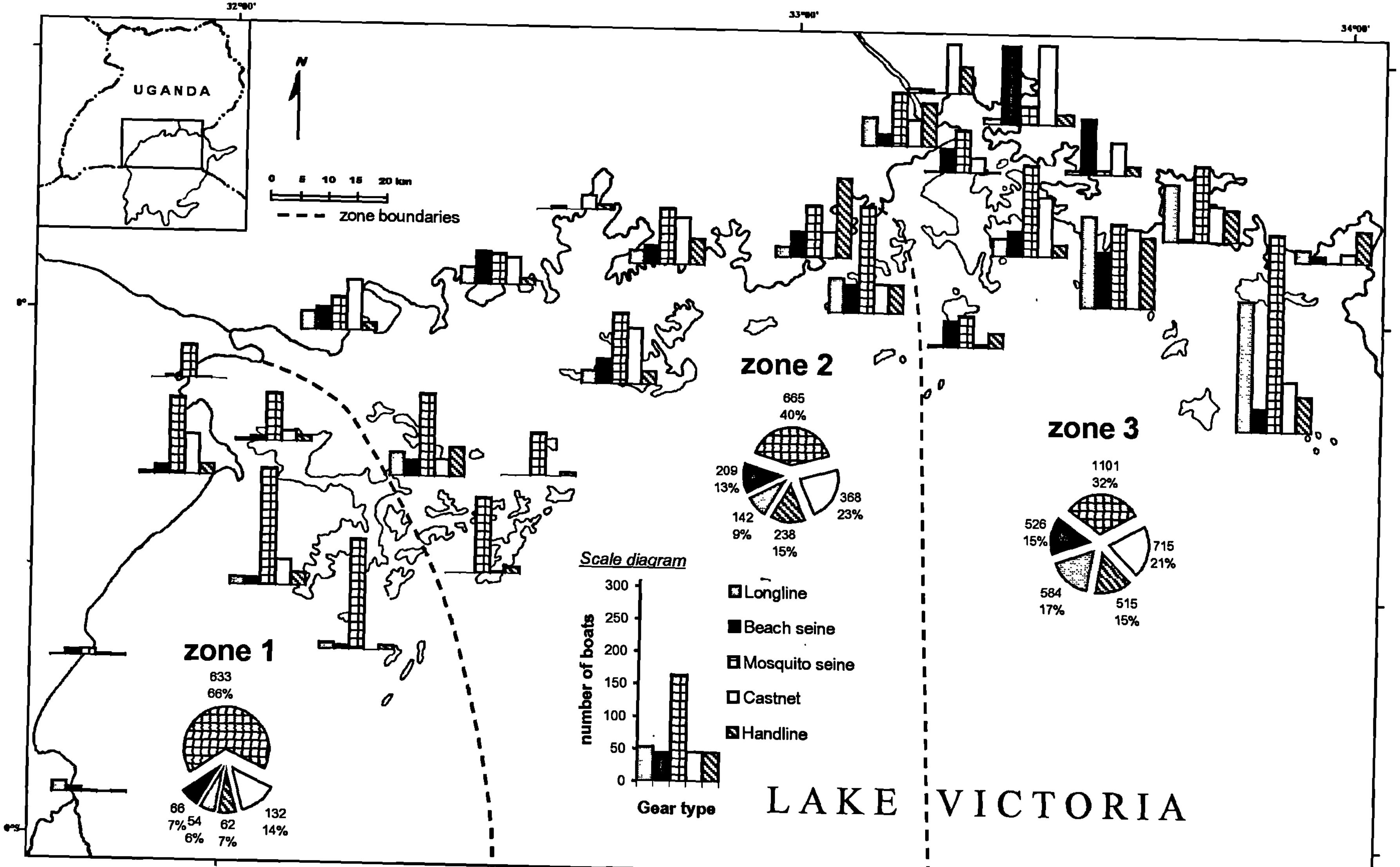


Figure 3.7 Map of Ugandan part of Lake Victoria showing spatial distribution of boats using the major fishing gears excluding gillnets. Bar charts show the number of boats using each gear plotted against approximate location of sub-counties (not shown) where they occurred. Pie charts show proportions of boats using each gear by zones (zones 1-3 are demarcations followed in recent fisheries research surveys).

Cast nets were the second in importance, used most in zone 2 by 23% of boats, 21% in zone 3 and 14% in zone 1. A higher percentage of boats used each of the remaining gears (beach seines, long lines and hand lines) in zone 3 than in the rest of the lake. The greatest numbers of boats using other gears was in Zone 3 followed by Zone 2 (Fig. 3.8).

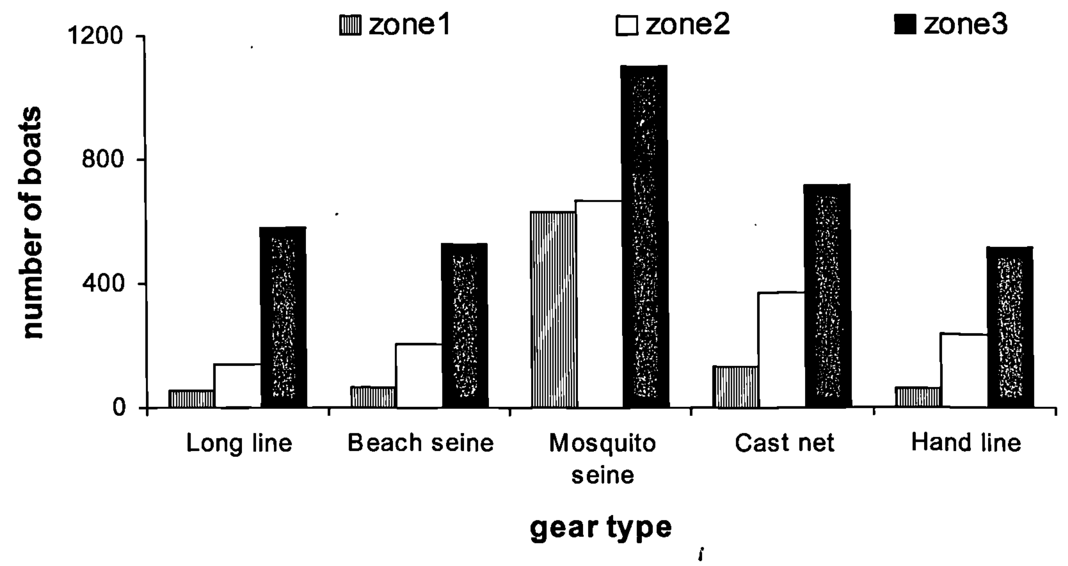


Figure 3.8 Number of boats using different types of gears excluding gillnets in zones 1-3.

3.4 Lake wide status of fishing effort

The current lake wide status of total fishing effort, on country-by-country basis, is reflected in the results of the frame survey conducted in March 2000 (summarised in Appendix 3.1).

3.4.1 *Lake wide distribution of fishing gears*

The proportions of the total numbers of fishing gears is not directly related to the surface area of the lake shared by the three countries, i.e. Kenya (6%), Tanzania (49%) and Uganda (45%) (Fig. 3.9). The Ugandan part of lake had the highest number of gillnets constituting 45.6% of the total number of gillnets used on the whole lake followed by Tanzania 34.9% and Kenya had the least (19.5%). The Ugandan part also dominated in the use of traps but had the least of all other gears except cast nets where it was second to Kenya. The Tanzanian part of the lake, which is the largest, only dominated in the number of long line hooks. The Kenyan part of the lake, which accounts for only 6% of the lake, had the highest proportion of the rest of the gears: 74% of beach seines; 77% of cast nets; 59% of hooks operated by hand lines; 66% of mosquito seines and 58% of other unclassified gears.

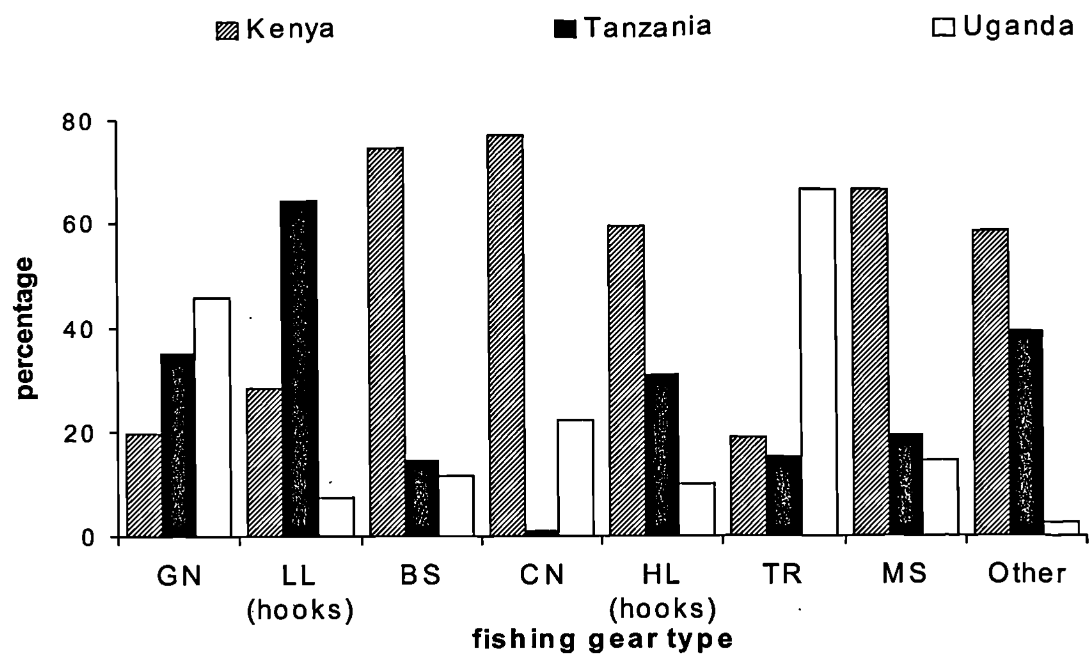


Figure 3.9 Distribution of different fishing gear types in the three countries (Kenya, Tanzania and Uganda) sharing Lake Victoria in 2000. GN = gillnet, LL = long line, BS = beach seine, CN = cast nets, HL = hand line, TR = traps and MS = mosquito seine.

Analysis of the numbers gear units per unit of lake surface area revealed disproportionately high fishing intensity in the Kenyan part of the lake for all fishing gears (Fig. 3.10). Although fishing intensity is higher in the Kenyan part of the lake, the actual differences in fishing intensity in the three countries should be lower than is implied by Figure 3.10. This is because far offshore areas in the Tanzanian and Ugandan waters are inaccessible to the artisanal fishers, unlike in Kenya where the whole part of the lake is fished and there could be some areas where fishing is locally intensive and comparable to the Kenyan part. Also there are fewer fish in the deep waters making the risk benefits lower. It is generally known that Kenyans fish across the borders in Ugandan and Tanzanian waters. In reality, therefore, the fishing effort (boats and fishing gears) recorded in the Kenyan sector of the Lake in the 2000 Frame survey is expended in an area wider than the Kenyan waters. It is thus important to recognise that both fishers and fish do not respect the physical borders in the lake, which has implications on the management strategies that should be adopted. This also emphasises the importance of harmonising management measures around the lake, treating the lake as one entity, rather each individual country (Kenya, Tanzania, and Uganda) having its own management strategies.

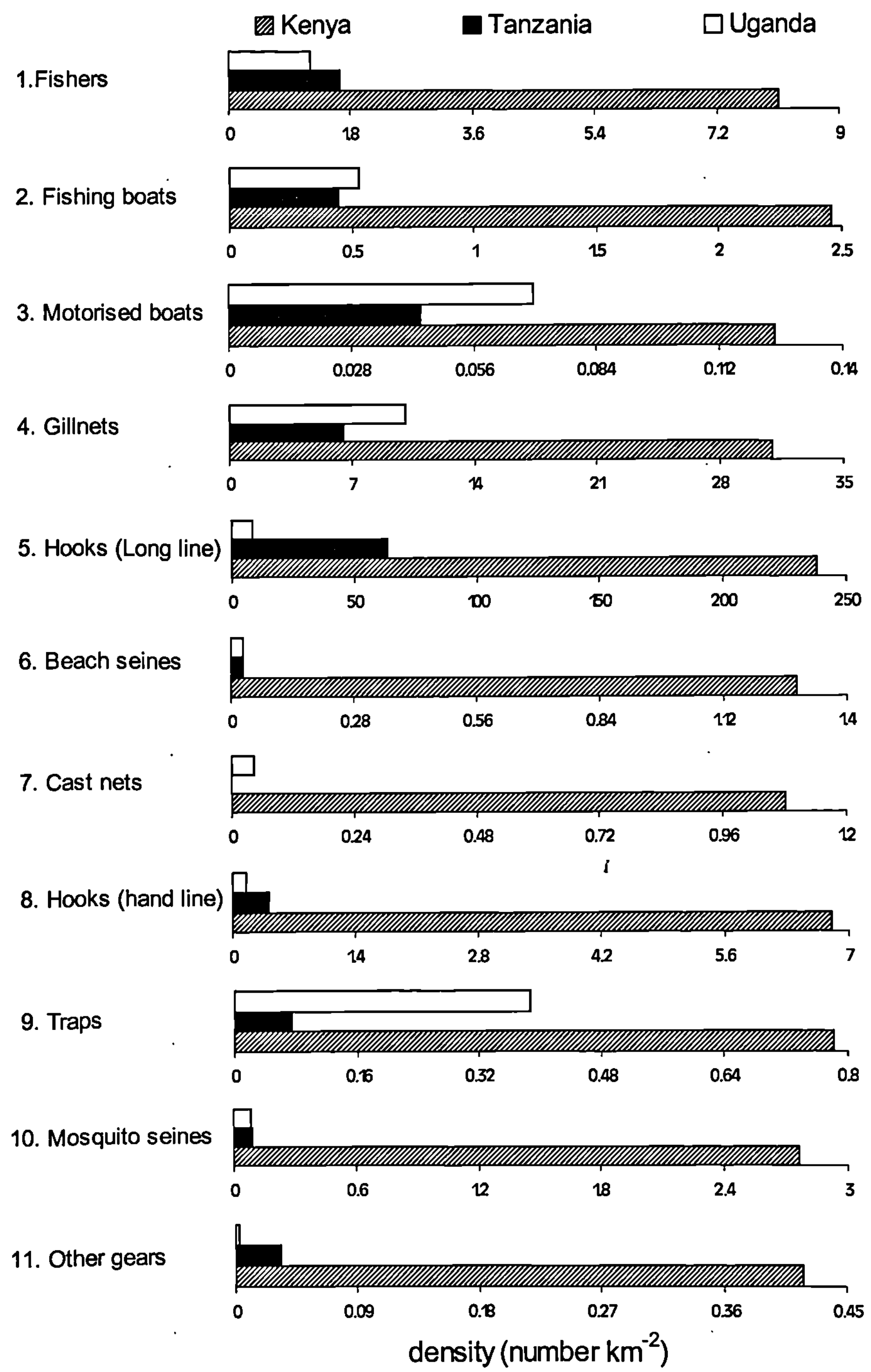


Figure 3.10 Density of fishers, fishing boats, motorised boats and different fishing gears in Kenyan, Tanzanian and Ugandan waters of Lake Victoria in 2000.

3.4.2 *Lake wide gillnet mesh size composition*

Illegal gillnet mesh sizes <127 mm were most common in the Kenyan part of the lake where they constituted 26.2% of all gill fleets (Fig. 3.11). They contributed 18.4% of gillnets in the Ugandan part of the lake and were least common in the Tanzanian part, where they contributed only 11.2%. In both Kenya and Uganda, the most common gillnets were of 152 mm mesh size, contributing 23.2 and 32.1% respectively. Although the 152 mm mesh size nets were also common in Tanzania (26.3%), the dominant mesh size was 127 mm, which contributed 39.1% of all nets. The gillnet mesh sizes in use were most diverse in Kenya, followed by Uganda, whereas in Tanzania the majority of nets (77.4%) occurred in a narrow mesh size range of 127 to 152 mm. In the whole lake, illegal gillnets <127 mm mesh size contributed 17.4% of the total number of gillnets estimated. The most dominant mesh sizes in the whole lake were 152 mm (28.4%), followed by 127 mm (22.8%), and 178 mm (13.9%).

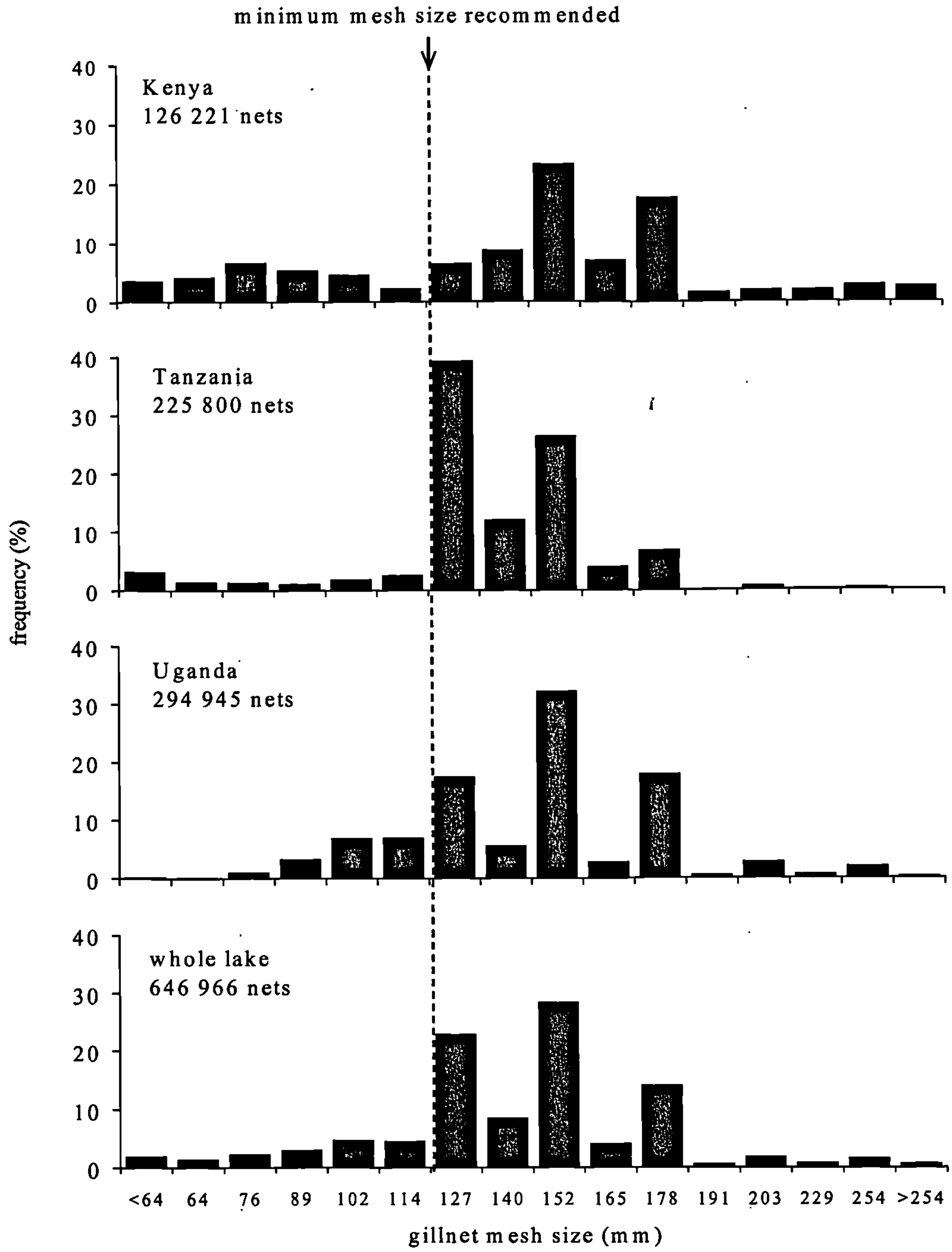


Figure 3.11 Mesh size composition of gillnets used in the Kenyan, Tanzanian and Ugandan parts of Lake Victoria in 2000.

3.5 Discussion

3.5.1 *Elements of fishing effort in the Lake Victoria fishery*

The magnitude of fishing effort in Lake Victoria is represented by several interrelated elements. The most obvious elements of fishing effort are the number of fishing boats operating in the fishery and the number of fishing gears. However, there are a number of other indirect elements of fishing effort that manifest in the form of innovations or fishing strategies that change the qualitative characteristics of fishing boats and/or fishing gears to increase their chances of catching fish to make the operations viable. The latter include shifting between fishing gears, changes in gear characteristics like mesh size and their mode of operation, changes in the quantities of gear units used per boat and shifting emphasis to use of particular types of boats, e.g. motorisation to gain access to the offshore waters. All these elements changed in a manner that exacerbates the tremendous increase in fishing effort in the Ugandan part of the lake between 1990 and 2000.

The total number of fishing boats increased from an estimated 2643 - 3264 in 1970-72 to 8000 boats in 1990 (Tumwebaze & Coenen 1991), a period of 28 years. By contrast, the rate of increase in effort throughout the 1990s to reach 15 462 boats in 2000 was substantially greater. This rapid increase in the 1990s reflects the huge changes that have occurred in the fishery associated with the explosion in Nile perch, coupled with the dominance of the species, plus *R. argentea* and Nile tilapia, in the fishery.

The shift in gear use is best displayed by the decline in the proportion of boats using gillnets between 1990 and 2000. Although the total number of gillnetting boats increased, the overall proportion of boats using gillnets declined considerably, by about 20%. This is partly explained by expansion of the *R. agentea* fishery, but also the increase in the proportion of boats using cast nets, beach seines, hand lines, traps and long lines. Motorised fishing boats with the ability to spread their search for fish over wider areas maintained the highest usage of gillnets compared with paddled Sesse and parachute/dugout boats that have limited fishing grounds. The widest diversification of fishing gears occurred in the eastern part of the lake, the region with the highest concentration of fishing boats, and was lowest in the western part that had the least density of fishing boats. This distribution suggests that the extent of adopting new fishing gears and fishing methods in Lake Victoria may be related to fishing pressure. Fish catch rates probably decline as fishing pressure increases greatly, therefore, the diversification of fishing gears is possibly a mechanism to maintain catch rates per boat using gears with greater fishing efficiency. The alternative explanation would be that fishing gears like cast nets, hooks on long lines and hand lines, and traps are relatively inexpensive compared with gillnets, thus a small catch would remain profitable as fish stocks decline. This could be linked to the open access nature of the fishery where new entrants, especially the poor, can start fishing with minimal investment, and is an issue that needs resolving. Furthermore, according to fishers, gillnets are also more prone to theft than other fishing gears, which could be contributing to the proportional reduction in their use. Irrespective, the end result is increased fishing effort beyond that which is implied by the change in numbers of boats *per se*.

The number of fishing gear units per boat is one of the primary factors that determine the amount of fishing effort imparted by the boat. Therefore the increase in the number of gear units per boat, especially the numbers of gillnets, long line hooks and traps, also points to more fishing effort than is implied by the increase in number of boats between 1990 and 2000. Further to the increase in number of gillnets per boat, marked declines in gillnet mesh sizes have occurred, thus shifting fishing effort to fish of smaller size, which has further ramifications (see section 3.2.3).

The increase in the numbers of boats from 1990 to 2000 was more biased to parachute and motorised boats than paddled Sesse boats, indicating that fishers were putting more emphasis on the former two categories of boats. Motorised boats allow operation in deeper offshore waters targeting mainly Nile perch, while parachute boats are specialised for use in the tilapia fishery in near shore waters. Paddled Sesse boats are less specialised, being the main craft in the *R. argentea* fishery, but used in both the Nile perch and tilapia fisheries. The emphasis on the former two categories of boats probably equates to increased searching for Nile perch and Nile tilapia and would imply greater fishing effort targeting the two species perhaps coupled with decline in catch rates. Notwithstanding, the use of motorised boats means that all fishing grounds in the lake are accessible and thus no heavens from fishing exist.

3.5.2 *Distribution patterns of fishing boats*

Two major types of fishing boats operate on Lake Victoria: (i) parachute boats, which are small, simple planked boats, made out of three planks of timber and have a flat bottom; (ii) Sesse boats that are made out of many planks of timber, have a keel, a

V-shaped bottom and their sizes vary widely depending on the intended use. The Sesse boat may either be pointed at both ends, to be propelled by only paddles and/or sail, or flat at one end, a modification for attachment of an outboard motor. The simple structure of parachute boats makes them more vulnerable to rough weather than the Sesse boats, thus their fishing operations are restricted to inshore areas that are sheltered from strong winds. The inshore areas of Lake Victoria have been described as the typical habitat for tilapia (Graham, 1929; Lowe-McConnell, 1958; Welcomme, 1966). Nile tilapia is now the main commercially important species caught in the inshore zone (Balirwa, 1995; 1998). Parachute boats, which operate exclusively in the sheltered inshore areas, are the main craft used in the tilapia fishery, therefore, their distribution is probably associated with the distribution of tilapia. The eastern shoreline of the Ugandan part of the lake has more sheltered inshore areas than the rest of the lake, partly explaining the higher prevalence of parachute boats in this region. Due to their simplicity, parachute boats are inexpensive and more easily acquired by fishers than any other fishing boat. The more rapid increase in their numbers between 1990 and 2000 compared with other categories of boats may be explained by the relatively low investment required to enter the fishery with a parachute boat even when there is little prospect for good returns on the investment. The tremendous increase in numbers of parachute boats may also imply a marked increase in fishing pressure on Nile tilapia stocks. If access to the fisheries of Lake Victoria continues to be open to everybody, the number of parachute boats is likely to continue increasing, adding more fishing pressure to the tilapia stocks, because of the low level of investment involved.

Paddled Sesse boats were more widely distributed than parachute boats but their occurrence seemed to be associated with areas of open waters that require use of a stable boat. They were also closely related to occurrence of mosquito seines, the gear used in the *R. argentea* fishery, for which they are the main fishing craft. For example, in the Sesse region, which had the greatest increase in numbers of these boats between 1990 and 2000, the occurrence of mosquito seines also featured prominently but they were sparsely represented in areas with extensive open waters where there were few mosquito seines, such as the southwest part of the lake. Motorised Sesse boats were also more common in the open waters, especially the island areas. The islands appear to act as launching sites for these boats, reducing the fuel and time requirements to access the fishing grounds in the deep offshore waters.

The eastern part of the lake exhibited a higher occurrence of parachute and motorised boats and generally higher fishing intensity than the rest of the lake. Three factors could be influencing the distribution of fishing intensity. Firstly, there is high demand for fish across the border in Kenya, where fish, especially Nile perch fetch a better price than in Uganda. Consequently, cross border trade in fish between Uganda and Kenya could be providing an incentive for greater fishing effort in the eastern part of the Ugandan waters than elsewhere. This eastern zone could also be experiencing a spill over of fishing effort from across the border in Kenya where fishing intensity is exceptionally high. Evidence of the spill over of fishing effort and/or influence of fishing strategies from across the border could also be deduced from the higher occurrence of illegal fishing gears such as under sized gillnets, beach seines and cast nets in this part of the lake. These gears are the mainstay in the Kenyan part of the lake. In addition to the above, substantial numbers of Kenyan boats fish across the border. Recently Uganda stepped up efforts to stop cross border fishing and fish trade on water, and as one of the strategies to discourage these practices, two fish processing factories were established in the border distinct of Busia in 2001.

Secondly, the human population density in the rural areas along the shores of the lake is highest in eastern Uganda and lowest in the west. Fishing provides badly needed employment opportunities for the rural folk and the high population density also imposes immense demand for fishery products. With few alternative sources of livelihood, most riparian communities turn to fishing (Geheb, 1997). Therefore, fishing intensity should also be closely related to population density of the riparian communities. Population density of the riparian areas could also be influencing occurrence of destructive, illegal fishing gears like beach seines and undersized gillnets. The small immature fish caught by these fishing gears are more affordable to the majority of the rural people compared with the large-sized fish that go to filleting factories and affluent markets in large towns. Therefore the high rural population density in the riparian eastern part of Uganda could be contributing to the high demand for immature fish, thus providing the incentive for greater use of destructive fishing gears in this part of the lake than elsewhere.

Lastly, lake productivity is another factor that could be influencing the spatial distribution of fishing effort in Lake Victoria. Shallow, inshore, sheltered waters of Lake Victoria are generally very productive and productivity decreases in deeper open waters (Hecky, 1993; Mugidde, 1993;Lehman *et al.*, 1996). The eastern part of the lake has more elaborate bays and Gulfs than any other part of the lake and therefore could be the most productive. Also, nutrient loading is directly related to population density as the rural population depends directly on subsistence agriculture, made possible by deforestation and encroachment of wetlands (Bugenyi & Magumba, 1996), activities that are more widespread in the eastern part of the lake. The majority of rivers that bring nutrients into Lake Victoria from the catchment are also in the eastern part of the lake, in the Kenyan sector. The high intensity of fishing in the eastern part of the Ugandan waters and the Kenyan sector of the lake is probably, partly supported by higher productivity of these waters.

3.5.3 *Distribution patterns of fishing gears*

The distribution pattern of fishing gears seems to be primarily influenced by the overall fishing effort. The number of gillnets correspond with the occurrence of particular categories of boats. Large numbers of gillnets were associated with the occurrence of large numbers of motorised and paddled Sesse boats while areas dominated by parachute boats had the least numbers of gillnets. Similarly, mosquito seines occurred in association with paddled Sesse boats. The overall intensity of fishing seemed to influence the occurrence of illegal gears, as the use of illegal destructive fishing gears, i.e. gillnets of mesh size <127 mm, beach seines and cast nets, was coupled with the increasing fishing intensity as one moves eastwards.

3.5.4 *The lake wide distribution of fishing effort*

All components of fishing effort are disproportionately high in the Kenyan part of the lake compared with the Tanzanian and Ugandan parts, as revealed by the density of all fishing gears but this does not account for the fishing effort the Kenyan fishers expend across the border in the Ugandan and Tanzanian waters. Fishing effort in the Tanzanian and Ugandan parts is generally comparable, differing only in details. The fishery in Uganda is relatively more dependent on gillnets than the fishery in Tanzania, while in the latter there is greater use of long lines. The cast net fishery, which is coming up in Uganda and more established in Kenya, is virtually absent in Tanzania. Cast nets are destructive fishing gears and their use in Lake Victoria is illegal, therefore, Tanzania should ensure fishers do not adopt them while their ban ought to be implemented in Kenya and Uganda.

In the discussion of fishing effort in the Ugandan part of Lake Victoria, above, it was suggested that human population density and lake productivity are probably the major factors that influence the distribution of fishing effort in the lake. The lake region in Kenya is densely populated, the majority of rivers that flow into the lake carrying nutrients from the catchment are in the Kenyan part, and a large section of the Kenyan waters is shallow (<20m depth, see Fig. 1.1) and more productive than open deep waters. The probably higher productivity of the Kenyan part of the lake may partly explain why it is supporting a higher density of fishers than the Tanzanian and Ugandan parts.

The general impression from the 2000 frame survey suggests that there is higher compliance of the existing regulations on fishing gears in Tanzania than in Uganda and least compliance in the Kenyan part of the Lake. A vivid example of greater adherence to gear regulation in Tanzania is demonstrated by the gillnet mesh size composition. The domination of gillnets used in Tanzania by the minimum mesh size recommended of 127 mm, however, reflects the move of fishers to use smaller mesh sizes probably to maintain catch rates. About 10 years ago, gillnets used in Tanzania waters of Lake Victoria had a strong mode at 203 mm mesh size (Litvoet & Mkumbo, 1990), but this mesh size is now barely represented. Although the current mesh size composition in Tanzania is largely within the limits of the minimum mesh size regulations, concentration of fishing effort at 127 mm mesh size gillnets may, in the long term result in loss of sustainability of the Nile perch harvest as suggested by Schindler *et al.* (1998).

Throughout this chapter percentage change was used more often than the actual figures, with the dangers of masking the huge increases in numbers of boats and fishing gears operating in the fishery. This was to overcome repeated use of large numbers that would render the document less comprehensible. Therefore for greater clarity, actual numbers of boats and gears were only used in the sections that summarised a particular change, such as in Figures.

3.5.5 *Summary and Conclusions*

In the Ugandan part of Lake Victoria, comparison of 1990 and 2000 frame survey results revealed tremendous increase in all aspects of fishing effort. The number of fishing boats almost doubled but the qualitative characteristics of fishing gears implied much higher increase in fishing effort. The number of gillnets, which are the dominant fishing gear for Nile perch and Nile tilapia, increased about 3.5 times coupled with substantial decline of mesh sizes, whereby the use of illegal mesh sizes <127 mm increased from 3.7% to 18.4% and those >154 mm decreased from 74.6% to only 26.5% from 1990 to 2000 respectively. The increase in the number of fishing boats was biased to parachute and motorised Sesse boats, which are specialised in the Nile tilapia and Nile perch fisheries, suggesting intensification of fishing pressure on Nile tilapia in inshore waters and wide dispersal of effort to offshore waters for Nile perch, respectively.

The diversification of fishing gears and the use of illegal fishing gears increased together with the general fishing intensity from the western part of the lake eastwards. There is therefore evidence of uneven distribution of fishing effort, which could guide the allocation of resources to achieve particular management objectives. Efforts to stamp out the use of destructive fishing gears and to reduce overall fishing effort should focus on the eastern part of the lake, whereas the management programmes in other areas should concentrate more on preventing further increases in those fishing attributes.

The lake wide fishing effort reflected by the 2000 Frame survey data is disproportionately high in the Kenyan part of the lake but relatively low and comparable in Tanzanian and Ugandan waters. Fishing effort appears to be least in the Tanzanian part of the lake where the composition of fishing gears reflects the highest compliance to the existing fishing regulations. The major setback in the Tanzanian part of the lake could be the concentration of fishing effort at the minimum gillnet mesh size of 127 mm, which in the long term, through recruitment overfishing of Nile perch, may erode the benefits of high observance of regulations of illegal gears and lead to the situation experienced elsewhere in the lake.

CHAPTER FOUR

4. FISHING EFFORT AND FISH CATCH RATES AT SELECTED LANDING SITES AND ESTIMATED TOTAL CATCHES

4.1 Introduction

The fisheries of the Ugandan part of Lake Victoria are entirely artisanal in nature. Fishing is undertaken from small boats propelled by paddle, sail or outboard motor. All fishing operations are of small-scale and manual. Fishing operations of boats powered by paddle are limited to near shore waters, whereas the sailed and motorised boats venture offshore. The fish catches are landed at numerous beaches located on the mainland shoreline and the offshore islands, mainly because of the limited range of operation of fishing boats. Recording of the fish catches is difficult given the disperse nature of the fishery and landing sites leading to a critical lack of reliable information about the fishery.

Catch assessment is one of the major responsibilities of the Fisheries Department field staff in Uganda. The functions of the Fisheries Department were decentralised to the local administrations in the districts in the mid 1990s leaving a skeleton staff at the centre that has little control over the daily activities of the fisheries field staff. They are accountable to the districts and are no longer obliged to report directly to the centre. Their work schedule is also guided by the priorities set by the individual districts, which emphasise revenue collection and social services, and little or no attention is paid to catch assessment. Ten districts in Uganda share Lake Victoria but there is insufficient coordination of fisheries-related activities between them. Fisheries field staffs are also poorly resourced and are not motivated to carry out catch recording. They therefore attend more to the immediate problems that include revenue collection, overseeing hygiene, enforcing fishing regulations and resolving conflicts, within their areas of jurisdiction. At present, there is no functioning catch assessment system in the Ugandan part of Lake Victoria. A similar situation exists in Tanzania but in the Kenya, Kenya Marine and Fisheries Research Institute (KMFRI) carries out a comprehensive catch assessment-sampling programme. The official fisheries statistics are largely arrived at by extrapolation of previous fishing scenarios when some data were being collected. This is irrespective of the dynamic state of the fisheries of Lake Victoria, thus giving a false impression of production. Amidst this data vacuum, there is no basis for designing appropriate management measures to address the true status of the lake's fisheries.

This chapter examines the major factors that characterise fishing effort in the Ugandan part of Lake Victoria and relates them to fish catch rates and catch composition. It provides spatial and temporal patterns of fish catch rates and identifies the aspects that need intervention by management. The fisheries of the three major commercial fish species in Lake Victoria, i.e. Nile perch, Nile tilapia and *R. argentea*, are examined in detail and the total annual catches in the Ugandan part of the lake are also estimated.

4.2 The Gillnet Fishery

4.2.1 *Fish catch rates of gillnetting boats*

Parachute (flat-bottom planked) boats

Parachute boats were rare on beaches sampled in the central zone and the few present rarely operated, whereas they were common in the eastern and western zones. In both latter zones they targeted Nile tilapia (Fig. 4.1).

In the eastern zone, catch rates of Nile tilapia changed significantly among parachute boats between quarters (*ANOVA*: $F_{6, 249} = 2.49$, $P < 0.05$) (Appendix 4.1). The highest catch rate, 28.4 ± 11.0 kg boat^{-1} day^{-1}, was recorded in September 1999 and the lowest, 11.9 ± 3.1 kg boat^{-1} day^{-1}, in October 2001. Overall, parachute boats in the eastern zone landed 18.5 ± 1.9 kg boat^{-1} day^{-1} of Nile tilapia, 1.7 ± 0.9 kg boat^{-1} day^{-1} of Nile perch and 1.1 ± 0.3 kg boat^{-1} day^{-1} other species.

In the western zone, Nile tilapia parachute boats' catch rates were not statistically different between quarters (*ANOVA*: $F_{6, 133} = 1.15$, $P > 0.05$) (Appendix 4.2). However, similar to the eastern zone the highest catch rate, 24.8 ± 8.1 kg boat^{-1} day^{-1}, was recorded in the last quarter of 1999. The lowest catch rate in this zone, 13.5 ± 4.7 kg boat^{-1} day^{-1}, was in June 2001. Overall, parachute boats in the western zone landed 19.4 ± 2.8 kg boat^{-1} day^{-1} of Nile tilapia, 0.9 ± 0.5 kg boat^{-1} day^{-1} of Nile perch and 1.3 ± 0.3 kg boat^{-1} day^{-1} other species.

Univariate two-way ANOVA (Appendix 4.3) showed that Nile tilapia catch rates of parachute boats were not statistically different between the eastern and western zones ($F_{1, 396} = 0.022$, $P > 0.05$); but there was an indication that they varied between the seven periods of sampling ($F_{6, 396} = 2.54$, $P < 0.05$). The interaction between zones and quarters indicated that quarterly catch trends of Nile tilapia were not statistically different in the two zones ($F_{6, 396} = 0.74$, $P > 0.05$).

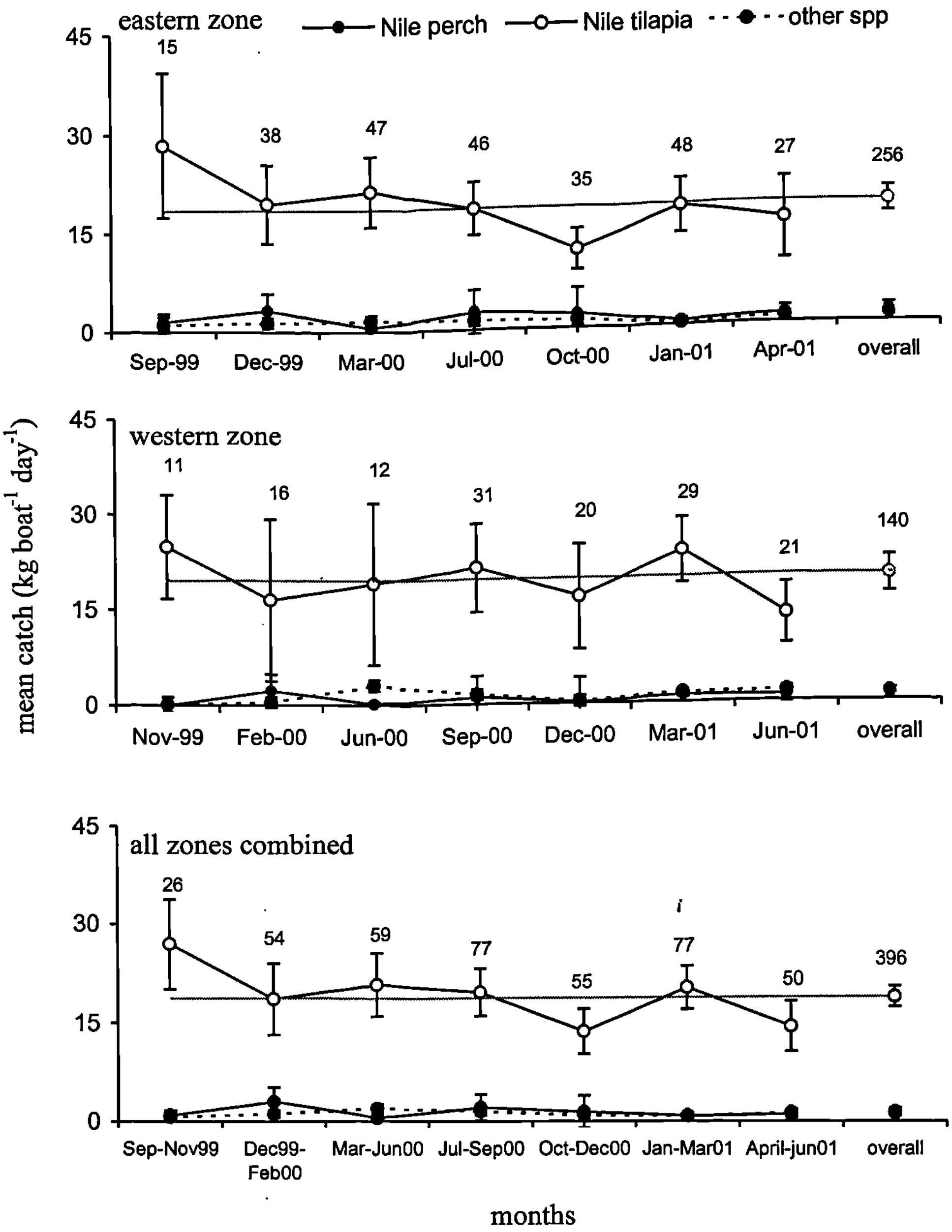


Figure 4.1 Mean fish catch rates of parachute boats in the Ugandan part of Lake Victoria. Numbers indicate the boats sampled, Error bars = 95%CL and the grey lines indicate the overall mean of Nile tilapia catches, the target fish species of these boats.

Gabriel's multiple comparisons post hoc tests, under the same analysis revealed that significant differences between quarterly catch rates resulted from the high catch rates in the September to November 1999 and the low catch rates in the October to December and April to June 2001 periods. Prior to the start of surveys in this study in September 1999 there was a period of about four months (April to August) of reduced fishing pressure due to a government ban on fishing following reports of some fishers using poisons to catch fish, especially Nile tilapia. The high catch rates of Nile tilapia observed in September and November 1999 could have resulted from the preceding period of reduced fishing pressure rather than being a seasonal phenomenon. When the high mean catch rates in September and November 1999 are ignored for the reasons above, those in the remaining survey periods do not exhibit any strong seasonal pattern as the mean catch rates become homogeneous.

Paddled Sesse boats

These boats target Nile perch although they are also the main craft used to catch Nile tilapia at the beaches sampled in the central zone (Fig. 4.2). In the eastern zone, differences in Nile perch catch rates of these boats between quarters were highly significant (*ANOVA*: $F_{6,\ 173} = 4.0$, $P < 0.01$) (Appendix 4.4). Catch rates increased progressively from 12.9 $\pm$ 9.4 kg boat^{-1} day^{-1} in September 1999 to a maximum of 33.1 $\pm$ 10.1 kg boat^{-1} day^{-1} in July 2000, and then declined to 9.4 $\pm$ 4.9 and 13.4 $\pm$ 6.7 kg boat^{-1} day^{-1}, well below average in January and April 2001, respectively. Catches of Nile tilapia improved slightly during periods of low Nile perch catches, i.e. 5.3 $\pm$ 3.4, 3.8 $\pm$ 2.5 and 5.2 $\pm$ 4.6 kg boat^{-1} day^{-1} in September 1999, January and April 2000 respectively, whereas it was much lower in the remaining months. Overall, paddled Sesse boats in the eastern zone landed 21.1 $\pm$ 4.5 kg boat^{-1} day^{-1} Nile perch, 2.7 $\pm$ 1.2 kg boat^{-1} day^{-1} Nile tilapia and 0.8 $\pm$ 0.3 kg boat^{-1} day^{-1} other species.

In the central zone, Nile perch catch rates were lowest in September 1999 at 11.0 $\pm$ 3.7 kg boat^{-1} day^{-1} and highest in December 1999 at 22.9 $\pm$ 7.4 kg boat^{-1} day^{-1}, however, the differences in Nile perch catch rates were not statistically significant between quarters (*ANOVA*: $F_{6,220} = 1.75$, $P > 0.05$) (Appendix 4.5). Nile perch contributed 16.0 $\pm$ 2.4 kg boat^{-1} day^{-1} to the overall catches followed by Nile tilapia 4.7 $\pm$ 0.1 kg boat^{-1} day^{-1} and all other species 0.3 $\pm$ 0.1 kg boat^{-1} day^{-1}.

In the western zone, the peak Nile perch catch rates, 40.1 $\pm$ 13.7 kg boat^{-1} day^{-1}, of paddled Sesse boats was in February 2000 and the lowest, 22.3 $\pm$ 10.1 kg boat^{-1} day^{-1}, in June 2000. Mean catch rates were above the overall average of 30.9 $\pm$ 4.8 kg boat^{-1} day^{-1} in the first quarters of 2000 and 2001 and below in the remaining quarters. However, the catch rates were not statistically different between quarters over the sampling period (*ANOVA*: $F_{6,\ 140} = 1.39$, $P > 0.05$) (Appendix 4.6). Nile tilapia and other fish species contributed 1.3 $\pm$ 1.5 and1.4 $\pm$ 1.3 kg boat^{-1} day^{-1}, respectively, to the overall catches.

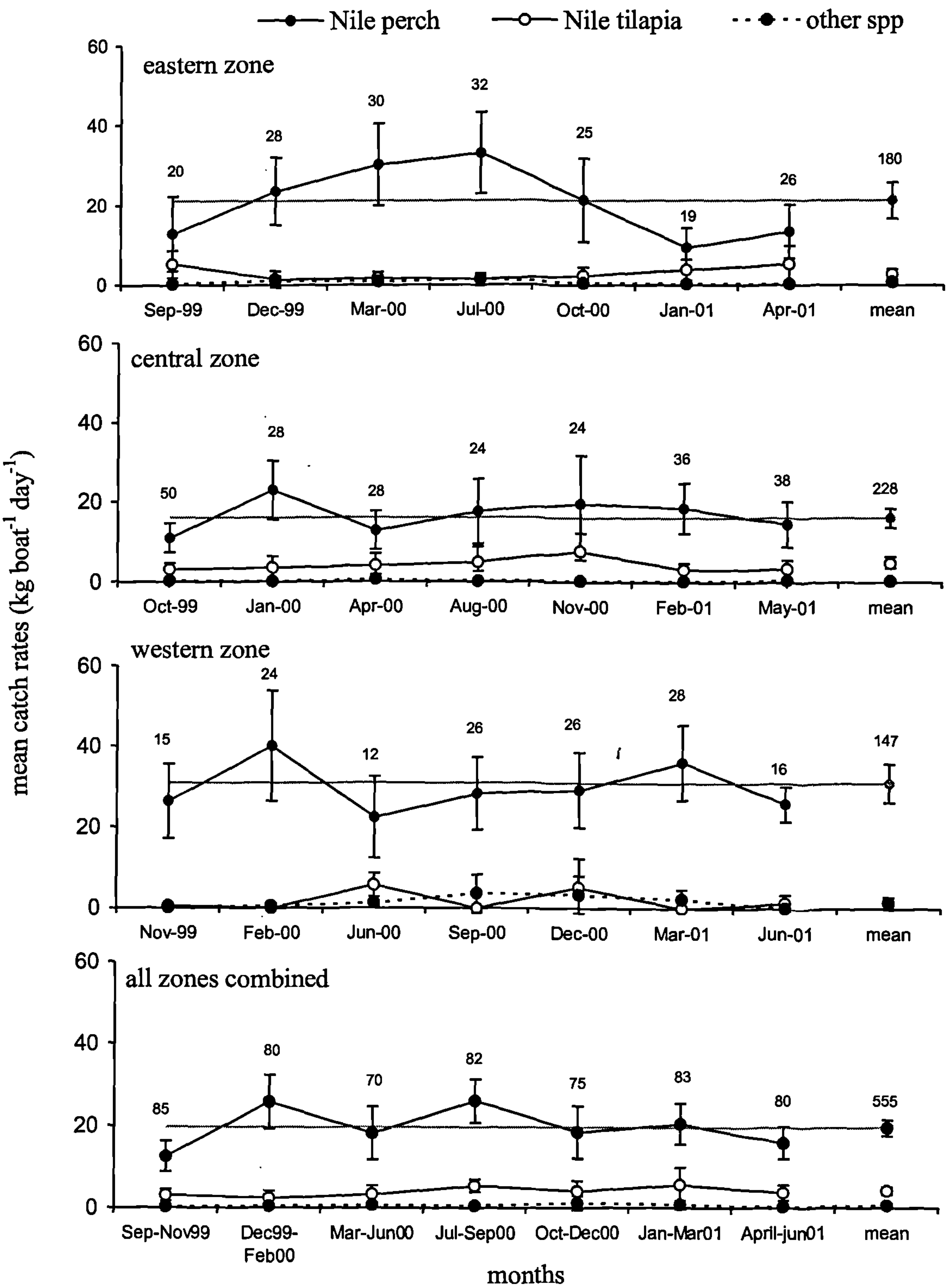


Figure 4.2 Mean fish catch rate of paddled Sesse gillnetting boats in the Ugandan part of Lake Victoria. Numbers indicate the boats sampled, Error bars = 95%CL and the grey lines indicate the overall mean of Nile perch catches, the target fish species of these boats.

Univariate, two-way ANOVA (Appendix 4.7) showed that the differences in Nile perch catch rates were highly significant between the three zones ($F_{2, 554}$ = 15.73, $P < 0.01$); and between the seven sampling periods ($F_{6, 554}$ = 3.04, $P < 0.01$). The interaction between zones and quarters also indicated that differences in quarterly catch trends were highly significant in the three zones ($F_{12, 554}$ = 2.28, P < 0.01). Gabriel's multiple comparisons post hoc tests, under the same analysis revealed that none of the mean Nile perch catch rates of paddled Sesse boats were homogeneous between the three zones, being lowest in the central zone, intermediate in the eastern zone and highest in the western part of the lake. They also showed that the significant differences between quarterly catch rates resulted from the low catch rates in the September to November 1999 and April to June 2001 periods; and the higher catch rates in December 1999 to February 2000 and July to September 2000. These observations would suggest bi-annual peaks of Nile perch catch rates in paddled Sesse boats, occurring in the first three months of the year and in the period July to September prior to the wet seasons. However, this evidence of biannual peaks in catches of Nile perch is rather weak and it is not entirely clear whether the variation reflects true seasonality.

Motorised/sailed Sesse boats

These boats targeted Nile perch, with other fish species occurring very rarely in the catches (Fig 4.3). In the eastern zone, differences in mean catch rates of Nile perch were highly significant between quarters (*ANOVA*: $F_{6, 176}$ = 3.95, P < 0.01) (Appendix 4.8) with the highest catch rates, 55.7 ± 14.2 kg boat^{-1} day^{-1}, in July 2000 and the lowest, 22.0 ± 6.8 kg boat^{-1} day^{-1}, in January 2001. Nile perch contributed 39.0 ± 4.0 kg boat^{-1} day^{-1}, Nile tilapia 0.8 ± 1.0 kg boat^{-1} day^{-1} and other fish species 0.03 ± 0.04 kg boat^{-1} day^{-1} to the overall catches of motorised boats in the eastern zone.

The catch rates changed systematically in the central zone over the sampling period. The differences in catch rates were highly significant between quarters (*ANOVA*: $F_{6, 356}$ = 13.6, P < 0.01) (Appendix 4.9), increasing consistently from 47.1 ± 9.4 kg boat^{-1} day^{-1} in January 2000 to the maximum of 84.2 ± 13.0 kg boat^{-1} day^{-1} in November 2000 and thereafter declining to the lowest level of 24.8 ± 3.6 kg boat^{-1} day^{-1} in May 2001. Overall, Nile perch contributed 57.5 ± 4.4 kg boat^{-1} day^{-1}, Nile tilapia 0.08 ± 0.05 kg boat^{-1} day^{-1} and other species 0.3 ± 0.1 kg boat^{-1} day^{-1}.

In the western zone differences in catch rates were also highly significant between quarters (*ANOVA*: $F_{6, 187}$ = 4.048, P < 0.01) (Appendix 4.10). They were well above the overall mean in November 1999 at 64.7 ± 13.0 kg boat^{-1} day^{-1}, September 2000 at 63.5 ± 14.0 kg boat^{-1} day^{-1} and March 2001 at 72.8 ± 13.4 kg boat^{-1} day^{-1}. Catch rates well below the overall mean were recorded in February 2000 at 42.7 $\pm$ 13.3 kg boat^{-1} day^{-1} and June 2001 at 44.2 $\pm$ 7.6 kg boat^{-1} day^{-1}. Overall, motorised/sailed boats in the western zone landed 53.6 $\pm$ 4.7 kg boat^{-1} day^{-1} of Nile perch, 1.5 $\pm$ 1.2 kg boat^{-1} day^{-1} of Nile tilapia and 0.12 $\pm$ 0.10 kg boat^{-1} day^{-1} other fish species.

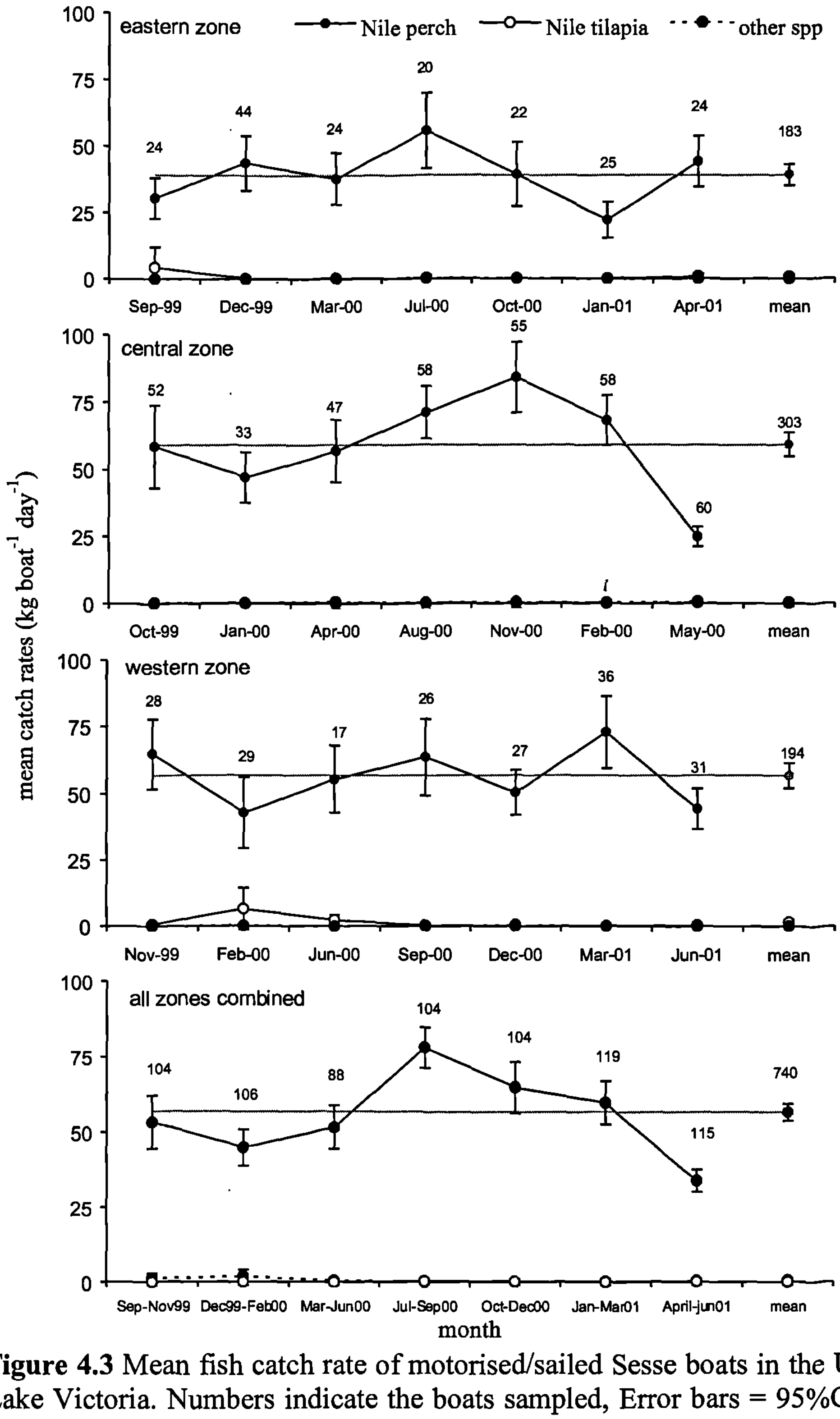


Figure 4.3 Mean fish catch rate of motorised/sailed Sesse boats in the Ugandan part of Lake Victoria. Numbers indicate the boats sampled, Error bars = 95%CL and the grey lines indicate the overall mean of Nile perch catches, the target fish species of these boats.

Univariate two-way ANOVA (Appendix 4.11) showed significant differences in Nile perch catch rates between the three zones ($F_{2, 736}$ = 14.6, P < 0.01) and between the seven sampling periods ($F_{6, 736}$ = 5.9, P < 0.01). The interaction between zones and quarters also showed that differences in quarterly catch trends were highly significant in the three zones ($F_{12, 736}$ = 6.0, P < 0.01). Gabriel's multiple comparisons post hoc tests, under the same analysis revealed that the mean catch rates in zones 1 and 2 were homogeneous, but those in zone 3 were significantly lower than in zones 1 and 2. The post hoc tests split the mean catch rates in the seven quarters covered by the sampling into three homogeneous subsets: (1) the lowest catch rates in the periods December 1999 to February 2000 and April to June 2001; (2) intermediate catch rates throughout the period September 1999 to June 2000; and (3) the highest catch rates in September 1999 and March 2000 to March 2001. These observations suggest seasonality in Nile perch catch rates of motorised/paddled boats but do not give clear-cut seasonal trends. They, however, indicate that Nile perch catch rates peak in the second half of the year around July to September and the lowest levels were attained in the first half of the year.

The central zone had the highest overall mean catch rate of 57.5 ± 4.4 kg boat^{-1} day^{-1} followed by the western zone at 53.6 ± 4.7 kg boat^{-1} day^{-1} and least in the eastern zone, 39.0 ± 4.0 kg boat^{-1} day^{-1}. Overall, across the lake, motorised/sailed boats landed 56.8 ± 2.8 kg boat^{-1} day^{-1} with the highest catch rate of 78.1 ± 6.7 kg boat^{-1} day^{-1} in the third quarter of 2000 and the lowest catch rate of 34.0 ± 3.7 kg boat^{-1} day^{-1} in the second quarter of 2001.

4.2.2 *Gillnet mesh size and catch composition of Nile tilapia and Nile perch*

Parachute boats

Parachute boats with gillnets were common in the eastern and western zones targeting Nile tilapia. They were rarely used exclusively for Nile tilapia in the central zone (see Fig. 3.5: Chapter Three). In the eastern part of the lake, mesh size composition varied between surveys with 127 mm mesh nets predominant except in March 2000 when 102 mm mesh nets were dominant (Fig. 4.4). Gillnets of 127 mm mesh size, the legal minimum, constituted 42.2 % of the overall composition of gillnet fleets of parachute boats in this zone. Larger meshed nets contributed 26.3%, while illegal nets, <127 mm mesh size, constituted the remaining 31.5% of overall nets.

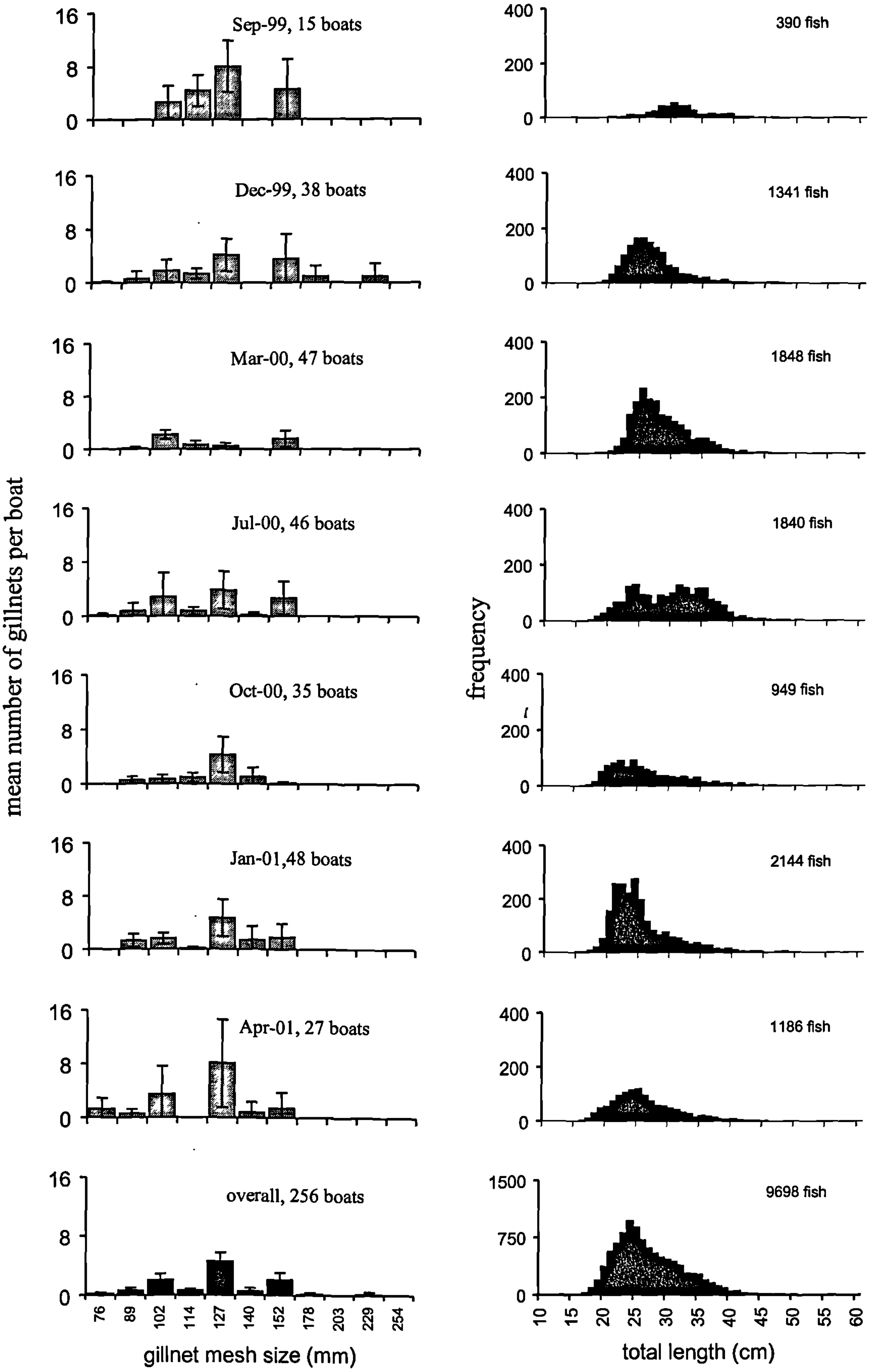


Figure 4.4 Gillnet mesh size composition and length frequency of Nile tilapia landed by parachute boats using gillnets in the eastern zone of the Ugandan part of Lake Victoria. Error bars = 95%CL.

The continuous changes in number and mesh size composition of gillnets should have affected the size composition of Nile tilapia caught in the different periods but some seasonal changes in availability of particular sizes of fish were also apparent. For example, large fish dominated the catches in September 1999, with the mode at 30 cm TL, although 36.0% of the gillnets used were small mesh sizes <127 mm. The length distribution of Nile tilapia catches in July 2000 was bimodal, one mode at 25 cm TL and the other, not clear-cut, above 30 cm TL. The high proportion of large fish in September 1999 may be attributed to the low fishing pressure in earlier months as explained earlier but the July 2000 phenomenon could be a seasonal pattern associated with breeding congregations of large fish in inshore areas. Nile tilapia catches in the rest of the survey periods were dominated by smaller fish with a mode around 25 cm TL irrespective of the proportion of large gillnet mesh sizes. It is, thus, difficult to deduce from these observations the time of peak recruitment of Nile tilapia into the fishery. Overall, Nile tilapia ≥ 30 cm TL, the size at 100% maturity, constituted 35% of the catch of parachute boats in this part of the lake.

Gillnet mesh sizes used by parachute boats at the beaches sampled in the western zone generally declined throughout the survey period (Fig. 4.5). In November 1999, the main gillnets used were 152 and 127 mm mesh size, constituting 46.3% and 36.6% of the gillnet fleet respectively. In all the surveys that followed, the 152 mm mesh size nets appeared occasionally in very small numbers while the 127 mm mesh nets were prominent only in February 2000, contributing 58.3% and September 2000 (30.9%). Overall, 127 mm mesh size nets constituted 22.0% and mesh sizes >127 mm only 7.0% of the total number of gillnets used. Illegal gillnet mesh sizes <127 mm dominated the gillnet fleets of these boats contributing 71.1%, amongst which the most prominent were the 102 mm mesh size nets contributing 40.2% overall.

Large fish were present in the catches in November 1999, February 2000, September 2000 and December 2000 than other periods. However, due to few large mesh gillnets being used in this part of the lake, the presence of large fish was not as pronounced as in the east, particularly in September and December 2000. The overall modal length of Nile tilapia landed occurred at 22 cm TL. Nile tilapia ≥30 cm TL, the size at 100% maturity, constituted only 10.2% of the total catches.

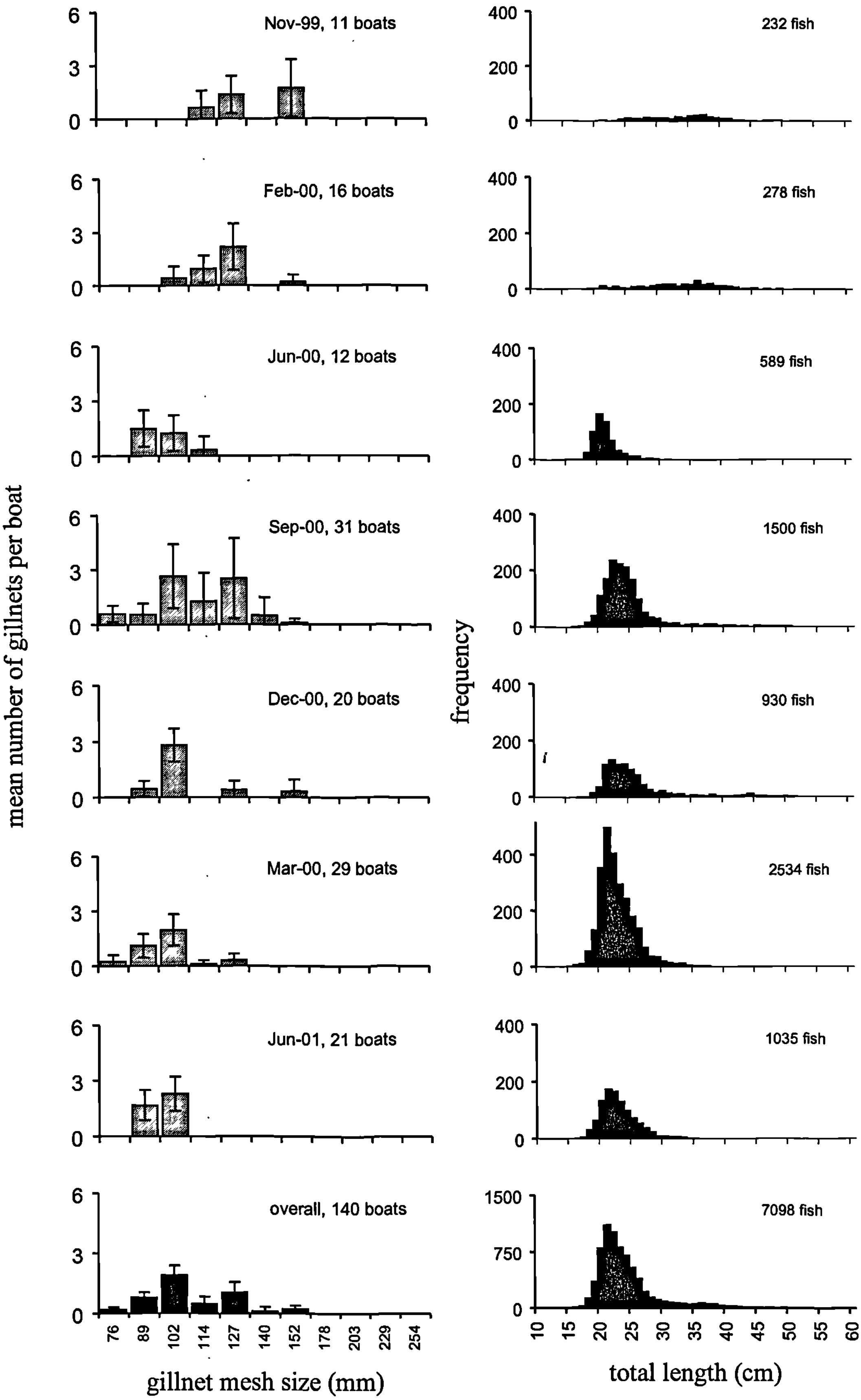


Figure 4.5 Gillnet mesh size composition and length frequency of Nile tilapia landed by parachute boats using gillnets in the western zone of the Ugandan part of Lake Victoria. Error bars = 95%CL.

Paddled Sesse boats

Paddled boats using gillnets targeted Nile perch in all parts of the lake, but they were also the main craft used to catch Nile tilapia at the beaches sampled in the central part of the lake (Fig. 4.2). In the eastern part of the lake, the illegal gillnets <127-mm mesh size featured prominently among paddled Sesse boats, and dominated the gillnet fleets in December 1999 (66.8%) and 53.5% in July 2000 (Fig. 4.6). They also made substantial contributions in March 2000 (48.8%) and in January 2001 (40.2%). However, gillnets of mesh size ≥127 mm were predominant in the gillnet fleets more often than the undersized nets for the remainder of the study period. Gillnets of 127 and 152 mm mesh size were the most important among legal mesh sizes with dominance continuously shifting between the two mesh sizes in different survey periods.

Despite large mesh sizes constituting a substantial proportion of the gillnet fleets of these boats, large Nile perch were rare in their catches. From September 1999 to October 2000, the modal size of Nile perch landed was between 32 and 35 cm TL, and fish of size 30 to 49 cm TL constituted 82 to 93 % of the catch by number. Over this period, smaller fish, <30 cm TL, contributed 0.9 to 13.0% of the catch while larger fish, ≥50 cm TL, contributed 2 to 8.4% of the total catch. The catch component of large Nile perch increased to 12.2% in January 2001 and 39.6% in April 2001. Overall, 80.7% of Nile perch landed by paddled boats in the eastern part of the lake were in the size range 30 to 49 cm TL, with the modal size at 34 cm TL. Smaller fish <30 cm TL constituted 12.4% and large fish ≥50 cm TL only 6.8% of the overall Nile perch catches.

In the central part of the lake mesh sizes <127 mm constituted between 26% and 33.5% of gillnets from October 1999 to February 2001 (Fig 4.7). Their contribution reached a maximum of 43.4% of nets in May 2001. Gillnet mesh sizes in the range 127 to 152 mm were the most common of the large mesh sizes ≥127 mm but use of 152-mm mesh size declined with time while 127 and 140 mm gained importance.

Similar to the eastern part of the lake, Nile perch catches were also biased to small sizes, despite substantial presence of large mesh sized nets in the gillnet fleets. From September 1999 to August 2000, Nile perch in the size range of 30 to 49 cm TL constituted 68.8 to 72.0 % of the catch with a modal size between 31 and 33 cm TL. During this period, fish <30 cm TL contributed 19 to 25% while fish ≥50 cm TL

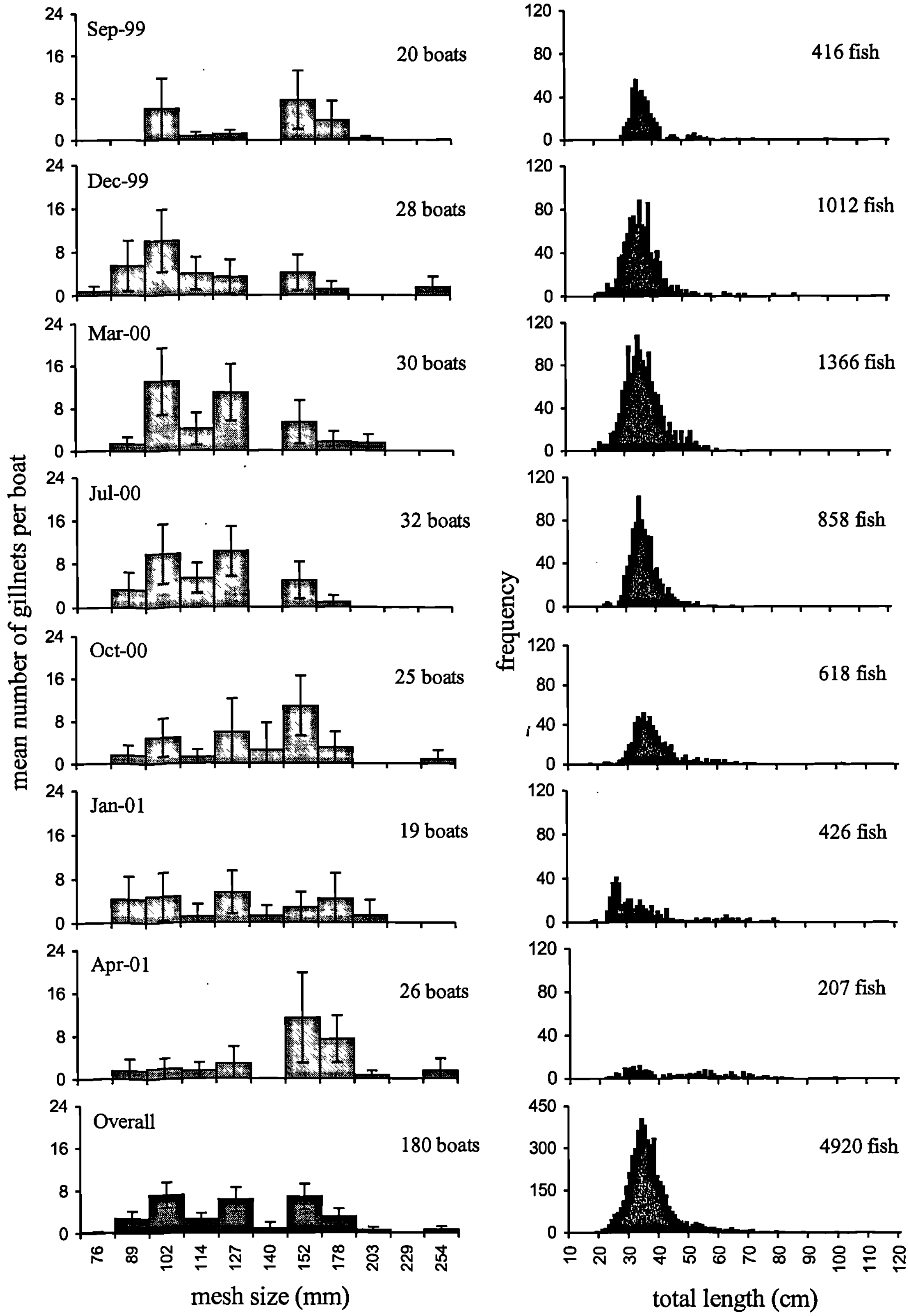


Figure 4.6 Gillnet mesh size composition per boat and length frequency of Nile perch landed of paddled Sesse boats using gillnets in the eastern zone of the Ugandan part of Lake Victoria. Error bars = 95%CL.

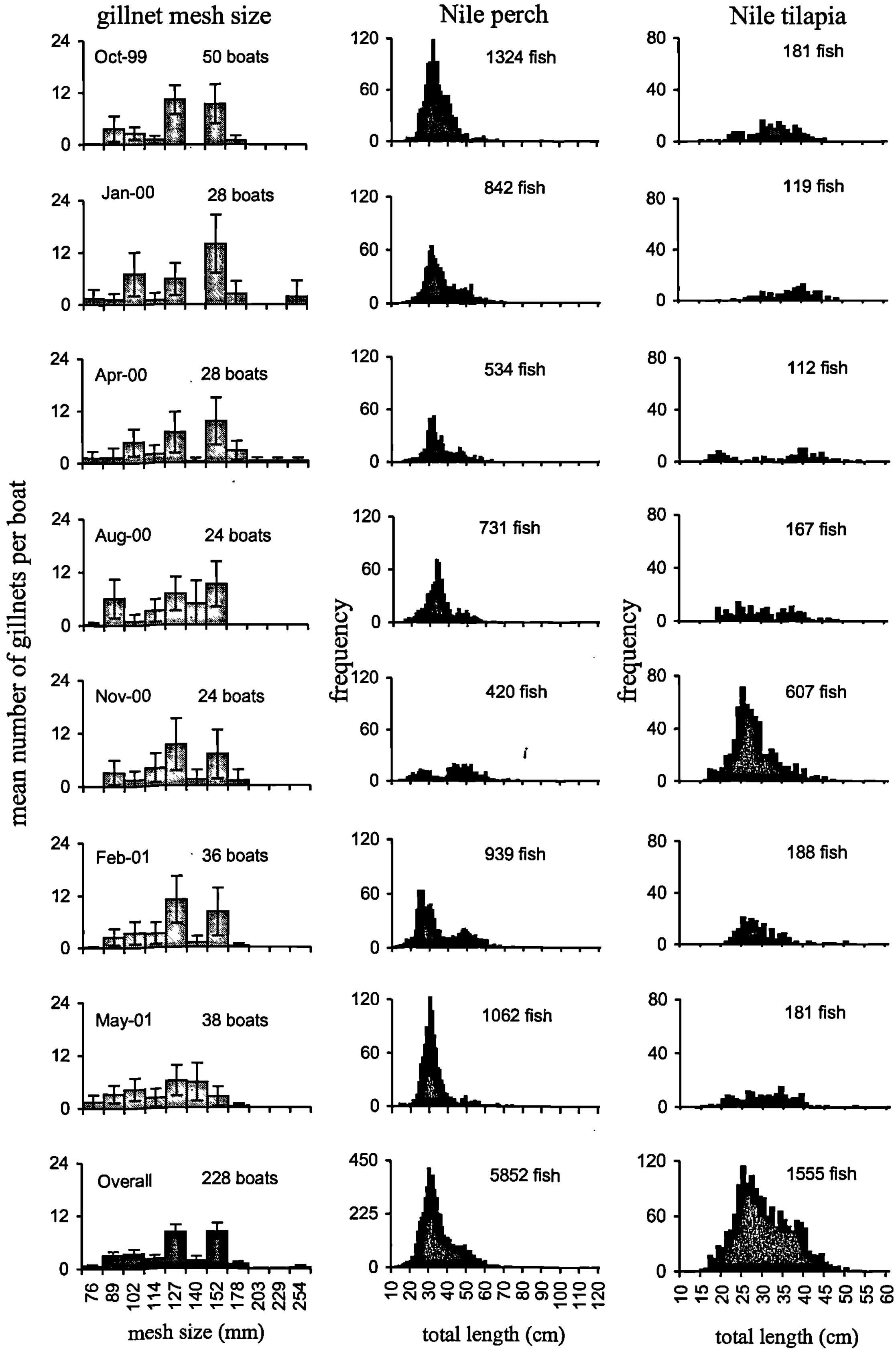


Figure 4.7 Gillnet mesh size composition per boat and length frequency of Nile perch and Nile tilapia landed of paddled Sesse boats using gillnets in the central zone of the Ugandan part of Lake Victoria. Error bars = 95%CL.

were 3 to 11% of the catch. Large fish became more common in November 2000 and February 2001 contributing 29% and 14.3% of the total catch respectively, with corresponding lower quantities of fish in the size range 30 to 49 cm TL of 47.9% and 39.6% respectively. Overall, Nile perch in the size range 30 to 49 cm TL contributed 61.9% of the catch. Smaller fish, <30 cm TL, constituted 29.1% of the catch while the larger fish, ≥50 cm TL, contributed only 9.0%.

At the fish landing sites sampled in the central part of the lake, paddled Sesse boats using gillnets were the main craft fishing for Nile tilapia in addition to their main target fish species, Nile perch. Nile tilapia ≥30 cm TL dominated the catches in October 1999 and January 2000 contributing 74.0% and 89.9% of the catch respectively. Smaller fish, <30 cm TL gradually increased their contributions to catches in April 2000, August 2000 and November 2000, increasing from 34% to 72% of the catches. Large Nile tilapia ≥30 cm TL regained dominance but at a lower proportion (53.0%) in May 2001. The overall catches of Nile tilapia in this part of the lake comprised 52.7% in the <30 cm TL size range. Nile tilapia ≥30 cm TL, the size at 100% maturity constituted 47.3%.

In the western part of the lake, gillnets mesh sizes <127 mm contributed between 18 and 46% of the nets used between November 1999 and March 2001, but their presence rose to 76.4% (38.4 nets) in June 2001 (Fig. 4.8). Amongst gillnets of mesh sizes ≥127 mm, 140-mm mesh nets dominated in November 1999 and February 2000 but were displaced by 152 mm nets in the following three surveys. In the surveys of March and June 2001 there was a decline in prominence of 127-mm mesh size nets and the larger meshed nets almost disappearing in June 2001.

Large sizes of Nile perch, ≥50 cm TL, were more common in this part of the lake compared with the eastern and central parts, contributing 23.5 to 38.4% of the catches between October 1999 and November 2000. The contribution of Nile perch ≥50 cm TL declined to 4.7% and 9.6% in March and June 2001 respectively, reflecting the decline in gillnet mesh sizes. A very small part of the catch, 0.4 to 2.9%, was in the <30 cm TL range except in February and May 2001 when it rose to 8.2 and 7.2% respectively. Overall, Nile perch <30 cm TL contributed 4.4%, the 30 to 49 cm TL range 76.8% and the ≥50 cm TL range 18.8%, of the total catches.

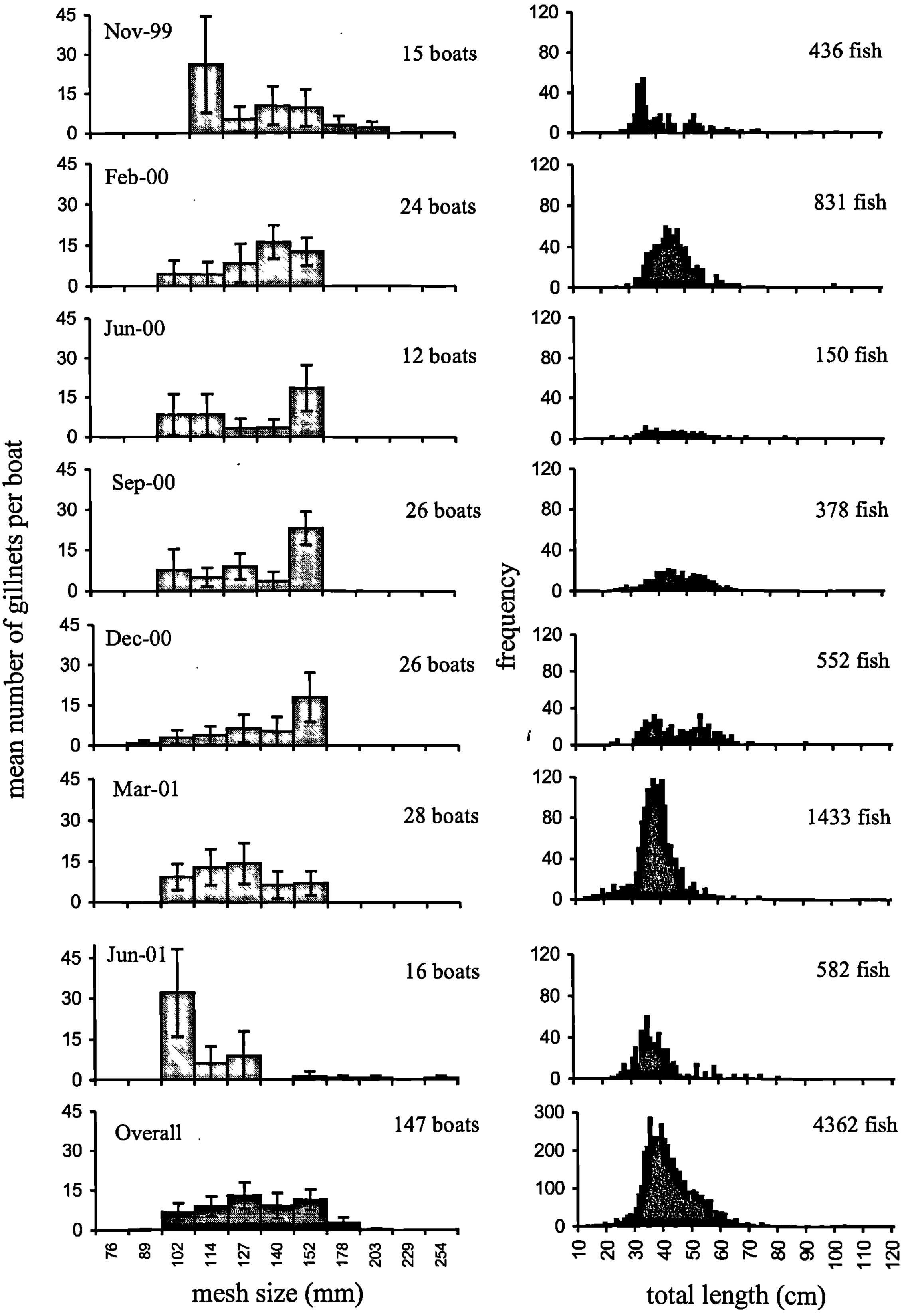


Figure 4.8 Gillnet mesh size composition per boat and length frequency of Nile perch landed of paddled Sesse boats using gillnets in the western zone of the Ugandan part of Lake Victoria. Error bars = 95%CL.

Motorised/sailed boats

Motorised/sailed boats in the three parts of the lake targeted exclusively Nile perch (Fig. 4.3). Between September 1999 and June 2001, motorised/sailed boats at the sampled beaches in the eastern part of the lake consistently used, almost exclusively, large mesh sized gillnets, ≥152 mm (Fig. 4.9). In September 1999, the gillnet fleets of these boats comprised 33.5% of 152 mm mesh size nets, 43.0% of 178 mm mesh size nets and 23.3% of 254 mm mesh size nets. By July 2000, the gillnet mesh size composition had changed from domination by 178-mm to 152-mm mesh size and in April 2001, mesh sizes larger than 178 mm were absent. Overall, gillnet mesh sizes <152 mm contributed 0.36%; 152 mm, 47.4%; 178 mm, 44.0%; and gillnet mesh sizes >178 mm 8.2%.

The bulk (61.1 to 87.3%) of Nile perch catches of motorised/sailed boats in the eastern part of the lake were of the size range 50 to 70 cm TL. Fish <50 cm TL were most common in the catches in September 1999 contributing 21.7% of landings and reached the maximum of 32.9% in March 2000. The lowest contribution of Nile perch <50 cm TL, was recorded in October 2000 (6.8%). Nile perch sizes >70 cm TL were most common in the catch in September 1999 contributing 11.7% and January 2001 (12.2%) but constituted only 2.6% of the catches in July 2000. Overall, Nile perch catches of motorised/sailed boats in the eastern part of the lake comprised 16.8% fish <50 cm TL, 77.4% fish 50 to 70 cm TL and 5.9% fish >70 cm TL.

Gillnet fleets of motorised boats at the beaches sampled in the central part of the lake were consistently dominated by 152 mm mesh size (Fig. 4.10). These accounted for 61.2% of nets in October 1999 but their proportion increased to 73.8% by May 2001. Over the same period the use of 178 mm in these boats declined from 26.8% to 7.8% and the presence of smaller mesh sizes (<152 mm) increased from 9.6 to 16.0 %.

High proportions of Nile perch <50 cm TL were recorded in the catches in October 1999 and May 2001, i.e. 38.4% and 42.4% respectively, and the corresponding proportions of the 50 to 70 cm TL size range were at their lowest at 58.3% and 55.6% respectively. At other times, Nile perch in the size range 50 to 70 cm TL constituted 71.2 to 83.3% of the catch. Nile perch sizes >70 cm TL were rare in the catch contributing less than 4%, except in January 2000 when they made up 7.9% of the total catch. Overall, Nile perch catches in the central part of the lake comprised 25.1% of <50 cm TL, 72.1% of 50 to 70 cm TL and 2.8% of >70 cm TL fish.

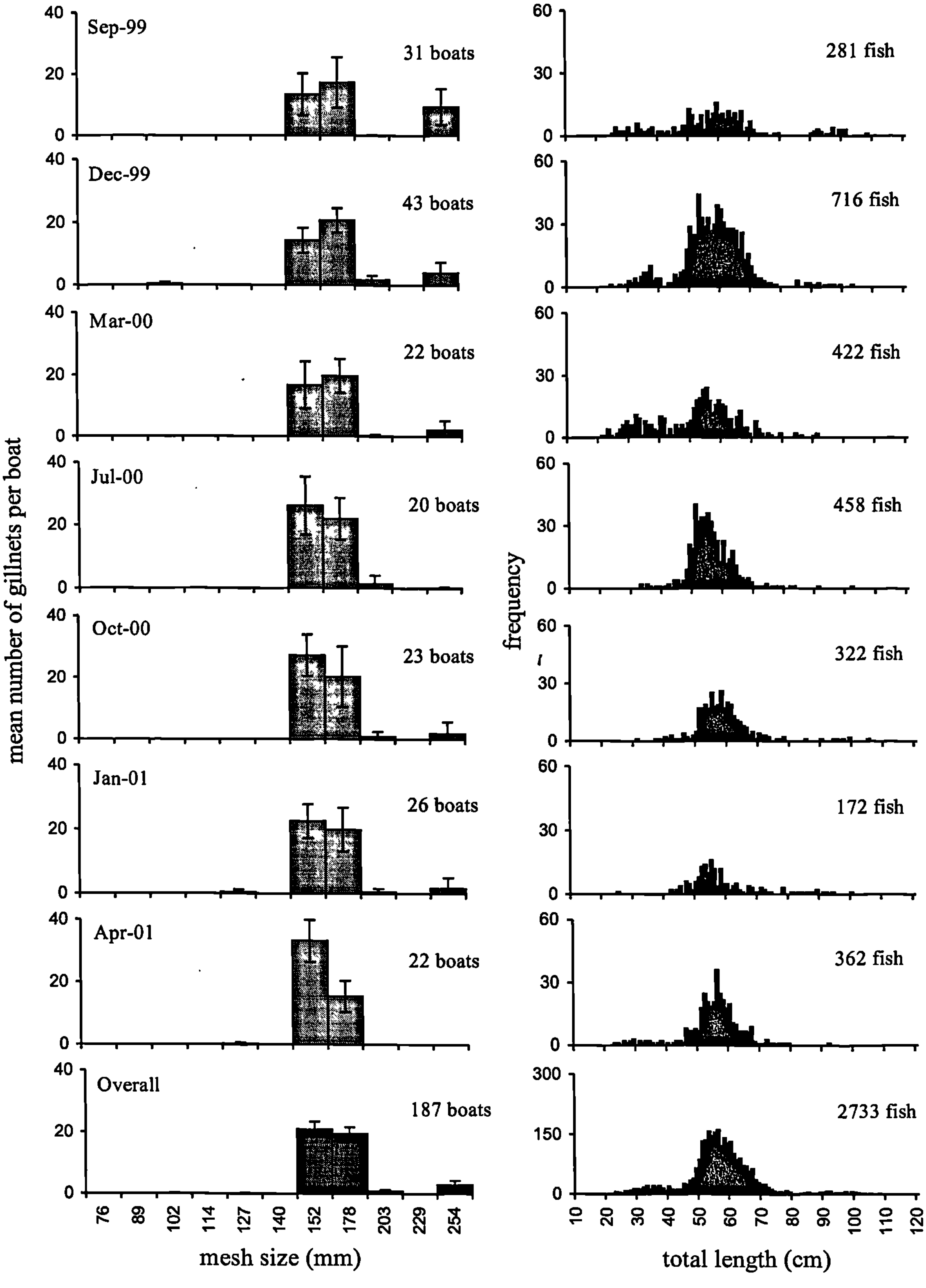


Figure 4.9 Gillnet mesh size composition per boat and length frequency of Nile perch landed of motorised Sesse boats using gillnets in the eastern zone of the Ugandan part of Lake Victoria. Error bars = 95%CL.

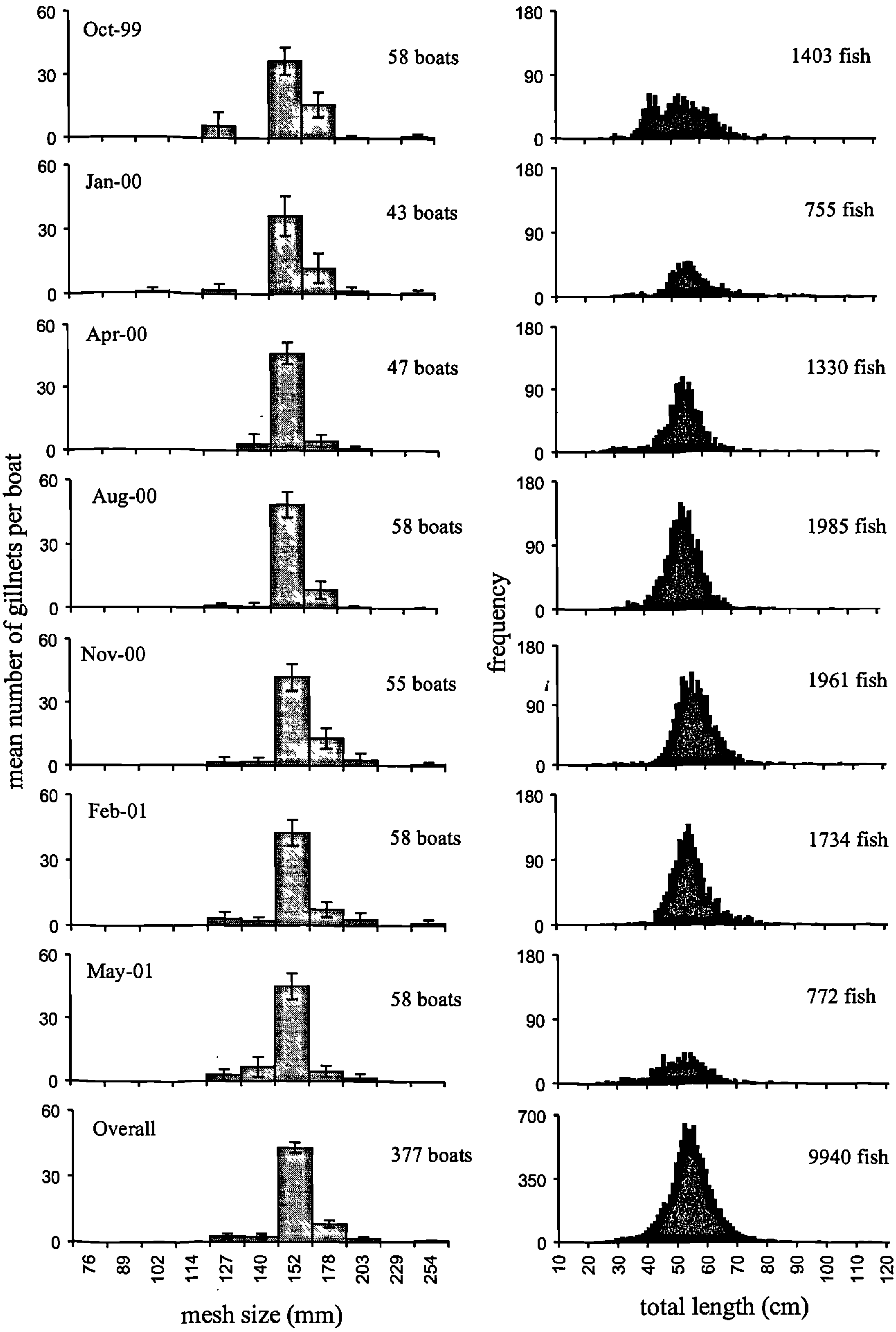


Figure 4.10 Gillnet mesh size composition per boat and length frequency of Nile perch landed of motorised Sesse boats using gillnets in the central zone of the Ugandan part of Lake Victoria. Error bars = 95%CL.

Gillnet fleets of motorised boats at the beaches sampled in the western part of the lake were the most diverse of the three zones (Fig. 4.11). In November 1999 they were dominated by the 152 mm and 178 mm mesh sizes accounting for 61.3% and 33.1% of the nets respectively. In February 2000, smaller mesh sizes, <152 mm, became more common, contributing 7.0% compared with only 0.9% in the previous survey. In later surveys, gillnets of <152-mm mesh size became dominant but with wide fluctuations in importance between mesh sizes.

The Nile perch catch composition in this part of the lake seemed to follow the changes in gillnet mesh size composition. In November 1999 when gillnet mesh size less <152 mm were almost absent, the highest proportion of Nile perch in the size range 50 to 70 cm TL (78.1%) was recorded. This proportion decreased to 61.1% when small gillnets started showing up in the fleets in February 2000. In the subsequent surveys Nile perch <50 cm TL were abundant in the catches, representing 82.8% in June 2000, 77.1% in March 2001 and 86.4% in June 2001. In September and December 2000 when the proportion of large mesh sized gillnets was high, the occurrence of large fish in the catches also increased to 56% for fish in the 50 to 70 cm TL size range and 5 to 8% for those >70 cm TL, despite the presence of small gillnet mesh sizes <152 mm. In this zone there appeared to be seasonal shifts in the composition of gillnet mesh sizes used. The smallest mesh sizes, 127 mm and below, were predominantly used by motorised boats around March to June, probably as a response to increased abundance of the small size classes of fish. However, such seasonal shifts of gillnet mesh sizes were not apparent in the central and eastern zones. Overall, Nile perch catches of motorised boats in the western part of the lake comprised 62.1% <50 cm TL, 35.3% in the range 50 to 70 cm TL and 2.6% >70 cm TL fish.

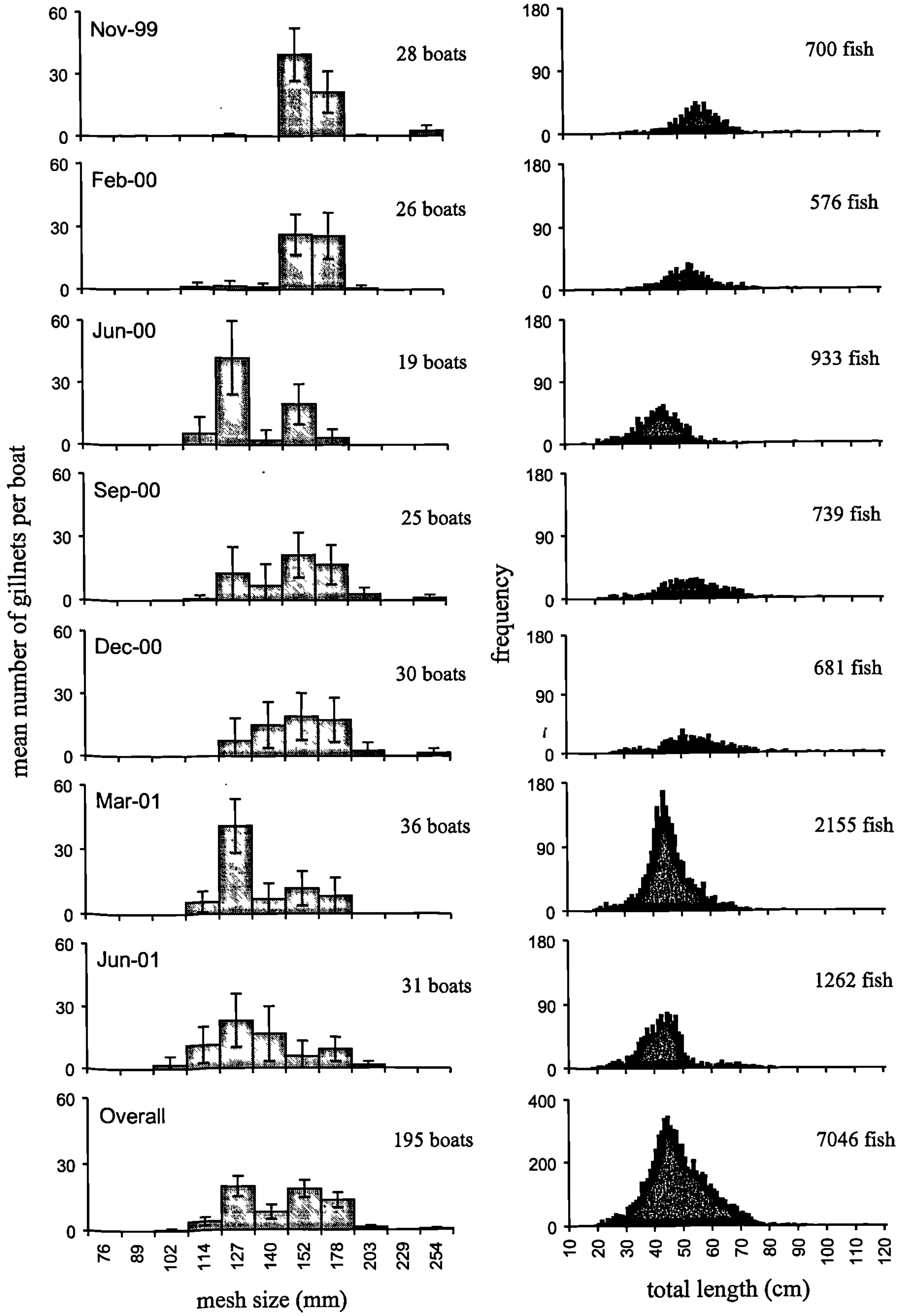


Figure 4.11 Gillnet mesh size composition per boat and length frequency of Nile perch landed of motorised Sesse boats using gillnets in the western zone of the Ugandan part of Lake Victoria. Error bars = 95%CL.

4.2.3 *Overall gillnet mesh size composition in the fishery*

The total number of gillnets in the Ugandan part of the Lake, determined by raising the number of gillnets per boat sampled to the total of gillnetting boats in the Frame Survey 2000 data, showed a similar mesh size distribution to that revealed by Frame survey data in all the three main categories of gillnetting boats (Fig. 4.12).

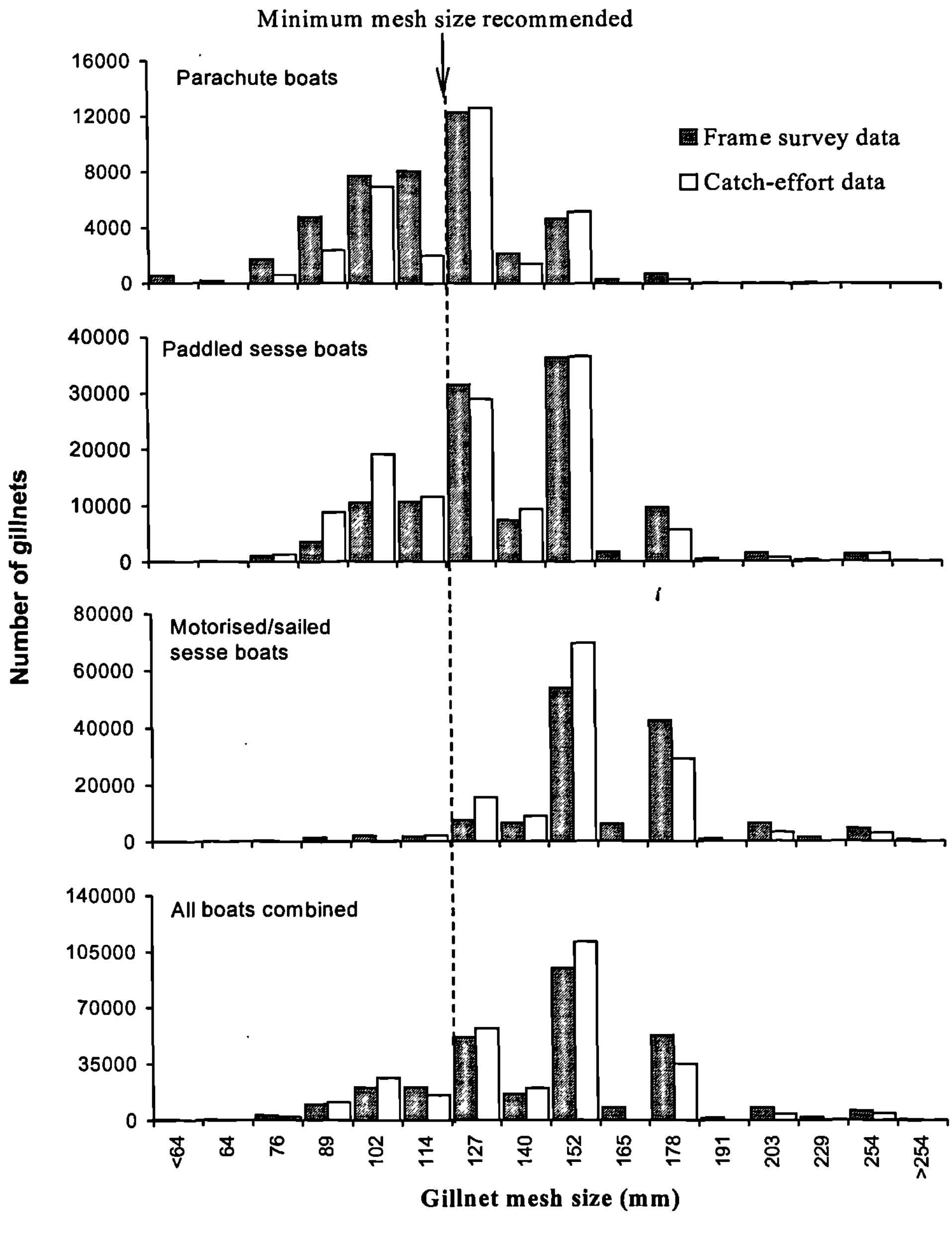


Figure 4.12 Comparison of gillnet mesh size composition estimated from Catch-effort data and Frame survey 2000 data in the Ugandan part of Lake Victoria.

The Students' two tailed *t*-test for matched pairs indicated there were no significant differences between the two data sets in the three categories of boats, i.e. in parachute boats (t_{15} = 1.88, P >0.05), paddled Sesse boats (t_{15} = 0.16, P >0.05), motorised/sailed boats (t_{15} = 0.16, P >0.05), and when data from all boats were combined (t_{15} = 0.297, P

>0.05). A breakdown of the proportions contributed by each gillnet mesh size in paddled and motorised/sailed Sesse boats, which use the bulk of gillnets on Lake Victoria and were encountered by this study in all zones, by zone, also showed, more or less, agreement between Frame survey and catch assessment survey data (Figs 4.13 & 4.14).

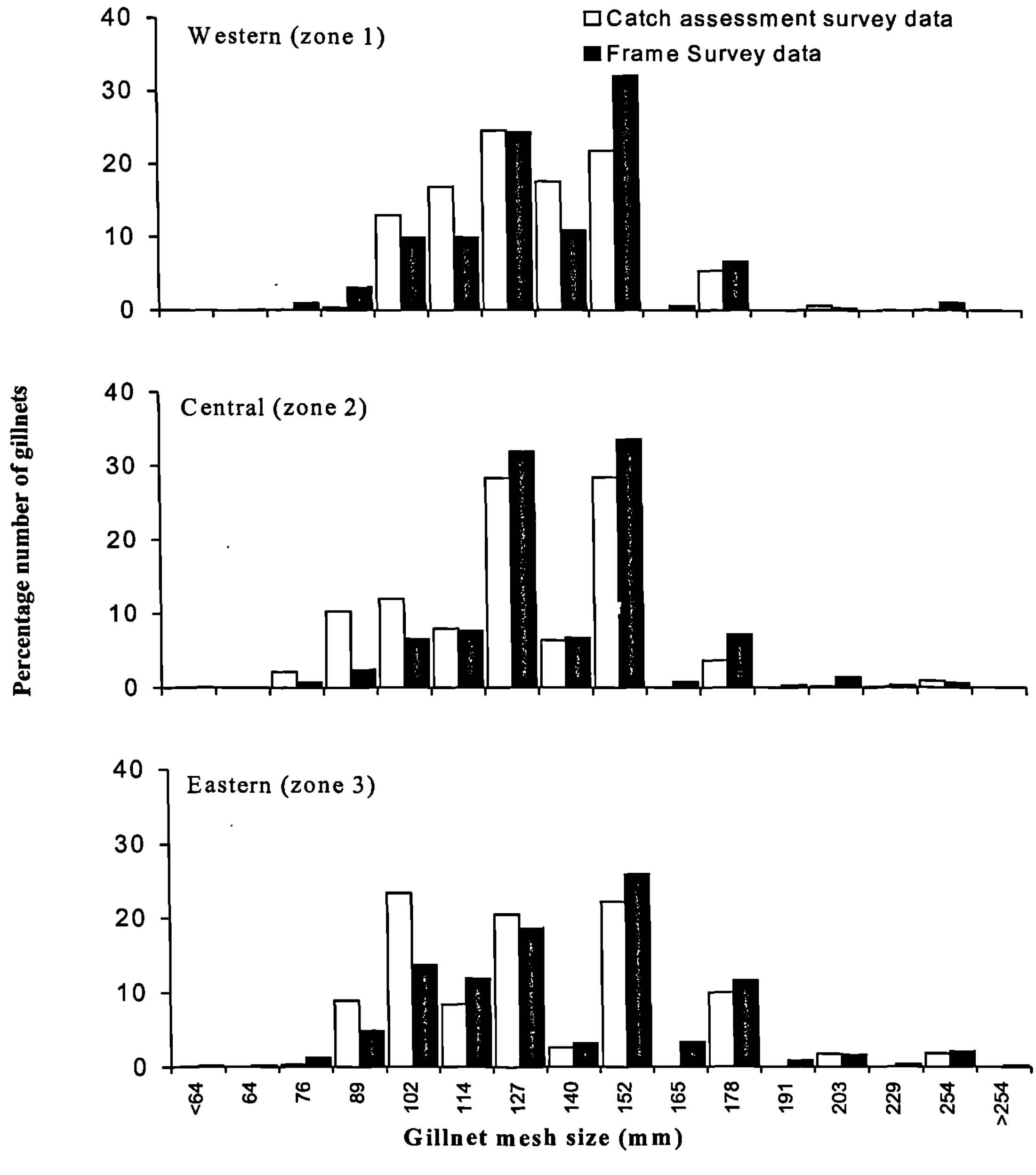


Figure 4.13 Comparison by zone of gillnet mesh size composition estimated from Catch assessment survey data and Frame survey 2000 data in paddled Sesse boats, which target Nile perch, in the Ugandan part of Lake Victoria.

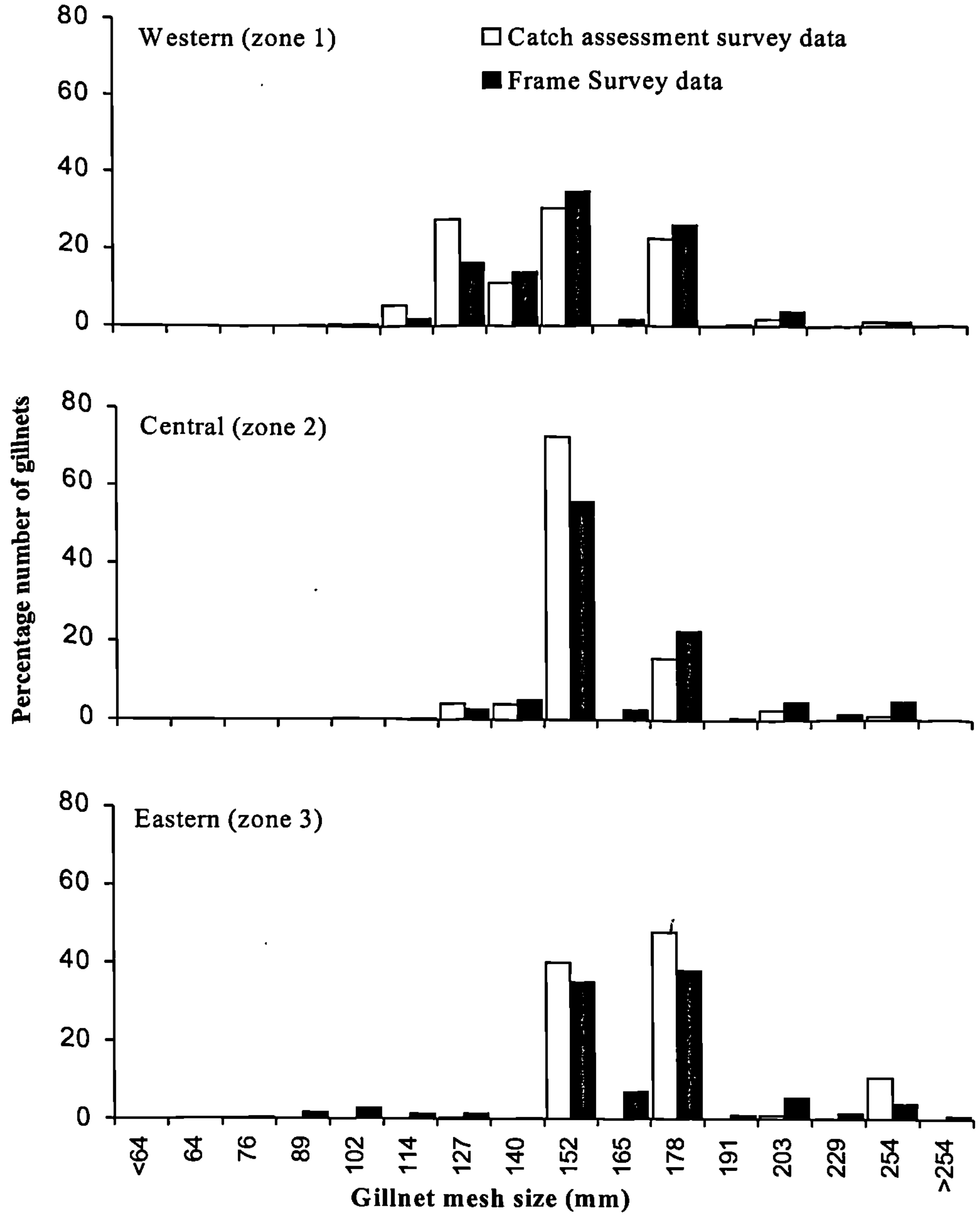


Figure 4.14 Comparison by zone of gillnet mesh size composition estimated from catch assessment survey data and Frame survey 2000 data in motorised/sailed Sesse boats, which target Nile perch, in the Ugandan part of Lake Victoria.

It was suspected that some fishers could have hidden illegal gillnets during the well-publicised Frame survey 2000 exercise but this analysis suggested that the frame survey data were a true reflection of the gillnet mesh size composition in the fishery. Both sets of data agree, the use of undersized gillnets <127 mm, the recommended minimum mesh size, is highest amongst parachute boats followed by paddled Sesse boats and least in motorised boats. However, amongst parachute boats, the proportion of undersized gillnets estimated from catch assessment data (38.0%) was lower than the frame survey value of 53.2% and vice versa in paddled Sesse boats where the estimate from the catch assessment data indicated 39.9% of nets were undersize compared with 22.4%

estimated from the frame survey data. The contribution of undersized gillnets is overwhelmed by the large numbers of nets carried by motorised/sailed boats to between 10.5 and 18.4% as estimated from catch assessment data and frame survey data respectively but their high representation in parachute and paddled Sesse boats should not be overlooked.

The spatial distributions of gillnet mesh sizes used in paddled and motorised/sailed Sesse boats which target Nile perch, from the Frame Survey 2000 data, showed approximate inverse relationship between mesh sizes used by the two categories of boats in a given zone (Fig. 4.15).

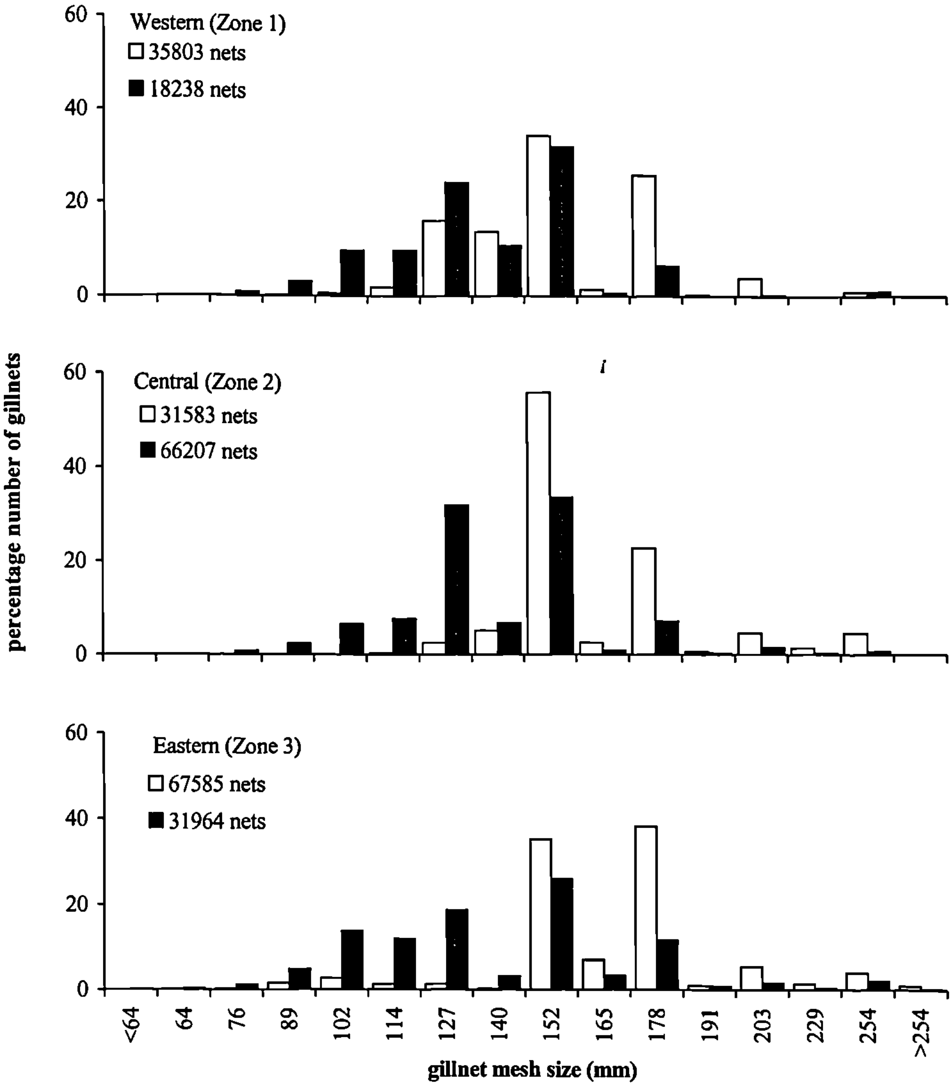


Figure 4.15 Overall gillnet mesh size composition by zones of motorised/sailed boats (clear bars) and paddled boats (shaded bars), which target Nile perch.

For instance, the relatively low occurrence of undersized gillnets in paddled Sesse boats in the western part of the lake corresponded with the highest occurrence of gillnets of mesh sizes smaller than 152 mm in motorised/sailed boats. Conversely, the highest occurrence of undersized gillnets in paddled Sesse boats in the eastern part of the lake, corresponded with the highest occurrence of gillnets of mesh sizes larger than 152 mm in motorised/sailed boats. The mesh size composition of gillnets in boats operating in the central zone was intermediate.

The gillnets <152 mm mesh size contributed 32.9% of the gillnets used by motorised/sailed boats operating in the western part of the lake (zone 1), but only 8 and 7% in the central (zone 2) and eastern (zone 3), respectively. The largest gillnet mesh sizes, ≥179 mm were most common in the eastern part of the lake, where they constituted 50.6% of the nets used by motorised/sailed boats, but decreased westwards to 33.7 and 31.2 in central and western zones respectively. The distribution of gillnets in the paddled Sesse boats that target small Nile perch showed the opposite trend with the illegal nets <127 mm mesh size constituting 32.2% in the eastern zone but 17.3 and 24.0% in the central and western zones respectively. This pattern is also reflected by Figures 4.6 to 4.11 and probably influenced the spatial composition of Nile perch catches.

4.2.4 *General size composition of Nile tilapia and Nile perch catches of the gillnet fishery*

Nile tilapia

The length frequency distribution of Nile tilapia catches in the three zones, when combined, showed patterns of abundance of particular sizes of fish in the catch that could be due to seasonality (Fig. 4.16). Periods with high occurrence of small fish could be regarded as when there is peak recruitment to the fishery and those of high occurrence of large fish could be associated with peak breeding periods when large fish aggregate in the breeding grounds and become more vulnerable to fishing.

Ignoring the September – November 1999 high occurrence of large fish in the catch that could have resulted from a period of low fishing pressure prior to this study as explained earlier, large Nile tilapia become more common in July to September 2000 suggesting peak breeding activity around this time. In the eastern part of the lake, where a fairly stable gillnet mesh size composition was maintained amongst parachute boats that targeted Nile tilapia, the size spectrum of Nile tilapia widened, including more large fish in July 2000, confirming increased availability of large fish at this time.

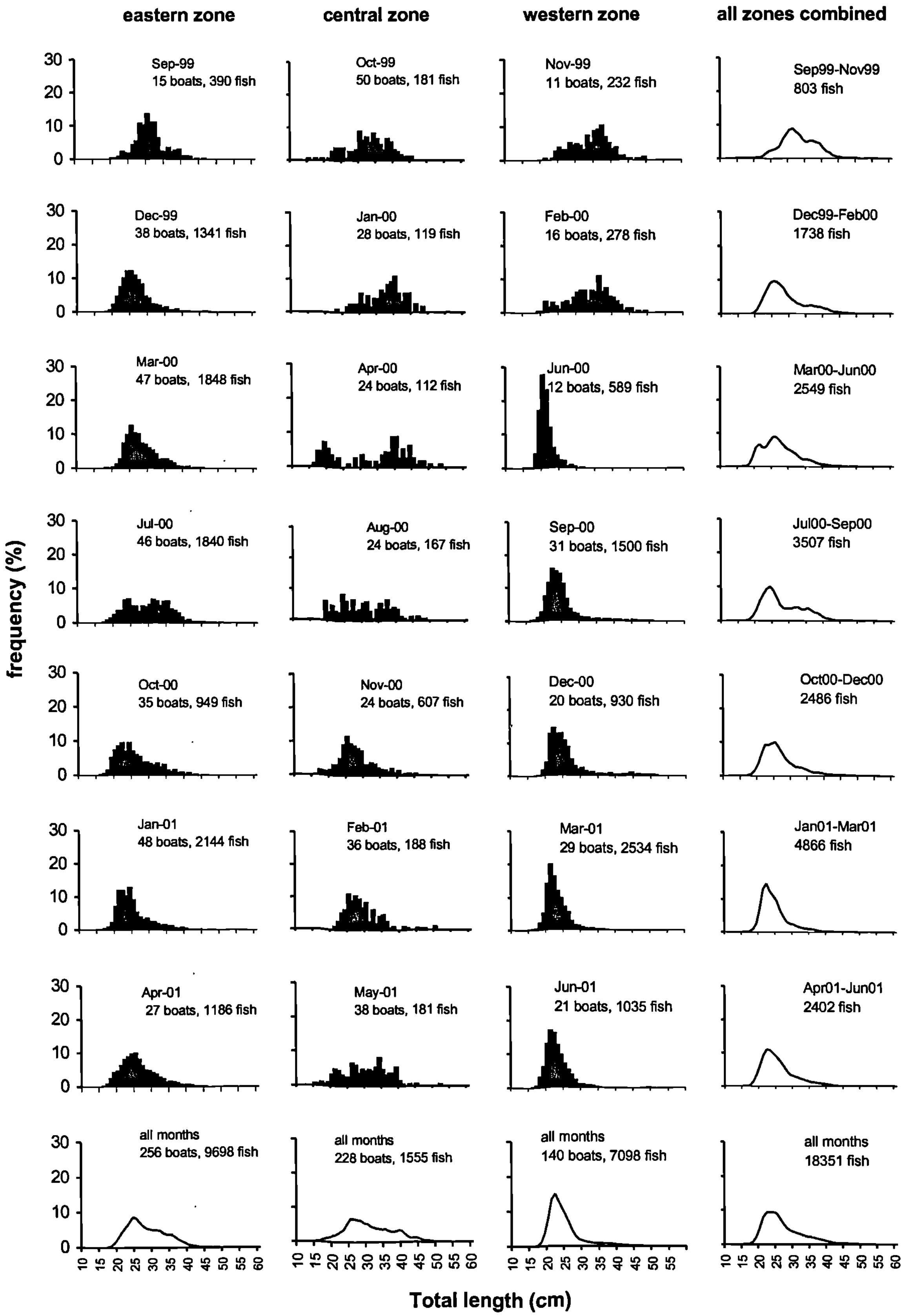


Figure 4.16 Length frequency of Nile tilapia landed by gillnetting parachute boats in the eastern and western zones and paddled Sesse boats in the central zone of the Ugandan part of Lake Victoria.

Similarly, in the western part of the lake, traces of large fish occurred in the catches in September 2000 despite the use of mainly small gillnet mesh sizes, which also suggests that there was increased availability of large fish, although they were not being targeted. Recruitment of small sized fish into the fishery first appeared in March to June 2000, forming a separate mode from the main mode, peaked in July to September 2000 and formed a plateau, spreading to larger sizes, in October to December 2000. Another peak of small size class fish appeared in January to March 2001 suggesting another lesser recruitment peak early in the year. Despite the two peaks, recruitment of Nile tilapia into the fishery appears to be more or less continuous.

The lake wide composition of Nile tilapia gillnet catches showed that 77% of the fish were caught at sizes smaller than the recommended size of 30 cm TL, the size at 100% maturity, with model lengths between 21 and 24 cm TL, which implies serious recruitment overfishing.

Nile perch

The lake wide size composition of Nile perch catches of paddled Sesse boats that targeted small fish and those of motorised/sailed boats that targeted larger fish in the three parts of the lake also indicated some seasonal patterns in abundance of particular sizes of fish (Figs 4.17 & 4.18). Amongst the paddled Sesse boats, the smallest size classes of fish showed three peaks in September to November 1999, then in July to September 2000 and April to June 2001. The small size class fish first formed a separate mode in the quarter preceding the April to June 2001 period, when they showed a clear peak. Only one annual pattern covering the year 2000 can be considered with certainty because of possible variations in strength of year classes and incomplete data sets for the other years. This pattern of catch composition suggests one recruitment peak in the period July to September although in 2001 there are suggestions of a second peak earlier in the year.

Amongst the motorised/sailed boats, which targeted large Nile perch, smaller individuals were most abundant in the catches in March to June 2000 and April to June 2001, i.e. in the first half of the year. They were rarer in the second half of the year in the period July to December 2000. The range of sizes caught became narrowest in July to September 2000 suggesting that large Nile perch become fully recruited into the fishery of these boats around this period. This was similar to the recruitment pattern

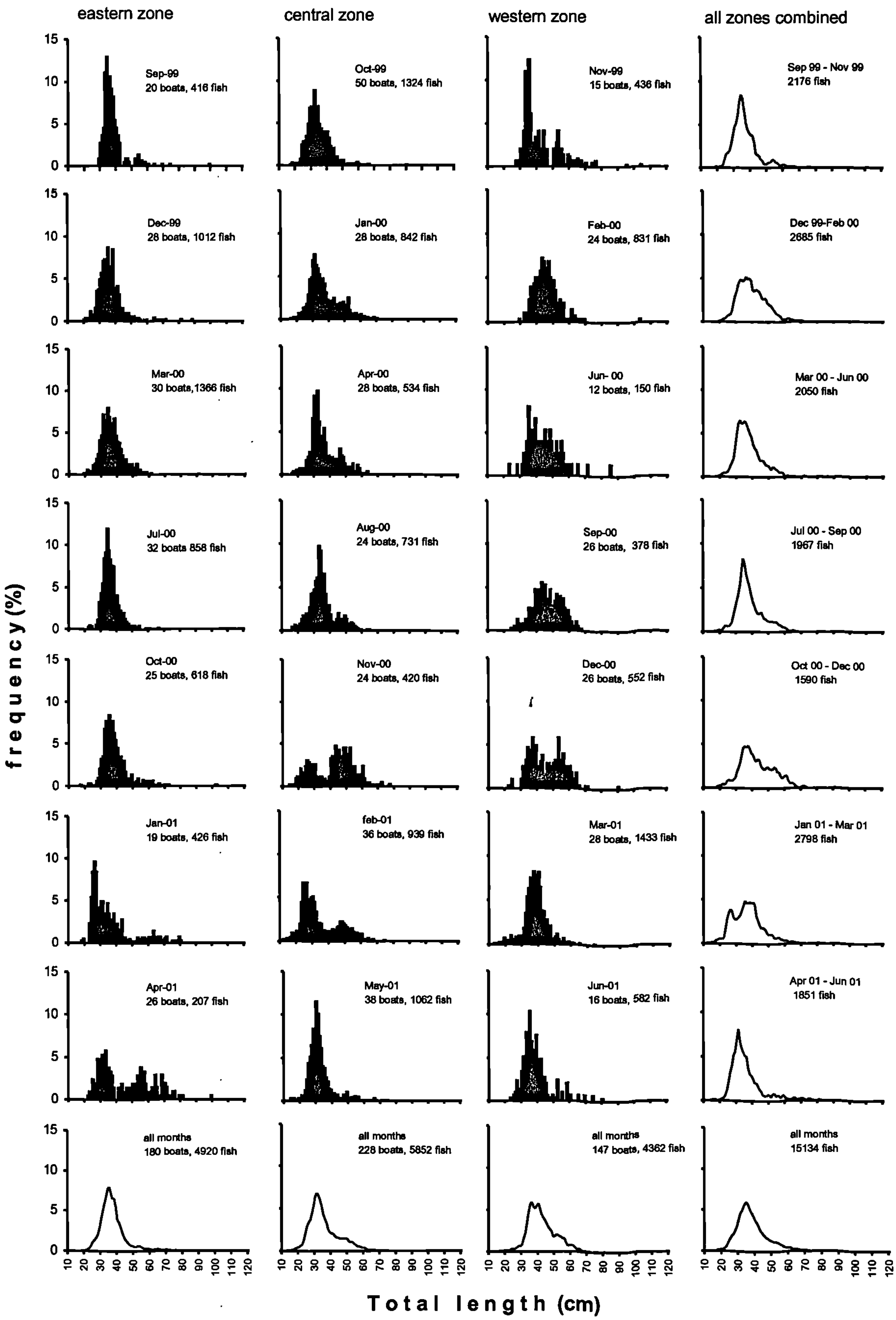


Figure 4.17 Percentage length frequency composition of Nile perch landed by paddled Sesse boats using gillnets in the Ugandan part of Lake Victoria.

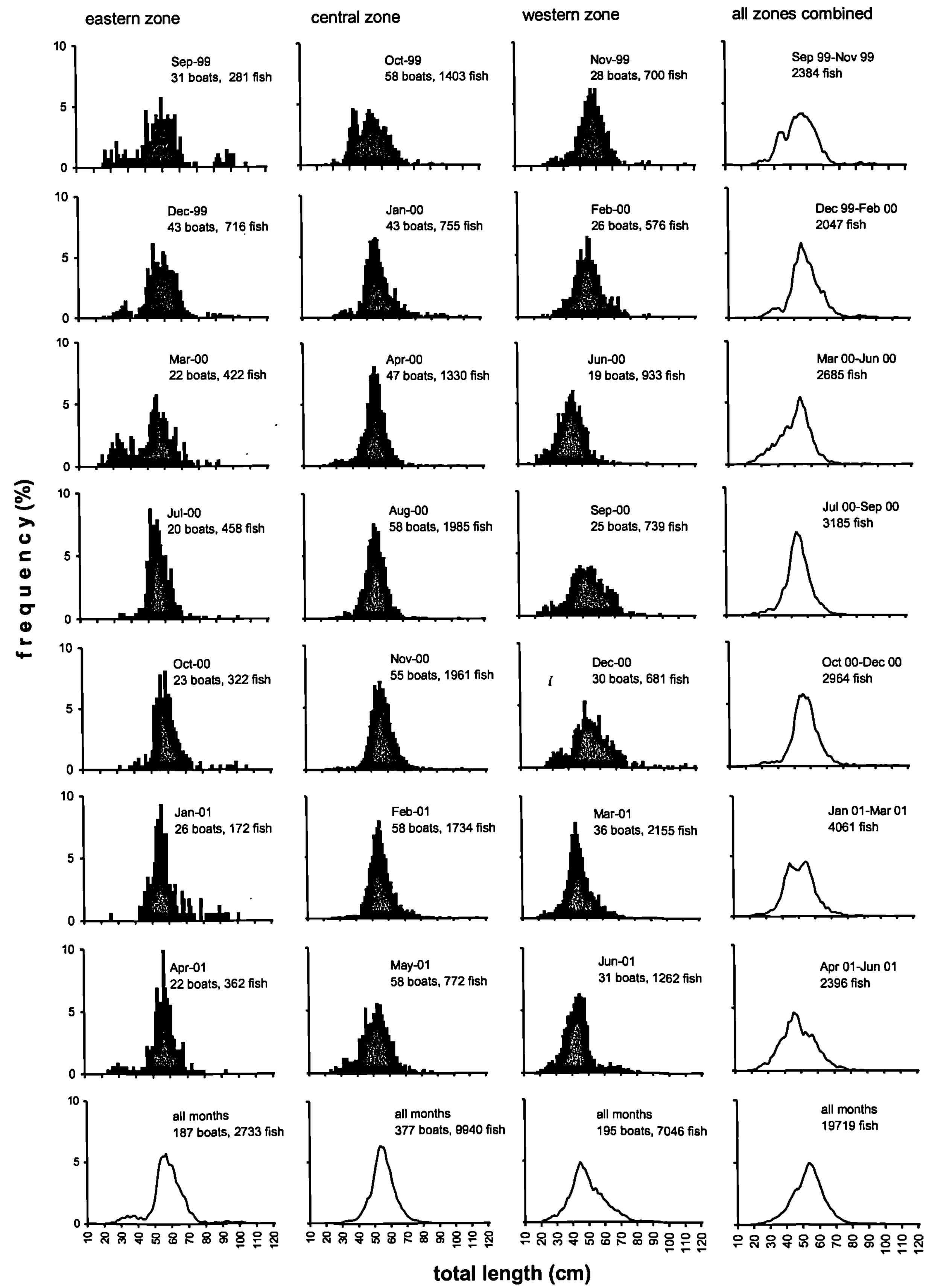


Figure 4.18 Percentage length frequency composition of Nile perch landed by motorised/sailed Sesse boats using gillnets in the Ugandan part of Lake Victoria.

found for paddled Sesse boats except the model length of the paddled boats was 34 cm TL whilst the model size of recruitment to the motorised/sailed boat fishery at around the same time of the year, was 52 cm TL. The lake wide size compositions of Nile perch gillnet catches of paddled boats with a modal length at 34 cm TL, and at 52 cm TL in the motorised/sailed boat fishery suggest that the paddled Sesse boats have a tendency towards recruitment over-fishing.

4.2.5 *Mode of operation of gillnets*

In the areas of Lake Victoria covered by this study, fishers operate gillnets in three main ways:

(1) active setting, where various methods are used to scare fish into the set net and several hauls are made at different sites in one night;

(2) passive setting, whereby gillnets are set at the bottom of the lake, anchored at one site overnight; and

(3) drift setting, where gillnets are set either in surface or mid waters and allowed to drift with the current throughout the fishing period.

Each mode of operation of gillnets predominated in a particular category of fishing boats (Fig. 4.19).

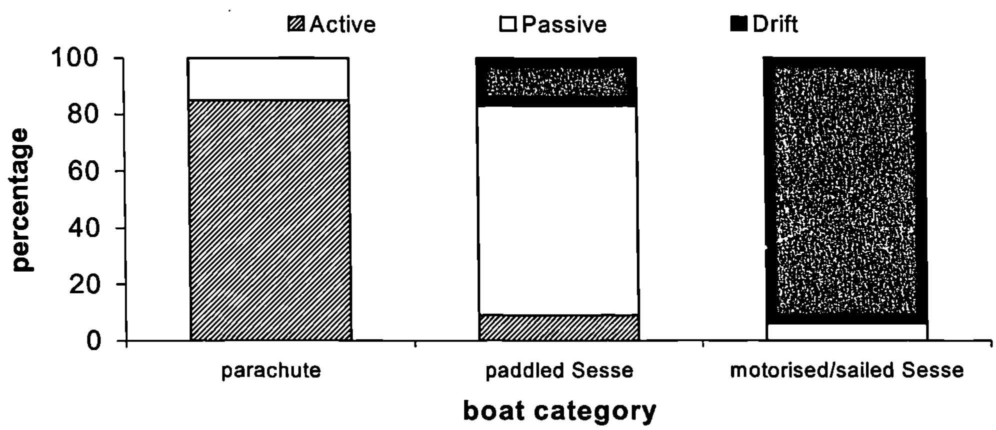


Figure 4.19 Percentage of number of boats in which gillnets were operated actively, passively or as drift nets in parachute, paddled Sesse, and motorised/sailed boats in the Ugandan part of Lake Victoria.

In 85% of parachute boats, gillnets were operated actively and the remaining 15% passively. On the other hand, in the majority of paddled Sesse boats (74%), gillnets were operated passively, 17% operated gillnets as drift nets and 9% as active gillnets. Most of the boats with sails or outboard motor (94%) operated gillnets as driftnets, the remaining 6% passively operated gillnets.

4.2.6 *The effects of mode of operation of gillnets on fish catch rates*

Parachute boats

In parachute boats, active operation of gillnets increased the mean catch per boat per day of Nile tilapia, their main target species (Fig. 4.20a). In the eastern part of the lake parachute boats operating gillnets passively landed an average of 8.7 $\pm$ 2.7 kg boat^{-1} day^{-1} of Nile tilapia, while for those that operated gillnets actively the catch rate was 20.6 $\pm$ 2.2 kg boat^{-1} day^{-1}, about 2.4 times higher. Similarly, the catch rate of Nile tilapia in parachute boats in the western part of the lake increased about three times from 6.8 $\pm$ 4.8 kg boat^{-1} day^{-1} in boats with passively set gillnets to 20.3 $\pm$ 8.3 kg boat^{-1} day^{-1} in boats with actively operated gillnets. Catch rates of Nile perch were higher in parachute boats with passively operated gillnets but those of other fish species remained more or less the same.

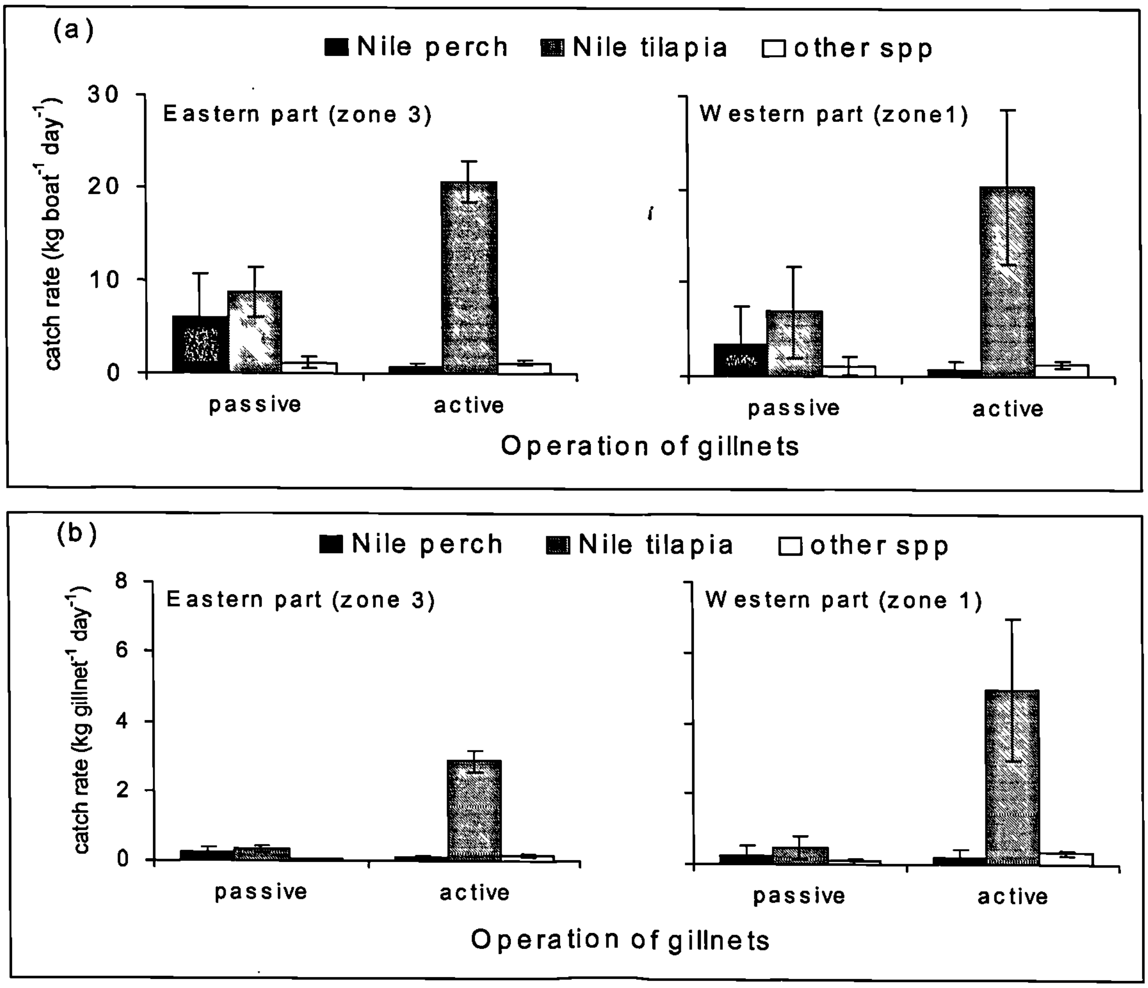


Figure 4.20 Fish catch rates, (a) per boat (b) per gillnet of parachute boats operating gillnets passively or actively in the Ugandan part of Lake Victoria. Error bars = 95%CL.

The parachute boats with passively set gillnets carried more than three times the number of gillnets carried by those in which gillnets were operated actively (Table 4.1). Active operation of gillnets increased the mean catch rate of Nile tilapia, the target fish species of parachute boats, from 0.3 ± 0.1 to 2.9 ± 0.3 and 0.5 ± 0.3 to 5.0 ± 2.0 kg net^{-1} day^{-1} in the eastern and western zones respectively (Fig. 4.20b). Conversely, the weight of Nile perch caught per net was higher in passively operated nets but the catch per net of other species was higher in actively operated nets. The catch per gillnet of actively operated nets appeared to be higher in the western zone but the differences between the two zones were not statistically significant (ANOVA $F_{1,344} = 3.34$, $P>0.05$).

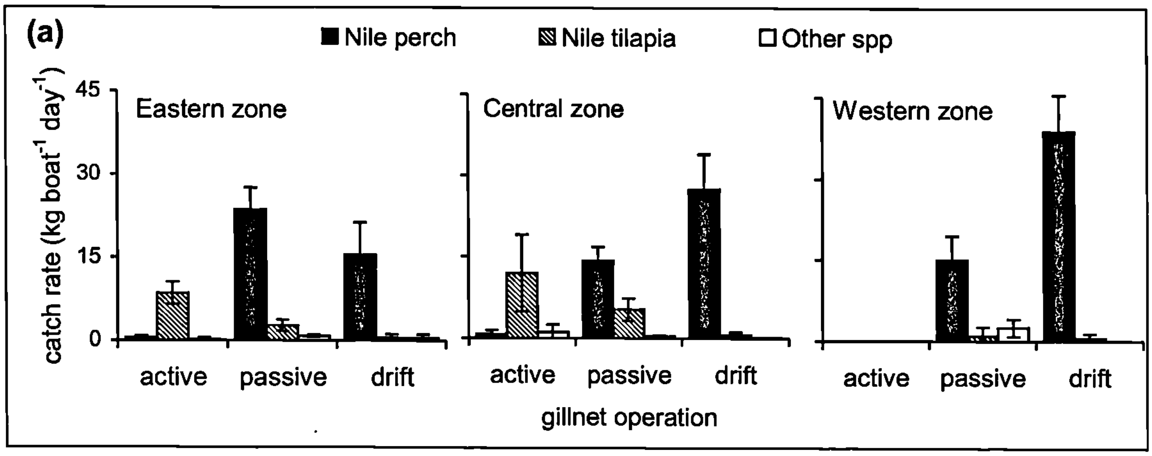
Table 4.1 Mean number of gillnets per boat operated actively and passively by parachute boats in the eastern and western parts of the lake

Part of the lake	active	passive
Eastern (zone 3)	7 ± 1	27 ± 5
Western (zone 1)	4 ± 1	14 ± 6

Paddled Sesse boats

Paddled boats in which gillnets were operated actively were encountered in the eastern and central parts of the lake. The boats in which gillnets were operated actively targeted Nile tilapia, like parachute boats, but those in which gillnets were operated passively, or as drift nets targeted Nile perch (Fig. 4.21a). High Nile tilapia catch rates of 8.6 ± 2.0 and 12.0 ± 2.1 kg $boat^{-1}$ day^{-1} were obtained by boats operating gillnets actively compared with 2.7 ± 1.0 and 5.3 ± 2.1 kg $boat^{-1}$ day^{-1} in boats that operated gillnets passively in the eastern and central parts of the lake respectively. Catch rates of Nile perch almost doubled, from 14.3 ± 2.5 kg $boat^{-1}$ day^{-1} in boats with passively set gillnets to 27.5 ± 6.3 kg $boat^{-1}$ day^{-1} in boats with drift gillnets in the central part of the lake. They also increased 2.6 times in the western part from 15.0 ± 4.4 to 38.8 ± 6.8 kg $boat^{-1}$ day^{-1}. However, there was a decrease in the eastern part of the lake from 23.6 ± 4.0 to 15.5 ± 5.7 kg $boat^{-1}$ day^{-1}, suggesting scarcity of large fish targeted by driftnets in the limited fishing range of paddled Sesse boats in this part of the lake.

Paddled Sesse boats with actively operated gillnets carried the least number of gillnets among the three modes of gillnet operation (Table 4.2). A similar number of passive and drift gillnets were carried by boats in the eastern zone whereas more drift than passive gillnets were carried by boats in the central part of the Lake. In both categories the largest number of gillnets was carried by boats in the western part of the lake.



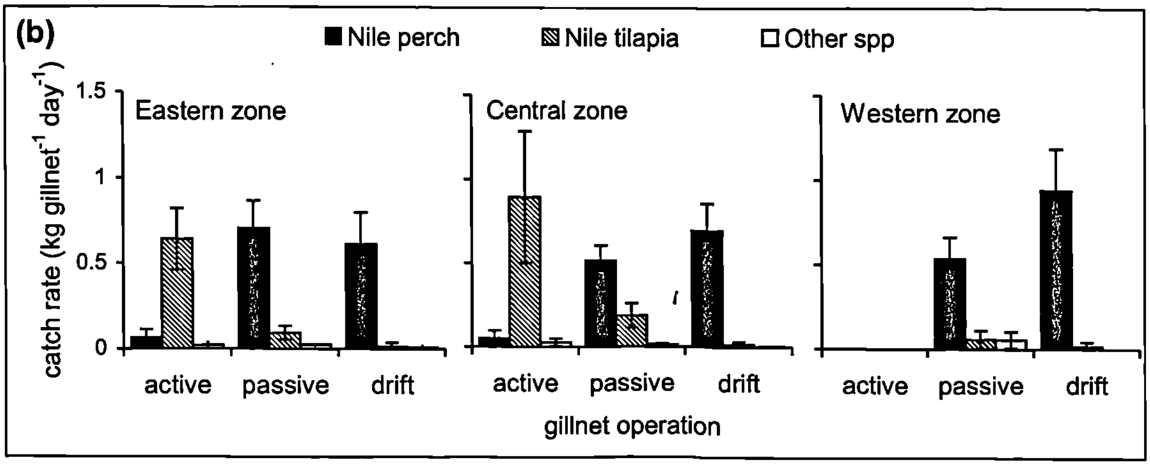


Figure 4.21 Fish catch rates, (a) per boat (b) per gillnet, of paddled Sesse boats operating gillnets passively, actively or as driftnets in the Ugandan part of Lake Victoria. Error bars = 95%CL.

Table 4.2 Mean number of gillnets per boat operated actively, passively or actively by paddled boats in the different parts of the lake

Part of the lake	active	passive	drift
Eastern (zone 3)	12 ± 3	31 ± 2	31 ± 6
Central (zone 2)	12 ± 7	28 ± 2	40 ± 4
Western (zone 1)	--	48 ± 3	41 ± 5

Similar to the parachute boats, the catch per gillnet per day of Nile tilapia was much higher in actively operated gillnets compared with the passive and drift settings, but those of Nile perch were higher in the later two (Fig. 4.21b).

In paddled Sesse boats, the catch rate of Nile tilapia in actively operated gillnets was 0.9 ± 0.4 kg gillnet^{-1} day^{-1} in the central part, higher than 0.6 ± 0.2 kg gillnet^{-1} day^{-1} in the eastern part of the lake, but catch rates were much lower in passively set nets and negligible in drift gillnets set in the central zone.

The catch rate of Nile perch in passively set and drifting gillnets followed the same pattern as the catch per boats above in the three parts of the lake. The catch per gillnet was lower in drift nets than in passively set gillnets in the eastern zone, whereas the reverse was true in the central and western parts of the lake. This also suggests relative scarcity of large Nile perch targeted with driftnets in waters plied by paddled Sesse boats in the eastern part of the lake compared with other parts. The highest catch per net of Nile perch in paddled Sesse boats operating driftnets was in the western zone, implying that this part of the lake had higher availability of large Nile perch within the limited area of operation of these boats.

Motorised/sailed boats

The catch per boat of Nile perch was significantly lower in the eastern part of the lake than in the central and western zones for both passively set gillnets (*ANOVA*: $F_{2, 26}$ = 3.78, $P<0.05$) (Appendix 4.12) and drifting gillnets (*ANOVA*: $F_{2, 711}$ = 19.3, $P<0.05$) (Appendix 4.13) (Fig.4.22 a&b). For both modes of gillnet operation, ANOVA showed that the catch per boat was similar in the central and western zones, in boats with passively set gillnets ($F_{1, 21}$ = 1.68, $P>0.05$) (Appendix 4.14) and boats with drifting gillnets ($F_{1, 532}$ = 0.01, $P>0.05$) (Appendix 4.15). The catch per net was similar in the three parts of the lake. Motorised/sailed boats in the eastern part used fewer gillnets than those in central and western parts of the lake (Table 4.3), which could explain the discrepancy in catch rates of boats compared with individual gillnets. Although the catch per net is similar in the three zones, fishing costs of motorised/sailed boats in the eastern zone are likely to be higher than in other zones because they use the largest gillnets mesh sizes ≥152 mm which are relatively more expensive (see Figs 4.9; 4.10 & 4.11). The exclusive use of large mesh sizes also suggests that motorised/sailed boats in the eastern zone fish exclusively in deep offshore waters compared with those in the western zone and to some extent the central zone, which may be fishing in near shore areas; therefore, they probably spend more on fuel per fishing trip.

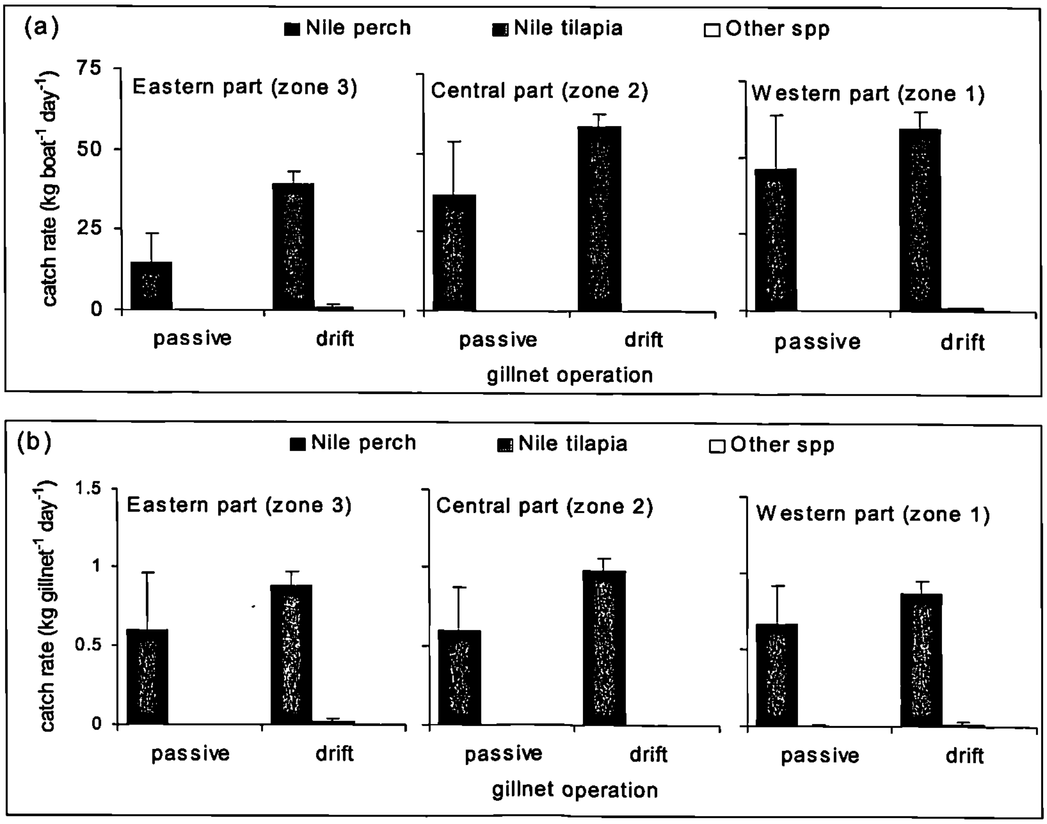


Figure 4.22 Fish catch rates, (a) per boat (b) per gillnet, of motorised/sailed Sesse boats operating gillnets passively or as driftnets in the Ugandan part of Lake Victoria. Error bars = 95%CL.

Table 4.3 Mean number of gillnets per boat operated passively or actively by motorised/sailed boats in the different parts of the Ugandan part of Lake Victoria

Part of the lake	passive	drift
Eastern (zone 3)	25 ± 23	45 ± 2
Central (zone 2)	61 ± 27	59 ± 1
Western (zone 1)	70 ± 15	69 ± 4

4.2.7 *Catch composition under different modes of operation of gillnets*

The different modes of operation of gillnet target different sizes of fish. In the Nile tilapia fishery, catches of gillnets operated actively, the predominant method used to target the species, caught a high proportion of fish smaller than the recommended size for harvest of 30 cm TL, compared with those operated passively (Fig. 4.23a). In the Nile perch fishery, passively operated gillnets targeted fish smaller than 50 cm TL, the minimum size recommended for harvest compared with gillnets operated as drift nets (Fig. 4.23b).

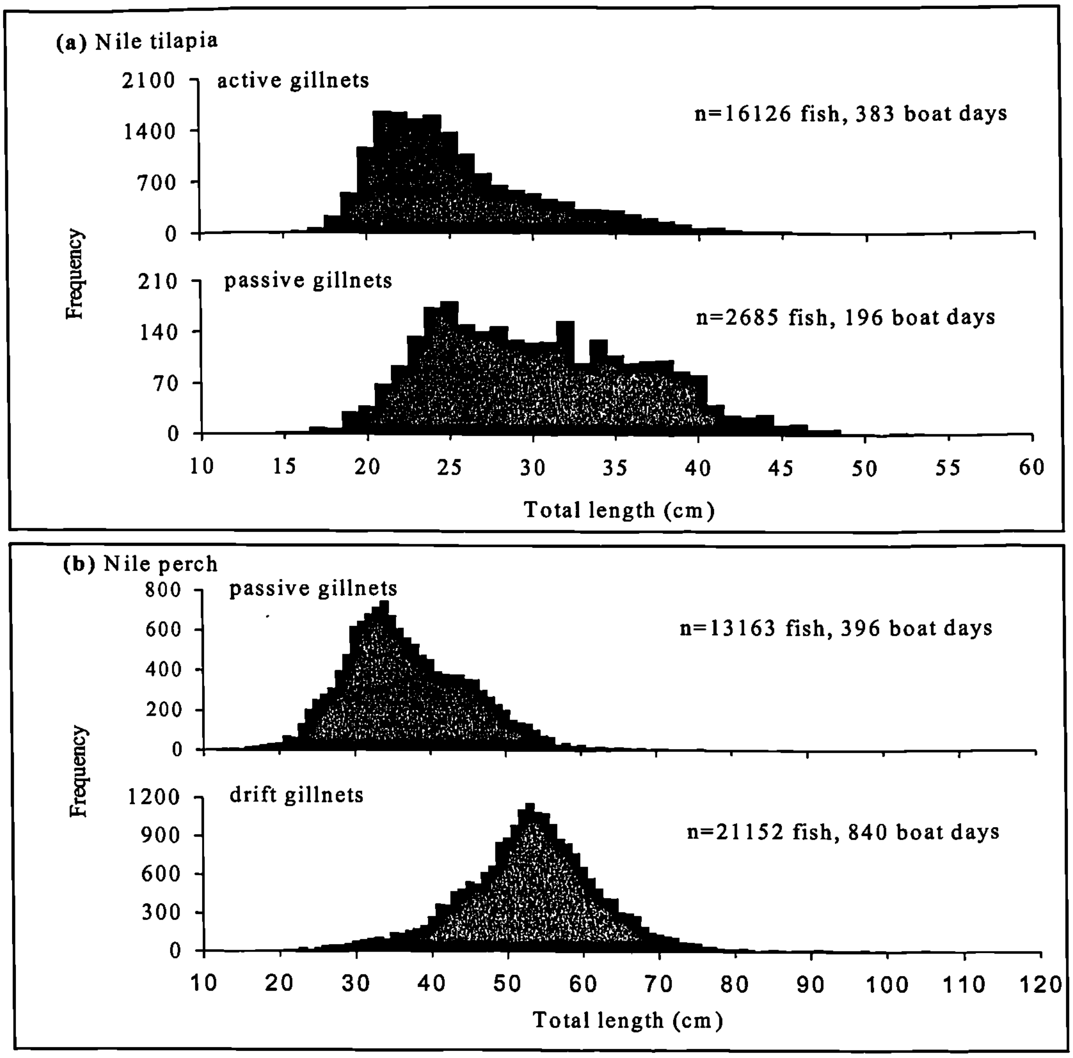


Figure 4.23 Size composition of (a) Nile tilapia caught by gillnets operated actively or passively and (b) Nile perch caught by gillnets operated passively or as driftnets, in the Ugandan part of Lake Victoria.

4.3 The hand line and long line Nile perch fishery

Hand lines or long lines are used mainly to target Nile perch, using a limited range of hook sizes, from size 10 (the smallest) to size 7 (the largest). Three categories of live bait, i.e. *Mormyrus kannume, Clarias* sp. and haplochromines, are used as bait.

4.3.1 *Fish catch rates of boats fishing with hooks*

Boats fishing with hooks were rarely encountered at the sampled landings compared with gillnetting boats. Initially few long lining boats were found at the sampled beaches but they increased gradually during the surveys. Boats using hooks, both on hand lines and long lines targeted Nile perch (Fig. 4.24). The mean quarterly catch rates for Nile perch amongst hand lining boats showed weak peaks of 20.8 $\pm$ 9.2 kg boat^{-1} day^{-1} and 20.3 $\pm$ 5.3 kg boat^{-1} day^{-1} in March to June 2000 and October to December 2000 respectively but were not statistically different (*ANOVA*: $F_{6,\ 32}$ = 1.03, P=0.05)

(Appendix 4.16). Overall, their catch rate was 13.0 ± 1.9 kg boat^{-1} day^{-1}. Nile perch catch rates amongst long lining boats were not statistically different between quarters (*ANOVA*: $F_{5,78}$ = 2.06, *P*=0.05) (Appendix 4.17). The apparently low catch rates, 20.5 ± 7.6 and 25.0 ± 7.0 kg boat^{-1} day^{-1} between December 1999 and June 2000 (Fig. 4.24) had very high variances owing to the small size of the sample and because hooks catch a wide range of Nile perch sizes, therefore a large difference in catch rate between boats could result from one large fish in one of the boats. For the same reasons, the high catch rate of 72.7 ± 12.7 kg boat^{-1} day^{-1} in October to December 2000 and the drop to 45 ± 9.0 and 54.8 ± 7.8 kg boat^{-1} day^{-1} in January to March and April to June 2001 respectively could not be confidently attributed to seasonality. Overall, the catch rate of long lining boats was 52.3 ± 4.6 kg boat^{-1} day^{-1}.

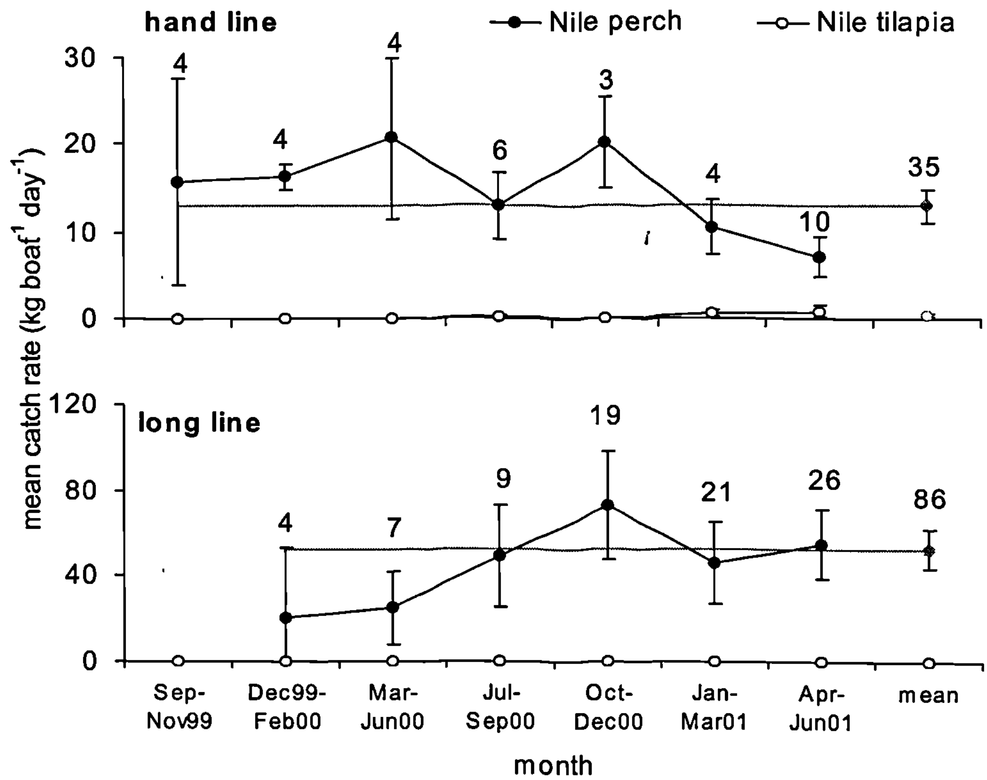


Figure 4.24 Mean fish catch rates of boats fishing with hooks on hand lines and long lines in the Uganda part of Lake Victoria. Grey lines indicate the overall mean and Error bars = 95%CL.

4.3.2 *Composition of Nile perch catches of boats fishing with hooks*

Nile perch catches by hooks were dominated by fish in the size range 30 to 60 cm TL, which contributed 90.4% of the hand line catches and 68.5% of long line catches. However, Nile perch between 60 and 120 cm TL were common, especially in long line catches. This wide range of Nile perch sizes caught by hooks is suggestive of non-selectivity of hooks for a particular size group of fish. The size composition of catches is probably influenced by the availability of certain sizes of fish in the fishing grounds, e.g. hand line hooks which are operated in inshore waters caught fewer large fish than long line hooks which are operated in offshore waters. Small juvenile fish < 50 cm TL dominated the overall Nile perch catches in boats fishing with hooks, contributing 53.1 and 80.7 % in long line and hand line catches respectively (Fig. 4.25).

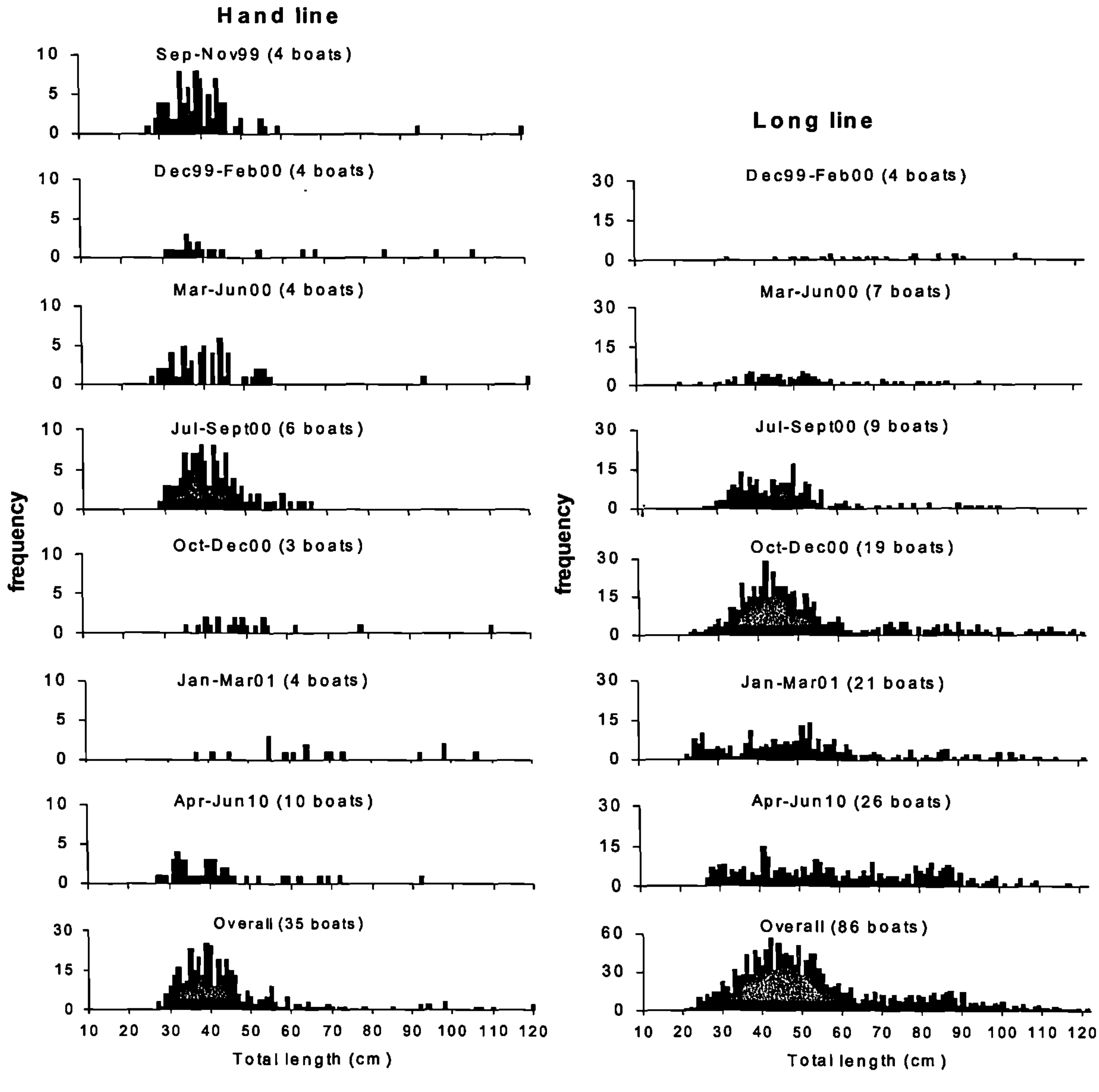


Figure 4.25 Size distribution of Nile perch landed by boats using hand lines and long lines in the Ugandan part of Lake Victoria.

Amongst long lining boats, small Nile perch <50 cm TL were most prevalent in the catches in the period July to September and October to December 2000 when they constituted 71% and 61.2% of the catches respectively. They were relatively scarce in the first half of 2001, especially the period April to June 2001, when they constituted only 37.1% of the catches. Similarly amongst hand lining boats, the second half of the year had the highest abundance of small Nile perch, constituting 90.8% in September to November 1999 and 86.6% in July to September 2000. These observations would suggest that major recruitment of young Nile perch into the fishery takes place in the second part of the year reaching a peak around September - October.

4.3.3 *Factors affecting Nile perch size selectivity of hooks*

The sizes of hooks

Four hook sizes, in the limited range of size 10 (the smallest) to size 7 (the largest) were encountered in the fishery, and the size distribution of Nile perch caught by these hooks appeared to be independent of the size of hook used (Fig. 4.26).

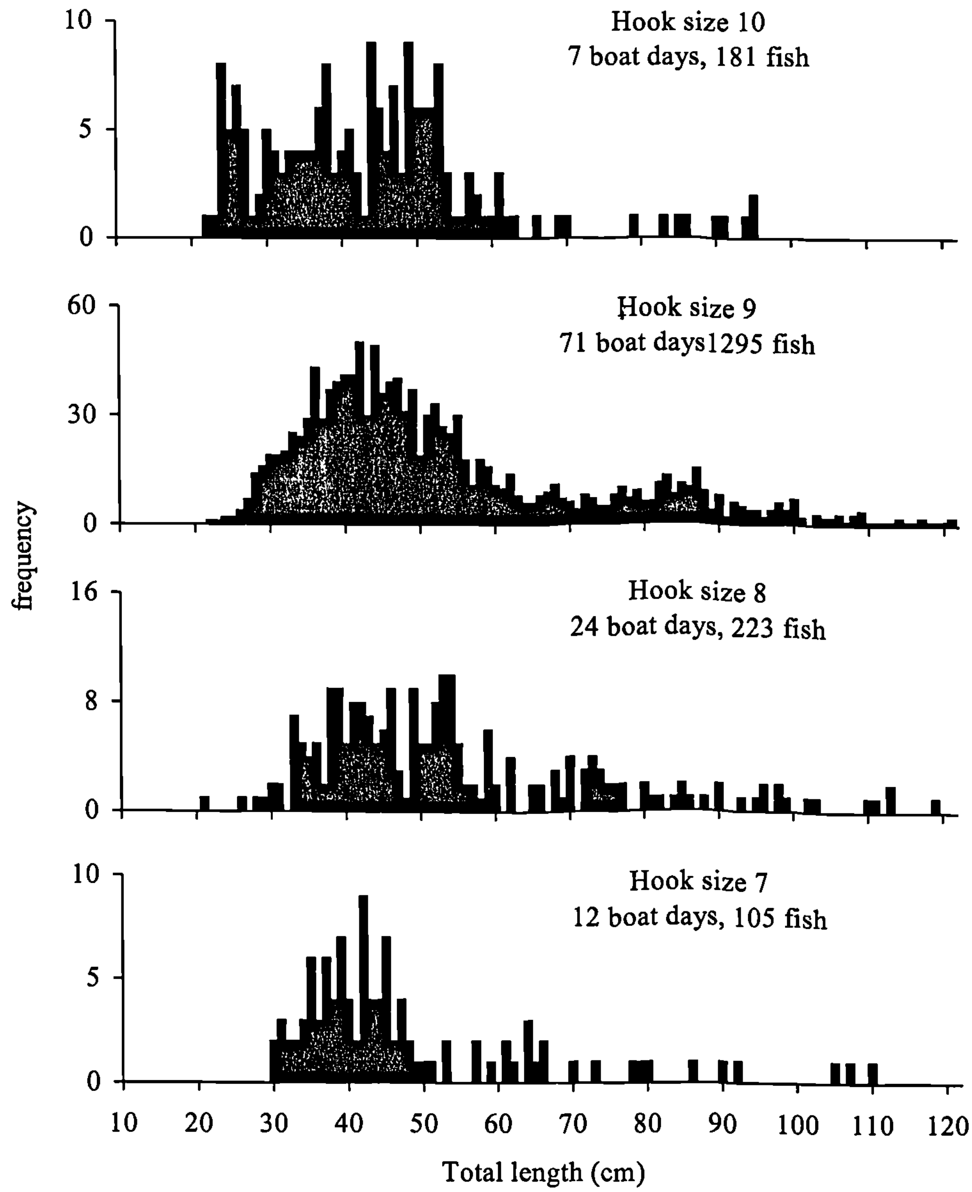


Figure 4.26 Length frequency of Nile perch caught by different sizes of hooks in the Ugandan part of Lake Victoria. Catches of long lines and hand lines are pooled.

The highest occurrence of small Nile perch < 50 cm TL, 73.3% and 69.6% was in catches of boats using the largest hooks (size 7) and those using the smallest hooks (size 10) respectively. Nile perch catches of boats using hook sizes 8 and 9 had the lowest component of fish <50 cm TL, 49.3% and 56.0% respectively. However, the interpretation of these data was unclear because the number of boat days for the hook sizes 10 and 7 were limited. In addition, some fishers probably used mixed hook sizes that were not detected because hook sizes following one another look similar especially in poor visibility as most sampling of hook catches was at night.

The type/size of bait

The size of Nile perch selected by hooks seemed to be substantially affected by the type/size of bait used (Fig. 4.27). Only three categories of bait were encountered in boats that used hooks: (i) *Mormyrus kannume*, used exclusively by hand line boats; (ii) *Clarias* sp.; and (iii) haplochromines, used by both hand line and long line boats.

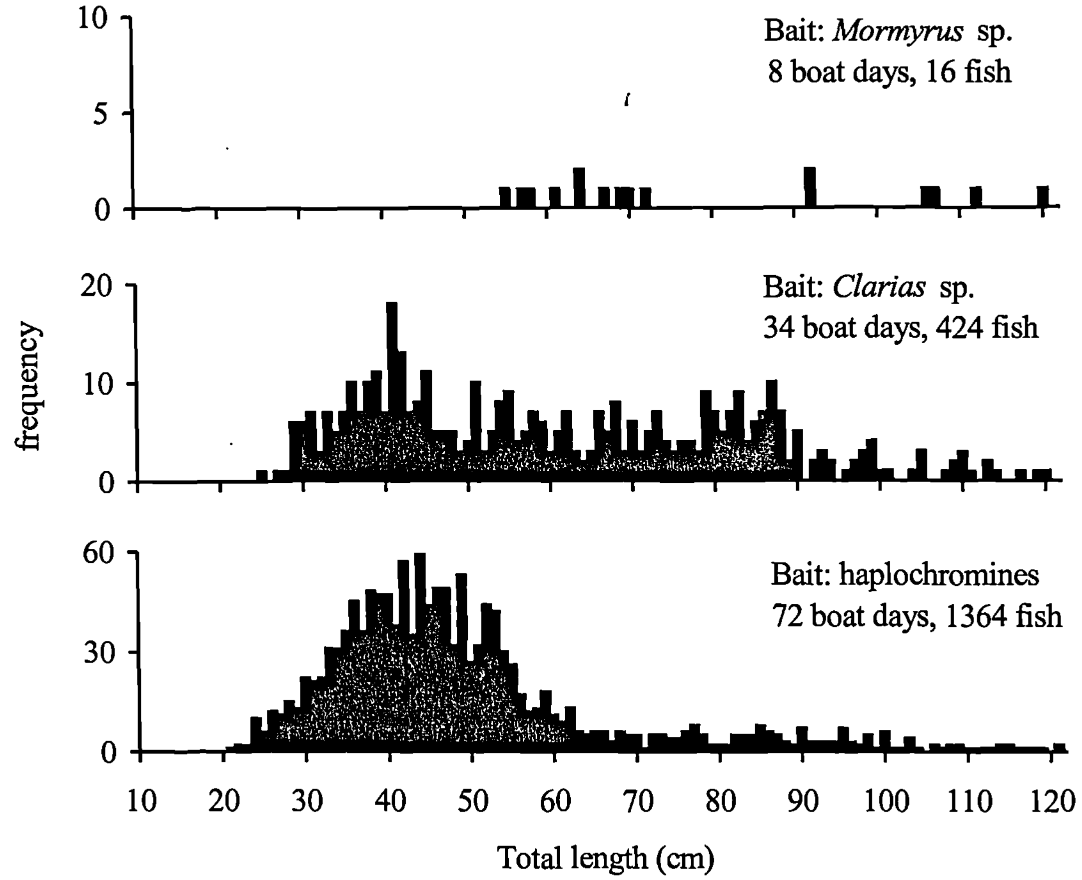


Figure 4.27 Length frequency of Nile perch caught by hooks with three different types of live bait in the Ugandan part of Lake Victoria. Data for long line and hand line catches are pooled.

The haplochromines were the smallest bait in use, their size varying mainly between 5 and 10 cm TL. *Clarias* sp. were of the widest size range from about 8 to 25 cm TL while the *M. kannume* used were all large, >15 cm fork length. Small Nile perch <50 cm TL were absent in catches of boats that used *M. kannume* bait but constituted 38.7% and 64.1% of fish in boats using *Clarias* sp and haplochromine bait respectively. Therefore, the occurrence of small fish in the catch could be directly related to the size of bait. Boats using *M. kannume* bait were rare due to difficulties in obtaining sufficient quantities of the bait. To catch *M. kannume* for bait, fishers set small mesh size gillnets (50 to 89 mm) in specific areas in the lake where this species occurs. *Clarias* sp, are caught using basket traps in swamps, transported in containers filled with water to fish landing sites and sold to Nile perch fishers.

The most common bait, haplochromines, are obtained easily in large quantities using mosquito beach seines of 5 mm mesh size just before the fishing trip. These mosquito seines often catch large quantities of juvenile Nile tilapia and Nile perch that are not targeted for bait. Mortality of haplochromines used for baiting hooks is very high compared with the other two species, thus fishers have to collect large numbers to increase the chances of enough live bait for the duration of the fishing trip. This is very wasteful, especially in terms of the quantities of juvenile Nile perch and tilapia that are caught, together with the haplochromines that are discarded in the process of bait collection and applying to the hooks.

4.4 Other fishing gears targeting Nile perch and Nile tilapia

The fishing gears for Nile perch and Nile tilapia that were less frequently encountered in the surveys included beach seines, cast nets and basket traps. Boats operating beach seines targeted Nile perch for which the overall catch rate was 51.4 $\pm$ 17.9 kg boat^{-1} day^{-1} whereas Nile tilapia and other fish species contributed only 0.7 $\pm$ 0.5 and 0.3 $\pm$ 0.2 kg boat^{-1} day^{-1} respectively (Table 4.4). The boats which operated cast nets or basket traps targeted Nile tilapia for which the overall catch rates were 11.8 $\pm$ 3.8 and 8.9 $\pm$ 5.7 kg boat^{-1} day^{-1} respectively, compared with 0.1 $\pm$ 0.1 and 0.2 $\pm$ 0.3 kg boat^{-1} day^{-1} of Nile perch and 0.1 $\pm$ 0.1 and 1.5 $\pm$ 1.2 kg boat^{-1} day^{-1} of other fish species respectively.

Table 4.4 Overall catch rates of rarely encountered Nile perch and Nile tilapia fishing gears

Gear type	No. of boats sampled	Fish catch rate (kg boat $^{-1}$day^{-1})		
		Nile perch	Nile tilapia	Other species
Beach seine	25	51.4 $\pm$ 17.9	0.7 $\pm$ 0.5	0.3 $\pm$ 0.2
Cast net	25	0.1 $\pm$ 0.1	11.8 $\pm$ 3.8	0.1 $\pm$ 0.1
Basket traps	9	0.2 $\pm$ 0.3	8.9 $\pm$ 5.7	1.5 $\pm$ 1.2

4.5 Size at first maturity of Nile perch and Nile tilapia

The data collected during LVFRP bottom trawl surveys in the Ugandan waters of Lake Victoria, from 1998 to 2000, were used for the analysis of the length at first maturity of Nile perch and Nile tilapia (LM_{50}), when 50% of individuals became mature.

4.5.1 *Spatial distribution of size at first maturity of Nile perch*

Male Nile perch matured at a larger size in the western part of the Ugandan waters (LM_{50} = 58.3 cm TL), than in the central and eastern parts, 56.6 and 56.4 cm TL, respectively (Fig. 4.28). The overall size at first maturity of male Nile perch in the Ugandan waters of Lake Victoria was 57.2 cm TL. Unlike for the males where there were sufficient specimens to allow for separate analysis of LM_{50} in different zones, females were few and meaningful analysis was only possible when the specimens from all zones were pooled. Approximately 50% of the mature female Nile perch specimens were from the eastern area (zone 3) of the Ugandan part of the lake (Table 4.5). The overall LM_{50} of female Nile perch in the Ugandan waters of Lake Victoria was 75.6 cm TL, but with wide variations. One possible source of variation could be dissimilarity in LM_{50} between zones. Larger sample sizes will be required to test this hypothesis in the future.

Table 4.5 Numbers of female Nile perch specimens by zones used in the analysis of LM_{50} in the Ugandan part of Lake Victoria (LVFRP trawl survey data 1998 to 2000)

	Zone 1	Zone 2	Zone 3	Total
Number of fish $\geq$40 cm TL	45	77	121	243
Number of mature fish	14	16	29	59

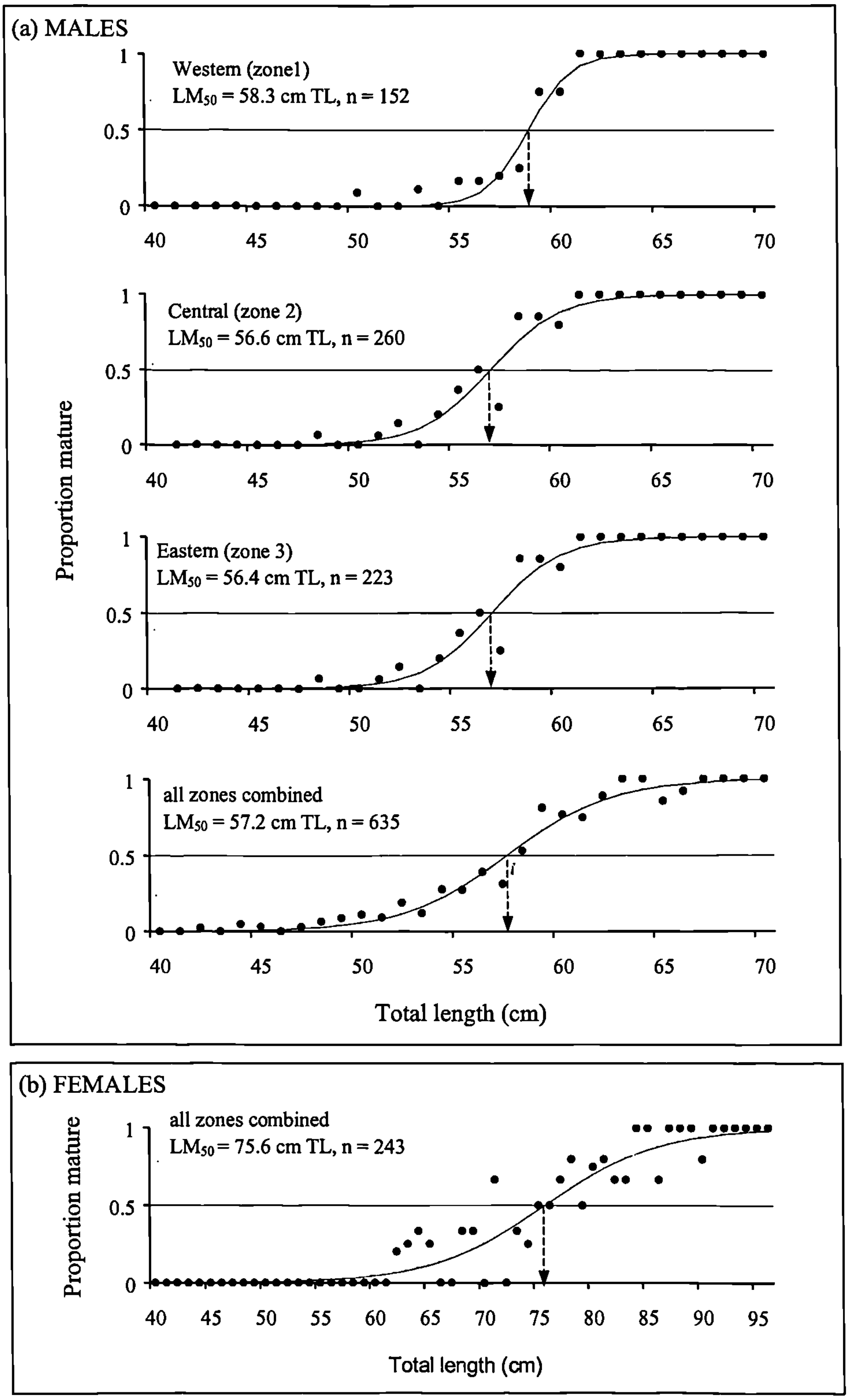


Figure 4.28 Proportions of mature Nile perch in the Ugandan part of Lake Victoria: (a) males by zones and (b) females - data from three zones combined. SOLVER smooth curves are fitted to the data points (Source: LVFRP trawl survey data 1998 to 2000).

4.5.2 *Spatial distribution of size at first maturity of Nile tilapia*

The size at first maturity (LM_{50}) of Nile tilapia generally increased from the eastern to the western part of the lake, with the largest differences observed in females, i.e. from 32.0 cm TL in eastern zone to 33.5 and 36.3 cm TL in central and western parts respectively (Fig. 4.29). The LM_{50} of male Nile tilapia was also lowest in the eastern part of the lake (30.9 cm TL), but the same in the central and western parts (31.9 cm TL). The overall size at first maturity of female Nile tilapia in the Ugandan waters of Lake Victoria was 33.1 cm TL whereas that of males was 31.7 cm TL.

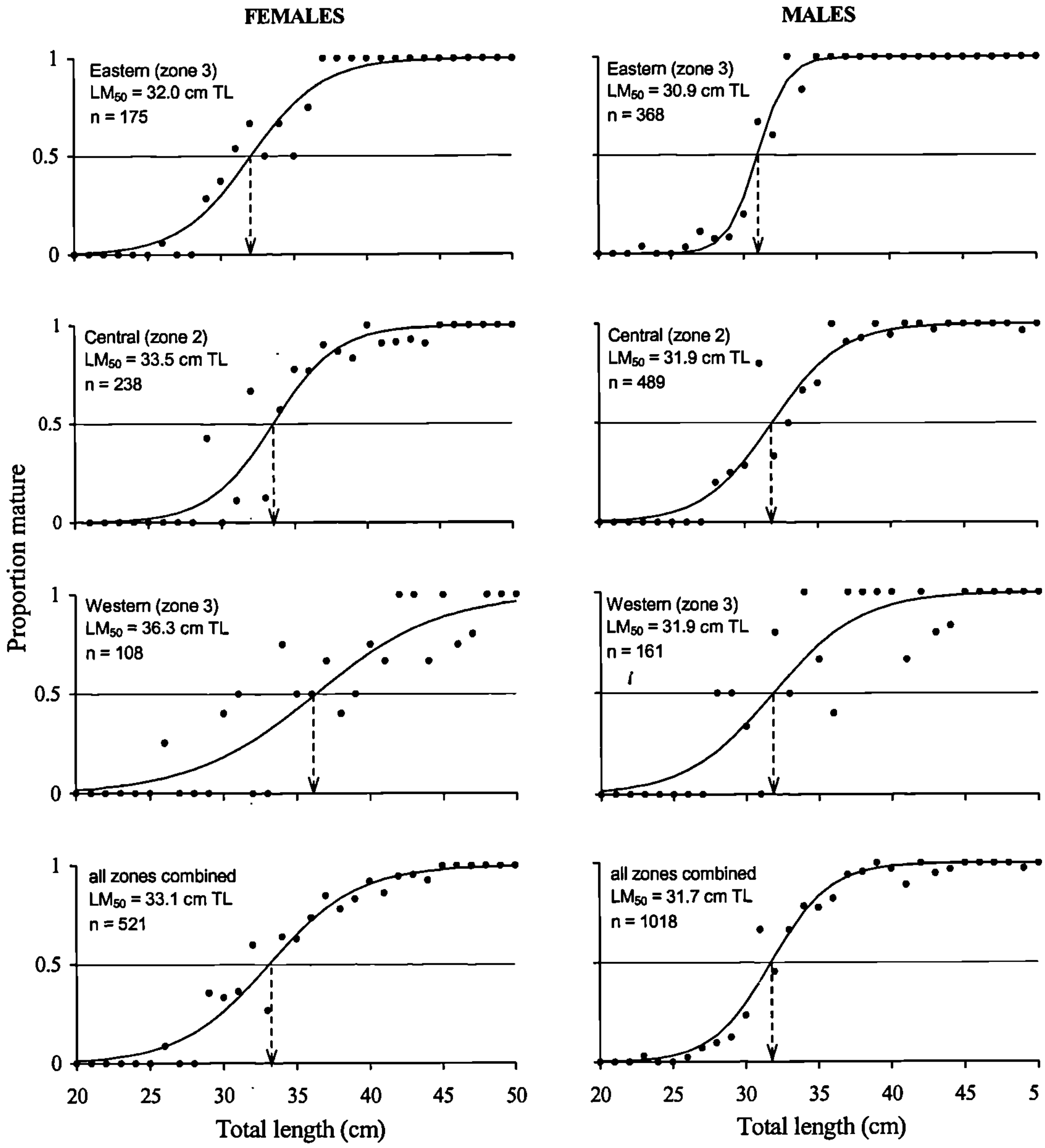


Figure 4.29 Proportions of mature female and male Nile tilapia in the Ugandan part of Lake Victoria. SOLVER smooth curves are fitted to the data points (Source: LVFRP trawl survey data 1997 to 2000).

4.6 Size of Nile perch and Nile tilapia caught by different fishing gears and methods

Fishers targeting Nile perch used four major fishing gears/methods, which selected for different sizes of fish (Fig 4.30). Beach seines caught the smallest Nile perch with the mode at 22 cm TL. Catches from gillnets operated passively had the mode at 34 cm TL and those operated as drift nets at 53 cm TL. Hooks on long lines or hand lines were not selective, they caught a wide range of Nile perch sizes between 20 and 120 cm TL with the mode at 42 cm TL.

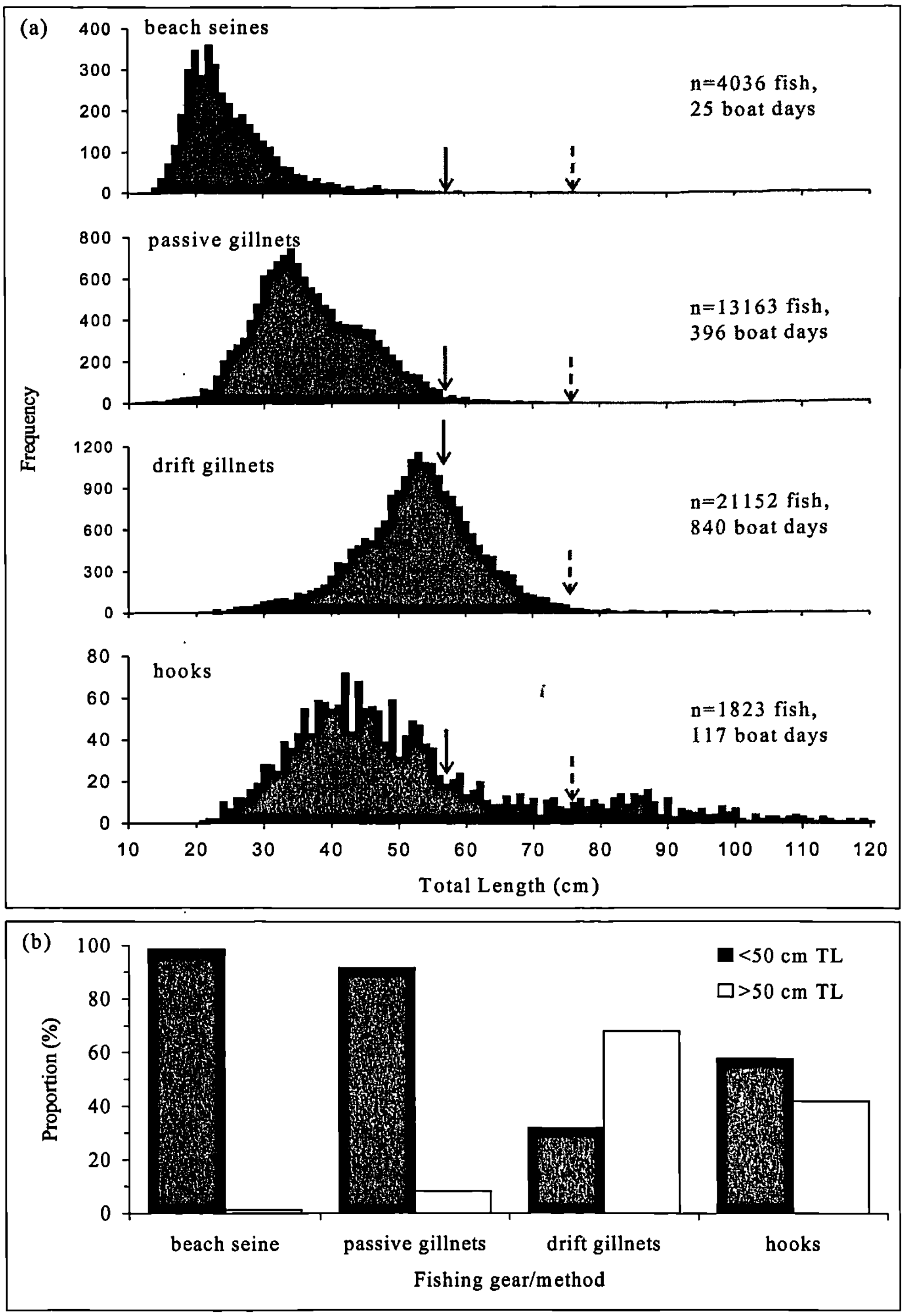


Figure 4.30 (a) Length frequency of Nile perch caught in the four fishing gears/methods that target Nile perch in the Ugandan part of Lake Victoria. The arrows indicate LM_{50}: males (solid line) and females (broken line). The grey area represents the sizes of Nile perch larger than 50 cm TL, the minimum size recommended for the onset of harvest (b) The percentage by number of Nile perch caught in each fishing gear/method relative to the recommended size at first capture of 50 cm TL.

Overall, Nile perch smaller than the recommended lower limit of capture of 50 cm TL, constituted 98.6 and 91.7% of the catches of beach seines and passively set gillnets respectively. Drift gillnets showed the best selection of Nile perch, with 68.1% of the fish caught larger than the recommended lower limit and only 31.9% below it. Nile perch larger than the LM_{50} of females, i.e. 75.6 cm TL, contributed only 1.5% of the catches of drift gillnets. In contrast, the Nile perch catches of hooks spread over a wide range of sizes, with 57.8% below 50 cm TL and 14.3% larger than 75.6 cm TL. Thus amongst the fishing gears/methods used to target Nile perch in Lake Victoria, it is the fishery with hooks that catches considerable quantities of breeding females, probably with potential consequences of reducing spawners to low numbers that could be inadequate for sustaining the Nile perch stocks.

Fishers targeting Nile tilapia used four major gears/methods that also selected for different sizes of fish (Fig. 4.31). Nile tilapia catches of basket traps and active gillnets were dominated by small fish, compared with passive gillnets and cast nets. Cast nets were basically non-selective, catching all sizes in the areas over which they were cast. Over 80% of the Nile tilapia catches from basket traps and actively operated gillnets were smaller than both the LM_{50} and the size 30 cm TL recommended for the onset of harvest of the species. In contrast, less than 50% of Nile tilapia catches of passively set gillnets and cast nets, i.e. 48.6 and 38.0% respectively, were <30cm TL.

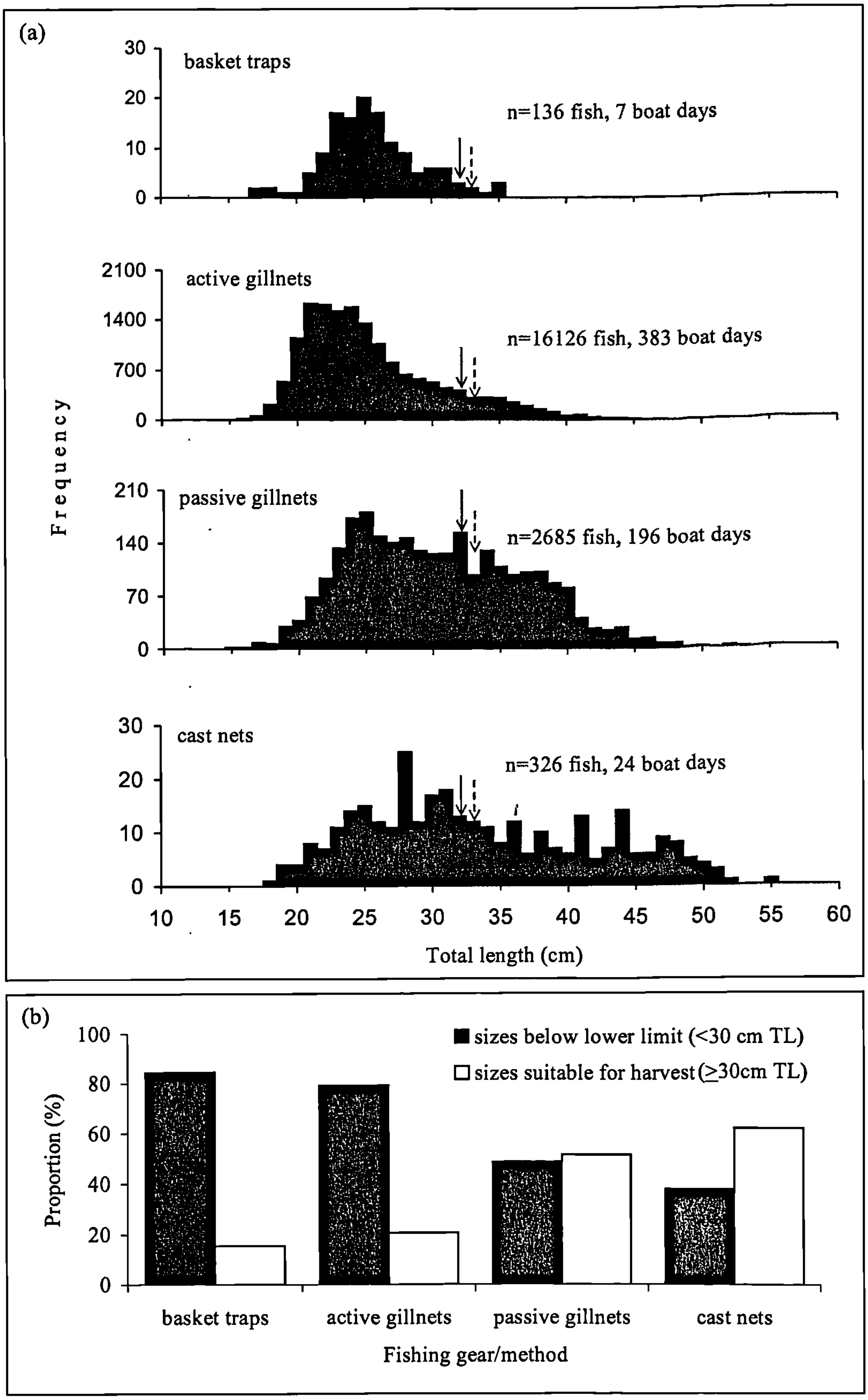


Figure 4.31 (a) Length frequency of Nile tilapia caught in the four major fishing gears/methods that target Nile tilapia in the Ugandan part of Lake Victoria. The arrows indicate LM_{50}: males (solid line) and females (broken line). The grey area represents the size of Nile tilapia recommended for harvest. (b) The percentage by number of Nile tilapia caught in each fishing gear/method relative to the recommended size at first capture of 30 cm TL.

4.7 The *R. argentea* fishery

Unlike the large fishes of Lake Victoria, i.e. Nile perch, Nile tilapia and other species, which are harvested by the fishing gears and methods considered above, the fishery of *R. argentea*, a small pelagic cyprinid, is unique in that it is based on the attraction of the fish by an artificial light source (kerosene pressure lamps in Lake Victoria). Nets of small meshes (mosquito nets), which can be operated as beach seines, boat seines, lift nets or scoop nets are used in this fishery. The predominant nets used in the Ugandan part of the lake are those operated as boat seines. At all the beaches where the *R. argentea* fishery was sampled, they used mosquito seine nets of 5 mm mesh size, operated as boat seines.

4.7.1 *Catch rates of* R. argentea

Boats using mosquito nets targeting *R. argentea* that were sampled in the eastern and central zones were all paddled Sesse boats whereas motorised Sesse boats, in addition to paddled Sesse boats, were sampled in the western zone (Fig. 4.32). In the eastern zone, differences in catch rates of *R. argentea* were highly significant between quarters (*ANOVA*: $F_{6,\ 104}$ = 4.01, $P<0.01$) (Appendix 4.18). They showed one major peak in catch rate of 340.7 ± 109.7 kg boat^{-1} day^{-1} in July 2000 and the lowest catch rates in March 2000, 133.1 ± 49.1 kg boat^{-1} day^{-1} and October 2000, 113.8 ± 94.9 kg boat^{-1} day^{-1}. Throughout the sampling period the overall mean catch rate was 229.5 ± 30.4 kg boat^{-1} day^{-1}.

In the central zone, catch rates of *R. argentea* decreased gradually throughout the sampling period from 261.4 ± 147.1 kg boat^{-1} day^{-1} in September 1999 to 184.4 ± 113.0 kg boat^{-1} day^{-1} in May 2001 without showing any peak. The average catch rate was 216.1 ± 42.4 kg boat^{-1} day^{-1}. Differences in catch rates between quarters were not statistically significant (*ANOVA*: $F_{6,44}$ = 0.48, $P > 0.05$) (Appendix 4.19).

In the western zone, where both paddled and motorised boats were encountered, the overall catch rate of motorised boats (488.5 ± 78.5 kg boat^{-1} day^{-1}) was almost twice as high as that of paddled boats, 214.8 ± 25.9 kg boat^{-1} day^{-1}. Catch rates of motorised boats showed two weak peaks in June 2000 and March 2001 and were lowest in December 2000, but these changes in catch rates between quarters were not statistically significant (*ANOVA*: $F_{5,66}$ = 1.381, $P > 0.05$) (Appendix 4.20).

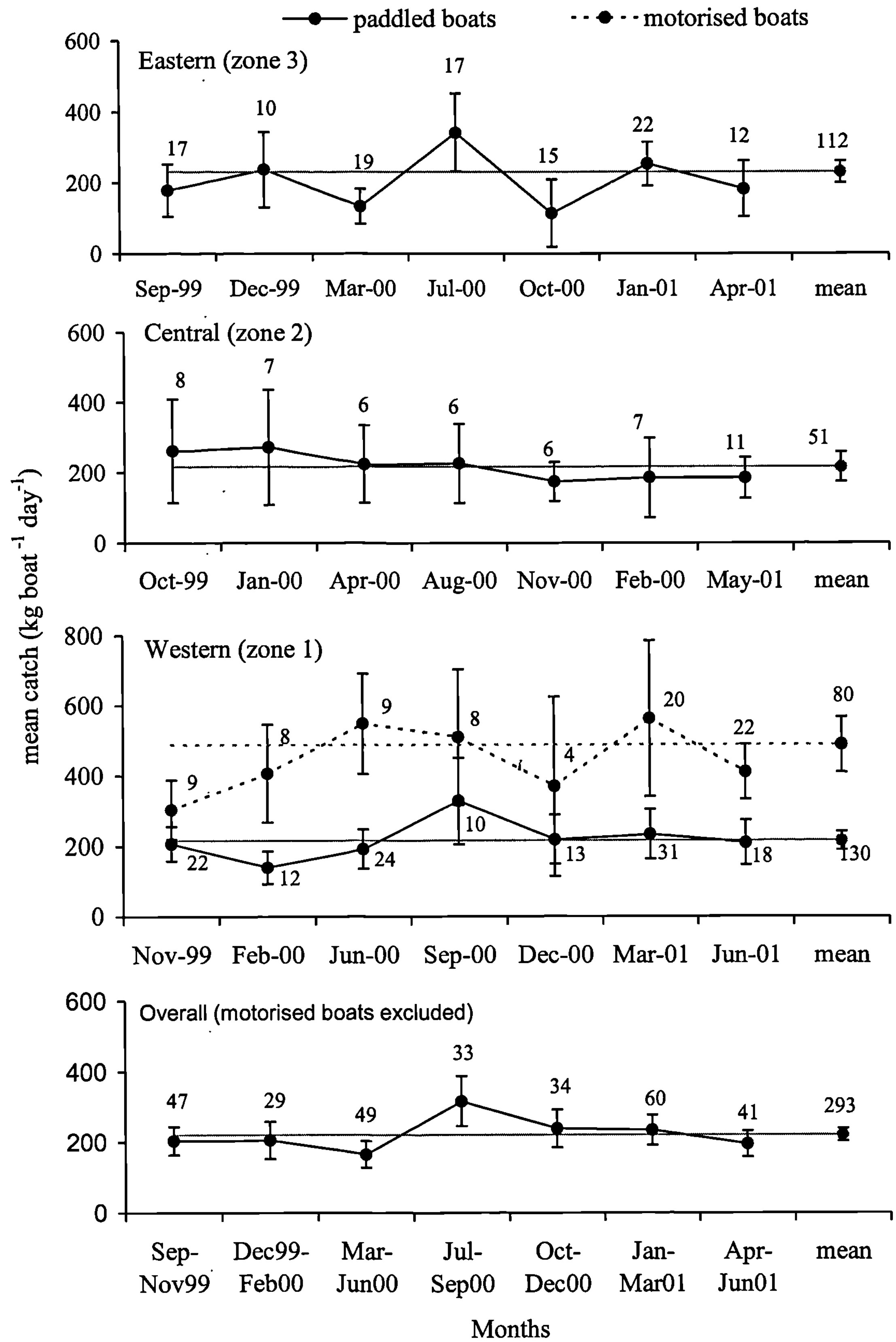


Figure 4.32 Mean catch rates of boats fishing for *Rastrineobola argentea* using mosquito seines in the Uganda part of Lake Victoria. Numbers indicate the number of boats sampled, Error bars = 95%CL and the grey lines indicate the overall mean weight.

Similarly, differences in catch rates of paddled boats between quarters were not statistically different (*ANOVA*: $F_{6,\ 123} = 1.72$, $P > 0.05$) (Appendix 4.21), although they showed a relatively strong peak in September 2000.

Lake wide, overall catch rates of *R. argentea* amongst paddled boats which were encountered in all parts of the lake were lowest, well below the overall mean of 220.58 $\pm$ 17.8 kg boat^{-1} day^{-1}, between September 1999 and June 2000 and April - June 2001. A single peak of 316.0 $\pm$ 70.0 kg boat^{-1} day^{-1} occurred in the period July to September 2000. Univariate two-way ANOVA (Appendix 4.22) showed that *R. argentea* catch rates in paddled boats, were not statistically different between the three zones ($F_{2,292}$ = 0.09, P=0.05); and between the seven sampling periods ($F_{6,292}$ = 1.84, P = 0.05). The interaction between zones and quarters also showed that quarterly catch trends were not statistically different in the three zones ($F_{12,\ 292}$ = 1.49, P=0.05). Although the above test showed no significant differences between the mean quarterly catch rates, the Gabriel's multiple comparisons post hoc tests revealed that the mean catch rates in July to September 2000 were significantly higher than those in September to November 1999, March to June 2000 and January to March 2001. This suggested peak catch rates of *R. argentea* in the period July to September.

4.7.2 *Spatial distribution of size at first maturity of* **R. argentea**

The length at first maturity of *R. argentea* (LM_{50}), when 50% of individuals were mature, varied within zones in inshore and offshore stations and between zones (Fig. 4.33). Females matured at the biggest size in the eastern zone and the smallest size in the western zone. The size at first maturity amongst females decreased from inshore to offshore waters in the eastern and western zones but increased slightly in the central zone. In the eastern zone catches at Lingira landing, obtained from well sheltered bays north of Buvuma islands showed the highest LM_{50} in females of 43.5 mm SL. Catches at Lukale landing where fishing was mainly in sheltered bays in the east of Buvuma islands showed a slightly lower LM_{50} in females of 43.2 mm SL. The LM_{50} decreased to 40.4 mm SL at Kiko landing where fishing was mainly in the deep offshore open waters off Bugaya islands. There was substantial decrease of LM_{50} in females in the western part of the lake from 38.8 mm SL at Lambu landing on the mainland to 33.8 mm SL at Buda landing located south of Sesse islands where fishing was in offshore open waters.

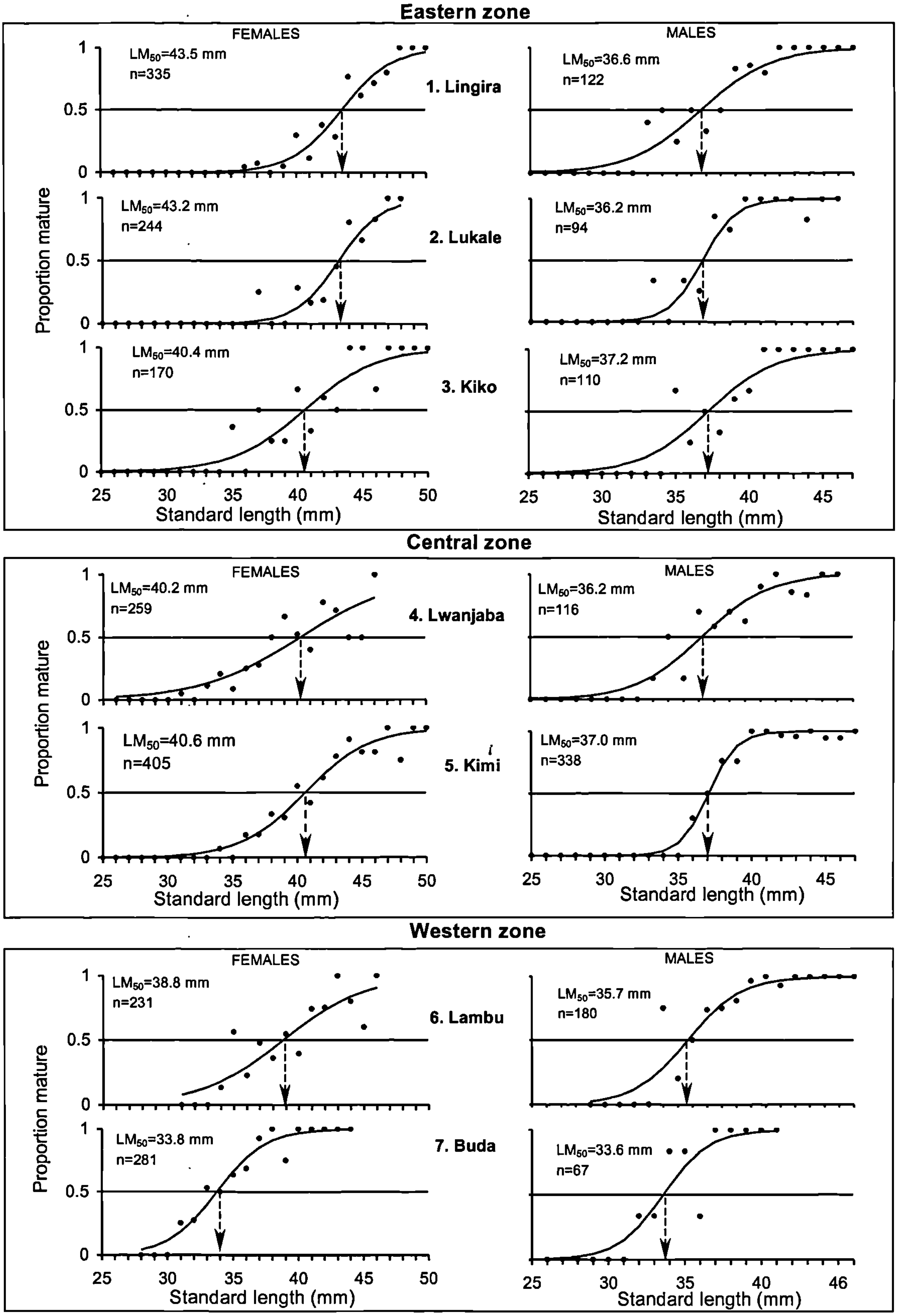


Figure 4.33 Proportion of mature *Rastrineobola argentea* at fish landing sites numbered 1-7 in the eastern, central and western zones of the Ugandan part of Lake Victoria (SOLVER smooth curves fitted to the data points).

The size at first maturity of males varied between 36.2 and 37.2 mm SL in the eastern and central zones showing a slight increase in offshore open waters. However, as in the case of females, the LM_{50} of males was lower in the western zone at 35.7 mm SL in fish landed at Lambu landing site on the mainland, and decreased to 33.6 mm SL in fish landed at Buda landing site from where catches were from offshore open waters. When data from the seven sampled beaches were pooled the lake wide size at first maturity for the Ugandan waters was 41.1 mm SL for females and 36.2 mm SL for males (Fig 4.34).

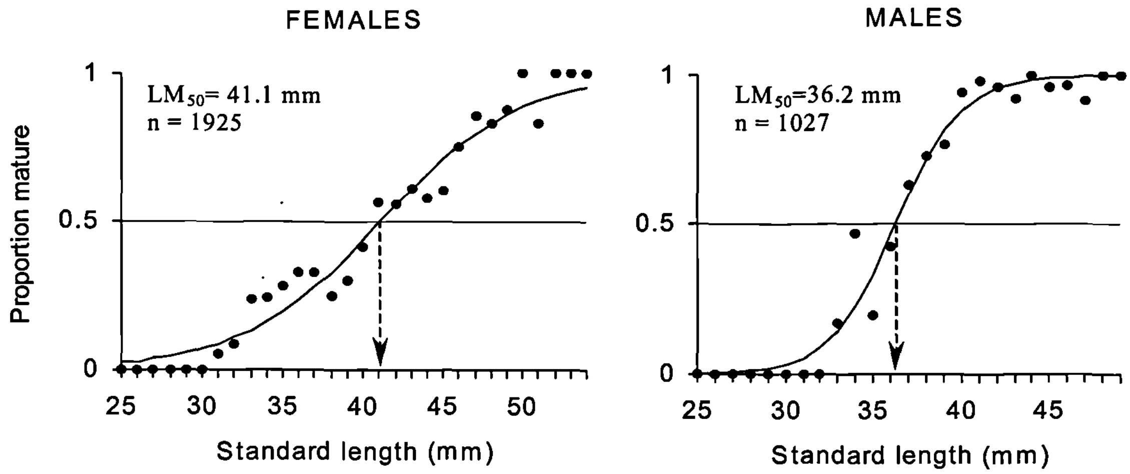


Figure 4.34 Lake wide size at first maturity of *Rastrineobola argentea* in the Ugandan part of Lake Victoria.

4.7.3 *Spatial distribution of sex ratio in* **R. argentea** *populations*

In all the samples of *R. argentea* from seven landing sites that were analysed for the stage of sexual maturity, females out numbered males (Table 4.6). The Chi-square test showed the sex ratio, females: males, was significantly different from 1:1 (x^2_6=188, *P*>0.05). Of the 2952 specimens that were examined lake wide, 1925 specimens were females and 1027 males, an overall sex ratio of approximately two females to one male.

Table 4.6 Sex ratio in *R. argentea* populations of the Ugandan part of Lake Victoria

Landing site	Females	Males	Female:males
Ligira	335	122	2.7:1
Lukale	244	94	2.6:1
Kiko	170	110	1.5:1
Lwanjaba	259	116	2.2:1
Kimi	405	338	1.2:1
Lambu	231	180	1.3:1
Buda	281	67	4.2:1
All landings	1925	1027	1.9:1

4.7.4 *Spatial changes in size composition of* R. argentea *in the catches*

All fishers of *R. argentea* encountered in the survey used mosquito seines of the same mesh size (5 mm) but the size of fish caught increased from inshore to offshore waters suggesting high abundance of young fish inshore (Fig. 4.35).

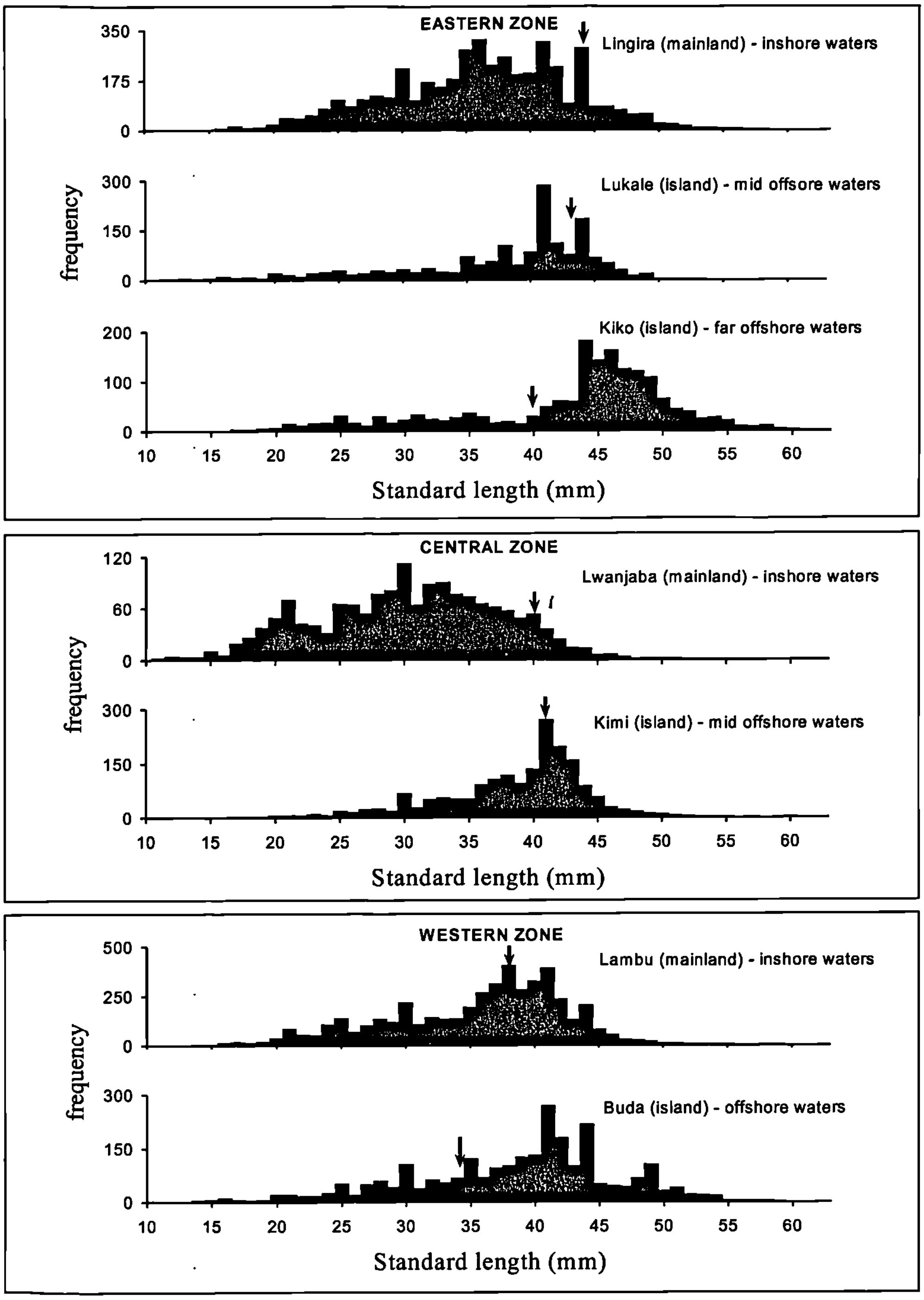


Figure 4.35 Length frequency of *Rastrineobola argentea* caught in inshore and off shore waters using mosquito seines of the same meshes (i.e. 5 mm) in the Ugandan part of Lake Victoria. The arrows indicate the size at which 50% of females are mature in different parts of the lake.

Since females attain sexual maturity at a larger size than males and their abundance is more critical than that of males in maintaining the *R. argentea* population through egg production, the LM_{50} of females in the different parts of the lake can represent the size below which the catch could be considered immature and unsuitable for harvest. The highest amount of immature fish was landed at Lingira and Lwanjaba in the eastern and central zones respectively, representing over 90% of the total catch. Fishing boats at these two landing sites operated exclusively in shallow inshore waters of sheltered bays. At Lambu landing, located on the mainland in the western zone, where fishers operated in both shallow inshore and open waters, immature fish in the catch constituted 67.5% of the total catch. The catch composition at Lambu was thus comparable with that at Lukale and Kimi in the eastern zone and central zones where immature fish contributed 77.5 and 67.0% of the catch, respectively. The two landings where fishers operated in deep offshore waters, Kiko in the eastern zone and Buda in the western zone, immature fish constituted only 26% of the total catch.

4.7.5 ***Temporal changes in size composition of*** **R. argentea** ***catches***

At the landings where fishers operated in waters close to the mainland, catches of *R. argentea,* in the first quarter of the year, January to March contained the lowest proportion of fish (53.3%) smaller than the lake wide size at first maturity of females of 41 mm SL. This proportion rose to 81.2% in the second quarter (April to June) and down to 78.3 and 75.2% in the third and fourth quarters respectively (Fig. 4.36). Fish smaller than 41 mm SL were most abundant in the catches of boats operating from the islands, further away from the mainland in the first quarter, January to March and the third quarter July to September, contributing 46.1 and 54.7% of the total catches respectively.

The abundance of small fish in the catches was more or less out of phase between inshore and offshore, especially in the first half of the year, suggesting that recruitment starts earlier in the open waters than in the sheltered bays, although this may be a result of sample size effect. The smallest size classes of *R. argentea* ($\leq$30 mm SL) were somewhat simultaneously abundant in both inshore and offshore samples in July - September, suggesting peak recruitment of young fish into the fishery around this time of the year. Abundance of the smallest size classes of *R. argentea* remained high in the inshore catches in October - December but was lesser in offshore waters, suggesting prolonged recruitment inshore.

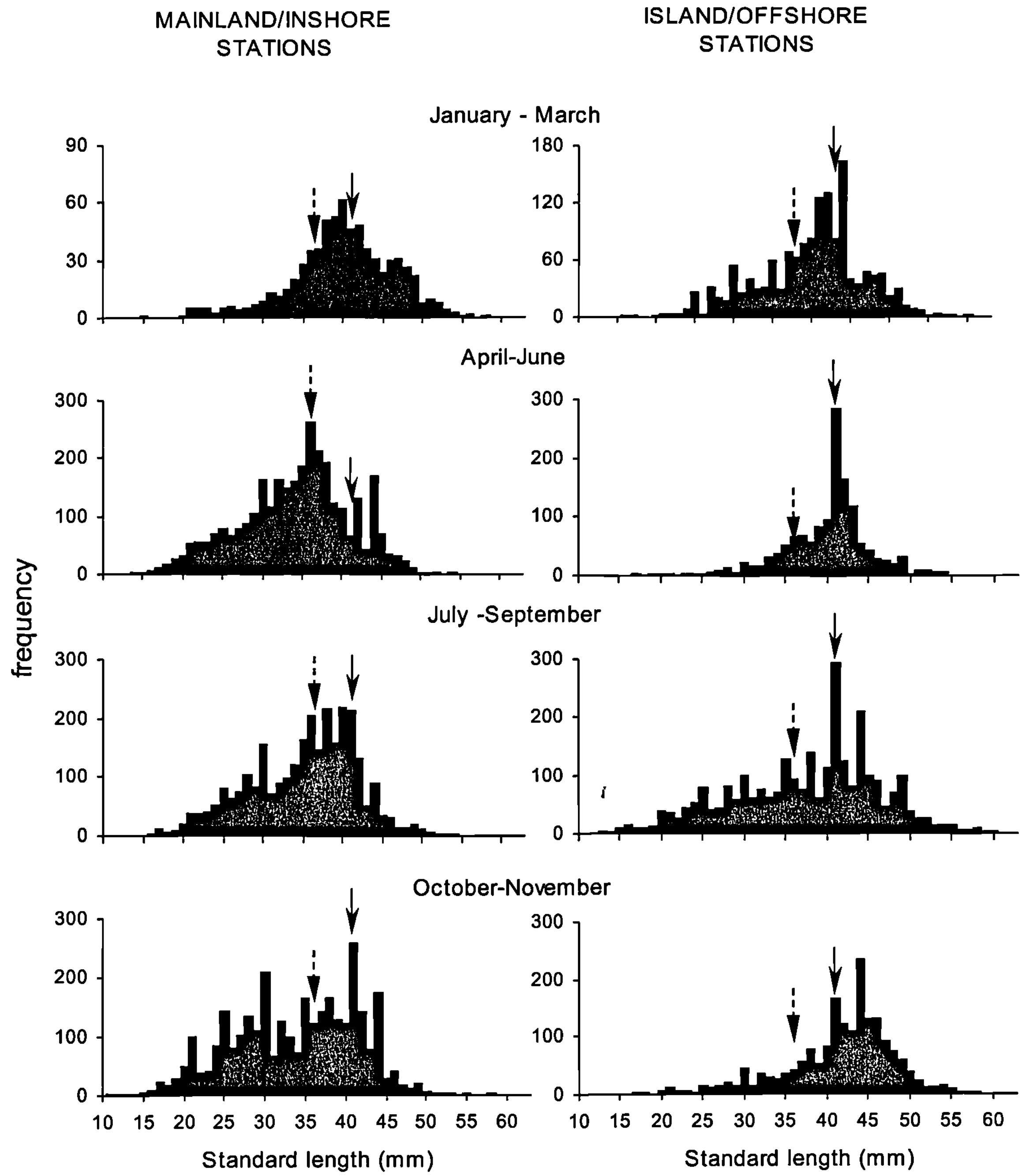


Figure 4.36 Quarterly size composition of *Rastrineobola argentea* catches in inshore and offshore waters of the Ugandan part of Lake Victoria in 2000. Arrows indicate the lake wide size at first maturity of males (broken arrows) and females (solid arrows).

4.8 Estimates of total fish catches

Total fish catches were estimated by zones on a quarterly basis using the fish catch rates of individual fishing boats estimated by this study as input data, and the fraction of boats fishing daily; the number of days in a quarter; and the total number of boats recorded in the 2000 Frame Survey, as the raising factors.

4.8.1 *Quarterly estimates of total catches of gillnetting boats*

Nile tilapia

The largest quarterly total catches of Nile tilapia were attributed to catches of parachute and dugout boats, the main crafts used in this fishery. They ranged between the highest, 6346.2 t, in the last quarter of 1999 and the lowest, 3176.1 t, in the second quarter of 2001 (Fig. 4.37)

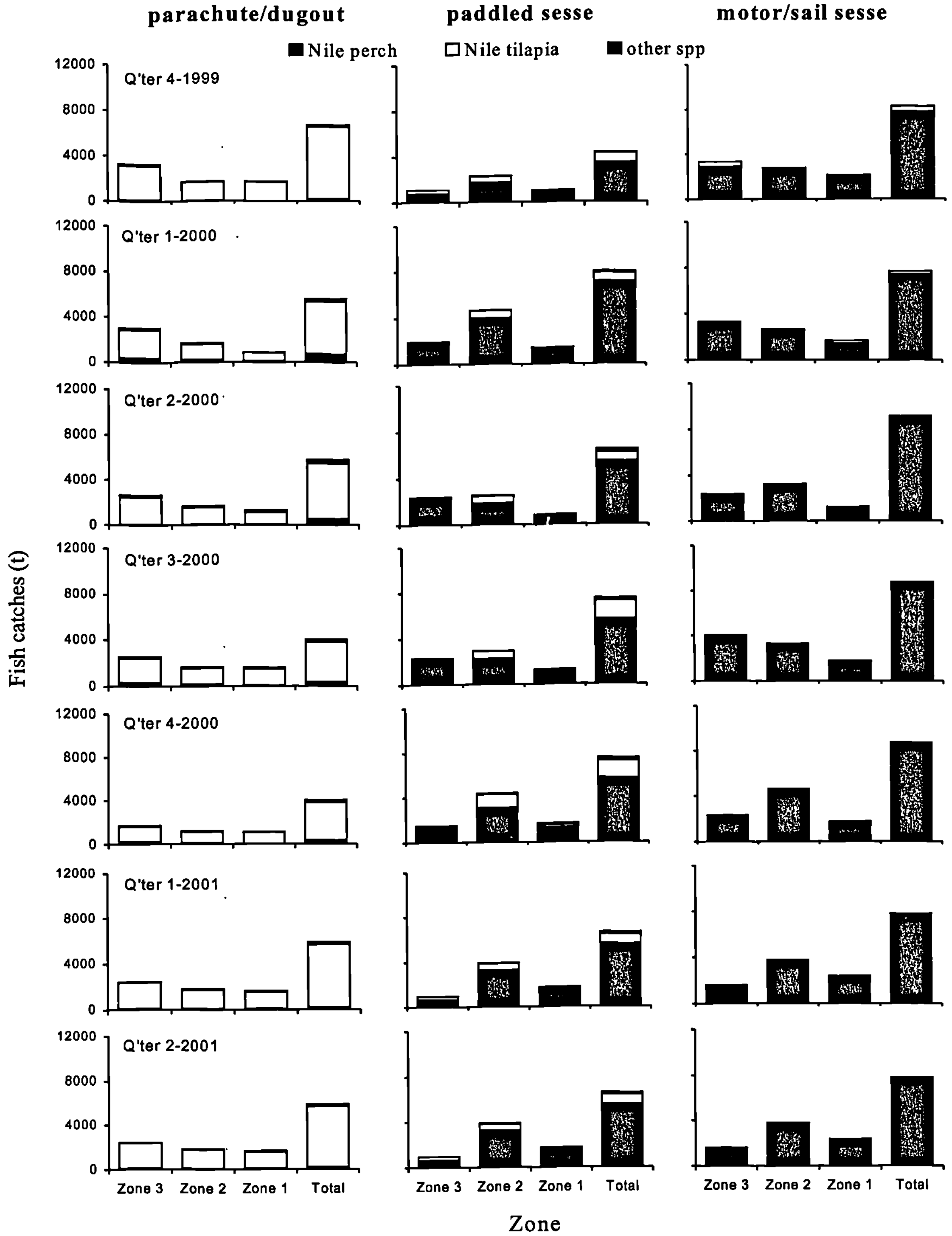


Figure 4.37 Estimated quarterly fish catches of gillnetting fishing boats in the Ugandan part of Lake Victoria by zones, September 1999 to June 200.

In the three zones, the highest catches of Nile tilapia for parachute/dugout boats were allotted to the eastern part of the lake (zone 3), followed by the central part (zone 2) and least in the western part (zone 1), throughout the sampling period. The estimated quarterly total catches of Nile tilapia amongst paddled Sesse boats were highest in the central part (zone 2) ranging from 473.4 to 1209.0 t per quarter compared with 0.0 to 225.6 t in the western part (zonel) and 89.6 to 382.1 t in the eastern part (zone 3). The least catches of Nile tilapia were expected from motorised boats in all zones.

Nile perch

The lowest quarterly total catches of Nile perch were from parachute and dugout boats, ranging between 118.3 t, in the second quarter of 2000 and 732.7 t in the first quarter of 2000. Amongst paddled Sesse boats, the quarterly catches of Nile perch lay between 3486.5 t in the last quarter of 1999 and 7152.0 in the first quarter of 2000. Nile perch catch of these boats in the central part (zone 2) were higher than in other parts of the lake, except in the second quarter of 2000 when the eastern part slightly exceeded it by 330.6 t. Nile perch catches estimated for paddled Sesse boats in the western zone were generally the lowest. Estimates of Nile perch catches were highest for motorised and sailed boats ranging from 5712.4 t, in the second quarter of 2001 to 9118.3 t, in the third quarter of 2000. The highest catches for Nile perch among these boats alternated between the central and eastern parts of the lake while the western part exhibited the lowest total catches

Other species

Fish species, other than Nile perch and Nile tilapia, that were landed by gillnetting boats included nine fish taxa, i.e. haplochromines, *Synodontis* sp. *Bagrus* sp. *Clarias* sp. *Tilapia rendalli*, *Mormyrus* sp., *Oreochromis leucostictus*, *Protopterus* sp. and *Tilapia zillii.* The estimated contribution of these fish taxa to total catches of parachute boats was between 162.3 t in the last quarter of 1999 and 492.1 t in the second quarter of 2000. Their estimated contributions to total catches were much less in the paddled Sesse boats, i.e. between 71.4 t and 260.5t; and least in motorised/sailed boats, between 11.5 and 36.8 t. The four most common taxa included: *Tilapia zillii* contributing between 59.3 and 249.7 t; *Protopterus aethiopicus* 32.0 to 130.1 t; *Oreochromis leucostictus* 5.0 to 157.6 t and *Mormyrus kannume* 2.8 to 170.8 t, per quarter (Fig. 4.38).

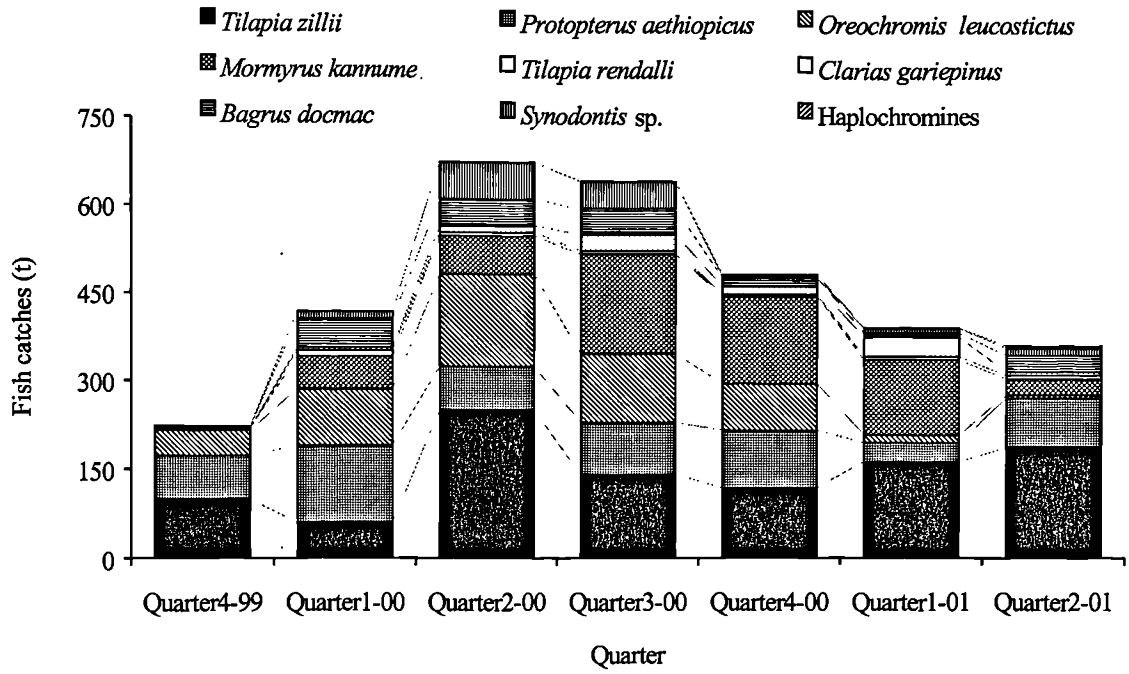


Figure 4.38 Estimated quarterly total catches of gillnetting fishing boats, excluding Nile perch and Nile tilapia, in the Ugandan part of Lake Victoria, September 1999 to June 2001.

4.8.2 *Quarterly total catches of all fishing gears excluding mosquito seines*

Nile tilapia

Three main fishing gears, gillnets, cast nets and traps are used in the Nile tilapia fishery. The estimated contribution of traps to total Nile tilapia catches increased from 51.3 t in the western zone to 107.6 t in the central zone and was highest, 135.4 t, in the eastern zone (Fig 4.39). Similarly cast net quarterly catches were lowest, between 70.7 and 188.2 t, in western zone, increasing to between 197.2 and 534.4 t in the central zone and 383.0 to 1019.5 t, in the eastern zone. Overall, estimated quarterly total catches of Nile tilapia were highest, 9266.5 t, in the last quarter of 1999 and lowest, 5116.1 t, in the second quarter of 2001.

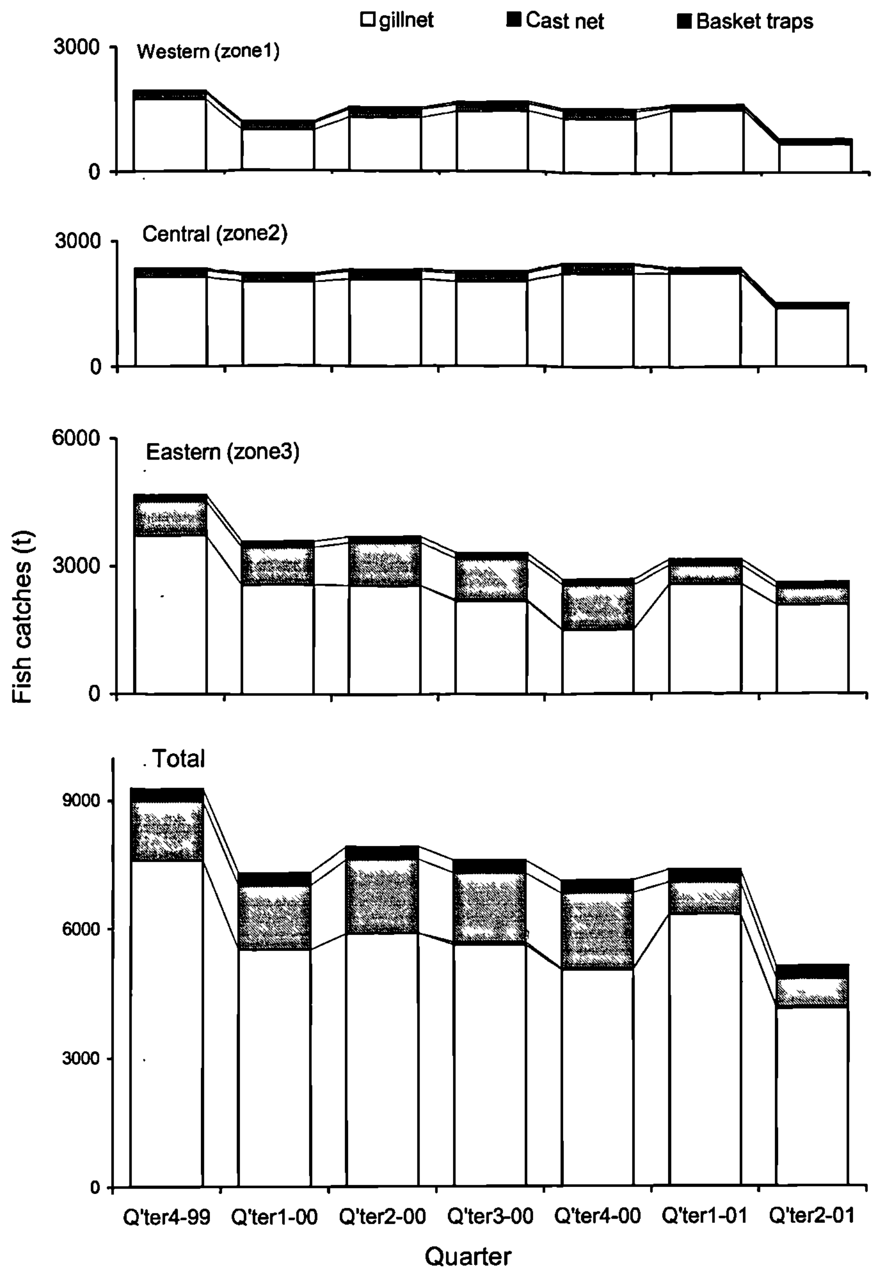


Figure 4.39 Estimated quarterly total catches of Nile tilapia of all the major fishing gears by zones in the Uganda sector of Lake Victoria for the period September 1999 to June 2000.

Nile perch

The estimated contributions of long lines, hand lines and beach seines to total catches of Nile perch were of least importance in the western zone, increasing in the central zone and highest in eastern zone (Fig 4.40). The estimated quarterly catches of long lines ranged from 67.8 to 165.6 t in the western zone, 223.3 to 435.4 t in the central zone and 708.7 7 to 1790.5 t in the eastern zone. Similarly estimated quarterly Nile perch catches of hand lines increased from 23.5 to 94.3 t in the western zone, to between 90.1 and 362.1 in the central zone and were highest in the eastern zone, between 194.9 and

783.5 t. Beach seine quarterly catch estimates ranged from 92.3 to 221.5 t in the western zone, 292.2 to 701.6 t in the central zone and were also highest in the eastern zone, between 735.3 and 1765.8 t. Overall quarterly catch estimates of Nile perch were highest, 19 222.7 t, in the third quarter of 2000 and lowest, 15 286.7 t in the last quarter of 1999.

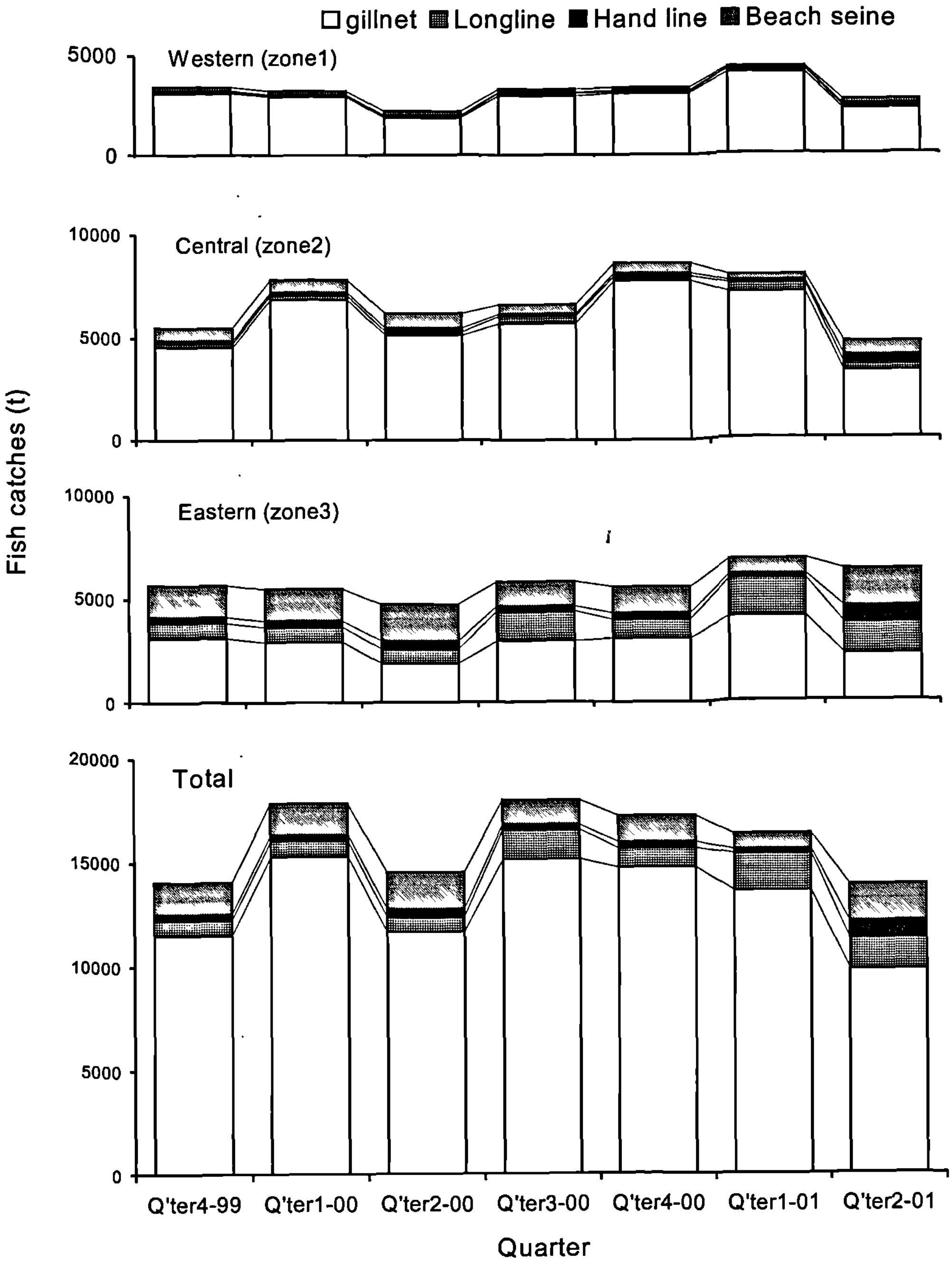


Figure 4.40 Estimated quarterly total catches of Nile perch of all the major fishing gears by zones in the Ugandan part of Lake Victoria, September 1999 to June 2000.

4.8.3 *Quarterly total catches of* R. argentea *by mosquito seines.*

Among the three zones, the highest catches of *R. argentea* were anticipated in the eastern zone where the estimated quarterly catches ranged from 5044.1 t in the fourth quarter of 2000 to 12136.7 t in the third quarter of 2000 (Fig. 4.41). The catch estimates were higher in the central zone than in the western zone from the last quarter of 1999 to the second quarter of 2000, but thereafter the western zone surpassed the central zone. Overall, *R. argentea* catches were highest, 23 768.9 t, in the third quarter of 2000 and the lowest, 13,623.6 t, in the second quarter of 2000.

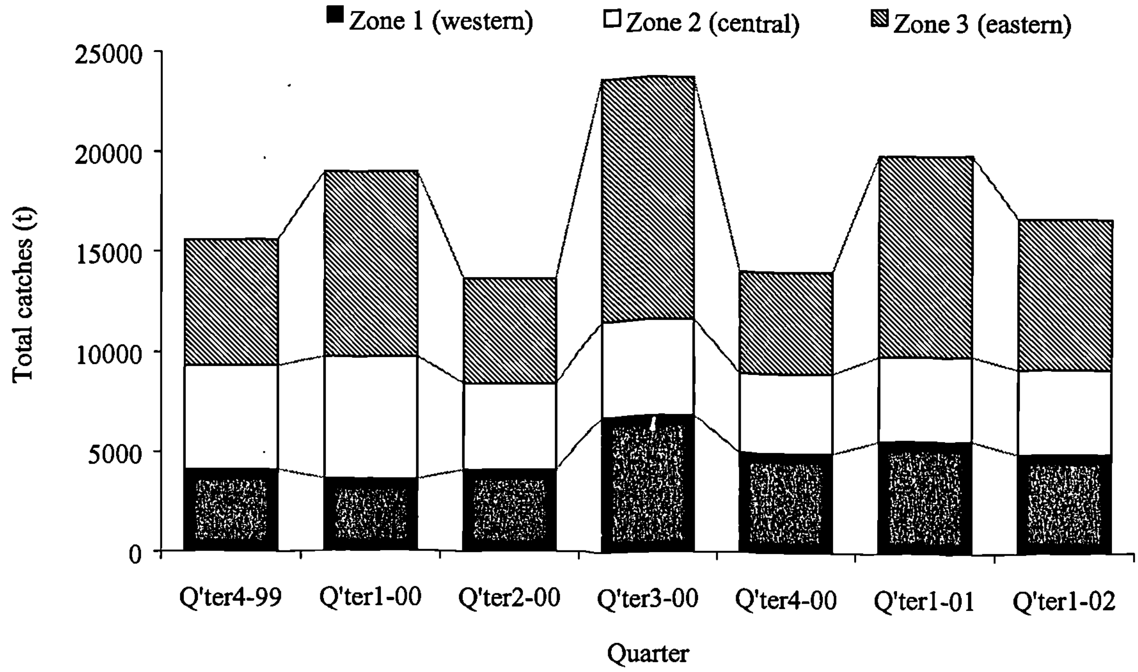


Figure 4.41 Estimated total fish catches of *Rastrineobola argentea* in the Ugandan part of Lake Victoria, September 1999 to June 2001.

4.8.4 *Estimated total quarterly fish catches*

The highest fish catches, 51,325.5 t comprising 19,222.7 t of Nile perch, 23,768.9 t of *R. argentea*, 7600.3 t of Nile tilapia and 733.5 t of other fish species, were estimated for the third quarter of the year 2000 (Fig. 4.42). The second quarters of 2000 and 2001 had the lowest estimated total fish catches, 38,247.2 and 37,964.8 t, comprising 15,925.5 and 15,741.4 t of Nile perch, 13,623.6 and 16,641.4 t of *R. argentea*, 7928.6 and 5116.1 t of Nile tilapia; and 769.5 and 466.0 t of other species, respectively.

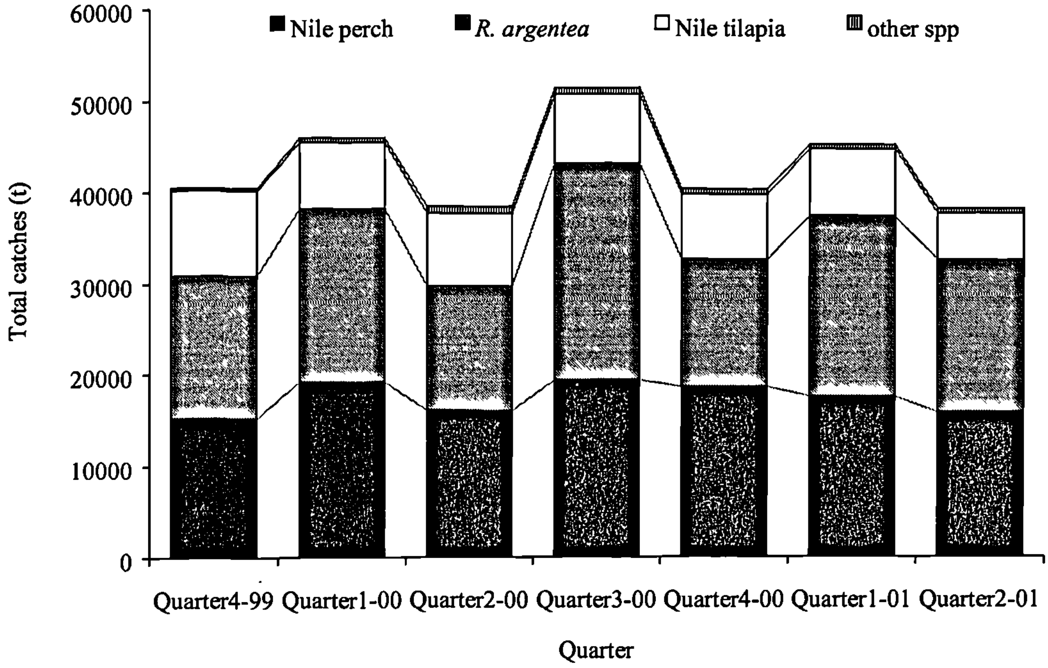


Figure 4.42 Estimated quarterly total fish catches, by major fish species, in the Ugandan part of Lake Victoria, September 1999 to June 2000.

4.8.5 *Estimated total annual catches for the year 2000*

Annual estimate of total fish catches for the year 2000 indicated that Nile perch contributed 72,632.2 t (41.4%) (Table 4.7), closely followed by *R. argentea,* 70,333.5 t, contributing 40.1% of the total catches. Nile tilapia contributed 29,959.4 t (17.1%) and all other fish species 2509.7 t (1.4%). The total fish yield of the Uganda part of Lake Victoria was estimated at 175,434.7 t for the year 2000.

The estimates indicate that the gillnet catches dominated in the Nile perch fishery contributing 78% of the total annual catch of which 42% was from catches of motorised/sailed boats and 32% from paddled boats. The other important gears were beach seines and long lines, which contributed 12% and 7% of the total catches respectively. Gillnet were also the dominant fishing gear in the Nile tilapia fishery, estimated to have contributed 73% of the annual total catches, of which 59% were from catches by parachute boats and 13% from those by paddled Sesse boats. Among other gears targeting Nile tilapia, cast nets were the most important, their catches contributing 22% of the total annual Nile tilapia catches

Table 4.7 Estimated annual fish catches (t) in the Uganda part of Lake Victoria in 2000

Fish species	Gillnetting boats			Other gears						
	Parachute or dugout	Paddled Sesse	Motorised or sailed Sesse	Long line	Hand line	Beach seine	Cast net	Traps	Total	%ge
L. niloticus	1734.4	23063.6	32054.0	5050.8	1944.	8712.1	44.7	27.9	72632.2	41.4
O. niloticus	17813.9	3916.4	342.9	0	0	92.9	6616.2	1177.0	29959.4	17.1
T. zillii	468.4	100.4	0	0	0	12.6	36.0	4.4	621.9	0.4
P. aethiopicus	362.1	27.9	0	0	0	0	0	79.3	469.4	0.3
O. leucostictus	449.3	0	0	0	0	11.1	0	110.2	570.7	0.3
M. kannume	16.5	422.7	3.9	0	0	0	0	0	443.1	0.3
T. rendalli	24.9	0.7	0	0	0	0	9.8	0	35.4	0.0
C. gariepinus	44.1	0	13.5	0	0	11.1	0	0	68.6	0.0
B. docmak	0	125.6	26.7	0	0	0	0	0	152.3	0.1
Synodontis sp	0	122.6	1.6	0	0	3.2	0	0	127.4	0.1
Haplochromines	3.0	1.4	0	0	0	0	0	0	4.4	0.0
Other species	8.4	5.8	2.4	0	0	0	0	0	16.6	0.0
Sub - total									**105101.3**	59.9
*R. argentea**									70333.5	40.1
Overall Total									**175434.7**	100.0

* *R. argentea* yield estimated from catches of mosquito seines

4.9 Discussion

4.9.1 *Factors influencing fishing effort in the Nile perch and Nile tilapia fisheries of Lake Victoria*

The grouping of fishing units with similar fishing characteristics provided an insight into the patterns of fishing effort in the artisanal fisheries of Lake Victoria that could be very instrumental in formulating workable management strategies for the lake's fisheries. This is more explicit in the gillnet fisheries, which are the predominant fisheries targeting two of the three major commercial fish species in the lake, Nile perch and Nile tilapia. This study provided evidence of specialisation of different categories of fishing boats to particular fish species and/or fish size composition (Fig. 4.43). The most important components of fishing effort in the gillnet fishery can be defined along three broad categories of fishing boats: (1) parachute (flat-bottom planked) boats and dugout boats; (2) paddled Sesse boats and (3) motorised/sailed Sesse boats. Each of the three categories of boats exhibits unique fishing strategies that must be considered when designing management options. In addition to the boats, the rigging and mode of operation of gillnets vary with depth and the fish species being targeted, probably to suit the habits, movements and reaction to stimuli which vary with species and age of the fish, as suggested by Welcomme (2001).

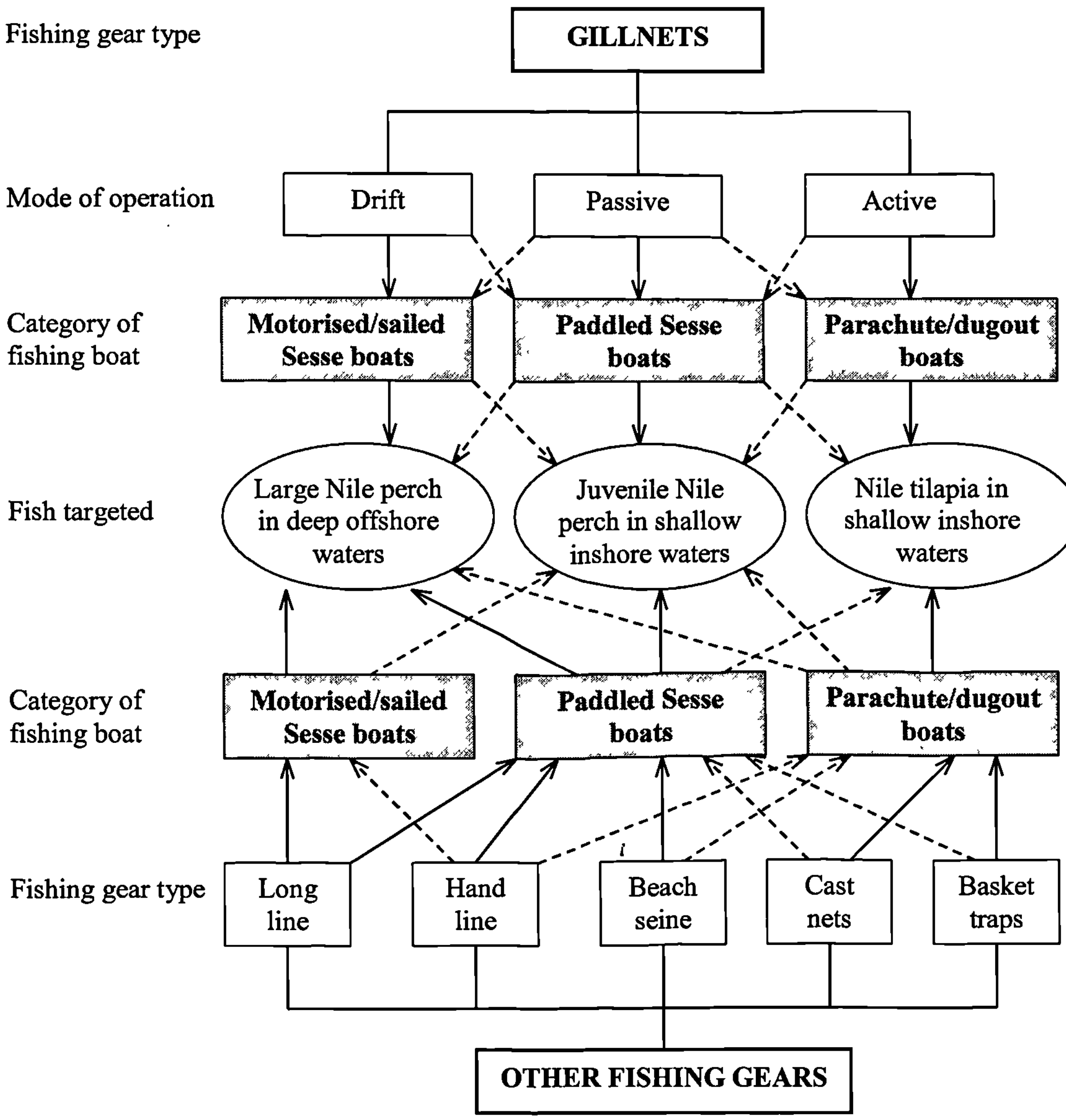


Figure 4.43 Flow chart showing a summary of the fishery characteristics of the Nile perch and Nile tilapia fisheries of Lake Victoria. The solid arrows are the dominant links and the broken arrows the rare ones.

The Nile tilapia fishery

Parachute and dugout boats (dugouts are rare), which operate gillnets, are specialised in the Nile tilapia fishery. The size and shape of these boats make them vulnerable to bad weather in open waters; therefore, they operate exclusively in sheltered bays and near shore areas. Like the endemic tilapiines (Graham, 1929), the introduced Nile tilapia in Lake Victoria is largely an inshore species thriving best in the littoral and sub-littoral areas, although large individuals can be encountered in the open waters to a maximum depth of about 30 m (Jackson, 1971; Okaronon, 1994; Balirwa, 1998). Due to their simplicity, parachute boats are the most affordable fishing craft on the lake, thus offering the lowest operating costs in the Nile tilapia fishery. They are unique in construction, almost exclusively target Nile tilapia and are the main craft used in this fishery. Therefore, management options for the Nile tilapia fishery should be designed, implemented and evaluated by focusing on the operations of these boats.

Various forms of active operation of gillnets have been adopted to enhance catch rates in the Nile tilapia fishery. The common active methods involve one or a combination of the following ways of scaring fish towards the set gillnet. They include: (i) setting the gillnet in semicircle and pounding the water surface with a wooden hammer, locally known as *tycoon*; working from a distance towards the inner side of the set gillnet; or (ii) the gillnet set as above and a metallic object attached to one end of a long wooden handle is used to hit through the water column and/or scratch the bottom, especially in areas with rocky substratum, a method locally known as *sokosa* (Fig. 4.44). The relatively less common methods are where fishers dive into the lake in turns to chase fish towards the set net, locally known as *sekeseke*, or operating the gillnet like a beach seine in combination with a *tycoon*.

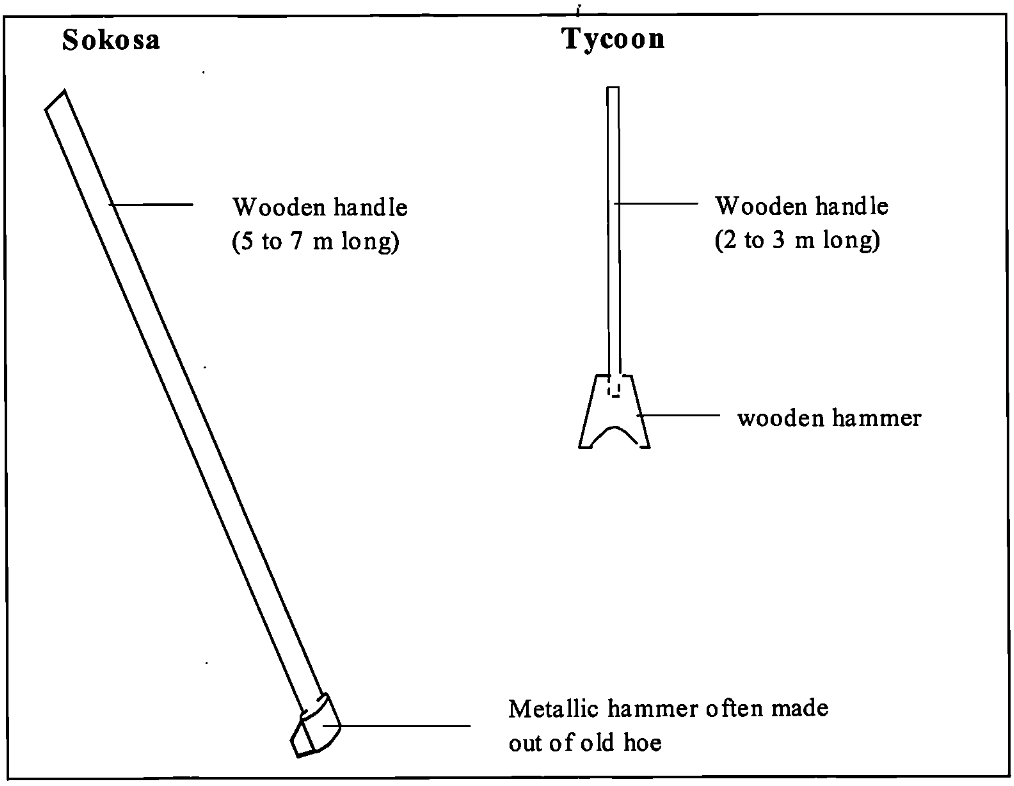


Figure 4.44 Tools used in the two common methods of active operation of gillnets in the Nile tilapia fishery of the Ugandan part of Lake Victoria.

These innovations in fishing methods are probably maintaining reasonably high catch rates of Nile tilapia while the stocks are possibly declining. Fishers argue that Nile tilapia can detect the set gillnets and avoid capture unless forced to encounter them. Similar arguments were raised when the native tilapiines were suspected to have became "educated" over a period of time following intensive fishing with gillnets and learnt to avoid stationary gillnets leading to rapid decline in catch rates, a theory which Jackson (1971) referred to as "remains to be proved" and considered that the stocks had in fact been reduced to dangerously low levels. The publications (Garrod, 1960; 1961; Jackson, 1971; Fryer & Iles, 1972), which describe the events during the collapse of the native tilapiine fisheries indicate rapid decline of gillnet catch rates to which fishers responded by lowering mesh sizes but do not indicate if active methods of operation of gillnets were introduced to improve catch rates. These fisheries eventually collapsed primarily due to overfishing (Ogutu-Ohwayo, 1990a; Ogutu-Ohwayo *et al.,* 1997), confirming that the decline in catch rates was a direct result of overfishing rather than the tilapia becoming net shy. In the present tilapia fishery, the very low catch rates in passively set gillnets compared with those of actively fished gillnets may not be the result of net shyness but a symptom of overfishing. In this case overfishing must be considered in the context of a multi gear fishery in which the destructive gears may be doing damage. Active operation of gillnets is illegal in Uganda but 85% of parachute boats in the study area that targeted tilapia operated gillnets actively. This study only provides evidence that the current catches of Nile tilapia rely on active fishing and their sustainability in the long-term could be questionable. There is no other information to show how active operation of gillnets evolved and how the catch rates associated with it have changed over time.

In boats using fishing gears other than gillnets to target Nile tilapia, the important fishing strategy appears to be the adoption of the particular gear rather than the boat type. They include basket traps, which are operated in inshore areas with emergent plants, cast nets that are also operated in shallow waters close to the shoreline for which any small boat can be used. Besides these gears, the use of beach seines is also common, taking juveniles and destroying breeding areas of tilapia.

The Nile perch fishery

The two categories of Sesse boats, paddled and motorised/sailed, target Nile perch but they differ in fishing strategies. The fishing operations of paddled Sesse boats are restricted to shallow waters close to the home-landing site because of the limitations of manual propulsion whereas the motorised/sailed Sesse boats extend further into deep offshore waters. The differences in the depth ranges where these boats operate are also reflected in the differences in the mode of gillnet operation. In paddled Sesse boats, gillnets are predominantly set passively, i.e. stationary at one site, anchored at the bottom of the lake throughout the fishing period, whereas almost in all motorised/sailed boats, gillnets are set in mid-waters and allowed to drift with the current. The choice of mode of operation of gillnets is probably dictated by the distribution pattern of Nile perch, the targeted fish species of these boats. In recent bottom trawl surveys conducted in the Ugandan part of the lake (Okaronon, 1994; Okaronon *et al.,* 1999), catch rates of Nile perch declined drastically with increasing depth in waters exceeding 30 m depth. In the recent past, prior to the Nile perch boom, the water column of Lake Victoria was fully mixed and oxygenated to the bottom, except during January to May in water deeper than 60 m (Talling, 1966), and supported an abundant and species rich benthic fish fauna (Witte *et al.,* 1992). However, simultaneous with the Nile perch boom, there have been reports of low oxygen concentration in the hypolimnion of deep waters during prolonged periods of stratification and anoxia for the entire year in some permanently stratified regions of the lake deeper than 50 m (Hecky & Bugenyi, 1992; Hecky *et al.,* 1994). In the shallow waters, especially areas less than 10 m deep, there is always sufficient oxygen throughout the water column because thermal stratification there is slight and largely diurnal, lasting for very short periods especially when wind velocity is low (Talling, 1966; Hecky & Bugenyi, 1992; Hecky *et al.,* 1994). The low oxygen concentration or anoxia in the hypolimnion during periods of persistent thermal stratification in deep waters could be restricting Nile perch to the upper layers above the thermocline. The predominance of bottom set gillnets in paddled Sesse boats confirms that they operate in shallow waters whereas the motorised boats operate with mainly mid-water set drift nets in deep waters. Therefore, although both categories of Sesse boats target the same fish species, their fishing grounds are separated, in space both in vertical and horizontal dimensions.

Another factor showing disaggregation between the fishing strategies of paddled boats and those of motorised/sailed boats is the size of Nile perch they target. Small Nile perch formed the bulk of the catches of paddled boats whereas motorised/sailed boats caught larger fish. Recent bottom trawl data from the Kenyan, Tanzanian and Ugandan parts of the lake showed higher abundance of the juvenile Nile perch in shallow waters

<20 m deep than in deeper waters (Getabu & Nyaundi, 1999; Mkumbo & Ezekiel, 1999; Okaronon *et al.*, 1999). This is the area of operation of paddled Sesse boats where they seem to be targeting the abundant juvenile Nile perch. Despite the presence of large gillnet mesh sizes in paddled boats similar to those used by motorised/sailed boats the catch composition does not reflect their contribution to the catches. Large fish could therefore be rare in the areas of operation of these boats as a result of either habitat preference or overfishing. In the western part of the lake, where fishing intensity was relatively lower than in other parts (see Chapter Three), the Nile perch catches of paddled boats contained higher proportions of large Nile perch. This would suggest that overfishing has contributed to the decline of abundance of large Nile perch in the waters where paddled Sesse boats operate. The gillnet fleets of paddled Sesse boats contained large proportions of small illegal mesh sizes. The habit of fishers to adopt smaller mesh nets when catches of large sized fish decrease in order to maintain catch rates by exploiting the undersized fish is not new in Lake Victoria (Fryer & Iles, 1972; Fryer, 1973; Ogutu-Ohwayo, 1990a) or other fisheries of the world (Welcomme, 2001). It is thought to have been the prime cause of the collapse of the native tilapiine fisheries of Lake Victoria by cropping immature individuals. Similarly, the adoption of smaller gillnet mesh sizes by fishers using paddled boats is likely to be a response to declining catches in the larger meshes and could lead to collapse of the Nile perch fishery by intensifying fishing pressure on immature fish stocks. This is a common scenario in heavily exploited fisheries where the catch rates fall (Welcomme, 2001).

Motorised boats in the western zone used the widest range of gillnet mesh sizes, including substantial quantities of nets <152 mm mesh size, for this category of boats. By contrast motorised boats in the eastern zone, where fishing intensity was highest in the Ugandan waters, hardly used gillnets <152 mm mesh size, but instead used more gillnets of mesh sizes >152 mm compared with the western and central zones. A similar pattern of gillnet mesh size distribution with fishing pressure is reciprocated at the regional level (see Fig. 3.11: Chapter Three). In the Kenyan part of the lake, where fishing pressure was very high compared with Tanzania and Uganda (see Fig. 3.10: Chapter Three), a situation synonymous with that in the eastern zone of the Ugandan part of the lake, the proportion of gillnets of large mesh sizes ≥178 mm was highest. In the Tanzanian part of the lake, which probably has the lowest fishing pressure, gillnets in use were dominated by 127 mm mesh size, a situation synonymous with the western part of the Ugandan part of the lake. In the areas where fishing pressure is low, motorised boats probably fish in relatively more inshore areas where a wide range of Nile perch sizes could be abundant compared with heavily fished areas where the inshore waters are over fished and these boats probably ply waters further offshore where the large fish have not been depleted yet. Indeed there was a tendency of both paddled and motorised boats to use similar gillnet mesh sizes in the western zone of the Ugandan waters suggesting that they targeted similar Nile perch stocks but this waned eastwards, with increasing fishing pressure, where the motorised boats probably fished exclusively in deep offshore waters while paddled boats operated inshore (Fig. 4.15). The strategy of reorienting fishing to far offshore, with increased fishing pressure, is also implied by the spatial distribution pattern of motorised boats in the Ugandan waters, whereby; the eastern zone contains the majority (42%) of motorised boats (see Fig. 3.5: Chapter Three). Similarly, on the regional basis, the density of motorised fishing boats was very high in Kenyan waters, which probably have the highest fishing pressure and lowest in the Tanzanian waters, where fishing pressure is perhaps the lowest (see Fig. 3.10: Chapter Three). The fish processing factories, who are the main buyers of fish landed from motorised boats, seemed to be encouraging the lowering of gillnet mesh sizes in the western zone of the Ugandan waters of the lake, albeit indirectly, because their agents were buying Nile perch as small as 37 cm TL. The pattern of fishing in this part of the lake, therefore, indicates a rush for the juvenile Nile perch, which may harm the fishery in the long-term.

4.9.2 *Spatial and temporal patterns of Nile perch and Nile tilapia catch rates*

Nile tilapia

In the Nile tilapia fishery, the highest catch rates and contribution of large fish to the catches of gillnets were observed at the beginning of the surveys but these were suspected to have resulted from the four-month period of reduced fishing pressure prior to the start of the surveys during a government ban on fishing. If the fishing ban was responsible for these high catch rates, it would demonstrate that the Nile tilapia fishery could respond quickly to management interventions aimed at regulating fishing intensity. The ban on fishing is likely to have overshadowed seasonal patterns in the first surveys which became more apparent in later months. These seasonal patterns in catch rates could be related to the seasonal breeding cycles. Nile tilapia tends to spawn throughout the year but show peak breeding activity in periods correlated with rainy seasons (Lowe-McConnell, 1975; Twongo, 1995; Balirwa, 1998). In Lake Victoria there are two breeding peaks, the first and more prolonged phase commences sometime after the onset of the main rainy period towards the end of May and the second peak commencing after the onset of the short rainy season towards the end of October, thus primarily associated with rising water level (Balirwa, 1998). When the lake level rises, shoals of tilapia disperse and brooding females take shelter in flooded macrophyte beds (Kolding, 1993; Balirwa, 1998). This might explain the decrease in catch rates observed in October to December 2000 and April to June 2001. However, before the supposed dispersal of brooding females and consequent drop in catch rates there appears to be a period of increased occurrence of large-sized fish in the catches, as was observed in the period July to September 2000, probably during courtship and mating aggregations of brood stock in inshore waters that become more vulnerable to fishing.

The catch per unit of effort (CPUE) of Nile tilapia by parachute boats, at the level of boat as the unit of effort, was not different in the western and eastern parts of the lake. However, boats in the eastern part of the lake used about twice as many nets as those in the western part of the lake causing the CPUE at the level of a gillnet as the unit of effort in the eastern part of the lake to be about half of that in the western part. Therefore, fishers for Nile tilapia in the eastern part of the lake could be compensating for the fall in catch rates resulting from the higher fishing effort in this zone by using more nets. This may not be sustainable from either an economic or resource availability perspective.

Nile perch

In the Nile perch fishery, the lowest catch rates of paddled boats were in the central part of the lake followed by the eastern part and highest in the western part of the lake. The catch per unit of effort (CUPE), both at the level of boat and gillnet as units of effort, for boats operating passively set gillnets which operate in shallow inshore waters showed the same pattern. Frame survey data (Chapter Three) indicate that 63% of boats in the central zone were paddled Sesse boats compared with 43% in the eastern zone and 40% in the western zone. Few parachute boats operate in this zone probably because most of the area is open to strong winds, thus requiring more stable boats. The low catch rates of the paddled Sesse boats in the central zone, therefore, could be partly because these boats were used to target both Nile perch and Nile tilapia (Fig. 4.2). Alternatively, since these boats operate in a limited area there is probably higher competition for Nile perch amongst them in the central zone than elsewhere.

The relatively good catch rates of paddled Sesse boats operating passive gillnets in the eastern zone, despite this zone having the highest fishing pressure with destructive gears (Chapter Three), especially beach seines and undersize gillnets, would suggest there is high abundance of small Nile perch in the eastern part of the lake, probably due to the more extensive areas of shallow waters and bays. High abundance of young Nile perch could also be the factor attracting the highest presence of beach seines and under-sized illegal gillnets in this zone compared with other zones. However, probably due to the intensive use of destructive fishing gears in this zone, the seemingly abundant small Nile perch are perhaps overfished before they grow to become available to driftnets in similar proportions in waters within the range of paddled boats. For instance, CPUE of the few paddled Sesse boats that operated driftnets was considerably higher than that of boats operating passive gillnets in the central and western zones but vice versa in the eastern zone (Fig. 4.21). This observation shows that the availability of Nile perch to driftnets that are operated in near shore areas in paddled boats were highest in the western zone and decreased eastwards. This would probably explain why motorised boats in the eastern zone used the largest gillnet mesh sizes because they have to go further offshore in deeper waters, where recent trawl surveys in the lake found a relative scarcity of juvenile stages of Nile perch (Mkumbo & Ezekiel, 1999; Okaronon *et al.*, 1999). On the other extreme, motorised boats in the western zone can probably obtain satisfactory catches of Nile perch when they operate at a relatively shorter distance from the shore in areas dominated by smaller Nile perch, and this would be the reason why they used the highest proportion of gillnets <152 mm mesh size among the three zones.

The catch rates of Nile perch did not show any related seasonal patterns in the three zones but the overall mean catch rates indicated weak biannual peaks that suggest recruitment of the smallest Nile perch into the fishery in the first and third quarters of the year. This pattern is probably related to biannual spawning peaks associated with the two rain seasons in the year, although Nile perch in Lake Victoria, like many other tropical fishes, appears to have a continuous breeding cycle throughout the year (Mkumbo, 2002). Similar breeding cycles have been observed for Nile perch in Lake Albert (Hamblyn, 1962) and Lake Chad (Hopson, 1972). However, the breeding patterns are expected to differ for the Kenyan and Ugandan waters because the rainfall patterns differ (Spigel & Coulter, 1996).

Nile perch catch rates by motorised/sailed boats followed different patterns in the three zones, but overall they peaked in July to September 2000, the same period when these boats selected a narrow range of Nile perch sizes that appears to represent peak recruitment of a year class into the fishery. The catch rates were significantly lower in the eastern part than in other parts of the lake, reaffirming the effects of overfishing in this part of the lake. CPUE at the level of the boat as the unit of effort amongst drift netting boats, the dominant mode of operation of gillnets of these boats, was significantly lower in the eastern part of the lake. However, CPUE at the gillnet level as the unit of effort was comparable throughout the lake, owing to differences in numbers of gillnets used. As noted above, gillnets used by motorised boats were consistently of the largest mesh sizes in the eastern part of the lake and the smallest mesh sizes were most common in the western part. The larger the gillnet mesh size, the thicker the twine it is made of, therefore, gillnets of large mesh size are heavier and more bulky than those of smaller meshes and the numbers of gillnets a boat can carry is inversely related to their mesh sizes. This explains why boats in the western part of the lake carried more nets. Due to the differences in gillnet mesh size composition the mean size of fish landed by these boats decreased westwards. The western part of the lake is therefore also likely to start experiencing the symptoms characteristic of overfishing if the rush to harvesting juvenile Nile perch by the lowering of gillnet mesh sizes is not urgently reversed. The issue of fishers continually changing their fishing gears to target different stock components appears to be a major problem hindering tracking of changes using comparable gears over time. Future studies should investigate if changes in gear use e.g. gillnet mesh sizes follow a systematic pattern.

The catch rates determined from LVFRP trawl survey data in the Ugandan part of Lake Victoria (Table 4.8) are consistent with the findings of this study. Between the three zones, the trawl catch rates of Nile perch were highest in the western part of the lake, which had the lowest fishing pressure and declined to the lowest level in the eastern part of the lake which had the highest fishing pressure (see Chapter Three). In the case of Nile tilapia, the highest catch rates in trawl surveys were in the central zone. The distribution pattern of fishing boats (Fig. 3.5: Chapter Three) indicated that only 25% of boats in the central zone were parachute boats, which exclusively target Nile tilapia, compared with 41 and 44% of boats in the western and eastern zones respectively. Therefore, there was, probably lower fishing pressure for Nile tilapia in the central zone than elsewhere leading to higher abundance of the species, and its higher catch rates in the trawls. These observations suggest that high fishing effort is responsible for the declines in fish catches.

Table 4.8 Mean catch rates (kg hr^{-1}) of fish caught during bottom trawling in the Ugandan part of Lake Victoria in 1999 to 2000 (from J.O. Okaronon, unpublished)

	Zone 1 (Western)	Zone 2 (Central)	Zone 3 (Eastern)	All Zones
Nile perch	302.0	194.1	183.2	207.6
Nile tilapia	12.4	39.4	11.1	23.6
Haplochromines	5.2	12.4	4.4	8.2
Other species	0.1	0.4	1.5	0.7
Total	**319.7**	**246.3**	**200.2**	**240.1**

4.9.3 *Factors that influence the size composition of Nile tilapia catches*

Actively operated gillnets caught smaller sizes of Nile tilapia compared with passively set gillnets. Gillnets are operated actively in shallow waters, close to the vegetated shoreline areas but are set passively in more open waters, further away from the shoreline. Habitat differences between the two fishing grounds are suspected to be contributing to the differences in the size composition of the catch. Balirwa (1998) suggested that the Nile tilapia population of Lake Victoria comprise two parts, one part occupying the vegetated shoreline habitats which mature at a small size due to relatively unstable physical chemical conditions there, while the other part stay in more open waters where conditions are more uniform over time and grows to a larger size but utilises the shallow littoral habitats during breeding periods. Growth plasticity in Nile tilapia has been observed in various environments of varying physical and chemical composition (Lowe-McConnel, 1955, 1958; Kolding, 1993). Additionally, since fishing for tilapia is more intense in the littoral areas, the population there could be prone to higher fishing mortality than that in the more open waters, leading to reduction in mean size of the population and possibly inducing maturation at a smaller size (Lowe-McConnell, 1975). Therefore, the observed disparity in the sizes of fish caught in actively and passively operated gillnets could result from differences in distribution of fish sizes in the habitats where these two types of operation are applied. The lack of large fish and reduced size of maturity (Balirwa, 1998) in the littoral zone could be largely a consequence of high fishing intensity, in addition to other possible environmental causes. The proportion of large Nile tilapia increased in the catches of parachute boats, which predominantly operate gillnets actively in July to September 2000. This could be a result of large fish migrating from open waters to the littoral areas to breed, as suggested by Balirwa (1998).

Similar to actively operated gillnets, basket traps also select for small sizes of Nile tilapia. This could be because basket traps are exclusively operated in the vegetated areas that are dominated by small Nile tilapia, although the size of their openings could also be limiting to the size of fish that can be caught. The widest range of Nile tilapia sizes were caught in cast nets. Cast nets are constructed with graded mesh sizes, from as small as 76 mm innermost to as large as 152 mm on the periphery, thus are capable of catching a wide range of fish sizes. Cast nets are operated in shallow inshore areas but fishers tend to look for areas where Nile tilapias are concentrated, which tend to be the breeding areas. They therefore could be targeting the brood stock, which may explain why they catch the largest fish amongst all the gears that target Nile tilapia. Cast nets could be destructive in three ways: (i) indiscriminate catching of fish including the juveniles; (ii) disrupting breeding activities and flattening out nests; (iii) destruction of the brood stock. The wide spread use of moving gears in the breeding areas of Nile tilapia in inshore waters, principally the beach seines and cast nets, plus the active operation of gillnets, is probably preventing Nile tilapia from exercising its full reproductive potential because of the excessive disturbance, thus hindering the productivity of the fishery and threatening its long term sustainability. Boats fishing with basket traps, one of the few persevering traditional fishing methods in Lake Victoria, are very few compared with other fishing gears (see Chapter Three), and probably do not pose any threat to the sustainability of the Nile tilapia fishery, although they catch immature fish. Nevertheless, active operation of gillnets which is currently the prominent technique of fishing for Nile tilapia, as well as cast netting, which appears to be expanding rapidly, are major issues that should be addressed.

4.9.4 *The fishery of Nile tilapia and size at first maturity*

The size at first maturity (LM_{50}) of Nile tilapia in the Ugandan part of Lake Victoria was estimated by Balirwa (1998) at 18 and 24cm TL and 100% maturity at 30 and 32 cm TL in males and females respectively. The present analysis using data from LVFRP trawl surveys (Fig. 4.29) indicated the overall LM_{50} of Nile tilapia in the Ugandan part of the lake was 31.7 and 33.1 cm TL in males and females respectively. The latter estimates are in close agreement with those in the Kenyan part of the lake where the

LM_{50} of male and female Nile tilapia were estimated at 30.8 and 34.6 cm TL respectively (LVFRP unpublished). The disparity between the estimates from LVFRP trawl survey data and those of Balirwa (1998) probably arises from two sources:

(i) Balirwa (1998) considered individuals with gonad stage 3 to have attained maturity whereas the analysis of LVFRP survey data, both in Uganda and Kenya, considered mature individuals to be those with gonad stage 4 and above. Otherwise, both analyses were alike in that the same gonad stage classification as in Lagler (1978), modified to apply to Nile tilapia was used. Essentially, the gonad stage referred to as the size at 100% maturity (Balirwa, 1998) is probably synonymous with the LM_{50} indicated by analysis of LVFRP data. Balirwa (1998) further indicated that the size of first spawning was around 30 cm TL corresponding to the estimated size at 100% maturity and recommended the size at first capture to be around this size.

(ii) The specimens analysed by Balirwa (1998) were mainly obtained from gillnet catches set in the littoral and sub-littoral inshore areas, whereas those in LVFRP surveys were from bottom trawls, conducted entirely in open waters deeper than 5 m. Balirwa (1998) suggested that part of the Nile tilapia population inhabiting shallow vegetated habitats of inshore waters where habitat conditions are unstable mature at a smaller size than the part of the population inhabiting more open waters where habitat conditions are relatively uniform.

Based on the viewpoints above, the differences in size at first maturity of the two studies do not necessarily reflect an increase of LM_{50} but, probably, the difference in the populations sampled, even when considering the size at 100% maturity (Balirwa, 1998) to be synonymous with the LM_{50} estimated from LVFRP survey data. The observed spatial distribution of LM_{50} of Nile tilapia, being lowest in the eastern part of the lake and generally increasing westwards, may, for the same reasoning, be explained by the differences in habitats sampled, rather than a response of the species to fishing pressure (Caddy & Mahon, 1995), or both. This is because LVFRP trawl surveys covered more shallow bays and gulfs in the eastern part of the lake compared with other areas.

Accounting for the reproductive characteristics of Nile tilapia, a minimum size of about 30 cm TL has been recommended for the size of first capture, which equates to minimum gillnet mesh size of 127 mm (Ogutu-Ohwayo *et al.* 1998, Balirwa, 1998). Harvesting of Nile tilapia < 28.5 cm TL is also illegal in Uganda. The current gillnet fishery for Nile tilapia in Uganda, which is dominated by active operation of gillnets, is therefore characterised by heavy growth and recruitment overfishing, based on the catch composition (Fig. 4.31), and is probably not sustainable. Nile tilapia is a brood spawner and also needs to guard nests, ecological functions that are vital for its reproductive success, and which are probably enhanced at large size. Therefore, it may probably be possible to increase Nile tilapia fishery production from the present levels by enforcing regulations that would reduce the harvest of undersized fish.

4.9.5 *Factors that influence the size composition of Nile perch catches*

The catches of Nile perch in both beach seines and passively operated gillnets were biased towards small sizes, but beach seines caught the smallest sizes of Nile perch. Unlike gillnets, which are highly selective, and the size of fish caught depends on the mesh size, beach seines are non-selective over a wide length range of Nile perch sizes and the medium-sized beach seines in use catch Nile perch of up to about 80 cm TL (Ligtvoet *et al.,* 1995). Beach seines are continuously operated in the same areas where the bottom of the lake is free of snags, which could have caused local overfishing eliminating the larger sizes of fish. Beach seines appear to be the most destructive and wasteful of all gears that target Nile perch, by cropping huge quantities of tiny Nile perch that are of little commercial value and could lead to severe growth overfishing of the Nile perch fishery.

Amongst gillnetting boats, the selection of small-sized Nile perch by passively set gillnets and larger sized fish by driftnets was undoubtedly caused by differences in the mesh size composition of gillnets used. Passively set gillnets predominated in paddled Sesse boats and as argued above, the areas in which they are operated are overfished compared with the areas where driftnets are operated using motorised/sailed boats. Thus, the lowering of the mesh sizes in passively set gillnets could be a response to poor catches by larger mesh nets. The composition of fish catches, therefore, appears to be primarily associated with the choice of fishing gear type, although some seasonal patterns were apparent in gillnet catches. The mode of operation of the gear and habitat where it is operated also explain variations in catch composition.

The study of Nile perch gillnet selectivity using passively set experimental gillnets, (Asila, 2001b), provided the optimum fish lengths for the most efficient capture by various gillnet mesh sizes (Table 4.9).

Table 4.9 Optimum lengths for most efficient capture of *L. niloticus* by gillnets of various meshes, using the hanging ratio of 0.6 (from Asila, 2001b)

Mesh size (mm)	51	76	101	127	152	178	203	228	254
L. niloticus (cm TL)	19.7	29.6	39.4	49.3	59.1	69.0	78.8	88.7	98.5

The optimum Nile perch length of 49.3 cm TL caught in 127 mm mesh size nets looks appealing for maintaining the minimum mesh at 127 mm. However, the observations of the Nile perch composition of commercial catches of this study suggest that the catch composition of the experimental gillnets should be treated with caution. The modes of Nile perch catches of driftnets in motorised boats observed under this study (Figs 4.9, 4.10 and 4.11) were generally lower than the optimum fish lengths suggested by Asila (2001b), although it was impractical to apportion the catches to the mesh sizes in which they were caught. The hanging ratios of gillnets used in the commercial drift gillnet fishery ranged from 0.49 to 0.55 whereas Asila (2001b) used a larger hanging ratio of 0.6. It appears to be the strategy of fishers to use smaller hanging ratios in order to boost their catches by catching smaller fish for a given gillnet mesh size. The operation of gillnets as drift nets could also have an effect on size selection of Nile perch, but there is no scientific evidence to support this proposition.

4.9.6 *The fishery of Nile perch and size at first maturity*

The analysis of the size at maturity of Nile perch in the Ugandan waters of Lake Victoria, using data from LVFRP trawl surveys (Fig. 4.28), indicated the overall LM_{50} was attained at 57.2 cm and 75.6 cm TL in males and females respectively. In Kenya and Tanzania, the LM_{50} for male was estimated at 55 and 54 cm TL respectively and around 75 cm TL in females (LVFRP data, UNECIA, 2002). The ideal practice in fisheries management is to set the lower size limit of the fish that should be cropped at LM_{50} (Beverton & Holt, 1957), aiming at allowing approximately 50% of the individuals the chance to breed before they are cropped, to sustain the stocks. Notwithstanding this logic, the size at first capture of Nile perch cannot be set at LM_{50}. This is because Nile perch is a top predator, which shifts from a predominantly invertebrate diet to a more piscivorous diet, including cannibalism, at the size of around 50 cm TL, before attaining the LM_{50}. This size (50 cm TL), was accordingly recommended to be the size at first capture of Nile perch in Lake Victoria (Ogutu-Ohwayo *et al.*, 1998). Females are very essential for propagating the species but their

LM_{50} around 75 cm TL is much higher than the size of 50 cm TL recommended for first capture. Therefore, to ensure good recruitment, some protection should be accorded to good numbers of large breeding females.

The spatial distribution of LM_{50} indicated that males matured at the largest size in the western zone of the Ugandan waters at 58.3 cm TL compared with 56.6 and 56.4 in the central and eastern zones. These sizes of males are basically within the limits of those reported by earlier studies, between 50 and 60 cm TL, (Acere, 1985; Asila & Ogari 1988; Ligtvoet & Mkumbo, 1990; Ogutu-Ohwayo, 1988; 1994; Hughes, 1992) and would not imply any response of the species to fishing pressure, but the LM_{50} of females has dropped markedly from mainly above 90 cm TL observed in the above studies to around 75 cm TL currently. This reduction in the LM_{50} of females is probably an indicator of stress facing the Nile perch population in Lake Victoria resulting from overfishing.

4.9.7 *Trends of* **R. argentea** *catch rates*

Seasonal changes in catch rates of *R. argentea* were only significant in the eastern part of the lake showing peak catches in July 2000. The combined catch rates for the three zones indicated a significant peak in catch rates in the period July-September 2000 and a weak one in January – March 2001. The data of this study suggest that catches improve in the drier months preceding the long rains in May and short rains in October, but do not provide evidence of any strong seasonality of catch rates. Fish landing sites for *R. argentea* are located in areas with suitable open surfaces (sand or rock) on which the catch is spread for sun drying. As a consequence, fishing effort is concentrated in the waters close to these landing sites. Motorised boats in the western part of the lake used similar fishing gear as the paddled boats, but maintained higher catch rates than the paddled boats, probably because they extended fishing to more rewarding areas where fishing intensity was low.

4.9.8 *Size at first maturity of* **R. argentea**

Two general trends in size at 50% maturity (LM_{50}) of *R. argentea* populations in different parts of the lake are discernible. The LM_{50} decreased from inshore to offshore waters and from the eastern part of the lake westwards, save for the males in the eastern and central zones and females in central zone where it increased slightly offshore. Organisms make tradeoffs between growth, and reproduction to ensure the best chances of passing their genes to the next generation before they die (Wootton, 1990). Under circumstances of increased mortality resulting from stressful influences such as predation, overfishing and food availability, fish respond by changing their reproductive strategies such as maturing earlier at a smaller size, achieved through either phenotypic or genetic selection (Wootton, 1990). This strategy increases the chances of reproduction at a younger age, rather than placing more effort into reproducing later when there is higher chance of mortality, which would decrease the chance of reproductive contribution to the population (Campbell, 1996). As a result of these tradeoffs, earlier maturation may result in reduction of overall fish length and generation time. Pitcher & Hart (1982) and Lowe-McConnell (1987) classified cyprinids as typically r-selected with a high fecundity and high rate of biomass increase. Being a fast growing species and with high turnover rate, *R. argentea* is capable of reacting to environmental stress like higher fishing pressures within a short time (Wandera, 1992). Whereas the variations in LM_{50} of *R. argentea* populations observed in this study could result from the effects of fishing pressure, it may not be the sole factor responsible, as other environmental factors may be in play. For example, the highest LM_{50} of females of 43.5 mm SL observed at Lingira is not different from, between 43 and 44 mm SL, reported by Wanderá (1992) for the same area more than ten years ago. This is despite heavy fishing pressure for *R. argentea* over a long time in this area, as Lingira is one of the oldest sites where fishing for *R. argentea* started in Uganda. However, the LM_{50} of males declined appreciably from 40 – 41 mm SL (Wandera, 1992) to 36.6 mm, which would imply that fishing pressure has had an impact.

The inshore waters are generally more productive than deep offshore waters, e.g. gross phytoplankton production was about 62% higher inshore (Pilkington Bay) than offshore (Bugaya) in 1989-91 (Mugidde, 1993), they receive nutrients from runoff and the water is continuously mixed. On the other hand, in deep offshore waters nutrients are locked in the hypolimnion during prolonged periods of stratification and are not available for algal production. On the basis of lake productivity, there should be higher algal production in inshore waters that supports high zooplankton production, the main food of *R. argentea*. Therefore, food should be less limiting in inshore waters than offshore waters, and the patterns of size at first maturity observed could be partly attributed to zonal variability in lake productivity. Lake productivity also tends to decrease from the eastern part westwards, which could explain why the size at first maturity decreased westwards.

Another biotic factor that could be causing stress on *R. argentea* populations in Lake Victoria is Nile perch predation. Wandera (1992) indicated that *R. argentea* from Lake Kyoga, where there was no commercial fishery for the species at that time, were maturing at a much smaller size than those in Lake Victoria with a growing commercial fishery. He attributed the differences to the predatory effects of Nile perch, which was introduced and established itself much earlier in Lake Kyoga than in Lake Victoria. This explanation based on the predatory effects of Nile perch could be viable for the observed patterns of size at first maturity. The sites showing the highest size at first maturity of female *R. argentea,* i.e. Lingira and Lukale, are surround by waters with a poor Nile perch fishery probably as a result of heavy exploitation with beach seines and undersize gillnets. Although this explanation that attributes the changes in LM_{50} of *R. argentea* to Nile perch predation looks convincing, data on feeding of Nile perch indicate otherwise. In the Mwanza Gulf, *R. argentea* contributed up to 27% of the diet of Nile perch at the end of the 1980s (Mkumbo & Ligtvoet, 1992), but data collected over the whole lake in 1998 to 2000, about ten years later, indicate that its importance in the diet of Nile perch has declined to <10%, in spite of its high abundance in the lake (LVFRP data, UNECIA, 2002). Therefore it is unlikely that Nile perch predation is the cause of the decrease in size at first maturity of *R. argentea* observed in some areas of the lake.

An analysis of spatial distribution of LM_{50} of *R. argentea* samples collected from the whole lake (Marshall, 2001) indicated that the Kenya waters had a lower LM_{50} of 36.8 mm SL compared with the whole lake average of 38.7 mm SL and the sites within the shallow inshore waters of the Nyanza Gulf had much lower LM_{50} than in Kenyan open waters. He attributed the Kenyan status to higher degree of fishing pressure. The Lake wide Frame Survey 2000 indicated that the Kenyan part which is only 6% of the lake contained 66.3% of the total number mosquito seines in Lake Victoria while Tanzania and Uganda contributed only 14.4 and 19.3% respectively (Chapter Three). This would suggest that the fishing pressure in inshore sheltered waters from which the samples of this study were obtained, especially in the eastern part of the lake, has not reached the threshold to cause drastic reduction of LM_{50}. However, the low LM_{50} status of the western part of the lake could be the result of high fishing pressure because boats using mosquito seines in the Ugandan part of the lake were more concentrated there (Chapter

Three) than in other areas, except for the area close to the Kenya/Uganda board which was not sampled in this study. Therefore high fishing pressure and probably low lake productivity in the western part of the lake could be responsible for the lowest LM_{50} of *R. argentea* observed in this part of the lake.

4.9.9 *Size composition of* **R. argentea** *catches*

The observations of this study agree with those reported by Wanink (1999) that the fraction of juveniles in the catches depends on the distance from the shore. Despite the use of uniform mosquito seine nets of 5 mm mesh size by all boats sampled, the proportions of juveniles were higher in catches from inshore waters near the mainland than at island stations. Within the inshore waters, the juveniles were more abundant in the catches from sheltered bays in the eastern and central zones compared with more open waters in the western part of the lake, suggesting higher abundance of juveniles in sheltered bays. *Rastrineobola argentea* was believed to be a pelagic spawner (Graham, 1929) but there is growing evidence to suggest that it spawns in the littoral waters which are subsequently used as nurseries by the larvae (Wanink, 1999). The alternative explanation for high abundance of juveniles in inshore catches is that in the deep waters the juveniles move from the surface towards mid water at sunset whereas the adults move to the surface waters, therefore the offshore light fishery catches mainly adult *R. argentea* (Wanink, 1992). This would suggest that the juveniles are present in the deep waters but they are not available near the surface where the light fishery is operated, therefore the possibility of pelagic spawning in offshore waters would remain valid. Marshall (2001) found that the proportions of mature running males and females were low in populations close to the shore, increasing offshore. He was thus cautious with the theory that *R. argentea* were inshore breeders without evidence to show that fish maturing for breeding in the offshore waters migrate inshore for spawning. If *R. argentea* were largely inshore breeders, then the continued use of small mesh size mosquito seines in inshore areas is a potential threat to the future prospects of the fishery, but would not be very harmful if operated in deeper waters offshore.

Another potential issue facing the *R. argentea* fishery is the high prevalence of the cestode *Ligula intestinalis*. This parasite is found in more than 50% of fish larger than 40 mm TL, reducing fecundity of infected females and preventing males from maturing, thus compromising recruitment of the stocks (Marshall, 2001). The high infestation rates and their effects on reproduction are in all parts of the lake and could contribute to a collapse in the fishery (Marshall & Cowx, 2003).

4.9.10 *Fish yield*

The estimates of fish yield were obtained by relating the spatial distribution of fishing boat types/categories and fishing gears, by zone (Chapter Three) to the quarterly fish catch rates observed in this study. This procedure accounted for variations in numbers of boats by boat type/category and fishing gear type and their seasonal fish catch rates between the three zones. The eastern zone had the highest estimated quarterly yield of Nile tilapia amongst the three zones because it had, in addition to gillnets, the highest number of parachute/dugout boats that exclusively target tilapia as well as the highest number of boats using cast nets and basket traps that are also used to target Nile tilapia. Similarly, the yield estimates for Nile perch were apportioned to the different gears in use. Although the total number of gillnets used in zone 3 was about double those in zone 1 (chapter three), the estimated yield of Nile perch from gillnets in the two zones were comparable because of lower catch rates in zone 3. On the other hand, the estimated yield of Nile perch from gillnets in the central zone were the highest because this is the area where the highest catch rates were recorded among motorised boats, and the overall total number of boats using gillnets was also high. The estimates of Nile perch yield of other fishing gears were highest in zone 3 because these gears were more represented there than elsewhere. The yield estimates of *R. argentea* in the three zones also followed the respective catch rates and the total numbers of boats operating mosquito seines.

Fish yield estimates for the Ugandan part of Lake Victoria were systematically updated, indicating the contribution of different species to the total catch for the period 1965-88 (Fig. 4.45). Thereafter, further estimates of contribution of different species were made in 1994-95. Total fish yield was estimated throughout the period 1965-98 although it is not clear how the figures were derived.

The annual yield estimates for the year 2000 indicate a large increase when compared with the 1998 UFRD estimate, which is explained by the large increase in catches of *R. argentea*. Indeed, the *R. argentea* fishery has expanded rapidly in the recent past as revealed by the growth in number of boats using mosquito seines by over 600% over the last decade, from 269 boats in 1990 to 2130 boats in 2000 (Chapter Three).

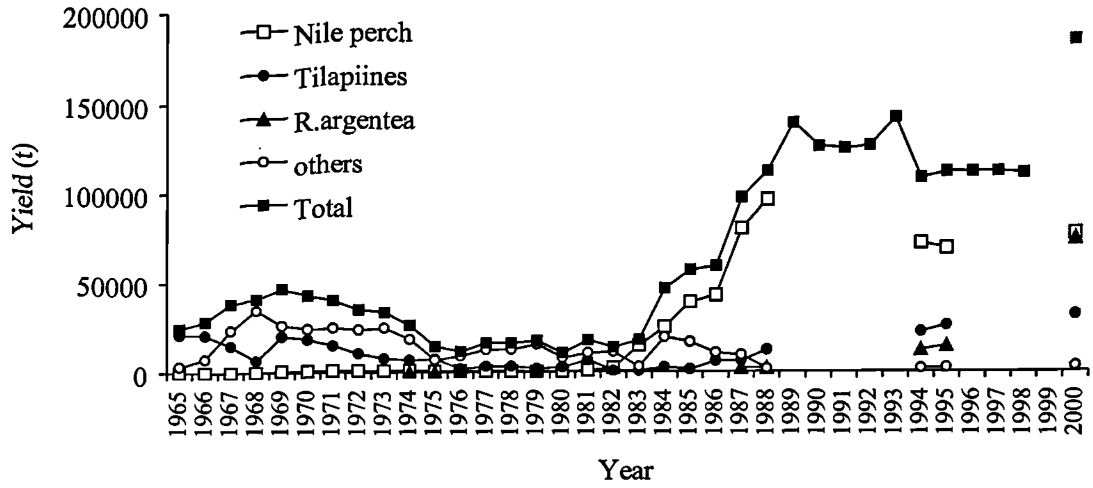


Figure 4.45 The estimated fish yield in the Ugandan part of Lake Victoria (source of data 1965-98: Reynolds & Greboval, 1988 and UFRD records). Data points in the shaded area are estimates of annual fish yield from this study for the year 2000.

The Nile perch yield estimates of this study are slightly higher than the UFRD estimate of 1995, but consistent with the general downward trend of total catches since the peak catches in the late 1980s, despite the approximate doubling of fishing effort between 1990 and 2000. About half of the Nile perch yield is composed of undersize fish from the combined catches of paddled Sesse boats operating gillnets and those operating beach seines, an indication of gross growth and recruitment overfishing. The contribution of *R. argentea* and Nile perch to total yield was similar and *R. argentea* catches could soon overtake Nile perch because there is potential for its expansion especially in the central zone where boats operating mosquito seines are less common (Chapter Three), or if more motorised boats enter the fishery.

4.9.11 *Summary and Conclusions*

Fishing strategies of boats in terms of the habitats where they fish, the target fish species and/or size of fish targeted vary with boat type. In the gillnet fishery, which is the predominant fishery targeting Nile perch and Nile tilapia, fishing boats can be grouped into three categories: (i) parachute/dugout boats that largely operate gillnets actively in waters close to the shoreline targeting Nile tilapia; (ii) paddled Sesse boats that largely operate gillnets passively in shallow waters up to about 10 m depth targeting juvenile Nile perch; and (iii) motorised/sailed boats that largely operate gillnets as driftnets in mid-waters of deep offshore waters targeting large Nile perch. The operations of each category of gillnetting boats have unique impacts in the fishery therefore requiring a distinctive set of management actions.

In the Nile tilapia fishery, active fishing, although illegal, is the prevalent mode of operation of gillnets. Adoption of active operation of gillnets could be a sign that the fishery is heavily over exploited and its effects should be investigated further. The size composition of catches of actively operated gillnets suggest reduction in mean size of Nile tilapia in the littoral zone populations that could be a result of overfishing compared with larger fish caught further away from the shore in passive gillnets.

In the Nile perch fishery, results suggest that shallow waters where gillnetting paddled Sesse boats and beach seines operate are over fished, especially in the eastern and central parts of the lake as implied by the rare occurrence of large Nile perch irrespective of use of large mesh size nets. Approximately half of the Nile perch yield in the Ugandan part of Lake Victoria is from catches of these boats, which target juveniles, evidence of gross growth and recruitment overfishing that ought to be reversed. There is also an apparent rush for small Nile perch in the less exploited waters of the western part of the lake, which soon or later could result in rapid decline of Nile perch in this part of the lake.

Driftnets appear to be the most suitable fishing gear for selecting the size of Nile perch recommended for harvest when their mesh size are $\geq$152 mm, but smaller mesh sizes catch undersize fish as observed in the western part of the lake.

The results suggest that Nile perch size selectivity of hooks is largely dependent on the size/species of bait but further research should be carried out to determine suitable bait that would be selective for the desirable size of Nile perch. Otherwise, the current Nile perch fishery with hooks is non-selective and should be discouraged.

Presently, the legal mesh size for the *R. argentea* fishery of 10-mm is not used at all in the Ugandan waters of Lake Victoria. The 5-mm mesh size mosquito nets now in use appear to have little effects on juveniles when operated in offshore open water populations but in inshore sheltered waters juveniles are dominant in the catches. Closed seasons are probably inappropriate to protect immature fish in inshore waters because they dominated the catches throughout. Therefore, the opportunities for protecting immature *R. argentea* probably lie in either increasing the mesh size of mosquito seines used inshore or restricting fishing to open, offshore waters. Since most fishing for *R. argentea* is in inshore areas, a larger mesh size should be determined for inshore areas that would reduce contribution of juveniles in the catch to less than 50%. If overfishing was responsible for the observed decrease in size at first maturity, then the western part of the lake is over fished and prospects of expansion of the *R. argentea* fishery is preferential in other areas.

CHAPTER FIVE

5. POPULATION DYNAMICS OF NILE PERCH (*Lates niloticus* L.), NILE TILAPIA (*Oreochromis niloticus* L.) AND MUKENE (*Rastrineobola argentea*) IN THE UGANDAN PART OF LAKE VICTORIA

5.1 Introduction

The basic purpose of studies on fish population dynamics is to provide advice on the optimum exploitation of the particular fish species. When population abundance, its rate of change, and growth, mortality and recruitment rates are estimated using appropriate techniques, it is possible to determine the relationship between catch from a stock to the amount of fishing and the size of fish at first capture (Dill & Pillay, 1968). Fish population assessments may be described as the search for the exploitation level that in the long run gives the optimal yield from a fishery (Sparre & Venema, 1998).

The present study applies length-based methods to determine the population dynamics of Nile perch (*Lates niloticus* L.), Nile tilapia (*Oreochromis niloticus* L.) and *Rastrineobola argentea* in the Ugandan part of Lake Victoria using fishery dependent data, obtained by sampling fish catches of artisanal fishers. Application of length based methods (Pauly, 1980; 1982; 1983; 1984; Pauly & David, 1981; Munro, 1984) and the rapid development of computer based packages to solve complex mathematical models applied in studies of fish population dynamics have contributed to the rapid research progress on tropical fish populations in the last two decades. Length based methods are being increasingly used in tropical fish stock assessment, where age information is unavailable or difficult to obtain (Sparre & Venema, 1998). They are even used where age data are available because length composition data are collected easily and more cost effectively compared with the tedious and time-consuming methods of ageing fish from hard body structures. Thus, the proxy measurement of length or size has become popular (Morgan, 1987; Gallucci *et al.,* 1996). The element of cost is particularly important for tropical small-scale fisheries in Africa where funding of fisheries work is insufficient but large quantities of length frequency data can be obtained relatively cheaply from commercial catches.

Studies of fish population dynamics comprise the determination of two categories of population parameters. In the first category are growth parameters, which are used to predict growth rates and the body size of a fish when it reaches a certain event, such as size of recruitment to the fishery or size at first maturity (Pauly, 1982). In the second category are mortality parameters that reflect the rate at which fish die. The mortality rates include fishing mortality that accounts for death caused by fishing, and natural mortality, death due to all other causes such as predation, disease and old age. On the basis of these two categories of parameters, prediction about the abundance of fish populations is possible (Rothschild, 1986).

In the present study on the dynamics of Nile perch, Nile tilapia and *R. argentea* only length frequency data obtained from catches of the commercial gillnet fisheries were used to estimate the population parameters. Gillnetting is the main fishing method used to target the two species in Lake Victoria (Chapters Three & Four). Each of the two species is targeted by a unique mode(s) of operation of gillnets and/or type of boat (Chapter Four). For Nile perch, catches of bottom set passive gillnets and mid water set drift gillnets operated from paddled Sesse and motorized/sailed boats that targeted the species were used, but catches in parachute boats and all actively operated gillnets were excluded because these were targeting Nile tilapia. For Nile tilapia, catches of all parachute boats and paddled Sesse boats in which gillnets were operated actively were used, excluding catches of bottom set passive and drift gillnets operated in paddled Sesse and motorised/sailed boats that targeted Nile perch. Data from catches of other fishing gears (i.e. beach seine, hand line, long line, cast net and basket trap) were used together with those from gillnet catches in the predictive models to estimate total annual catches. The latter were excluded from the estimation of population parameters because, unlike gillnets, they were not encountered in all parts of the lake and their selectivity characteristics were not known. Data from gillnet catches were adjusted for selectivity, using selectivity factors from an independent study (Asila, 2001b); therefore the analysis of population growth parameters is based on adjusted data. In the case of *R. argentea*, length frequency data from all samples were used because all boats sampled used the same type of gear (5-mm mesh size mosquito seines), operated in the same manner as a boat seine (lampala).

This chapter provides knowledge on population characteristics and estimates of total annual catches of the three most important commercial fish species, Nile perch, Nile tilapia, and *R. argentea* in Ugandan part of Lake Victoria. This information will be used to suggest management options for the fisheries of the three major commercial species in Lake Victoria (Chapter Six). The methodologies followed in the analyses of population dynamics of the three major commercial fish species in Lake Victoria are presented earlier (Chapter Two: Section 2.4).

5.2 Population dynamics of Nile perch (*Lates niloticus*)

5.2.1 *Growth*

The estimated von Bertalanffy growth parameters, *L*∞ and *K*, described by growth curves superimposed on the restructured length frequency samples (Fig 5.1), were 221 cm TL and 0.17 year^{-1} respectively. The Munro's growth performance index (ϕ ') was estimated to be 3.9.

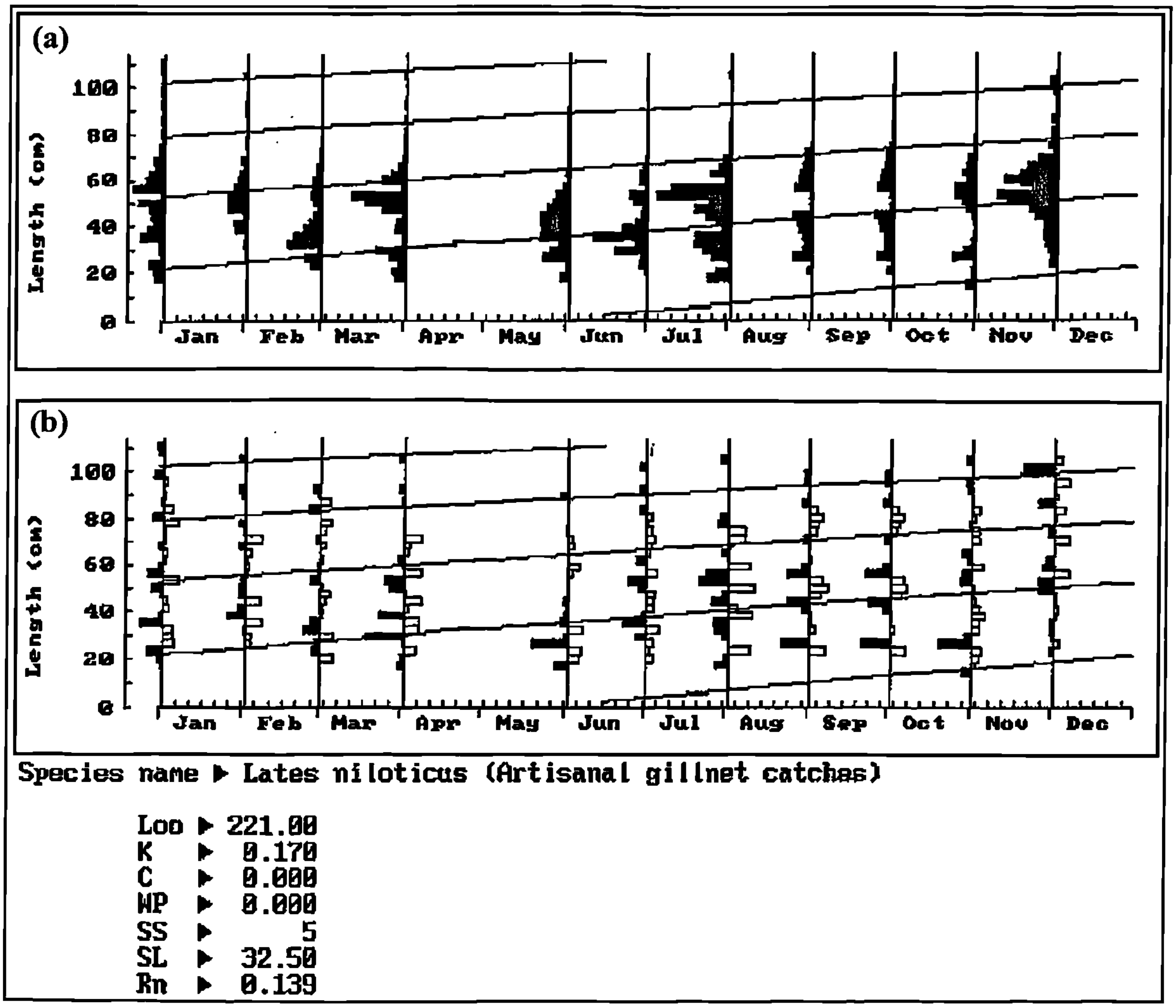


Figure 5.1 Growth curves fitted by ELEFAN I on the (a) observed and (b) restructured length distribution of Nile perch (*Lates niloticus* L.) in the Ugandan part of Lake Victoria, in 2000.

5.2.2 *Mortality and exploitation rate*

The total mortality (*Z*), estimated using the linearised length converted catch curve, was 2.18 yr^{-1}. The natural mortality (*M*), calculated using Pauly's empirical formula (Pauly, 1980), was 0.30 yr^{-1}, and the fishing mortality (*F*), the difference between *Z* and *M*, was

1.88 yr^{-1} (Fig. 5.2). The exploitation rate ($E = F/Z$) was thus estimated to be 0.86.

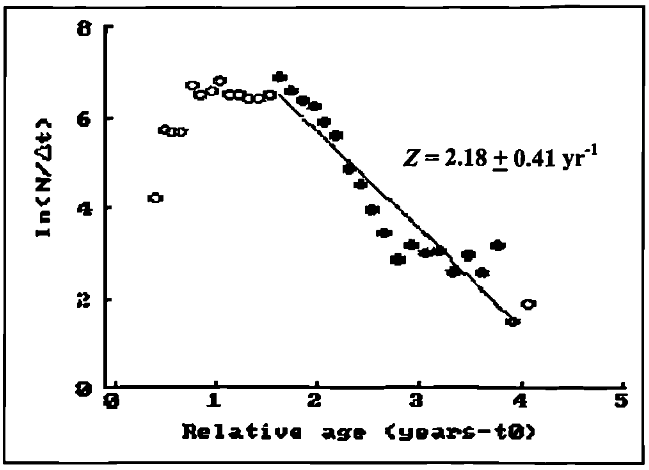


Figure 5.2 Linearised length converted catch curve analysis in FISAT to estimate total mortality (*Z*), from the length frequency distribution of Nile perch (*Lates niloticus* L.) in the Ugandan part of Lake Victoria, in 2000. The dark points were used for estimation of the catch curve parameters.

5.2.3 *The length at first capture (Lc)*

The probability of capture analysis estimated the length at first capture (L_c=L_{50}), the length at which 50% of Nile perch were vulnerable to the gillnet fishery, at 44.6 cm TL. The length at which 25% and 75% of Nile perch were vulnerable to the gillnet fishery, i.e. L_{25} and L_{75}, were estimated at 28.9 and 49.6 cm TL respectively (Fig.5.3).

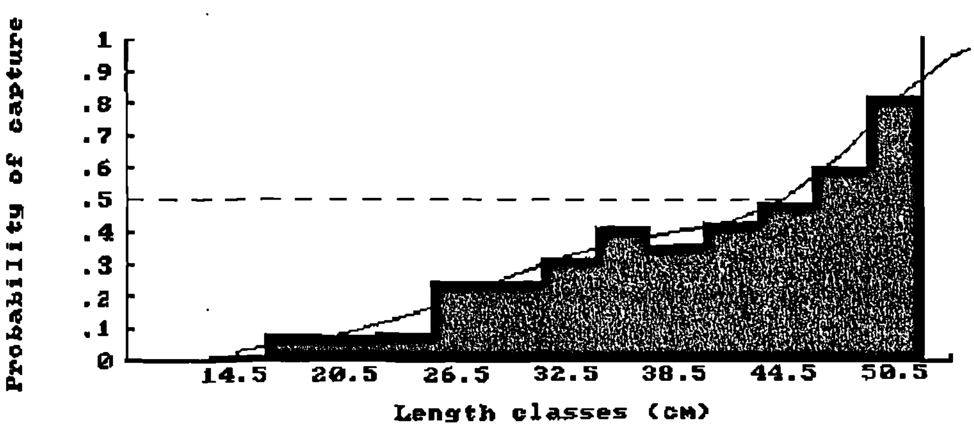


Figure 5.3 A plot of probability of capture against length classes to estimate length at first capture (Lc = L50) of Nile perch (*Lates niloticus* L.) of the gillnet fishery in the Ugandan part of Lake Victoria, in 2000. The curve of running averages is used for the estimates while the shaded bars show the length classes used.

5.2.4 *Recruitment pattern*

The FiSAT plot of the percentage recruitment of Nile perch into the fishery showed two pulses (Fig. 5.4). The weak recruitment pulse, representing about 20% of annual recruitment occurred in February and March whereas the major recruitment pulse (60%) was in July and August, extending into September. A similar recruitment pattern was implied by the quarterly size composition of Nile perch caught in the gillnet fishery (Chapter Four: section 4.2.4).

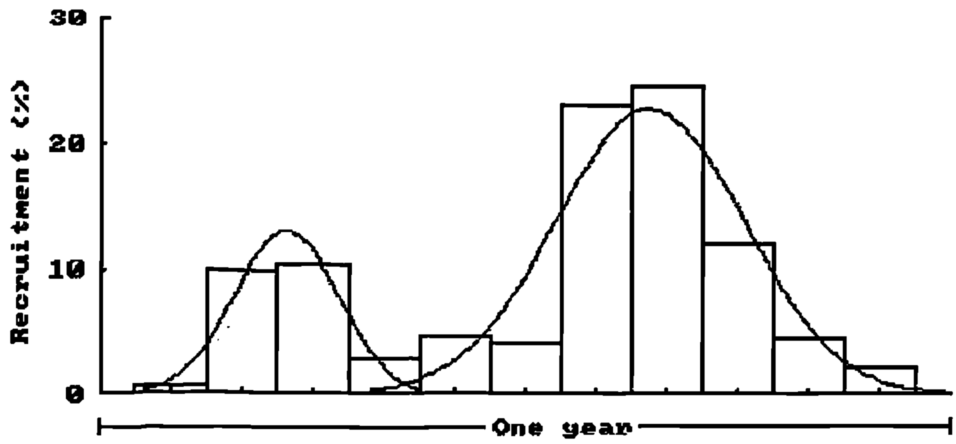


Figure 5.4 Monthly recruitment pattern (%) of Nile perch (*Lates niloticus* L.) into the gillnet fishery in Ugandan part of Lake Victoria in 2000.

5.2.5 *Length-weight relationships of Nile perch*

The values of the parameters describing the length weight relationships of Nile perch, *a* and *b*, that were later input into Virtual Population Analysis were estimated to be 0.010445 and 3.0369 respectively (Fig.5.5)

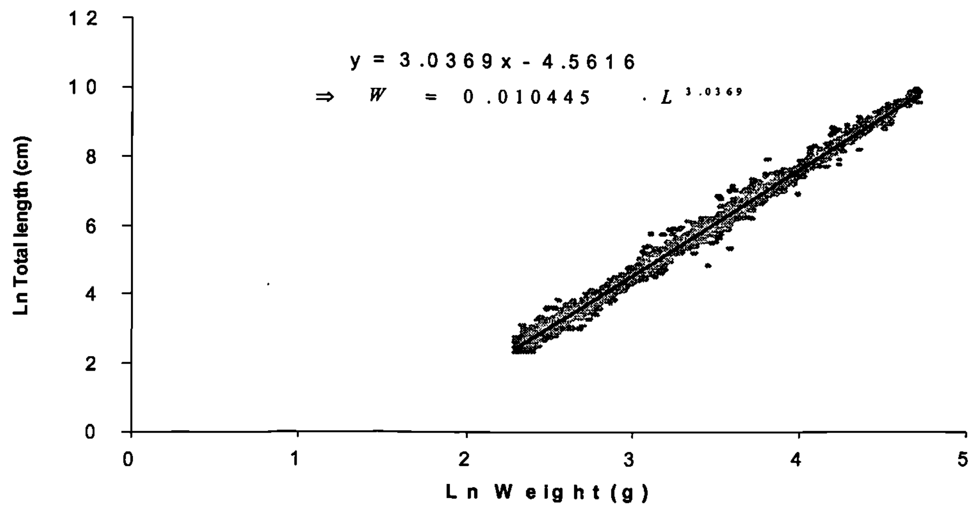


Figure 5.5 Linearised relationships between length and weight of Nile perch (*Lates niloticus* L.) in the Ugandan part of Lake Victoria in 2000.

5.2.6 *Virtual Population Analysis (VPA)*

The length-structured VPA analysis in FiSAT estimated fishing mortality, population size and annual catch for each length class. Catches of the four fishing gears used to target Nile perch, i.e. beach seines, gillnets, hand lines and long lines, were treated separately (Fig. 5.6; Table 5.1).

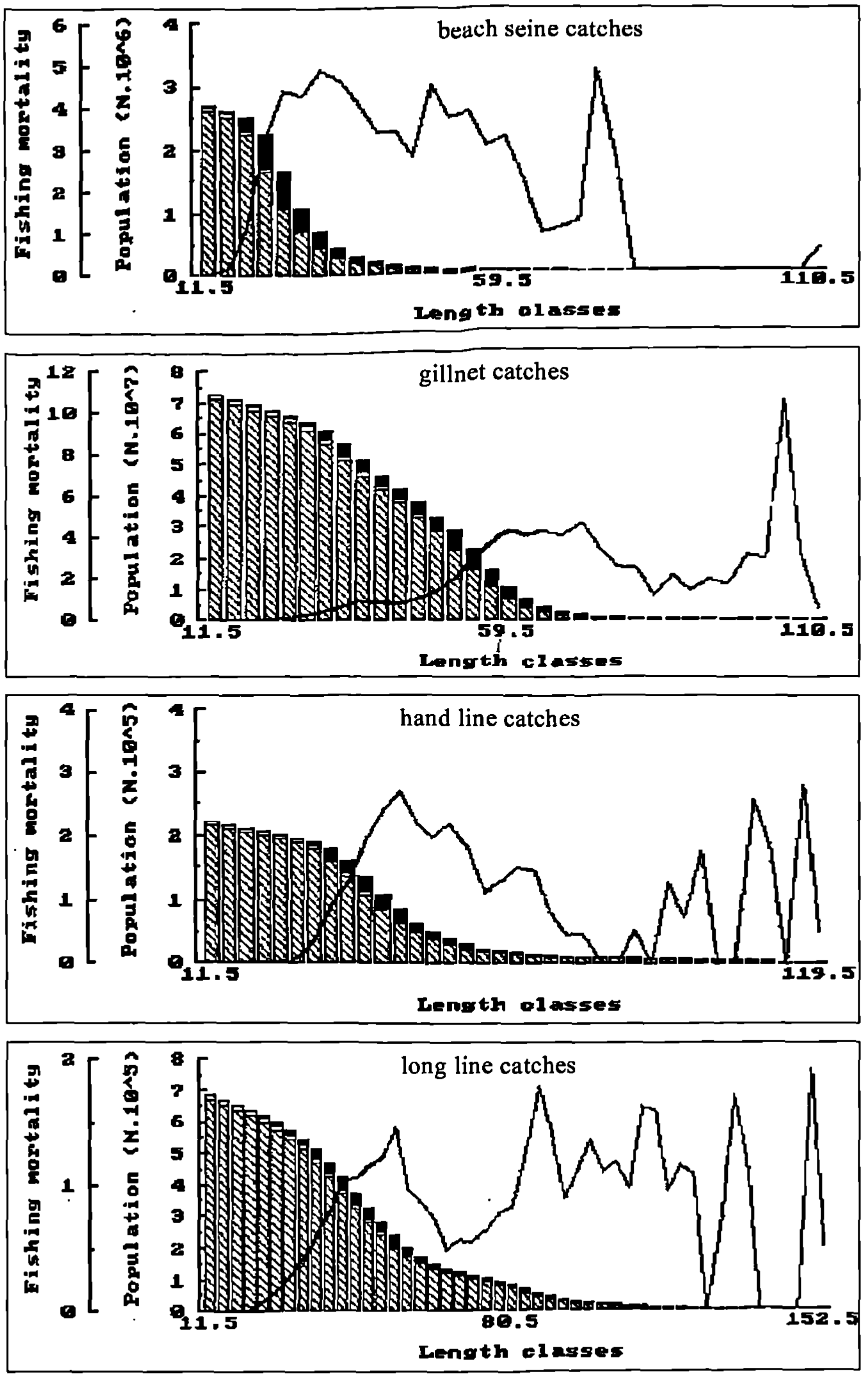


Figure 5.6 Output of Virtual Population Analysis showing distribution of fishing mortality (curve) and population (histogram) by length class for Nile perch (*Lates niloticus* L.) for the four fishing gears used to target the species in the Ugandan part of Lake Victoria in 2000. In the histograms the shaded parts represent the catch, bare parts the natural losses and the hatched parts the survivors.

The estimated mean fishing mortality was about three times higher for beach seines than in the other three gears and lowest in long lines. Beach seines attained peak fishing mortality of 4.9 year^{-1} at the smallest length class of 28 to 31 cm TL. The first peaks of fishing mortality for hand lines and long lines were estimated at 2.7 and 1.2 year^{-1} in the length classes 43 to 46 and 49 to 52 cm TL respectively. Fishing mortality gradually increased across length classes in gillnets and remained above 2.0 year^{-1} between 52 and 70 cm TL. The total annual catch of Nile perch estimated by VPA in the Uganda part of the lake for the year 2000 was 81,988.6 t (Table 5.1). This figure was 13% higher than catch assessment estimate of 72,632.2 t (see Chapter Four).

Table 5.1 The Virtual population analysis outputs for four fishing gears used to target Nile perch in the Ugandan part of Lake Victoria

Gear type	Mean *E*	Mean *F*	Catch (t)
Beach seine	0.868	1.977	621.37
Gillnets	0.698	0.694	79867.90
Hand line	0.703	0.711	244.75
Long line	0.628	0.507	1254.64
TOTAL			81988.66

5.2.7 *Exploitation level (E) and relative yield per recruit (Y'/R)*

The E_{max}, $E_{0.1}$ and $E_{0.5}$ values estimated by the relative yield per recruit analysis were 0.45, 0.42 and 0.27 respectively (Fig. 5.7).

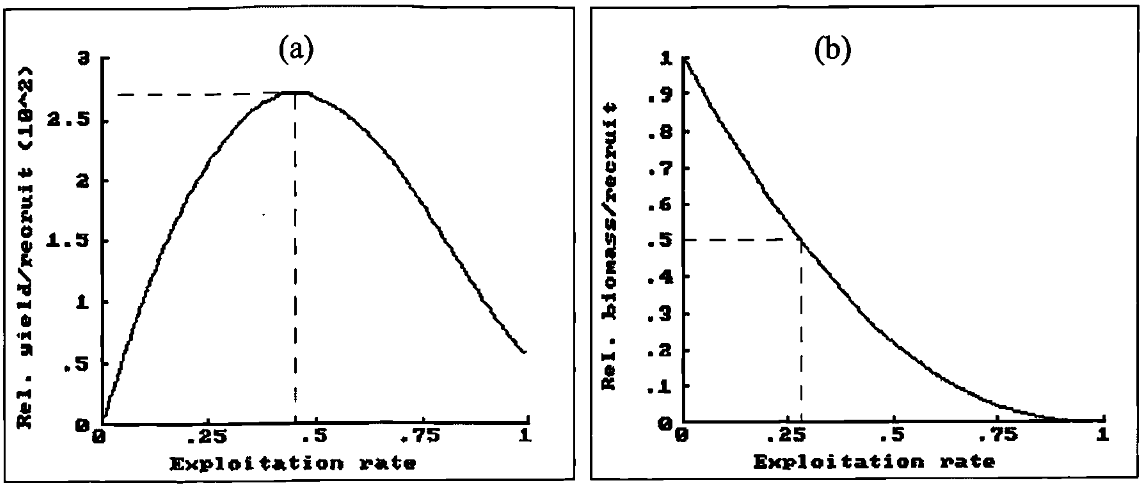


Figure 5.7 Relationship of (a) relative yield-per-recruit (Y'/R) and (b) relative-biomass-per recruit (B'/R) to exploitation rate, for Nile perch (*Lates niloticus* L.) in the Ugandan part of Lake Victoria.

The exploitation rate (E = 0.86) was about two times higher than the maximum acceptable limit (E_{max} = 0.45), the exploitation level that would maximise relative yield per recruit Y'/R, and the biological optimum ($E_{0.1}$ = 0.42). This observation would suggest that the Nile perch population in the Uganda waters of Lake Victoria is being heavily overexploited.

5.2.8 *Thompson and Bell analysis*

The yield, value and biomass corresponding to a series of f-factors were predicted for the Nile perch fishery (Fig. 5.8).

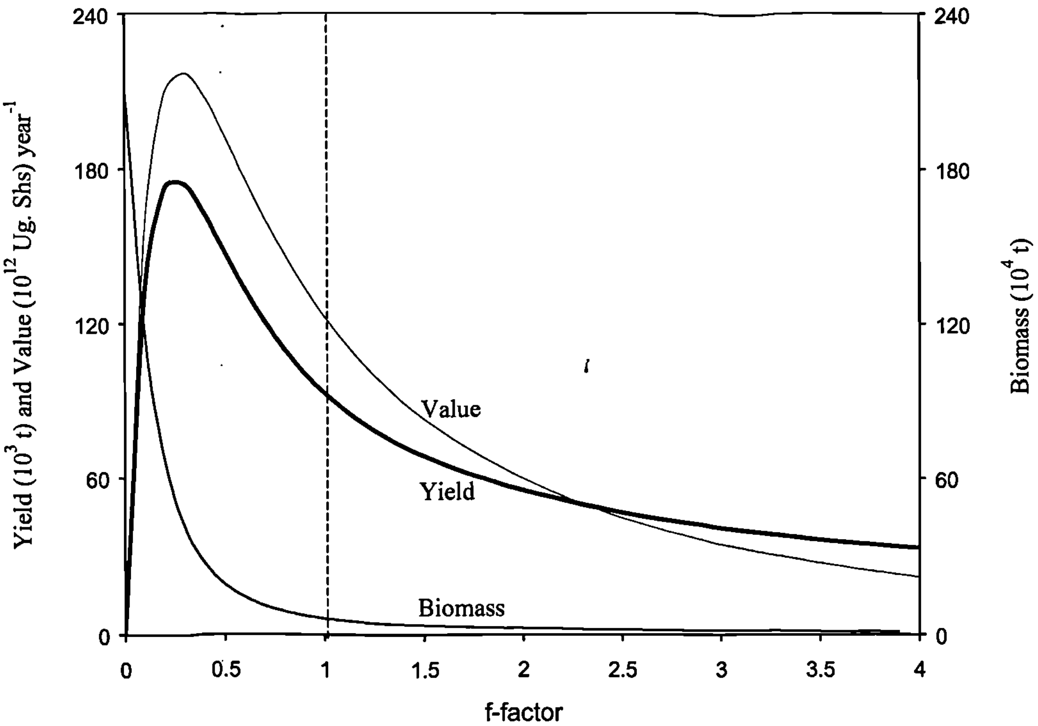


Figure 5.8 The Thompson and Bell output curves for Nile perch (*Lates niloticus* L.) in the Ugandan part of Lake Victoria.

Using 1 as the present f-factor for the fishery:

(i) to achieve the maximum yield, the present f-factor should be reduced to 0.3, a reduction of fishing effort by 70%;

(ii) to obtain maximum value, the present f-factor should also be reduced to 0.3, a reduction of 70%; and

(iii) to attain optimum biomass, the present f-factor should be reduced to 0.2, a reduction of fishing effort by 80%.

The results of this analysis suggest that the present fishing effort for Nile perch exceed the management targets by a very big margin indicating heavy over-fishing.

5.3 Population dynamics of Nile tilapia (*Oreochromis niloticus*)

5.3.1 *Growth*

The estimated von Bertalanffy growth parameters of Nile tilapia, *L∞* and *K*, described by growth curves superimposed on the restructured length frequency samples (Fig 5.9), were 67 cm TL and 0.38 year^{-1} respectively. The Munro's growth performance index (ϕ ') was estimated to be 3.2.

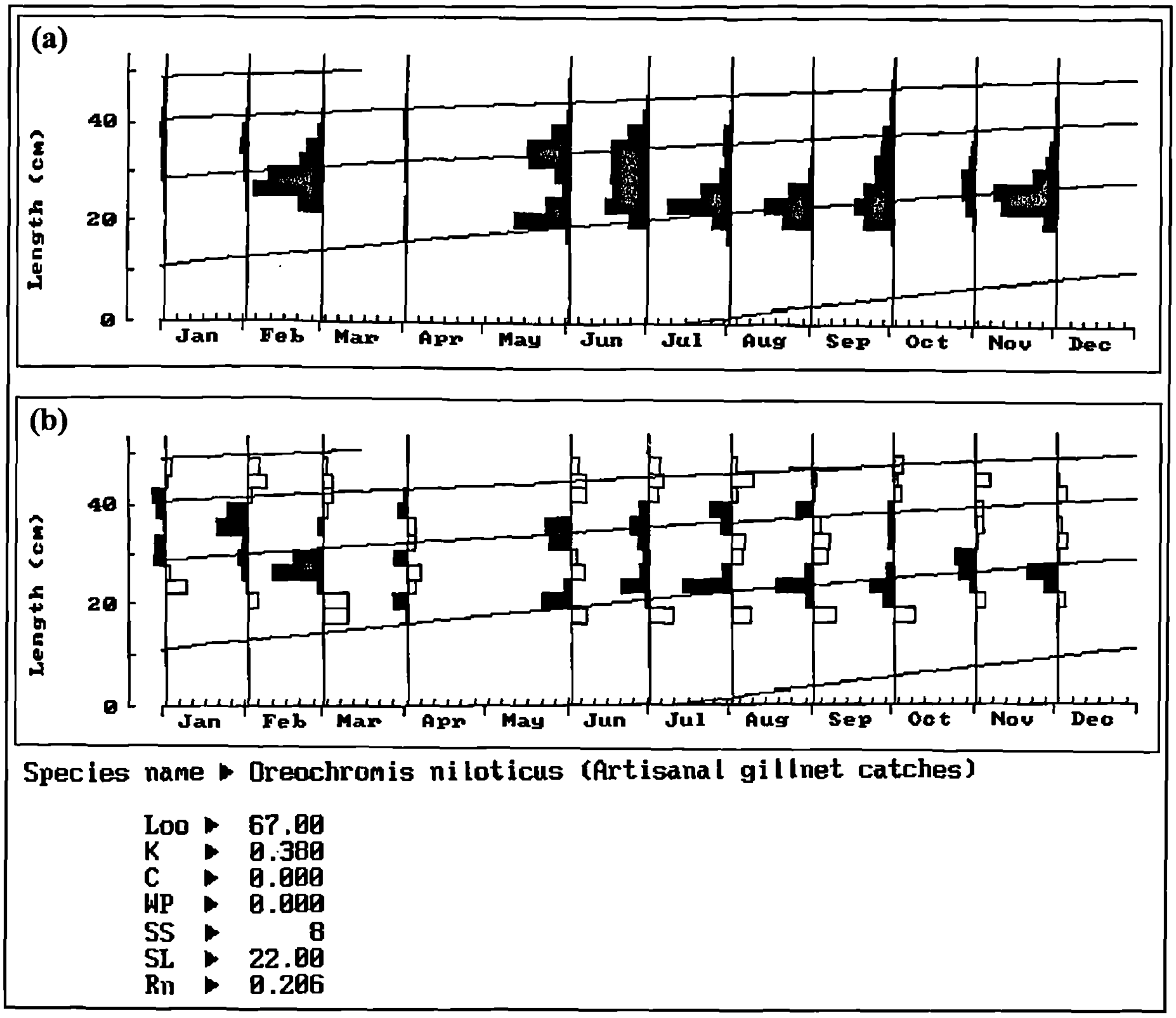


Figure 5.9 Growth curves fitted by ELEFAN I on the (a) observed and (b) restructured length distribution of Nile tilapia (*Oreochromis niloticus* L.) in the Ugandan part of Lake Victoria, in 2000.

5.3.2 *Mortality and exploitation rate*

The total mortality (*Z*), estimated using the linearised length converted catch curve, was 1.84 yr^{-1}. The natural mortality (*M*), calculated using Pauly's empirical formula (Pauly, 1980), was 0.72 yr^{-1}, and the fishing mortality (*F*), the difference between *Z* and *M*, was

1.12 yr^{-1} (Fig. 5.10). The exploitation rate ($E = F/Z$) was thus estimated to be 0.61.

5.3.3 *The length of first capture (Lc)*

The probability of capture analysis estimated the length at first capture (L_c=L_{50}), the length at which 50% of Nile tilapia were vulnerable to the gillnet fishery, at 22.0 cm TL. The length at which 25% and 75% of Nile tilapia were vulnerable to the gillnet fishery, i.e. L_{25} and L_{75}, were estimated at 19.4 and 24.7 cm TL respectively (Fig. 5.11).

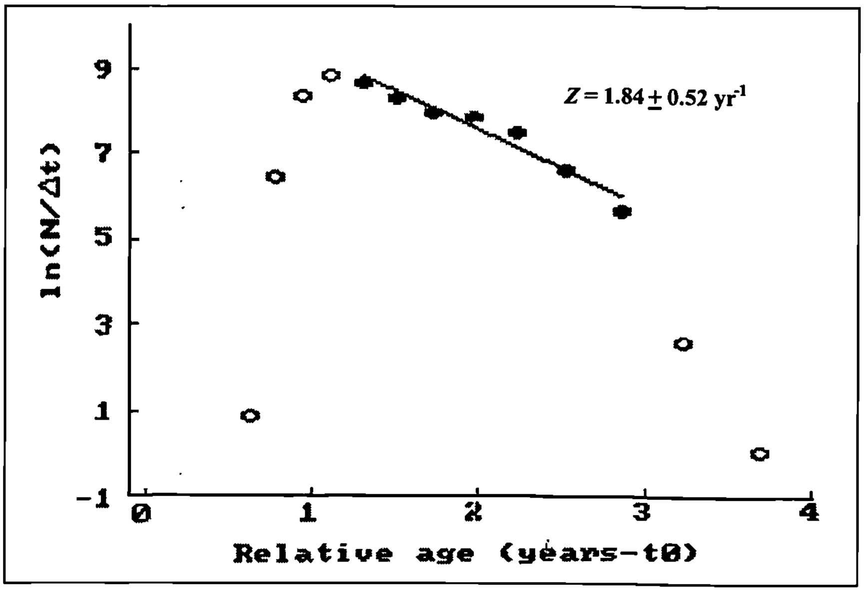


Figure 5.10 Linearised length converted catch curve analysis in FiSAT to estimate total mortality *Z*, from the length frequency distribution of Nile tilapia (*Oreochromis niloticus* L.) in the Ugandan part of Lake Victoria, in 2000. The dark points were used for the estimation of the catch curve parameters.

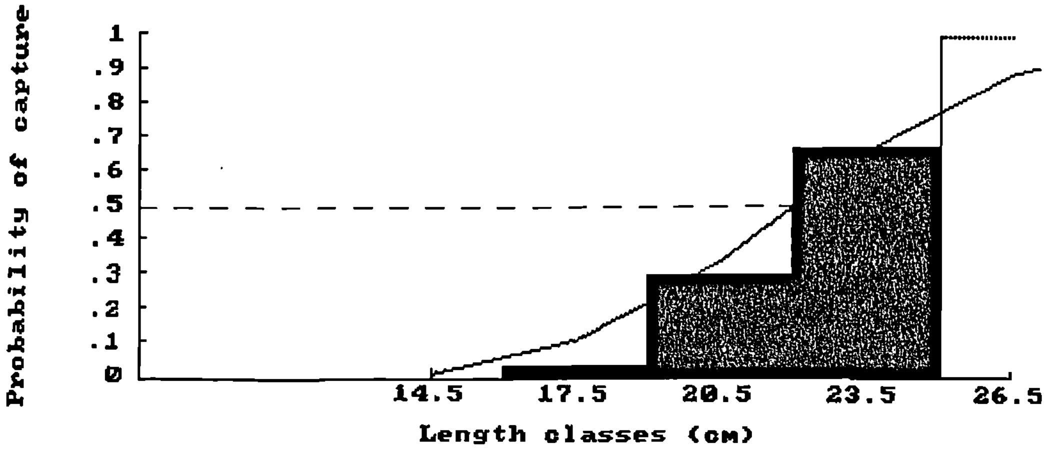


Figure 5.11 A plot of probability of capture against length classes to estimate length at first capture (Lc = L_{50}) of Nile tilapia (*Oreochromis niloticus* L.) in the Ugandan part of Lake Victoria, year 2000. The curve of running averages is used for the estimates while the shaded bars show the length classes used.

5.3.4 *Recruitment pattern*

The FiSAT plot of the percentage recruitment of Nile tilapia into the fishery showed more or less continuous recruitment from January to October with a peak (62%) in May to August (Fig. 5.12).

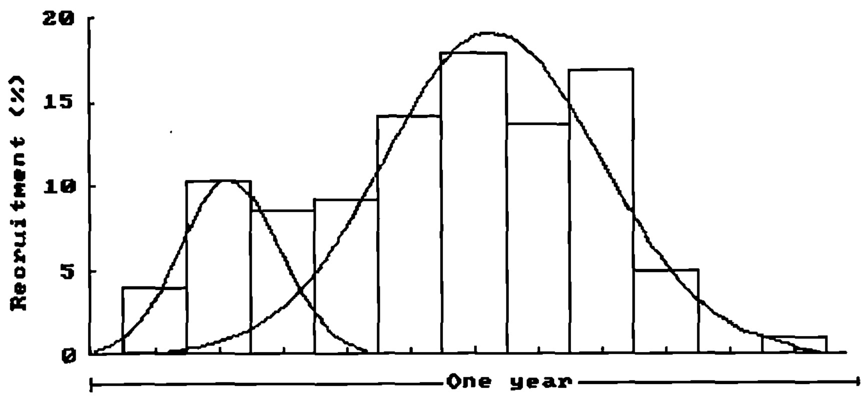


Figure 5.12 Monthly recruitment pattern (%) of Nile tilapia (*Oreochromis niloticus* L.) into the gillnet fishery in Ugandan part of Lake Victoria, in 2000.

5.3.5 *Length – weight relationships of Nile tilapia*

The values of the parameters describing the length-weight relationships of Nile tilapia, *a* and *b*, that were later input into Virtual Population Analysis were estimated to be 0.014763 and 3.108 respectively (Fig.5.13).

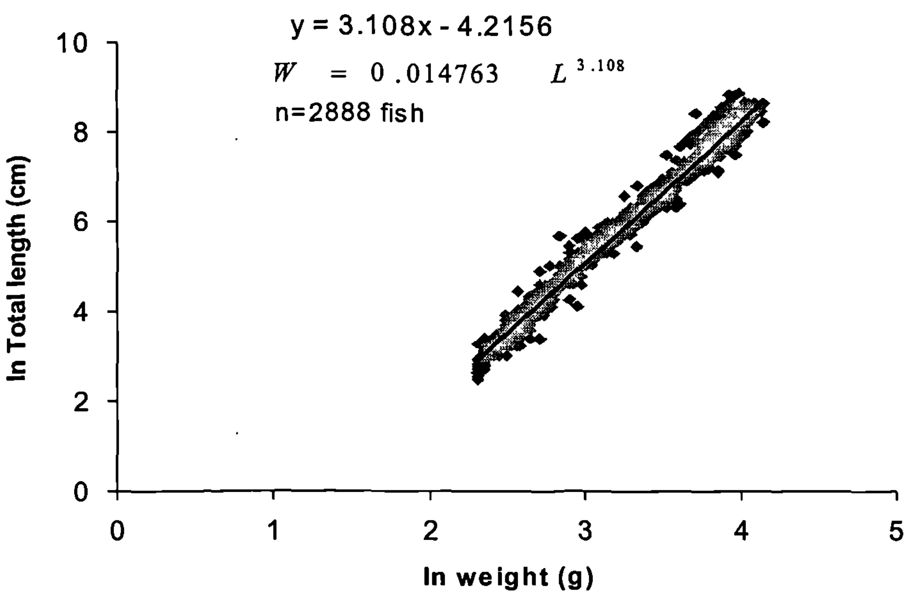


Figure 5.13 Linearised relationships between total length and weight of Nile tilapia (*Oreochromis niloticus* L) in the Ugandan part of Lake Victoria in 2000.

5.3.6 *Virtual Population Analysis (VPA)*

The length-structured VPA analysis in FiSAT estimated fishing mortality; population size and annual catch by length class. Catches of the four fishing gears used to target Nile tilapia, i.e. gillnets, cast nets, basket traps and beach seines were treated separately (Fig. 5.14; Table 5.2).

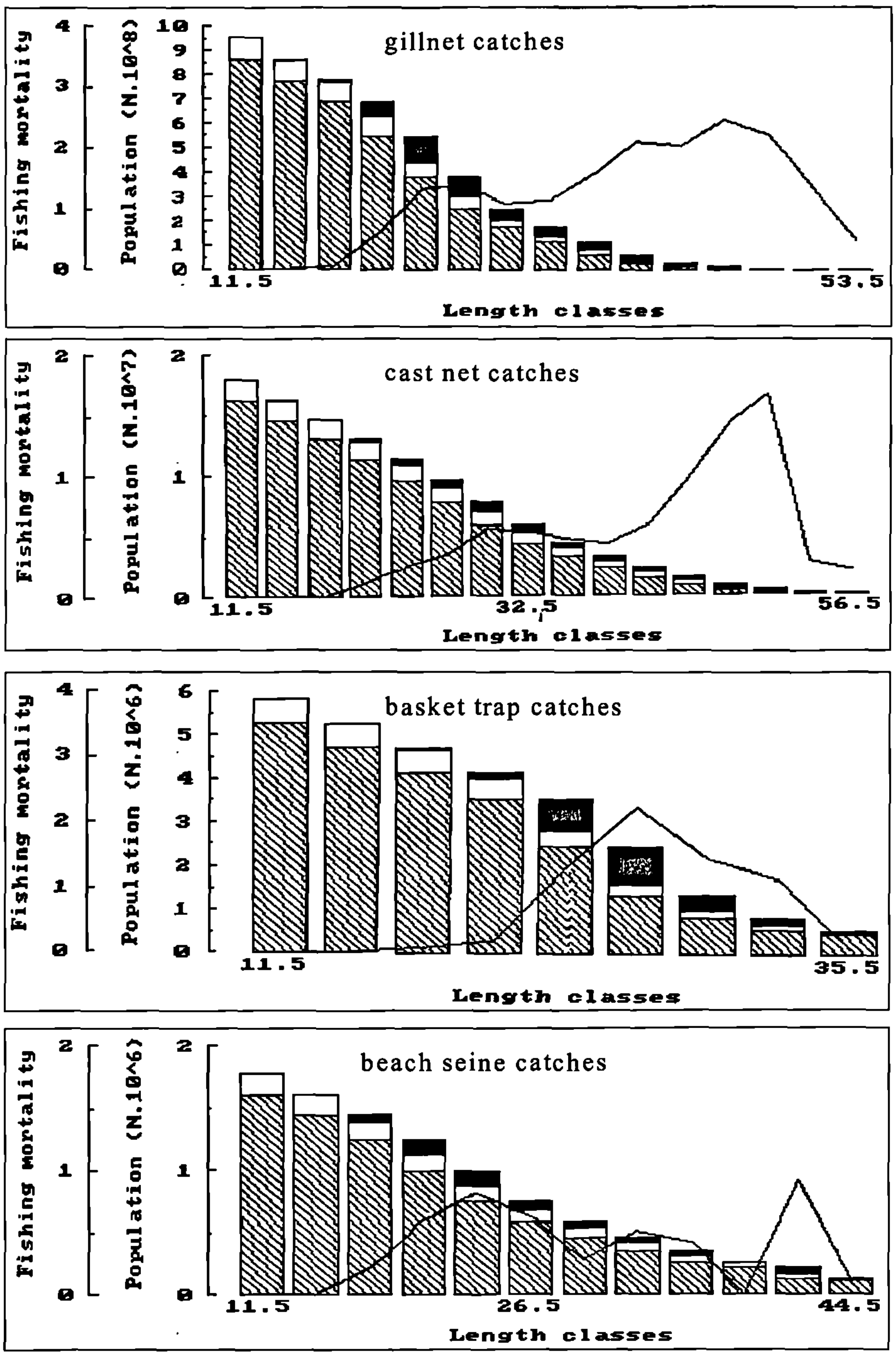


Figure 5.14 Output of Virtual Population Analysis showing distribution of fishing mortality (curve) and population (histogram) by length class for Nile tilapia (*Oreochromis niloticus* L.) for the four fishing gears used to target Nile tilapia in the Ugandan part of Lake Victoria. In the histograms the shaded parts represent the catch, bare parts the natural losses and the hatched parts the survivors.

The estimated mean fishing mortality of tilapia was highest in gillnets at 0.576 yr^{-1} and lowest in cast nets at 0.26 yr^{-1}. The total annual catch of Nile tilapia estimated by VPA in the Uganda part of the lake for year 2000 was 29278.34 t (Table 5.2). This figure was 2% less than catch assessment estimate of 29959.4 t (see Chapter 4).

Table 5.2 The Virtual population analysis outputs for four fishing gears used to target Nile tilapia in the Ugandan part of Lake Victoria

Gear type	Mean E	Mean F	Catch (t)
Gillnets	0.444	0.576	23165.36
Cast nets	0.265	0.260	4892.36
Basket trap	0.398	0.476	939.20
Beach seine	0.306	0.317	281.42
Total catch			**29278.34**

5.3.7 *Exploitation level (E) and relative yield per recruit (Y'/R)*

The E_{max}, $E_{0.1}$ and $E_{0.5}$ values estimated by the relative yield per recruit analysis were 0.56, 0.52 and 0.31 respectively (Fig. 5.15). The exploitation rate (E = 0.61) was slightly higher than the maximum acceptable limit (E_{max} = 0.56) and the biological optimum ($E_{0.1}$ = 0.52), suggesting that the Nile tilapia population in the Uganda waters of Lake Victoria is slightly overexploited compared with Nile perch.

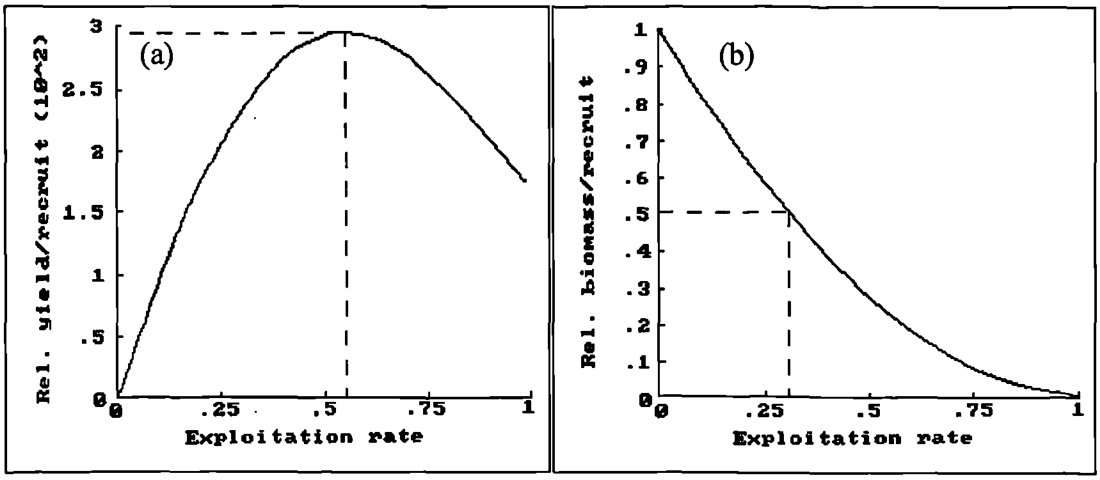


Figure 5.15 Relationship of (a) relative yield-per-recruit (Y'/R) and (b) relative-biomass-per recruit (B'/R) to exploitation rate, for Nile tilapia (*Oreochromis niloticus* L.) in the Ugandan part of Lake Victoria.

5.3.8 *Thompson and Bell analysis*

The yield, value and biomass corresponding to a series of f-factors were predicted for the Nile tilapia fishery (Fig. 5.16). Using 1 as the present f-factor for the fishery:

(i) to achieve the maximum yield, the present f-factor should be reduced to 0.6, a reduction of fishing effort by 40%;

(ii) to obtain maximum value, the present f-factor should be reduced to 0.5, a reduction of 50%; and

(iii) to attain optimum biomass, the present f-factor should be reduced to 0.3, a reduction of fishing effort by 70%.

The results of this analysis suggest that the present fishing effort for Nile tilapia is higher than management targets indicating over-fishing.

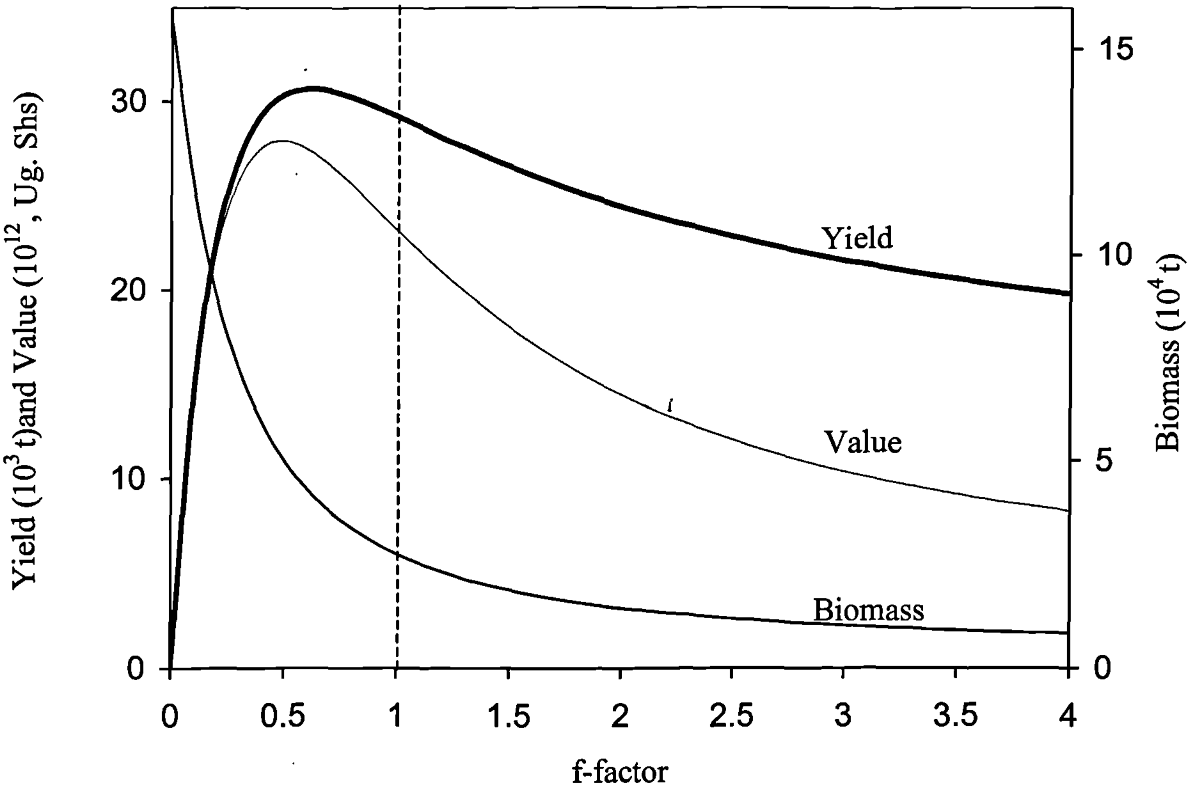


Figure 5.16 The Thompson and Bell output curves for Nile tilapia (*Oreochromis niloticus* L.) in the Ugandan part of Lake Victoria.

5.4 Population dynamics of *Rastrineobola argentea*

5.4.1 *Growth*

The estimated von Bertalanffy growth parameters of *R. argentea*, *L∞* and *K*, described by growth curves superimposed on the restructured length frequency samples (Fig 5.17), were 69 mm SL and 0.99 year^{-1} respectively. The Munro's growth performance index (ϕ ') was estimated to be 3.67.

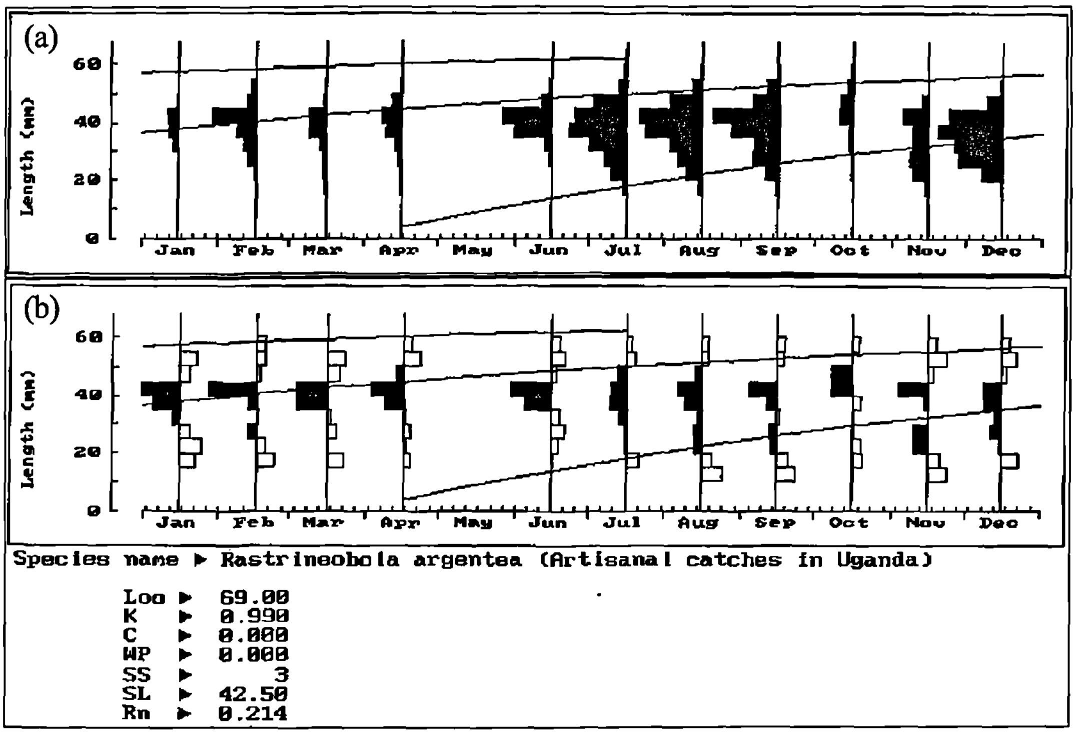


Figure 5.17 Growth curves fitted by ELEFAN I on the (a) observed and (b) restructured length distribution of Mukene (*Rastrineobola argentea*) in the Ugandan part of Lake Victoria, in 2000.

5.4.2 *Mortality and exploitation rate*

The total mortality (*Z*), estimated using the linearised length converted catch curve, was 5.40 yr^{-1}. The natural mortality (*M*), calculated using Pauly's empirical formula (Pauly, 1980), was 1.33 yr^{-1}, and the fishing mortality (*F*), the difference between *Z* and *M*, was 4.07 yr^{-1} (Fig. 5.2). The exploitation rate ($E = F/Z$) was thus estimated to be 0.75.

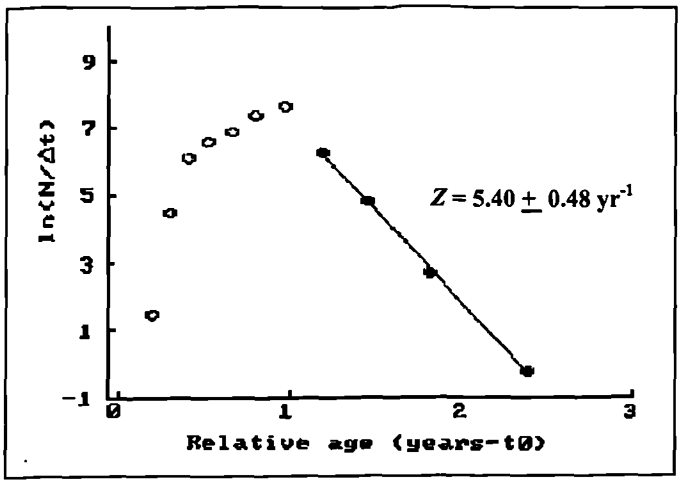


Figure 5.18 Linearised length converted catch curve analysis in FiSAT to estimate total mortality *Z*, from the length frequency distribution of Mukene (*Rastrineobola argentea*) in the Ugandan part of Lake Victoria, in 2000. The dark points were used for the estimation of the catch curve parameters.

5.4.3 *The length of first capture (Lc)*

The probability of capture analysis estimated the length at first capture ($L_c=L_{50}$), the length at which 50% of *R. argentea* were vulnerable to the 5 mm mesh size mosquito seines, at 37.5 mm SL. The length at which 25% and 75% of *R. argentea* were vulnerable to the mosquito seine fishery, i.e. L_{25} and L_{75}, were estimated at 33.6 and 41.8 mm SL respectively (Fig. 5.19).

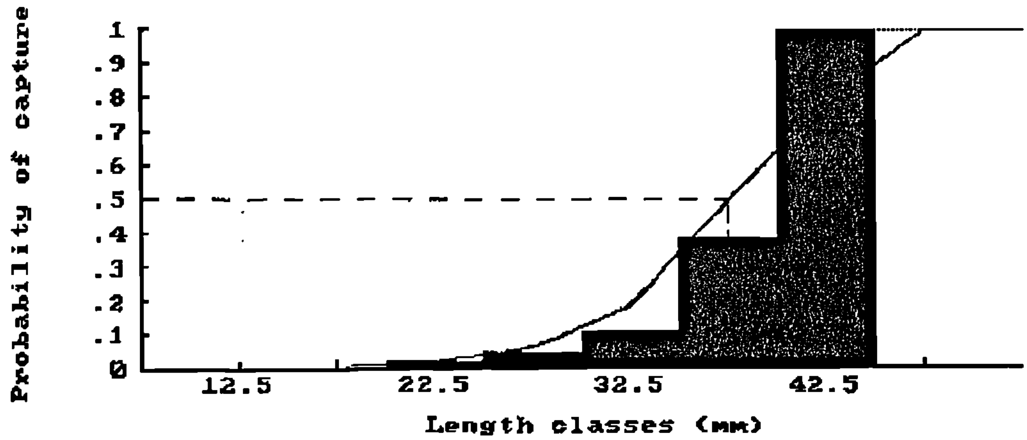


Figure 5.19 A plot of probability of capture against length classes to estimate length at first capture (Lc = L_{50}) of Mukene (*Rastrineobola argentea*) in the Ugandan part of Lake Victoria, year 2000. The curve of running averages is used for the estimates while the shaded bars show the length classes used.

5.4.4 *Recruitment pattern*

The FiSAT plot of the percentage recruitment of young *R. argentea* into the fishery showed one annual recruitment peak (89.6%) in July to September, 42.1% of which was in August (Fig. 5.20).

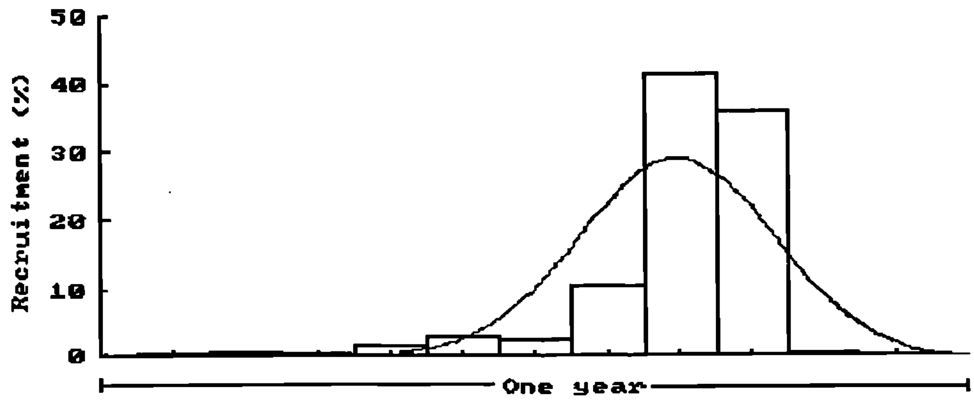


Figure 5.20 Monthly recruitment pattern (%) of *R. argentea* into the mosquito seine fishery in the Ugandan part of Lake Victoria, in 2000.

5.4.5 *Exploitation level (E) and relative yield per recruit (Y'/R)*

The E_{max}, $E_{0.1}$ and $E_{0.5}$ values estimated by the relative yield per recruit analysis were 0.747, 0.706 and 0.374 respectively (Fig. 5.21). The exploitation rate $E = 0.75$ was approximately the same as the maximum acceptable limit ($E_{max} = 0.747$) and slightly higher than the biological optimum ($E_{0.1} = 0.706$), suggesting that the *R. argentea* population in the Ugandan waters of Lake Victoria is being exploited around the maximum sustainable yield.

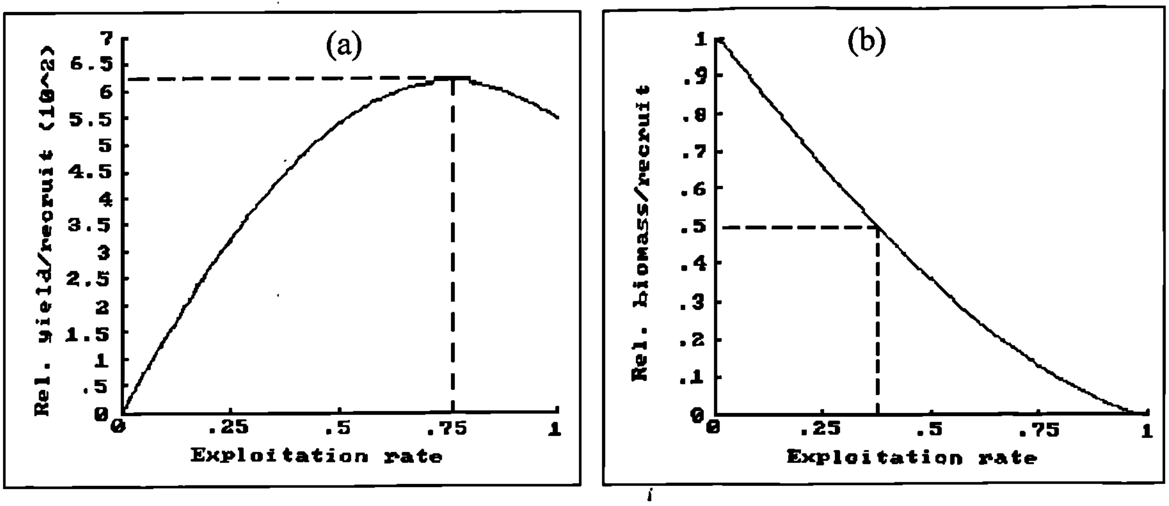


Figure 5.21 Relationship of (a) relative yield-per-recruit (Y'/R) and (b) relative-biomass-per recruit (B'/R) to the exploitation rate, for *Rastrineobola argentea* in the Ugandan part of Lake Victoria.

5.5 Discussion

5.5.1 *Mitigation of sampling biases for the estimation of population parameters*

Amongst the sampling biases, possibly the most important is the size selectivity of fishing gears, especially gillnets, which are the dominant commercial fishing gear for both Nile perch and Nile tilapia in Lake Victoria. To minimise the selectivity bias, the length frequency data were adjusted for gillnet selectivity (Gayanilo & Pauly, 1997) using selectivity factors determined in an independent study (Asila, 2001b). Also, only data from gillnet catches were used for estimation of population growth parameters because the selectivity characteristics of other fishing gears were not known.

5.5.2 *Growth, mortality and exploitation rate of Nile perch*

Growth

The growth parameters of Nile perch in Lake Victoria, based on length-frequency data, were first estimated for the Ugandan waters from data collected in the period 1964-77, during its colonisation of the lake and expansion after its introduction around 1960 (Acere, 1985). Subsequent estimates of its growth parameters were made from data collected from the Nyanza Gulf of the Kenyan waters in 1978-84 (Asila & Ogari, 1988) and the Speke Gulf of the Tanzanian waters in 1987-88 (Ligtvoet & Mkumbo, 1990), during the establishment and subsequent boom of its fishery in the lake (Table 5.3).

Table 5.3 von Bertalanffy growth parameters (L_∞, K) of Nile perch during the periods of colonisation, establishment and boom of its fishery in Lake Victoria

L_∞ (cm)	K (year^{-1})	Area	Period	Source
251	0.09	Uganda waters	1964-77	Acere (1985)
205	0.19	Nyanza Gulf (Kenya)	1978-84	Asila & Ogari (1988)
185	0.17	Speke Gulf (Tanzania)	1987-88	Ligtvoet & Mkumbo (1990)

Recently, growth and mortality parameters of Nile perch in Lake Victoria were estimated under the Lake Victoria Fisheries Research project (LVFRP), lake wide stock assessment exercise using length frequency data from bottom trawl surveys. The estimates of LVFRP in the three countries sharing the lake (unpublished data) and those of this study are compared in Table 5.4.

Table 5.4 Comparison of growth, and mortality parameters of Nile perch in lake Victoria obtained in this study and those estimated from recent bottom trawl survey data by LVFRP

	L_∞ (cm TL)	K (year^{-1})	Z (year^{-1})	M (year^{-1})	F (year^{-1})	E
LVFRP data: 1998-00, Kenya (UNECIA, 2002)	204	0.21	1.78	0.36	1.42	0.80
LVFRP data: 1998-00, Tanzania (UNECIA, 2002)	216	0.19	2.29	0.33	1.96	0.86
LVFRP data: 1998-00, Uganda (UNECIA 2002)	256	0.29	1.59	0.42	1.17	0.73
This study (Uganda, 2000)	221	0.17	2.18	0.30	1.88	0.86

The von Bertalanffy growth parameters estimated by this study were comparable to the LVFRP values in Kenyan and Tanzanian waters but differed substantially from those in the Ugandan waters. The Munro's growth performance index (ø'), which indicates if the new pair of L_∞ and K is in accordance with previous results (Pauly & Munro, 1984), was uniform for this study and the LVFRP estimates in Kenyan and Tanzanian waters at 3.9 but higher for the LVFRP estimates in Ugandan waters at 4.3. In the earlier estimates of Nile perch growth parameters (Acere, 1985; Asila & Ogari, 1988; Ligtvoet & Mkumbo, 1990), the value of ø' was between 3.8 and 3.9. Therefore, the LVFRP estimates of growth parameters of Nile perch in the Ugandan waters of Lake Victoria appear to have been biased, probably by a few large fish in the catches and dominance of huge numbers of small fish <12 cm TL in the trawl catches.

The K value of 0.17 $year^{-1}$ estimated by this study is similar to the estimates in the 1980s (Asila & Ogari, 1988; Ligtvoet & Mkumbo, 1990) but substantially higher than the K value of 0.09 $year^{-1}$ estimated by Acere (1985) for the Ugandan part of the lake. This would suggest increase in the growth rate of Nile perch in the Ugandan waters. However, the estimates of Acere (1985) appear to be associated with two possible sources of bias: (i) length-frequency data used were obtained from a multiplicity of fishing gears (commercial gillnets, beach seines, long lines and bottom trawl) but there is no evidence that the selectivity characteristics of these gears were accounted for before pooling data for analysis; and (ii) it appears length frequency data collected between 1964 and 1967 were pooled without taking into account the time of the year fish were captured, thus invalidating the analysis, a concern also raised by Hughes (1992). On the other hand, the earliest estimates of growth parameters in the Kenyan and Tanzanian parts of the lake (Asila & Ogari, 1988; Ligtvoet & Mkumbo, 1990) were based on length frequency data obtained from catches of basically non-selective bottom trawls and large beach seines respectively, and were probably more reliable. The K value of 0.17 $year^{-1}$ estimated by this study is much lower the value of 0.29 $year^{-1}$ from analyses of bottom trawls survey data in the Ugandan waters in 1998 - 2000 (LVFRP data, UNECIA, 2002). On the basis of these results, therefore, there is no firm evidence of any substantial change in the growth rate of Nile perch in Lake Victoria since the 1980s. In accordance with the life-history patterns of fishes (Wootton, 1990), however, the tremendous increase of fishing effort over the years would be expected to induce faster growth in the Nile perch population of Lake Victoria.

Mortality and exploitation rate

In Nile perch of Lake Victoria the natural mortality was low (M = 0.30 $year^{-1}$) but fishing mortality (F = 1.88 $year^{-1}$) seemed to be high, and inappropriate to the life history strategy of the species. This was reflected in the high exploitation rate (E = 0.86) and in the output from the Beverton & Holt (1966), yield-per-recruit model, which indicated that the Nile perch stocks are being heavily over fished. The mortality estimates of this study were comparable to the LVFRP estimates in the Tanzanian part of the lake but lower than those in the Kenyan and Ugandan parts of the Lake (Table 5.4). It should however be noted that these estimates of exploitation rates were made by different individuals, in Kenya, Tanzania and Uganda, using Stock Assessment tools in FiSAT which are very subjective. The choice of the von Bertalanffy growth parameters, (K & $L\infty$) used in the analysis by different individuals can therefore lead to differences in the estimates of exploitation rates. The differences in the value of E (Table 5.4), therefore, do not necessarily confirm higher exploitation in Tanzania and Uganda than in Kenya which would contradict the expectations based on the distribution of fishing effort (Chapter Three). Notwithstanding the differences between the recent estimates of fishing mortality in the region, they all indicated that Nile perch stocks are overexploited and probably not capable of sustaining the present fishing effort. The yield per recruit analysis suggests the fishing effort should be reduced by at least 50% to achieve optimal yield and profit from the Nile perch fishery.

A substantial reduction of fishing effort in the artisanal and subsistence multi-species fishery of Lake Victoria is impractical from the socio-economic and political point of view. However, a lot can be achieved by implementing measures that would increase the length at first capture through mesh size regulations and enforcement of the ban on use of destructive fishing gears and methods. The length-structured VPA demonstrated that the continued illegal use of beach seines that target small length classes of Nile perch was contributing immensely to the overall fishing mortality. Similarly, the length at first capture of Nile perch in the gillnet fishery (Lc_{50} = 44.6 cm TL) was very low due to the rampant use of undersized illegal gillnet mesh sizes. The capture of small fish damages the reproductive potential of the species, and reduces the fishery yield, and profit. Increasing size at first capture to at least 55 cm TL to correspond with the size at first maturity of males through fishing gear regulations could achieve substantial reduction in fishing mortality and boost the reproductive potential of Nile perch. However, to ensure good recruitment, some protection should be afforded to females, but making the size at first capture close to 75 cm TL would be unrealistic as discussed in Chapter Four. Consequently, alternative methods of regulating the fishery are required.

5.5.3 *Growth, mortality and exploitation rate of Nile tilapia*

Growth

Nile tilapia shows great variation in growth rates, maturation sizes, and relative maturation and final sizes of males and females according to the habitat conditions (Lowe-McConnell, 1987). Data compiled in Fishbase indicate that under pond, tank or cage culture conditions, Nile tilapia attains very high growth rates; the value of *K* often exceeding 2.0 $year^{-1}$, but their growth rate is generally low in lake conditions. The growth rate of Nile tilapia estimated in this study (K= 0.38 $year^{-1}$) is consistent with the values reported for the species in the literature for Lake Victoria and some other African lakes (Table 5.5).

Table 5.5 Growth parameters estimated for Nile tilapia in Lake Victoria and several other lakes in Africa

Lake	$L\infty$ (cm TL)	K (year-1)	ϕ'	Author
Lake Kainji	70.4	0.45	3.11	Kapetsky & Petr (1984)
Lake Nasser	58	0.55	3.07	Kapetsky & Petr (1984)
Lake Chard	45.5	0.31	2.81	Merona *et al.* (1988)
Lake Albert	48	0.50	2.98	Merona *et al.* (1988)
Lake George	40	0.24	2.58	Palomares (1991)
Lake Turkana	59.5	0.325	2.87	Rabuor *et al.* (1998)
Lake Victoria	64.6	0.254	3.025	Getabu (1992)
Lake Victoria	70	0.27	2.92	Moreau *et al.* (1995)
Lake Victoria	61.3	0.35	3.12	Dache (1995)

However, both the results of this study and the recent estimates by LVFRP data (UNECIA, 2002) indicate that Nile tilapia in Lake Victoria has a faster growth rate than recorded before (Table 5.6). This increase in growth rate is probably a sign of overfishing.

Table 5.6 Growth, and mortality parameters of Nile tilapia in Lake Victoria obtained in this study and the recent estimates from bottom trawl survey data by LVFRP

	L_∞ (cm TL)	K (year^{-1})	Z (year^{-1})	M (year^{-1})	F (year^{-1})	E
LVFRP data: 1998-00, Kenya (UNECIA, 2002)	58.8	0.59	1.92	0.80	1.12	0.58
LVFRP data: 1998-00, Tanzania*	--	--	--	--	--	--
LVFRP data: 1998-00, Uganda (UNECIA, 2002)	75	0.40	1.67	0.72	0.95	0.57
This study (Uganda, 2000)	67	0.38	1.84	0.72	1.12	0.61

*No data are available for Tanzania as few tilapia were caught during the study period (O.C. Mkumbo *personal communication*).

Mortality and exploitation rate

Apart from the recent LVFRP data (Table 5.6), mortality parameters of Nile tilapia had never been estimated for the Ugandan part of Lake Victoria. In the Kenyan part, fishing mortality was 0.468 year^{-1} (Getabu, 1992) and 0.69 year^{-1} (Dache, 1995), about 10 years ago. The status of fishing effort in Uganda and Kenya waters is different and the trends in fishing mortality could also be different (Chapter Three), but assuming that they were similar, the results of this study and those of LVFRP (Table 5.6) would indicate fishing mortality of Nile tilapia has increased since the early 1990s. The yield-per-recruit analysis suggests the fishing effort targeting Nile tilapia should be reduced by at least 40% to achieve optimal yield and value from the fishery.

The optimum yield could be achieved more easily in the Nile tilapia than in the Nile perch fishery in the short term because overfishing of Nile tilapia, although quantified in relative terms, is still within manageable levels if compared with the Nile perch fishery. The relatively higher resilience of Nile tilapia to exploitation could be arising from its higher growth rate, rapid reproduction and abundant food resources. The length of first capture of Nile tilapia of the gillnet fishery (Lc_{50} = 22 cm TL) is much less than the size at first maturity (LM_{50}), which is above 30 cm TL (Chapter Four). This growth and recruitment overfishing probably reduces the production potential of the Nile tilapia fishery and is not sustainable in the long term.

As revealed by VPA, the highest fishing mortality of Nile tilapia emanates from the gillnet fishery. Reducing fishing mortality of Nile tilapia could be achieved by reducing the use of undersize gillnets, which contribute up to 53% of gillnets used by parachute boats that target the species. This would also increase the Lc_{50} from the present 22.0 cm TL to a larger size thus boosting the reproductive potential of the species. Fishing mortality by gillnets could also be substantially reduced by stopping the active operation of gillnets but enforcement of this would be relatively impractical. Among the gears that target the Nile tilapia, cast nets impact the lowest fishing mortality as shown by VPA, because they catch the largest sizes of fish but these positive attributes are negated by their disruption of breeding activities and targeting the brood stock as indicated in Chapter Four. Enforcing the ban on use of cast nets would probably reduce disruption of breeding activities of tilapia caused by fishing.

5.5.4 *Recruitment patterns of Nile perch and Nile tilapia*

The recruitment pattern of Nile perch into the fishery had one major peak in the dry cool period of July and August, extending into September, prior to the onset of the short rains and a lesser one in the drier months, February to March, prior to the onset of the long rains. It has been suggested that Nile perch in Lake Victoria breeds continuously but attains peak spawning in the rainy seasons in May/June and November/December (Acere & Pauly, 1988; Ligtvoet & Mkumbo, 1990). The observed recruitment pattern is therefore consistent with the occurrence of biannual spawning peaks. The major recruitment peak corroborates the overall catch rates of Nile perch (Chapter Four), which also peaked over the same period. The recruitment pattern of Nile tilapia is also consistent with the observations that Nile tilapia tend to spawn thought the year but with increased breeding activity in periods correlated with rainy seasons (Lowe-McConnell, 1958; 1975; Twongo, 1995; Balirwa, 1998).

The timing of peak recruitment could be associated with the seasonality of lake productivity and food supply. The rising water level towards the end of the long rains between April and June probably increases nutrients input from catchment drainage and expands the habitat range of Nile tilapia in the littoral areas. Between June and August there is also absence or feeble development of thermal stratification, due to the cooling effect of the southeast trade winds, causing prolonged deep mixing in offshore waters (Talling, 1966). Deep mixing offshore relaxes the nitrogen limitation on primary production, thus increasing lake productivity in the lower food web (Talling & Talling, 1965; Mugidde, 1993; Lehman & Branstrator, 1993; Lehman *et al.*, 1996). Since Nile perch is a top predator, the abundance of its food would be expected to increase after a time lag, therefore the difference in the onset of the major recruitment peak in Nile tilapia (May) and Nile perch (July) may be explained by the differences in diet, if increased productivity of the lake were responsible for the timing of recruitment. Management measures seeking to protect the new recruits from overexploitation like closed season or restriction on particular fishing gears could be effective for the Nile perch fishery in July and August when there is a prominent peak but would be relatively unfocussed in the Nile tilapia fishery where recruitment is prolonged.

5.5.5 *Growth, mortality and exploitation rate of* Rastrineobola argentea

The von Bertalanffy growth parameters of *R. argentea* in the Ugandan waters of lake Victoria were estimated from samples collected in the Buvuma Channel in 1987-88 (Wandera & Wanink, 1995). At that time, fishing pressure for *R. argentea* was very low in the Ugandan part of the lake, e.g. only 296 boats targeted the species in 1990 (Chapter Three). The growth parameters estimated by this study suggest little change in the maximum length attained by the *R. argentea* population in this part of the lake and a uniform growth rate over the last decade (Table 5.7). This is despite the large increase in fishing pressure from 296 boats in 1990 to 2130 in 2000.

Table 5.7 Growth, and mortality parameters of Mukene (*Rastrineobola argentea*) in Lake Victoria estimated in this study and by other studies

Location	L_∞ (mm SL)	K yr^{-1}	Z yr^{-1}	M yr^{-1}	F yr^{-1}	E	ϕ'	Reference
Buvuma Channel (Uganda), 1987 – 88	65	0.99	3.9	2.5	1.4	0.36	3.62	Wandera & Wanink (1995)
Mwanza Gulf (Tanzania), 1988	65	1.08	4.4	2.6	1.8	0.41	3.66	Wandera & Wanink (1995)
Winam Gulf (Kenya), 1990-91	63.8	0.94	3.3	--	--	--	3.58	Manyala (1993)
Kenyan waters 1998 – 2000	64	1.04	4.36	1.40	2.96	0.68	3.63	LVFRP data (UNECIA, 2002)
Ugandan waters 2000	69	0.99	5.40	1.33	4.07	0.75	3.67	This study

The lack of substantial changes in growth parameters of the *R. argentea* population, with increasing fishing pressure is probably because the fishing pressure has not reached the threshold to induce changes. Other changes in the ecology and fish community structure like the declining Nile perch stocks and resurgence of pelagic haplochromines (Witte *et al.*, 2000) may also be affecting the resilience of the *R. argentea* population to fishing. However, over the same period, there have been substantial changes in mortality, with marked increase of fishing mortality. This is partly explained by the differences in the selectivity characteristics of the fishing gears. The samples from Buvuma Channel in 1987-89 (Wandera & Wanink, 1995) were obtained from catches of 10-mm mesh size seines while those of the present study were obtained from catches of 5-mm mesh size seines. The growth rate '*K*' and growth performance index 'ϕ'' of *R. argentea* in Lake Victoria are low if compared with those of similar small pelagic fish species, *Stolothrissa tanganicae* (Regan, 1917) and *Limnothrissa miodon* (Boulenger, 1906) in lakes Tanganyika, Kariba and Kakora Bassa (Table 5.8).

Table 5.8 Growth, and mortality parameters of *Stolothrissa tanganicae* and *Limnothrissa miodon*

	L_∞ (mm SL)	K yr^{-1}	ϕ'
Stolothrissa. tanganicae (Tanganyika), (Roest, 1978)	94	2.52	4.34
Stolothrissa .tanganicae (Tanganyika), (Chapman & van Well, 1978)	90	2.52	4.13
Limnothrissa miodon (Kariba), (Marshall, 1987)	74	3.05	4.22
Limnothrissa miodon (Cahora Bassa), (Marshall, 1987)	70	5.40	4.42

5.5.6 *Estimation of yield*

The difference between estimates of fish yield from VPA and those from catch assessment (Chapter Four) is very small (Table 5.9). It appears therefore that the VPA analyses could be used for estimating yield and thus the importance of regular collection of length frequency data is demonstrated. Application of the two complimentary methods of deriving total annual catches could provide the benchmark for improving accuracy of catch assessment survey data on Lake Victoria.

Table 5.9 Comparison of the estimates of total annual catches of Nile perch and Nile tilapia from catch assessment data and length structured VPA in the Ugandan part of Lake Victoria in 2000

Species	Estimates from catch assessment (t)	Estimates from length structured VPA (t)	Difference (%)
Nile perch	72632.2	81988.7	12.9
Nile tilapia	29959.4	29278.3	2.3
Total	102591.6	111267.0	8.5
*R. argentea**	70333.5	--	--

*No attempt was made to estimate the total annual catches of *R. argentea* using length-structured VPA in FiSAT because this would require input of length–weight coefficients and raising the numbers of fish in the sample to the total catch, requirements which could not be realistically determined in this study.

5.6 Summary and conclusions

The key message from the analysis of population dynamics of Nile perch and Nile tilapia in the Ugandan waters of Lake Victoria is the exploitation rates and fishing mortalities are excessive and unsustainable. To achieve optimum yield fishing effort targeted to Nile perch and Nile tilapia should be reduced by up to 70% and 40% of the present effort, respectively. High fishing effort emanates from the open access policy of the fisheries, which should be regulated in a protracted process involving all stakeholders, because of the socio-economic and political complexities involved. In the short-term, substantial reduction in fishing mortality could be achieved through immediate enforcement of the banned fishing gears, like beach seines and under-sized gillnets. On the other hand, the analysis of population dynamics of *R. argentea* in Ugandan waters indicated the present fishing effort was producing approximately the maximum sustainable yield. The *R. argentea* fishery in the Ugandan part of the lake is more or less limited to inshore areas using mosquito seines and would probably become unsustainable if fishing effort were allowed to exceed the present level. Expansion of fishing effort without endangering sustainability of the fishery would probably be viable if fishing was reoriented to offshore stocks by motorisation of fishing boats and adoption of fishing gears like lift nets, which are appropriate for fishing in open waters.

CHAPTER SIX

6. TOWARDS SUSTAINABLE MANAGEMENT OF THE ARTISANAL FISHERIES OF LAKE VICTORIA

6.1 Introduction

Lake Victoria, the world's largest tropical lake (68,500 km^2, lying 0°20'N - 3°0'S), is shared by Kenya (6%), Tanzania (51%) and Uganda (43%). Fishing in the lake was for subsistence until the start of the 20th Century when it started to have a commercial orientation after the introduction of gillnets in 1905 (Jackson, 1971). The first attempts to regulate the fisheries of Lake Victoria followed recommendations of the first fisheries and limnology survey of the lake in 1927-28 (Graham, 1929). The report of this survey recommended a minimum gillnet mesh size of 127 mm, a regulation promulgated in 1933. It also stressed the need for formation of two institutions: (i) a research laboratory to conduct fisheries research on the lake; and (ii) a Lake Victoria Fisheries Service (LVFS), to collect fisheries statistics, give advice and enforce any necessary legislation. The research laboratory, named the East African Fisheries Research Organisation (EAFRO) and the LVFS were formed in 1947 and they worked in close association with each other (Lowe-McConnell, 1997). The LVFS had a station in each of the three riparian territories, Kisumu in Kenya, Mwanza in Tanzania and Entebbe in Uganda, from where they supervised a network of fish recorders on beaches around the lake (Lowe-McConnell, 1997). The LVFS was disbanded in 1959 when it proved very difficult to control the illegal use of smaller meshed nets (Lowe-McConnell, 1997). After their independence in the early 1960s, the riparian countries formed the East African Community (EAC), and research on the lake continued under EAFRO until 1977, when the EAC collapsed. Thereafter, each country carried out research in the lake independently, but the Food and Agriculture Organisation of the United Nations (FAO), through the CIFA sub-committee for Lake Victoria, coordinated some activities of the riparian states on Lake Victoria's fisheries (Bwathondi *et al.*, 2001).

In recognition of their common interest in the well being of Lake Victoria and its living resources, and their rational management and sustainability for the benefit of present and future generations, the governments of Kenya, Tanzania and Uganda formed the Lake Victoria Fisheries Organisation (LVFO) as recommended by the CIFA sub-committee for Lake Victoria (CIFA, 1992). The LVFO, with headquarters in Jinja, Uganda, was established by a convention signed in Kisumu, Kenya on 30 June 1994 by the three contracting governments. The LVFO is responsible for coordinating and harmonizing fisheries management issues of the Lake Victoria ecosystem. Achieving sustainable utilisation of Lake Victoria resources is the main objective of the strategic vision of LVFO (LVFO, 1999). It has both scientific and fisheries management committees with the mandate to promote regional research activities aimed at improving fisheries management.

Recent efforts to improve fisheries management in the 1990s have been supported by two lake-wide projects, namely the Lake Victoria Fisheries Research Project (LVFRP), financed by the European Union, and the Lake Victoria Environment Management Project (LVEMP), financed by the World Bank and the Global Environmental Facility (GEF). The first phase of LVFRP started in 1989 and was devoted to the strengthening of research infrastructure in the three countries sharing the lake. The second phase of LVFRP, implemented by the fisheries research institutes of Kenya, Tanzania and Uganda, started in June 1997. The main objectives were to encourage sustainable development of the Lake Victoria basin by assisting the LVFO in the creation and implementation of a viable regional fisheries management plan and the knowledge base required for the regional management of the fisheries of the lake. This study, which investigated the catch-effort characteristics of the artisanal fisheries in the Ugandan part of Lake Victoria, was part of the LVFRP - Phase II activities, and its outputs contribute to the above broad objectives of the project.

In this chapter, the outputs of this study presented in the preceding chapters are synthesised together with other information on the status of the fisheries of the Lake Victoria to suggest management initiatives that should be undertaken to ensure long-term sustainable fisheries in the lake. The management objectives, key issues and options are identified. The setbacks in the existing regulations and any earlier attempts in the management of Lake Victoria fisheries are highlighted. Finally the way forward, recommending the actions that should be undertaken to implement proposed options are suggested, emphasising those that should be undertaken immediately to save the fisheries from collapsing while others should be undertaken in the long term.

6.2 Status and importance of the fisheries of Lake Victoria

6.2.1 *Trends of fishing effort and fishery production*

Huge changes in fishing effort followed the establishment of Nile perch and Nile tilapia in Lake Victoria in the late 1980s, with an increase in the number of fishing boats from about 3470 boats in 1988 to 8000 and 15,418 boats in 1990 and 2000 respectively (Figs 1.2 & 3.1: Chapters One & Three). Concomitantly, over the last decade, the lake wide CPUE declined from 36 t $boat^{-1}$ $year^{-1}$ in 1989 to about 13 t $boat^{-1}$ $year^{-1}$ by 1998. The most popular gillnet mesh size also declined from 203 and 178 mm in 1990 to 152 mm and below in 2000. The use of illegal gillnets <127 mm mesh sizes increased from 5% in 1990 to 18.6% in 2000. The overall effect of these changes was continuous decline in the mean size of Nile perch and Nile tilapia landed. Use of undersized gillnets is predominant in small boats which operate in near shore areas, i.e. 53% and 23% of nets used by parachute and paddled Sesse boats respectively, but constitute only 1.9% of nets used by motorised boats. The mean number of gillnets per boat also increased by 50% in parachute boats, 34% in paddled Sesse boats and 32% in motorized boats between 1990 and 2000. These are classic indicators of a fishery moving towards overexploitation and suggest that the current level of fishing effort, especially in inshore areas, is probably not sustainable.

The total annual fish landings in the three riparian states of Lake Victoria remained stable over the 1990s (Fig 1.3: Chapter One) after the maximum achieved around 1990, but started rising again at the end of the 1990s. Notwithstanding the weaknesses in the fisheries statistics, the contributions of Nile perch dropped and have remained at lower levels since 1994, despite increasing fishing effort. The apparent increase in total catches from around 1997 arises from the increasing contribution of *R. argentea*, tilapias and other species, but poor catch assessment data prevent conclusive evaluation of trends in recent years.

6.2.2 *Economic importance of the fisheries of Lake Victoria*

The importance of the Lake Victoria fisheries to the economies of the three East African countries sharing the lake was not prominent until the1980s, when the lake's ecosystem was transformed from a multi-species fishery to one dominated by three species: Nile perch, *R. argentea* and Nile tilapia. The lake-wide total fish landings increased from about 100,000 t in the 1960s and 1970s, to approximately 400,000 t in the second half of the 1980s, making the lake the largest freshwater fishery in the world according to FAO statistics (Reynolds & Greboval, 1988; Greboval, 1990; Greboval & Mannini, 1992).

Following the tremendous increase in fish production, the fish markets expanded beyond the three riparian countries to other regional markets in Zaire, Rwanda, Burundi and Zambia, and fish processing factories were established to supply Nile perch fillets to the industrialised world (SEDAWOG, 1999a). The first fish processing plant was established in Kenya in 1980 (Abila, 1994), and eventually 35 plants were established in the three countries, but only 27 were operational at the end of the 1990s (SEDAWOG, 1999a), although a further two were licensed in Uganda in 2002. All sectors of the fishing industry, i.e. harvesting, processing and distribution, expanded together with the increase in fish production providing employment opportunities to both the unemployed and underemployed people in the region. The Nile perch fishery, in particular, was such a blessing to the extent that it was nick named 'the saviour' by the communities around the lake (Reynolds & Greboval, 1988; Reynolds *et al.*, 1995). The net economic benefits of the Lake Victoria fisheries, when expressed in monetary terms, were approximately US$16.8 million in 1975/76 but over the period 1975-1989 the cumulative net value amounted to about US$ 280 million, indicating progressive increase of net benefits under the Nile perch regime (Reynolds *et al.*, 1995). The other important dimension of benefit accumulation under the Nile perch regime was job creation. Reynolds *et al.*, 1995 estimated the total number of people employed in the Lake Victoria fisheries sector increased from 158,400 in 1975 to 422,000 in 1989. At present the fishing industry provides employment for between 0.5 and 1 million Ugandans, more than 0.5 million Tanzanians and 0.8 – 1.5 million Kenyans (Bwathondi *et al.*, 2001). The fisheries sector contributes 3% to the GDP of Uganda and Tanzania and 0.5% to that of Kenya. Most of the fish landed within the three countries comes from Lake Victoria. For example, the lake contributed 48.8% of the fish landed in Uganda in 1994; 90% of fish landed in Kenya in 1998 and 60% of fish landed in Tanzania in 1998 (Bwathondi *et al.*, 2001).

6.3 The key factors influencing the Lake Victoria fisheries

6.3.1 *Climate*

Climate influences fish survival and regeneration capacity indirectly through reproductive and recruitment patterns which are often synchronised to the climate. Lake Victoria moderates the local climate, which in turn influences the abundance of rainfall. The rainfall pattern within the catchment tends to affect lake productivity, fish reproduction and recruitment peaks. The entire catchment area of Lake Victoria is within the zone where the northeast and southwest trade winds meet. This zone receives heavy rains from conventional storms in two seasons related to the trade wind passage periods and equatorial equinoxes. The total amount of rain received, and its distribution within the catchment throughout the year, has a great bearing on the lake level (Bugenyi & Balirwa, 1989). Lake level changes have great effects on the lake's fish productivity (Ssentongo & Welcomme, 1985). For example, following the unusually heavy rains between 1961 and 1963, there was improvement in the fish catches (Welcomme, 1966). This was not observed following the exceptionally heavy rains and flooding of the late 1990s because catches were probably influenced by export bans on the Nile perch fishery (see later).

The seasonal or diurnal wind patterns, which stir and circulate the nutrients, determine the general rate of organic production and its seasonal variations. The local diurnal air currents contribute to the productivity of shallow inshore waters by maintaining vertical circulation, which ensures ample nutrient and oxygen distribution throughout the water column. These variables interact to produce conditions required to maintain a productive fishery in the inshore areas. The deep areas of Lake Victoria experience cycles of stratification, which are determined by the seasonal wind patterns (Talling, 1966; Kitaka, 1971). The nutrients are locked up in the hypolimnion in the calmer seasons because of thermal stratification but are stirred up by trade winds, in May to August, circulating the nutrients, and this leads to high primary production (Fish, 1957; Talling, 1965). Primary production benefits organisms in the higher trophic levels including fish. The climate of East Africa, like the overall global climate, has been undergoing a warming trend (Hastenrath & Kruss, 1992). Higher temperatures were recorded in Lake Victoria in 1989/1990 (Hecky, 1993) than the early 1960s (Talling, 1965; 1966), making the lake more stable and less able to mix effectively. This increased thermal stability could be contributing to persistence of anoxia in deep waters (Ochumba & Kibara 1989), with consequences of reducing fish habitat.

6.3.2 *Land use*

Lakes long since been appreciated as indicators of land use ills in the developed temperate world, and Lake Victoria, and other lakes of Africa, are now showing effects of environmental degradation (Hecky, 1993). In the socio-economic context of Africa, about 90% of people are involved in subsistence farming and animal husbandry, and human population growth in the watersheds is 3-4% per annum (Hecky, 1993; Bugenyi & Magumba, 1996; Ogutu-Ohwayo *et al.,* 1997). In East Africa, many of the rapidly growing urban and industrial centres are also located along the shores of Lake Victoria, increasing the demand for water supply and discharge of wastewater. Partially treated domestic and industrial wastes from urban centres contribute significantly to the pollution of the lake. The rapid increase in the rural population has increased the demand on land for livestock, agriculture and fuel wood accelerating the rates of de-vegetation and deforestation, thus enhancing erosion, sedimentation, siltation and nutrient loading of the lake (Hecky, 1993; Bootsma & Hecky, 1993; Ogutu-Ohwayo *et al.,* 1997). Deterioration of water quality through nutrient enrichment (eutrophication) and pollution is among the most serious potential problem facing the fisheries of Lake Victoria. Eutrophication has contributed to: reduction of water transparency; change of the nutrient balance; changes of the abundance and species composition of phytoplankton, zooplankton and benthic invertebrates; and prolonged, elevated anoxia in deep waters during stratification (Hecky, 1993; Bootsma & Hecky, 1993; Bugenyi & Magumba, 1996; Ogutu-Ohwayo *et al.,* 1997), processes that could contribute to serious loss of fish habitat and biodiversity. The lake was recently infested by the water hyacinth, which is considered the world's most problematic aquatic weed and tends to flourish in water bodies with high nutrient levels (Harley, 1990). It thrives in the shallow sheltered bays, which are also the most suitable breeding, and nursery grounds for many fish species, therefore it affects breeding and juvenile feeding of many fishes (Ogutu-Ohwayo *et al.,* 1997), in addition to a wide range of other negative environmental impacts (Masifwa *et al.*, 2001).

6.3.3 *Characteristics of the fishery*

The fisheries of Lake Victoria are open access, small-scale and artisanal, with little control on fishing methods. These fishery characteristics have been conducive to continuous build up of fishing effort and introduction of new fishing technologies without evaluation of their impacts. In the era before the advent of Nile perch in the 1980s, the fisheries collapsed due to overfishing (Fryer, 1972; Fryer & Iles, 1972). The Nile perch boom in the late 1980s induced rapid increase of fishing effort, e.g. in Uganda the numbers of fishing boats increased from 3470 in 1988 to 8000 in 1990 and 15,418 in 2000. Both the pre and post Nile perch boom fishery scenarios, coupled with environmental changes conform to the fishing-down process, which is a consequence of overfishing (Welcomme, 2001). The classic indicators of the fishing-down process that are characteristic of the fisheries of Lake Victoria include maintaining catch levels over a wide range of effort, but with qualitative change in catch composition. The main change to which all others are linked is a decline, of the mean size of fish in the population caused by progressive loss of large individuals and species, and their replacement by smaller ones. The shift to smaller fish also involves a drift from long-lived (K selected) species to short-lived (r selected) ones; a response to stress that is common to animal communities in general (Barret *et al.,* 1976). During the process of the collapse of the Tilapiine-based pre Nile perch boom fishery of Lake Victoria, fishers shifted effort to exploit the smaller species, principally the haplochromines and *R. argentea* (Ogutu-Ohwayo *et al.,* 1997). On the advent of the Nile perch boom in the late 1980s, fishers adopted large gillnet mesh sizes to harvest the large sized fish, but over the last decade the gillnet mesh sizes and size composition of Nile perch catches have been declining as the fishing effort increased (Litvoet & Mkumbo, 1990; Mkumbo *et al.,* 2002). Although total fish production from the lake has remained fairly high following the maximum around 1990, the proportion contributed by the r selected pelagic cyprinid, *R. argentea,* has increased steadily at the expense of Nile perch. The results of this study (Chapter Four) indicate the production of *R. argentea* is approaching that of Nile perch in the Ugandan part of the lake and could soon overtake it. The recovering pelagic haplochromines (Witte *et al.*, 2000) could also soon form a major fishery if overfishing for the large species continues unabated.

6.3.4 *Changes in the effective fishing effort*

Accompanying the fishing-down process is the gradual increase of effective fishing effort. In developing and developed fisheries, new gears and ways of locating fish are continually being discovered, thus fishing effort gradually becomes more effective even though the apparent effort remains the same (King, 1995). This study (Chapter Four) demonstrated that the traditional method of operation of gillnets as passive gear set stationary at one site has been largely abandoned. In the current tilapia fishery, over 85% of boats operated gillnets in a variety of active methods that are intended to increase catch rates. Similarly, in the Nile perch fishery, gillnets are predominantly allowed to drift with the current to increase the chances of encountering fish. Gillnets operated as driftnets are also joined to form a double panel of 52 meshes deep instead of the standard 26 mesh deep gillnets. This strategy doubles the surface area of the net in the water column, thus increasing the chances of encountering fish. The study further demonstrated, the increase in number of fishing boats over the last decade from 8,000 to 15,418 was biased to parachute (176.4%) and motorised boats (135.7%), which are specialised in the Nile tilapia and Nile perch fisheries respectively. These are huge increases if compared with only 39.2% rise in the number of the less specialised paddled Sesse boats. This specialisation is also an indication of increase in the effective fishing effort targeting the two species. Other forms of fishing strategies that should have gradually increased the effective fishing effort over the last decade include the decline of gillnet mesh sizes, increase in numbers of gear units per fishing boat and the diversification from use of gillnets to a multiplicity of other fishing gears. All these fishing attributes were higher in the eastern part of the Ugandan waters of the lake, which had the highest fishing intensity, suggesting that such strategies were commensurate with increase of fishing effort. When the effective fishing effort in a fishery increases, more fish can be caught for the same amount of apparent effort, and CPUEs would give the misleading impression that the abundance of the stock is high (or even increasing), when it is actually decreasing (King, 1995). The same effect would occur if effort was measured in terms of the number of fishing boats, and ones that are more efficient gradually replaced less efficient boats. It would therefore be necessary to find possible ways to correct for changes in effective fishing effort in order to generate CPUE time series.

6.3.5 *The fish processing industry*

The number of fish processing factories increased rapidly over the last decade from three in 1990 to 11 in 1999 in Uganda, and overall in the three countries sharing the lake, they increased by 88% over the same period (SEDAWOG, 1999a: Namisi, 2001). This is an indication of the region's recent entry into the global fish market. The rapid growth in demand for fish, particularly Nile perch, by these factories could be the major factor contributing to excessive fishing effort for Nile perch. On average, these factories operate far below the installed capacity: at 45%, 49% and 69% of total capacity in Uganda, Kenya and Tanzania respectively (SEDAWOG, 1999a). The inadequate supply of fish inevitably creates a competitive market environment that improves the price of fish at the fish landing site level thus encouraging further investments into the fishing operations. It could also be partly responsible for lowering of the size of fish purchased by factory agents, encouraging exploitation of juvenile Nile perch. To ensure that adequate and regular supplies are availed, factories offer competitive prices and prompt payment, and some 'tie' suppliers to themselves by offering loans and outboard engines (Wilson *et al.,* 1999; Namisi, 2001). The performance and growth of fish processing factories were restricted by occasional fish bans and accompanying quality regulations from their main EU market from 1997 to 2000 (Namisi, 2001), as can be illustrated by the drop in revenue from Ugandan fish exports over that period (Fig. 6.1). The fish bans could have kept the incentives for overexploitation of Nile perch low in the second half of 1990s, but the boost in export earnings that followed in 2001 with easing of export restrictions may translate rapidly into further strain on the Nile perch stocks. It is estimated that fish exports for Uganda in 2001 were of the order of 28,000 t with a value of approximately US$ 78 million making up a monthly total of about 2300 t of finished goods, which is equivalent to about 70,000 t wet fish (mostly Nile perch) harvested annually from the lake for export (Kaelin & Cowx, 2002). A further 50% of harvested fish, often immature, are consumed locally or exported to regional markets, principally the DRC, making the harvest of Nile perch in the Ugandan waters approximately 110,000 t in 2001 (Kaelin & Cowx, 2002). This estimate is much higher than 72,000 t estimated by this study in 2000, when the total export value was approximately US$ 34 million suggesting that the lifting of the EU ban in August 2000 could have resulted in further increase of fishing effort for Nile perch. This current rate of harvest is not considered sustainable, but is being driven to a large extent by the excess processing capacity that exists on a regional basis.

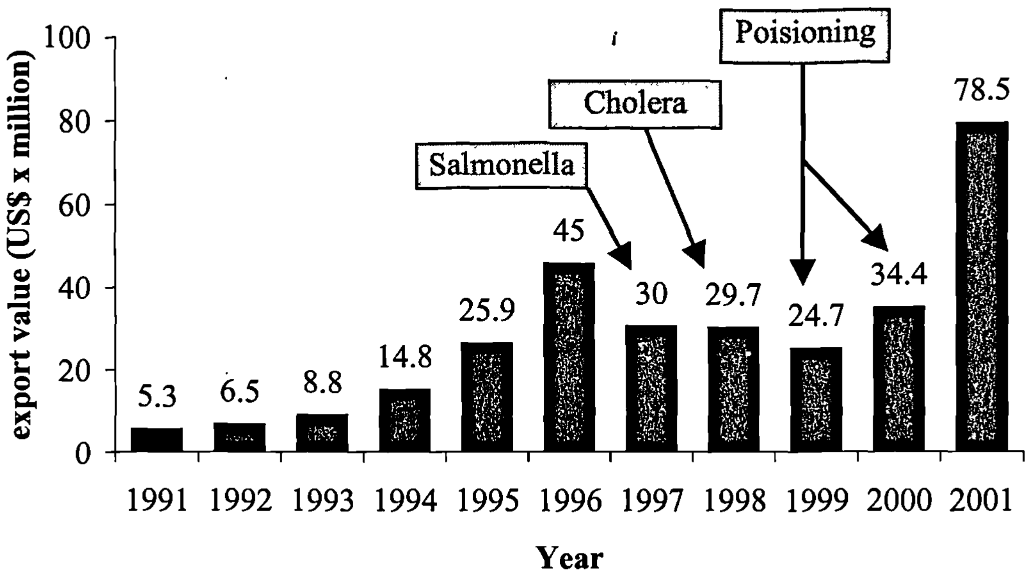


Figure 6.1 Total value of Uganda annual fish exports from 1991 to 2001. The grey boxes indicate the major reason for the EU ban of fish imports from Uganda in 1997 to 2000 (from Kaelin & Cowx, 2002)

Indeed, following the easing of export restrictions, the volume of fish exports has remained fairly stable, whereas their total value and unit value have been increasing steadily (Fig. 6.2), a situation that would imply constrained fish supply to the processing factories.

The international export of Nile perch is no longer limited to the traditional EU and Middle Eastern markets but has expanded to other global markets, including Japan, Australia, and northern and southern America, but the EU remains the most lucrative market (SEDAWOG, 1999a). This implies that there is growing global demand for the Nile perch.

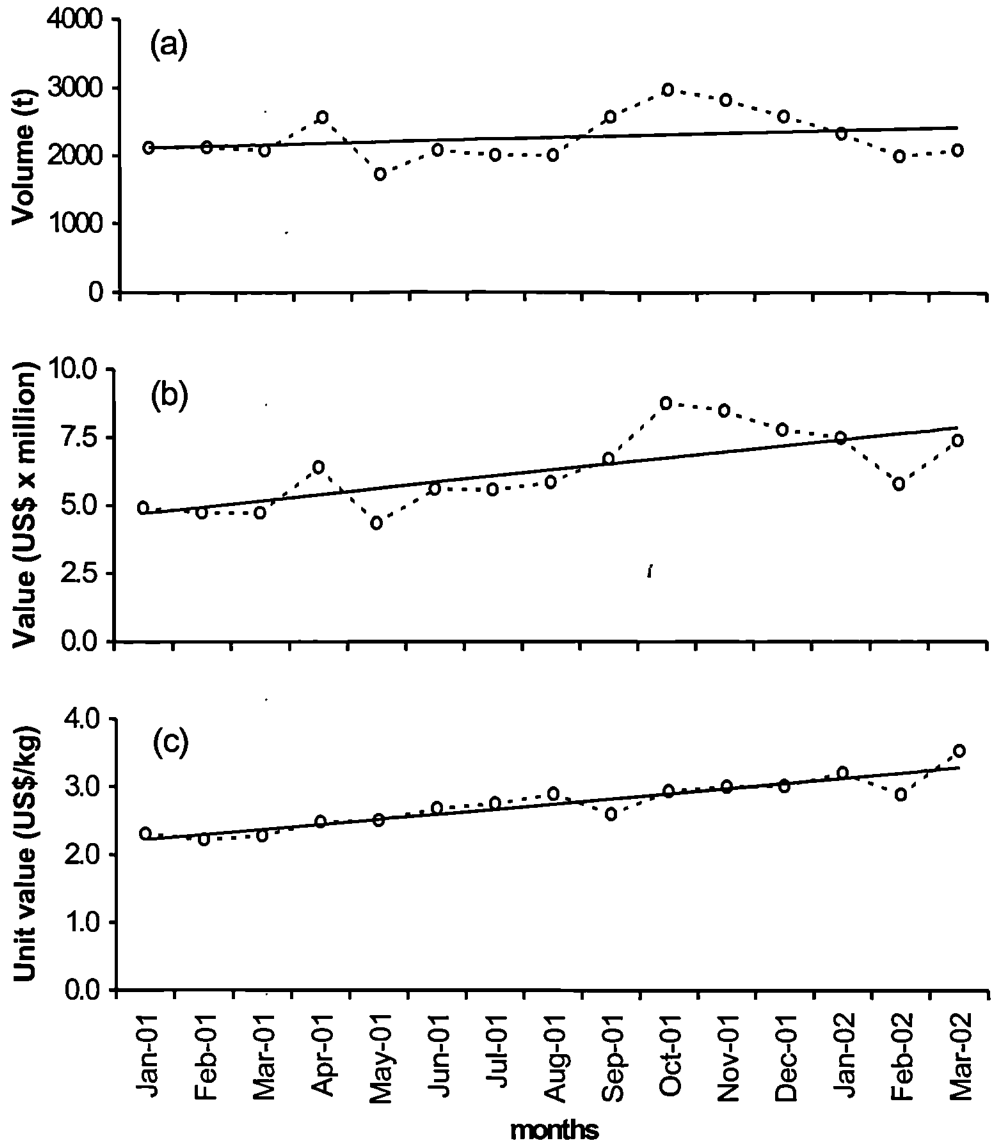


Figure 6.2 Uganda fish exports to the EU market in 2001 and the first quarter of 2002: (a) monthly quantities, (b) total value, and (c) unit value. The solid lines indicate trends (source: Uganda Fisheries Resources Department).

The fish processing factories are the most obvious factor driving exploitation of the fishery while the local and regional markets of fresh, smoked and salted fish apparently utilise some of the smaller sized fish rejected by the factories. Ever since the international Nile perch market was established in the early 1990s, the domestic and regional consumers have increasingly resorted to alternative low priced fish consisting mainly of juveniles, which in turn encourages the use of illegal destructive fishing gears (Namisi, 2001). The activities of fish processing factories are one major area that should, therefore, be closely monitored and controlled to avert over-exploitation of the Nile perch fishery resulting from the influence of market forces

6.3.6 *Socio-economic aspects of the lake fisheries*

The three East African countries sharing Lake Victoria are amongst the poorest in the world and their economies depend mainly on agriculture and other primary industries, which include capture fisheries. During the pre Nile perch era, most fishers around Lake Victoria engaged in subsistence fishing and were at that time classified as being part of the rural poor (Bwathondi *et al.,* 2001). The success of the Nile perch fishery since the late 1980s was recognised beyond East Africa and a thriving overseas market for the species was established, causing remarkable changes in the incomes of fishers and the overall social fabric of the lakeside communities over the past two decades. The success of the fishery inevitably attracted other users including wealthy people from urban areas who purchased fishing gears and vessels to access the resource, causing tremendous increase of fishing effort. The build up has been especially noticeable in the last decade (Chapter Three), with the Nile perch fishery subject to intense pressure, from not only increased capacity, but also through the use of illegal gears, including poisons (Crean *et al.*, 2002). The use of illegal fishing methods and gears in particular compromises and seriously threatens the future of fisheries in each of the riparian states (Owino, 1999).

The gaps between the richest and poorest fishers, and between the benefits obtained from the fishery by vessel owners and labouring classes, are widening (SEDAWOG 1999b). Market demand is also influencing the reallocation of the benefits obtained from exploiting the fisheries resources with serious impacts in the fisheries sector by intensifying the existing conflicts between users (Yongo, 2000). Theft, of fishing gears, outboard motors and vessels, as well as piracy, are rampant on the lake, and may become worse as the disparity in distribution of benefits from the fishery becomes more polarised. The deteriorating security situation on the lake poses serious threats to the fisheries, fishers, fishing communities and lake environment (Bwathondi *et al.,* 2001). These trends are symptoms of broader social, economic and developmental dislocations, which represent a grave threat to the sustainability of Lake Victoria's fisheries.

6.4 Fisheries management objectives

6.4.1 *General objectives of fisheries management*

From the point of view of the biologist, fisheries management is synonymous with fish stock management but in practice, fish stock management is constrained by socio-economic factors and fisheries management is a practice with socio-economic objectives, constrained by biological feasibilities (Raat, 1990). The main objective of fisheries management is the conservation of the fish stocks based on the knowledge of the dynamics of the stocks (Cowx, 1994). The aim of fisheries management is to regulate fishing pressure, to prevent overfishing, by imposing a number of regulations such as gear and mesh size restriction, licence restrictions, quotas and closed seasons (Cowx, 1994). Remedial measures to maintain and/or improve any environmental degradation must also be considered for effective management of the fishery (Cowx, 1994; 1998). Many socio-economic problems often arise during the implementation of the fishing regulations and environmental rehabilitation, because they usually have adverse consequences to their present livelihood and are usually considered unacceptable by the fishing communities (Cowx, 1994). Considering the increasing pressure on aquatic resources and increasing degradation of the aquatic environment, fisheries can no longer be treated in isolation and an integrated approach to aquatic resources management is required. The planning and management must be a multi-disciplinary approach dealing with all the existing and potential user groups, including potential land use (Cowx, 1998). In addition, modern fisheries management requires biological objectives to be extended to address additional economic, social and environmental objectives, such as fishers' welfare, economic efficiency, the allocation of resources and environmental protection (King, 1995). Future priorities for the management of inland waters and their living resources depend on the demands to be placed on the resources and the socio-economic priorities of the societies associated with them (Cowx & Welcomme, 1998).

6.4.2 *Management objectives for the fisheries of Lake Victoria*

In the three East African countries sharing Lake Victoria the fisheries policies aim at ensuring optimal and sustainable fish production. In Uganda, the overall fisheries management goal is to ensure increased and sustainable production and utilisation of fish and fishery products by properly managing the capture fisheries, promoting aquaculture and reducing post harvest losses. The key objectives of the fisheries sub-sector, as stated in the Uganda Fisheries Master Plan (MAAIF, 1998), are to:

- increase fish production;
- protect the aquatic environment in which fish is produced;
- ensure food security through self sufficiency in animal protein supply;
- have a reasonable amount of fish for export to contribute to foreign exchange earnings;
- reduce post harvest losses;
- improve the quality of fish products both for domestic and export markets;
- create employment; and
- improve the economic and social status of the fisher folk especially women and underprivileged groups.

Kenya and Tanzania have similar fisheries sector objectives. One of the strategies to achieve the above objectives is to improve the knowledge base of the capture fisheries, which this study seeks to provide with respect to the artisanal fisheries of Lake Victoria.

6.5 Key issues

A wide range of issues face the fisheries sector in general, and Lake Victoria fisheries in particular, but many of them are beyond the scope of this study. Therefore, the key issues presented below are only those, which are relevant to the findings of this study.

6.5.1 *Excessive fishing effort*

Results of the recent lake-wide Frame survey conducted in March 2000 (Chapter Three) demonstrate the high intensity of fishing effort in the lake in recent years. In all three countries, fishing effort in terms of numbers of fishing boats, fishers or fishing gears has more or less doubled over the past 10 years. Total catches and catch per unit of effort have decreased since around 1990 concomitant with the increases in number of fishing boats, gears per boat, reduction of gillnet mesh sizes and introduction of other qualitative changes in fishing operations that increase the effectiveness of fishing gears, such as active operation of gillnets. The contribution to the total catches by *R. argentea* is increasing and there is resurgence of haplochromines, which are indicators of a fishery under stress, conforming to the classic fishing down process whereby large fish species and/or large individuals of large fish species are eliminated from the fishery through overfishing. This is largely the result of inappropriate mechanisms of controlling entry into the fisheries of the primary elements of fishing effort, principally boats, gears and fishers; and the secondary factors like the fish processing factories, which influence fishing effort through market forces.

6.5.2 *Destructive fishing gears and methods*

The use of illegal fishing gears and methods, i.e. meshes below the legal or recommended sizes and/or banned fishing gears and methods, have increased. Mesh sizes of gillnets, which remain the predominant fishing gears on the lake, have progressively declined over the last 10 years with 26, 11 and 18% of gillnets in Kenya, Tanzania and Uganda, respectively, now below the recommended mesh size of 127 mm. The situation is particularly worrying in the heavily exploited inshore waters, e.g. in Uganda, undersize gillnets comprise 53% of the nets used in parachute boats which operate exclusively in inshore areas. Banned fishing gears, especially beach seines which possibly pose the highest risk to recruitment overfishing of Nile perch stocks as demonstrated by their catch composition (Chapter Four), still form a formidable proportion of fishing gears operating in the fishery (Chapter Three), and are probably on the increase. Active operation of gillnets and cast netting, both illegal destructive fishing practices, are now the predominant ways of targeting Nile tilapia. The occurrence of destructive fishing gears increases together with the overall fishing effort as revealed by the fishing gear composition in the Eastern zone of the Ugandan waters and the Kenyan part of the lake compared with other areas. This implies that the use of destructive fishing gears will probably increase with further increase of fishing effort. Rampant theft and piracy in the lake in addition to the high cost of the legal fishing gears are some of the reasons driving fishers towards use of illegal fishing gears and methods. However, the dominant factor appears to be the continuously declining CPUE, which makes fishing with the legal fishing gears and/or methods unprofitable unless one is capable of investing heavily in the fishing operations, e.g. in a large boat, outboard motor, and large quantities of gillnets. The majority of fishers in Lake Victoria cannot afford such investments and consequently resort illegal fishing practices.

6.5.3 *Growth and recruitment overfishing*

The pressure on the juvenile, immature, Nile perch is intense, especially in near shore areas where passively set gillnets, operated on paddled Sesse boats and beach seines, are the main gears used to target the species and principally catch juveniles. Similar pressure is imparted on juvenile Nile tilapia in areas close to the shoreline where active gillnets, which are the main method of fishing tilapia as well as basket traps are operated and catch predominantly immature fish. It is also noted that motorised boats operating gillnets, which target large Nile perch are concentrating effort at 152 mm mesh size compared with 178 and 203 mm meshed nets 10 years ago, and in some parts of the lake, e.g. the western zone of the Ugandan waters, there is increasing use of smaller meshes. Therefore, the overall mode of catches among these boats, which is presently at 53 cm TL, will probably fall as the fishery continues to under perform. The 5-mm mosquito seines also crop predominantly immature *R. argentea* when operated in inshore areas but are less destructive in open waters.

6.5.4 *Overexploitation of the fisheries resources*

The fishery exploitation indicators point towards heavy fishing pressure of Nile perch beyond that which the fishery can sustain in the long term. The mortality of Nile perch in Lake Victoria, due to fishing (F =1.88 yr^{-1}) and the exploitation rate of 0.86 (Chapter Five) are very high and could lead to collapse of the stock. The paucity of large Nile perch (>50 cm TL), especially in near shore areas where gillnetting paddled Sesse boats operate is also probably because of intense fishery pressure. Other indicators of overfishing include reduction in size at first maturity, particularly in females, from over 90 cm TL about 10 years ago to approximately 75 cm TL at present.

The Nile tilapia fishery is presently better performing than the Nile perch fishery, e.g. fishing mortality, F = 1.12 yr^{-1} and exploitation rate, E = 0.61, but Nile tilapia inhabits easily accessible inshore areas, offering the lower investment requirements of fishing vessel, nets and labour compared with the Nile perch and *R. argentea* fisheries. Therefore the Nile tilapia fishery is the most affordable choice of new entrants and those who lose out on the declining Nile perch fishery, and thus requires deliberate precautionary measures to guard against increase of fishing effort.

The *R. argentea* fishery in Uganda is young and does not show signs of overexploitation. However, there are uncertainties over the long-term effects of harvesting large quantities of immature fish in inshore areas, which calls for precautionary measures as fishing pressure for the species builds up. In Kenya where the fishery started earlier and is more developed, the species shows some indications of high fishing pressure, e.g. the CPUE from the mosquito seine fishery is declining (Othina & Tweddle, 1999), and there is substantial reduction of size at first maturity (Marshall, 2001).

6.5.5 *Inadequate information on the fisheries resources*

There is general lack of consistent time series fisheries data that are essential for making rational management decisions and assessment of the achievements of the implemented management measures. At present, there are no functioning institutional mechanisms for regular assessment of fish catches in Uganda and Tanzania. A systematic catch assessment programme is only in place in the Kenyan part of the lake, although serious biases exist in the programme (Othina & Tweddle, 1999). There is need for institutional mechanisms to establish a simple catch assessment programme, harmonised throughout the region, which will produce reliable estimates of fishery production necessary for making the right management decisions if supplemented by appropriate socio-economic and biological monitoring programmes.

6.5.6 *Open access to the fisheries resources of Lake Victoria*

The fisheries of Lake Victoria are open to all, only requiring one to pay for the fishing licence and registering the vessel being used. Even these minimum criteria for entry are not necessarily adhered to, e.g. in Uganda many fishing boats operate on the lake without registration and/or a fishing licence. In the absence of control, open access systems, both fisheries and other free-range resources invariably become over-exploited, leading to declining returns for all participants. This occurs in virtually all fisheries under open access, from small-scale artisanal fisheries to large-scale industrial fisheries whether national or international, and has been dubbed the "Tragedy of the Commons" (FAO, 1996). Where there is control of overall exploitation, the resource may be protected but serious social and economic distortions commonly still arise. Open access fisheries are characterised by a race to fish, in which all participants strive to catch as much of the resource as they can, before their competitors do so. This race to fish leads to shortened fishing seasons, poor product quality and sporadic availability, excess harvesting and processing capacity, and increased costs and related negative social and economic effects (FAO, 1997), most of which now feature in the fisheries of Lake Victoria. To maintain a share of the catch in a situation where the number of entrants into the fishery is ever increasing has encouraged some operators in Lake Victoria to use illegal fishing gears. In many areas the use of small meshed nets is prevalent, as is the use of beach seines. This is typical of short term measures fishers feel they are obliged to adopt even though there is widespread awareness amongst them of the damage this is inflicting on the resource base and market (Geheb, 1999). It should be recognised that fisheries resources are finite; therefore, serious considerations of limiting access to avert overexploitation caused by excessive fishing effort in Lake Victoria should be undertaken.

The greatest difficulty in moving from a system of open access to one of limited access is determining which of the present users should be granted access and to whom should it be denied. Equity in allocating rights requires that all current fishers be involved in the process. Particular attention should be given to those with long-standing traditions of fishing, especially, to indigenous people and those local communities highly dependent on fisheries for their livelihoods. In general terms, the advantage of granting access rights is that they encourage a sense of ownership in the user, which should lead to a greater sense of long-term responsibility to the resources and fishery, leading to more responsible fishing. The control of fishing effort through restricted access to the fishery will also require deliberate programmes that will provide incentives to encourage communities to diversify their activities into other sectors, including fish farming, crop propagation and forestry. These are potential avenues that could reduce pressure on the lake's natural resources by creating new employment opportunities.

6.5.7 *Increasing demand for fish*

There is overwhelming demand for fish by the fish processing factories, which cannot be satisfied by the present catches of Nile perch, and as a result, all factories operate far below the installed capacity. In an effort to obtain sufficient supply of fish, some fish processors are indirectly involved in fishing operations through provision of credit or loans to fishers who in return sell their fish catches to the processor (Wilson *et al.*, 1999). These are probably the strongest forces behind the increases of fishing effort in the Nile perch fishery despite declining catches. Domestic demand from the growing riparian human populations is also increasing. The local demand provides an attractive market of immature fish rejected by the processing factories, which perhaps motivates fishers to use illegal destructive fishing gears that crop large quantities of immature fish.

6.5.8 *Institutional weaknesses and inadequate regulatory framework*

Regulations governing fisheries exist in the countries sharing Lake Victoria. They include restrictions on fishing gears, banning those that are considered to be destructive; restrictions on entry through licensing and powers of passing bylaws, which are vested in the minister in charge of fisheries resources. If the existing regulations and recommendations were enforced, the fisheries of Lake Victoria would probably be in a better shape than they are today. However, banned fishing gears, e.g. beach seines, continue to operate freely and many boats operate without licenses. The underlying causes of this situation include:

(i) Lack of monitoring, control and surveillance capacity

The 'command and control' style of fisheries management since the establishment of the Lake Victoria Service (LVFS) in 1947 has not prevented the undesirable events of decline in catches, increasing levels of effort on the lake. This is probably because it is beyond the capacity of the countries sharing the lake to police it to enforce regulations. The dispersed nature of the fisheries, i.e. numerous fish landing sites scattered both on the mainland and the islands, that are typical of the, largely, artisanal fishery would require huge numbers of fisheries personnel to enforce regulations under the existing top down management system. Most landing sites on the mainland are in remote areas with very poor or no roads at all and substantial fishing is going on around the islands where permanent landing sites are established. Fisheries staff lack boats and outboard engines to reach such landings for monitoring and surveillance. The bureaucratic nature of the top down management style is also abused by some of the few available enforcement officers who solicit for bribes and other personal gains at the expense of enforcing the regulations.

(ii) Regulatory ambiguity

The existing management styles assume that fishing communities are homogeneous, and therefore such management systems cannot cope with the many cultures, claims, contentions and access differences, within and between, communities of resource users, and Lake Victoria being a multi species fishery exacerbates these problems (Geheb *et al.,* 2002). Regulations in many African fisheries, if at all enforced, become blurred by corruption because wealthy fishers can pay to be overlooked by Fisheries Department staff, while those who cannot afford such graft are punished. Examples of regulatory ambiguity in fisheries around the lake cited by Geheb *et al.*, (2002) include:

(a) In Kenya, fishing communities have no room for participation, and low level Fisheries 'scouts' will use the fishing communities' lack of knowledge about regulations as a means to extort graft.

(b) In Uganda the main activities of the Fisheries Field staff, popularly referred to as 'fish guards', revolve around income collection for local authorities, primarily through fishing licences and boat registration fees. What their law enforcement role is remains ambiguous. The communities may also fail to seize the opportunities for community-created regulatory by-laws, which are provided for in the 1997 Local government Act, because they are ignorant of the responsibilities they may assume under the Act.

(c) In Tanzania, Beach Management Units (BMUs), which were formed with the prime purpose of promoting co-managerial relationships, operate in the same manner as the traditional Fisheries Department staff upholding the state's laws and ran the risk of being mingled into community structures rendering regulations ambiguous.

When regulations are ambiguous, the room exists for the powers associated with these regulations to be abused, and utilised for ends to which they were not designed (Chapman, 1989). The regulations in place in Lake Victoria have provided moneymaking opportunities for underpaid, poorly motivated and ill-facilitated fisheries field staff reducing enforcement to an apathetic level, which pervades the fisheries regulatory structure (Geheb *et al.,* 2002). While there are problems in enforcing regulations, the user communities also have problems believing in them because of lack of sensitisation, as fisheries extension services are largely ineffective or even absent. It gets even more complex when the generally poorly trained Fisheries Enforcement staff at the landing sites themselves do not believe in the regulations as necessary tools in the fight for a sustainable fishery. These problems are not restricted to fishing landing sites but extend to components of the fishery that are relatively easier to regulate, e.g. the fish processing factories. Fishing communities need to be mobilised, sensitised, and trained to know their responsibilities with regard to management of the resources. This will require capacitating the Fisheries Extension staff through appropriate training to prepare them for conducting community fisheries training programmes.

(iii) Lack of resources and expertise

The ability of Fisheries Departments to deliver an effective regulatory service is, in addition to the above factors, limited by funding difficulties and inadequate training. For example in Kenya, the Fisheries Department has 611 staffs around its part of the lake. These should be sufficient for effective fisheries regulation. However, these personnel only draw wages and do not get funds to facilitate provision of services or for training and career development (Geheb *et al.,* 2002). There are acute staffing constraints due to recent retrenchments of public servants in Uganda and Tanzania, in addition to inadequate funding of fisheries activities. The fish levy system already being implemented in Tanzania, under which part of the revenue accruing from fisheries is ploughed back into fisheries management activities is a step in the right direction that should be emulated by Kenya and Uganda.

There is insufficient scientific backing of fisheries regulations as a result of inconsistent funding for fisheries research activities and inadequate development of human skills in fisheries research. For example, fish stock assessment on Lake Victoria has been attempted only at three points in time, i.e. 1927-28 (Graham, 1929); 1969-71 (Kudhongania & Cordone, 1974) and recently under LVFRP Phase II in 1997 - 2001, mainly because of lack of funds to support continuous monitoring of the fish stocks. Lack of long-term monitoring programmes, which would provide reliable scientific information, contributes to the reluctance of both managers and resource users to accept the status of the stocks defined by the studies and enforce fisheries regulations.

6.6 Approaches to regulate fishing in Lake Victoria

The FAO Technical Guidelines for Responsible Fisheries (FAO, 1997) provide a range management measures and approaches suitable for various types of fisheries. They indicate the only mechanism available to maintain the biomass and productivity of wild capture fisheries at a desirable level is regulating the amount of fish caught, when they are caught and the size or age at which they are caught. They suggest a number of approaches that can be used to regulate fishing mortality and each one will have different implications and different efficiencies for regulating fishing mortality, impact on fishers, feasibility of monitoring, control and surveillance and other facets of fisheries management. Three of these approaches are relevant to the Lake Victoria fisheries:

1. To ensure that management measures are compatible between the different jurisdictions because the fisheries of Lake Victoria are trans-boundary. This requires harmonisation of management measures in the three countries sharing the lake, which should be achieved through the support of LVFO.

2. Regulating the total catch, and hence the fishing mortality, imposed on a stock, assuming the total amount or mass of fish caught in a fixed period will depend on the concentration of fish in the fishing area, the amount of fishing effort employed during

the period and the efficiency of the gear used. FAO (1997) suggested three ways of regulating fishing mortality:

(i) **Technical measures**, which are restrictions or constraints to regulate the output, which can be obtained from a specific amount of fishing effort, for example gear restrictions, closed seasons and closed areas. These measures attempt to influence the efficiency of the fishing gear.

(ii) **Input controls** directly regulate the amount of fishing effort, which can be put into a fishery. In general, inputs are more easily monitored than the outputs but are associated with problems of determining how much effort is actually represented by each fishing unit.

(iii) **Output controls** directly regulate the catch which can be taken from a fishery and can be seen as an attempt to circumvent the problems associated with defining and enforcing appropriate technical measures and effort regulations by directly limiting the factor of primary concern, the total catch. However, catch controls also have problems largely associated with monitoring and surveillance. In most cases, fisheries are regulated by a combination of more than one of the three types of control measures.

3. The overriding consideration is the decision as to whether access to the resources will be open or limited. The fisheries resources of Lake Victoria are overfished because fishing effort is in excess of that required in the long-term. This implies limitation on total effort with access to the fishery may have to be imposed, while ensuring equity in the process.

6.7 Necessary adjustments in the current fishing regulations

The existing fisheries rules/regulations would probably make significant achievement towards sustainable fisheries in Lake Victoria if they were implemented. Information generated by this study provides the basis for possible fine-tuning of some of the existing regulations to provide more precise steps towards meeting the requirements of long-term sustainability of the Lake Victoria fisheries.

6.7.1 *Minimum gillnet mesh size regulation*

The composition of catches of motorised boats, which target Nile perch, revealed that it is gillnets of 152-mm or larger mesh sizes that harvest fish sizes essentially above the recommended size at first capture of 50 cm TL (Figs 4.9 & 4.10: Chapter Four). When the proportions of nets smaller than 152 mm (6") mesh size, principally 127 mm (5") and 140 mm (5.5") mesh sizes, increased, in the western part of the Ugandan waters (Fig. 4.11: Chapter Four), the mode of catches declined well below 50 cm TL. Considering that motorised boats carry large quantities of gillnets, fish exclusively for Nile perch aiming at the fish processing factory market, it is desirable to set the minimum mesh size of the gillnets they use at 152 mm (6"). This would probably select for fish sizes mainly above the lower recommended size limit. The 127 mm (5") minimum mesh size regulation should be retained for all other fishing boats, mainly parachute and paddled Sesse boats. This is necessary because:

(i) nearly all parachute boats and some paddled Sesse boats operate exclusively in the Nile tilapia fishery, where 127 mm gillnets catch mature fish, of sizes suitable for harvest; and

(ii) the majority of paddled Sesse boats operating gillnets, target Nile perch in near shore areas but the participants in this fishery belong to the poorer section of the fishing communities. Unlike motorised boats, which target the fish processing market, the catches of paddled Sesse boats form the main Nile perch commodity in the local and regional markets. In addition to the fishers, the catches of paddled Sesse boats also benefit a wide section of the fishing communities, mainly women, who are the main players in small-scale fish trade and traditional fish processing. They are therefore important for distribution of income amongst the people dependent on fisheries and promoting local food security. It is, thus, desirable to set their standards at a lower level than those of motorised boats to prevent unfair competition by the latter and more importantly to serve the social objectives of the fishery, i.e. ensuring food security, creating employment and improving the economic and social status of fisher folk especially women and underprivileged groups. The expected effect of enforcing gill mesh sizes at the two levels on Nile perch size selection is demonstrated below (Fig. 6.3).

It is probably possible to enforce gillnet mesh size regulation at the two levels because motorised boats can be easily distinguished from the rest of the fishing crafts. In addition, this regulation would probably be popular amongst ordinary fishers who are the majority in the fishing communities, therefore standing high chances of success in a co-managerial arrangement.

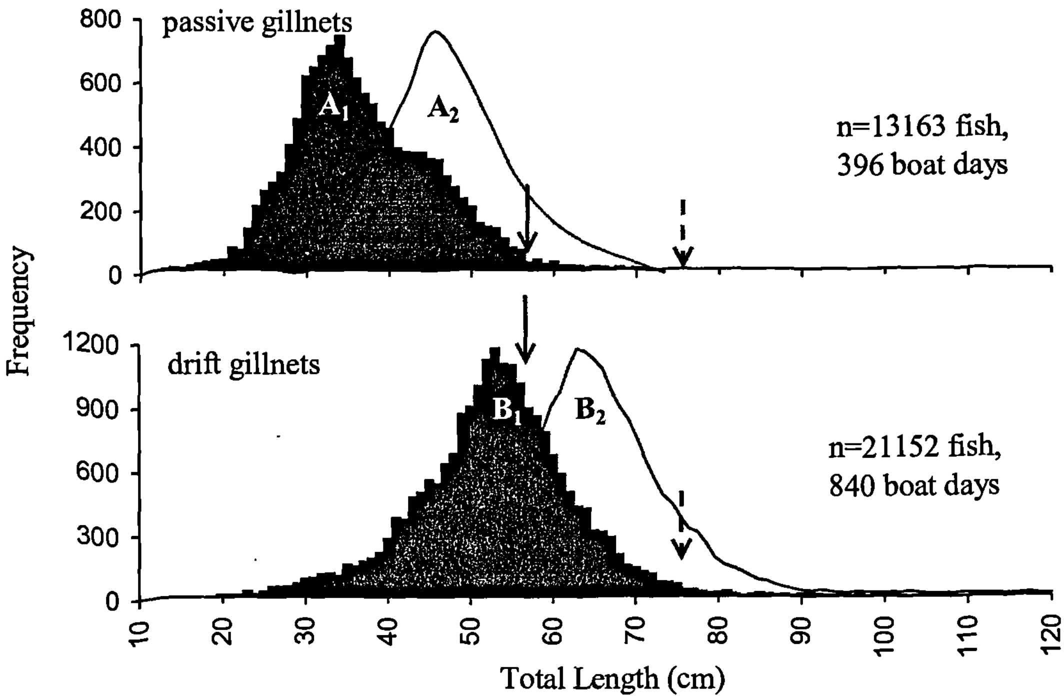


Figure 6.3 Present size selection of Nile perch by passive gillnets, principally, operated in paddled Sesse boats (A_1), and drift gillnets operated in motorised boats (B_1). A_2 and B_2 are respective hypothetical curves showing the likely shift of Nile perch size selection if the paddled boats used a minimum mesh size of 127 mm and the motorised boats used mostly 152 and 178 mm mesh sizes. The modes approximate to those expected based on catches of experimental gillnets (Asila, 2001b). The arrows indicate LM_{50}: males (solid line) and females (broken line). The grey area represents the ideal size limits within which Nile perch should be harvested, i.e. from the minimum size recommended for first capture (50 cm TL) to the size when almost all females are mature (85 cm TL). Nile perch $\geq$85 cm TL constitute the brood stock that should be protected to sustain the stocks.

6.7.2 *Regulating the numbers of gillnets*

Analyses of the population dynamics of Nile perch (Chapter Five) revealed the need to reduce fishing effort by up to 70% in order to maximise yield. One way of causing substantial reduction of fishing effort while observing equity would be, in addition to the mesh size regulation, to regulate the number of gillnets carried by motorised fishing boats. Whereas the numbers of gillnets are to some extent controlled by the small size of the boat and manpower requirements in parachute and paddled Sesse boats, these limitations do not arise for motorised boats. The overall mean number of gillnets used by these boats is currently approximately 64 nets boat^{-1}, having risen from 50 nets boat^{-1} in 1990 (Fig. 3.4: Chapter Three), but some individual boats operate up to 120 nets and more. The majority of these boats (94%) operate gillnets as driftnets (Fig. 4.16: Chapter Four), where two nets are joined vertically to form a panel of 52 meshes, twice as deep as the ordinary standard gillnets like those operated passively by paddled boats in inshore areas, which are 26 meshes deep. This implies that for the same number of nets, driftnets represent much more fishing effort than the ordinary passively set nets because the former expose twice as much fishing area in the water column as the latter. An arbitrary setting of the maximum number of gillnets per boat to 50 nets, the mean number of nets the motorised boats used in 1990, would achieve a crude proportional reduction of fishing effort of motorised boats by about 22%. A more stringent limit of the maximum number of nets per boat set at 40 nets would yield a proportional reduction in fishing effort of up to about 40%. The latter would yield ample reduction in fishing effort if the numbers of boats operating in the fishery are controlled at the present numbers or reduced.

Regulation of the numbers of gillnets used by fishing boats can be very difficult to enforce, in the present top down management system, because it would require immense resources for monitoring surveillance and control. However, it could be possible in a community-level system if the stakeholders are sensitised to realise it is the only way forward to reduce fishing effort to invigorate the declining Nile perch fishery without lay off of large numbers of boats and fishers.

6.7.3 *Minimum mesh size of* R. argentea *nets*

The minimum mesh size set for *R. argentea* nets of 10-mm does not seem to be supported by any current scientific evidence. The 10-mm nets were used lake wide at the start of the *R. argentea* fishery in Lake Victoria, e.g. in Uganda waters they were used up to 1988, operated as a beach seine, but since 1989 smaller meshed nets (5 mm) were introduced, which are now exclusively used, operated as boat seines (Lampala nets) (Ogutu-Ohwayo *et al.*, 1998). Recent data on selectivity characteristics of 5 and 10 mm mesh size nets from the Tanzanian part of the lake where both gears are in use (P. Nsinda, unpublished), are inconclusive because these gears are operated in different areas and by fishing boats of different capacities. It was found (Fig. 4.30: Chapter Four) that cropping of immature *R. argentea* decreased when the 5-mm meshed nets are operated in offshore waters. The answer for a sustainable *R. argentea* fishery in Lake Victoria may lie in reorienting the fishery of 5-mm mesh size nets from inshore to offshore waters rather than enforcing the 10 mm mesh size. Enforcement of the 10 mm mesh size regulation would probably face strong resistance from the fishers, who are now used to 5-mm mesh size nets, in addition to lack of sound scientific backing. There is need to conduct conclusive experiments of the selectivity characteristics of a wide range of mesh sizes e.g. from as small as 3 mm to 10 mm, operated side by side in both inshore and offshore areas rather than blindly implementing the 10 mm mesh size regulation. The results of the selectivity experiments should also be compared with economic viability of the fishing operations in order to come up with more acceptable recommendations. Perhaps, this kind of study will establish the appropriate form of regulation needed for the *R. argentea* fishery.

6.7.4 *Regulating the long line fishery*

The long line fishery for Nile perch is expanding but there are no appropriate regulations in place to control it. Size limit strategies are probably the most appropriate for managing the Nile perch stocks in Lake Victoria but they require very selective fishing gears to reduce incidental mortality (Hilborn & Walters, 1992). As revealed by this study (Figs 4.23 & 4.24: Chapter Four), there is no scientific basis to support regulation of the long line fishery on the basis of hook sizes and this issue needs sound scientific investigation. Amongst the prominent fishing gears targeting Nile perch in Lake Victoria, i.e. beach seines, hooks operated as long lines or hand lines, and gillnets, size limit strategies can only be achieved by using gillnets of suitable mesh size. In the Nile perch fishery with hooks, size selectivity is probably influenced by the type/size of bait, but there is inadequate information to support this premise. Research should be done to establish the bait type/size that selects for the desirable sizes of Nile perch. The present long line Nile perch fishery that is relying heavily on the easily obtained haplochromines is probably not sustainable because it crops large quantities of juveniles as well as larger fish >85 cm TL, which constitute the brood stock, a crucial part of the Nile perch population.

6.7.5 *Enforcement of legislation banning destructive fishing gears and methods*

With the exception of the ban on trawling which has been completely observed around the lake, after Kenya, the last country to effect the ban implemented it in 2001, other banned fishing gears and methods have continued to devastate the fisheries, and their use is probably on the increase. These gears, especially beach seines and undersized gillnets as well as cast nets, and the active operation of gillnets, were banned to stop destructive fishing. Therefore, a management strategy to achieve sustainable fisheries will inevitably have to tackle the problem of enforcing the ban on destructive fishing gears. The majority of destructive fishing gears, e.g. beach seines, undersized gillnets and cast nets are operated in the littoral areas where they cause a wide range of negative impacts to the variety of habitats that support high biodiversity. Implementation of the above fisheries regulations would therefore also help to conserve biodiversity of the lake in addition to achieving sustainable fisheries.

6.7.6 *Closed areas/seasons*

Protected areas and closed seasons are an attractive option for promoting conservation of biodiversity, breeding areas and other vital habitats. However, if they are to be used as a management tool, they need to be unambiguously defined, with clear boundaries and specific scientific knowledge of the species targeted. For instance it is necessary to be sure that the area demarcated as a protected zone for a particular species includes its breeding grounds. Protected areas can also be very difficult to enforce.

6.8 Recent efforts to adjust fishing regulations in Lake Victoria

Harmonised regulation of the fisheries of Lake Victoria was attempted under the Lake Victoria Fisheries Service (LVFS) from 1947 to 1959 and later under the Food and Agriculture Organisation of the United Nations (FAO) CIFA sub-committee for Lake Victoria. Currently under LVFO there are efforts to revive harmonised regulation of the lake's fisheries. A recent meeting of fisheries scientists and managers drawn from the region, sponsored by LVFRP, held in Mukono, Uganda in May 2001, which incorporated some views of the author, reviewed the existing regulations governing the fisheries of Lake Victoria. The management options that were considered were: do nothing, impose a slot size, gear regulations, access restrictions, closed areas and closed seasons, quotas, policy instruments, fiscal measures, plus mechanisms of enforcement. The following resolutions or recommendations were made with respect to management of Lake Victoria fisheries.

1. **Do nothing,** was considered inappropriate and the consensus was that something should be done.
2. **Slot size,** the recommendation was 50 - 85 cm TL for Nile perch with respect to input material to processing factories. This was supposedly representing catches of 127 - 229 mm (5 - 9") gillnet mesh sizes and hook sizes 6-10 (the latter subject to confirmation). It was noted that the slot size regulation must be implemented in

conjunction with effort/catch restrictions to avoid excessive exploitation within the slot size limits. The slot size has since been adopted and it is currently enforced in Uganda.

3. **On gear regulations**, the meeting upheld the need to enforce existing regulations on fishing gears for Nile perch and Nile tilapia, i.e. the minimum gillnet mesh size of 127 mm (5 inch) set by CIFA (1992), and implementation of the complete ban of trawling, beach seining and cast netting throughout the lake. It also raised the need for research to establish the effects of long lines to the Nile perch fishery because there was no existing regulation governing the use of the gear and there are fears of possible reduction of the spawning stock with continued use of the gear in the long term. The 10 mm minimum mesh size net regulation for *R. argentea* in Tanzania, was considered appropriate for the whole lake, and therefore was to be introduced in Kenyan and Ugandan waters and to be enforced in Tanzania. The introduction of new fishing gears without prior consultations was prohibited. It was noted that due consideration should be given to the implications of gillnet mesh size regulations on other fisheries and the needs of developing fisheries.

4. **On access,** a property rights system was recognised as necessary to implement management measures. Access should be controlled through licensing/permits of boats, fishermen, and gears - regulated through co-management initiatives.

5. **Quotas** were considered inappropriate on fishers but pertinent to processing factories. Control of effort *per se* was considered a better option.

6. **Closed areas/seasons,** was considered to be inappropriate because spawning and nursery areas were not well defined. Closed seasons on factories, which would be easy to implement, would also have negative affects on rural livelihoods if implemented.

7. **Policy instruments,**

(i) Co-management and community-based management mechanisms needed for more cost-effective implementation of regulations.

(ii) Strengthening of institutions required provision of appropriate funding for management.

(iii) Synergies with other sectors/stakeholders to development integrated management packages (e.g. forestry, environment and wildlife).

(iv) Recognition of need for improved data management systems and need for frame surveys linked to well-developed catch assessment systems for determining status and trends in the fisheries.

8. **Fiscal measures,** Emphasis was requirement to harmonise fiscal measures, e.g. taxes, levies and non-taxable revenues, between countries and link to macro-economic policies of individual countries.

9. **Enforcement**

(i) Doing nothing was considered inappropriate.

(ii) Introduce monitoring, control and surveillance schemes but this should be properly implemented and linked into a community based management approach.

(iii) Education and extension practices improved to support management initiatives.

(iv) Integration with other sector resources and enforcement institutions, e.g. police.

(v) Periodic review by partner states to evaluate efficiency of enforcement regimes.

6.9 Management approach and institutional framework

Pressing demands or needs, e.g. to satisfy economic interests, food or employment from fisheries, invariably take precedence over long-term goals including that of sustainability, which raises the fundamental need in fisheries management to address the question of dependence on fish resources and to reduce it to the level where other goals and objectives are likely to be considered (Cochrane, 1999). The two most important institutional features influencing the effectiveness of fisheries management around the world are the access regime and the extent of user participation in the process. Fisheries managements in the past have been characterised by open access and government controlled top-down approach. Without attempting to prescribe the system, the FAO Code of conduct for Responsible Fisheries (FAO, 1995) calls for fishing effort to be commensurate with the productivity of the stock, for only authorised fishers to be allowed to fish, and for a system which promotes suitable economic conditions. The prevalence of top-down systems has tended to isolate fisheries management agencies and officers from the fishers, leading to a lack of legitimacy of the former (and therefore their regulations) in the eyes of the user, and hence to poor compliance and cooperation (Jentoft, 1989). Cochrane (2000) identified political will, at all levels of governance, as the starting point for ensuring effective and accountable fisheries management. He indicated that political will is necessary to move to the level where general policy is turned into decisions and actions, frequently with some cost incurred either by excluding some fishers completely or by reducing the income of many. This is because as long as there are no acceptable alternative sources of employment and livelihood available to fishers, or a subset of the fishers, there will be extremely strong resistance to any changes that result in some of them loosing access. This problem is particularly acute in developing countries where opportunities for alternatives are very low and unemployment rates are high. While many developed countries can afford to buy out their fishers, this is not an option for the countries sharing Lake Victoria. Article 5 of the Code of Conduct recognises the particular difficulties faced by developing countries and calls for assistance, including financial and technical assistance, to be provided to developing countries to assist them in meeting their need to develop responsible fisheries. These needs must include finding alternative sources of livelihood for those who will be displaced from fisheries where effort is reduced to achieve sustainability. Solutions that do not adequately achieve this will either fail or will simply result in similar problems arising elsewhere. If in the fisheries of Lake Victoria, the problem of excessive dependency cannot be resolved, then achieving sustainability, economic efficiency or social uplift will remain secondary, and the most likely trend will be a decline over time in resource productivity, social benefits and economic performance. The solutions to the fundamental problem of excess dependency of fisheries lie mainly outside fisheries, in alternative opportunities (Cochrane, 2000).

The Lake Victoria Fisheries Management Plan prepared for LVFRP (Bwathondi *et al.*, 2001) provides different options for the management of the fisheries and other natural resources of the lake. In recognition of the complexity of the lake ecosystem, the often-abrupt perturbations occurring in the habitats and biological production systems of the lake, and the insufficient scientific information on interactions between all components of the ecosystem, the management plan stressed the need to apply both adaptive and precautionary management approaches. Adaptive management approaches allow rapid adjustment of options and regulations as soon as changes occur in the ecosystem or socio-economic aspects of the fishery. The adaptive management approach cannot work in a central government system, in which the process to change rules takes a long time. Rather, it would be most appropriate under a community-based approach since the decisions to change rules governing the fishery or communities involved in fishing would be introduced faster through byelaws. On the other hand, in the data limited scenario of Lake Victoria fisheries, the precautionary management approach (FAO, 1995) will allow for management actions to be taken with the best scientific evidence available.

The management plan recognises that these management approaches would operate best in an environment of increased community participation in decision-making, implementation, monitoring and enforcement. It singles out Co-management, i.e. the collaborative arrangement between the state and a community of the resource users aiming to conserve the resource base (Geheb *et al.*, 2002), as the effective strategy for the implementation of these management approaches. Co-management represents power sharing and a shift in power away from the state to the community, and therefore requires institutional reforms designed to empower the communities to make byelaws to safeguard the resources. Geheb *et al.*, (2002) suggested a three-tiered hierarchy for fisheries administration under the co-management framework, i.e. the community level, the meso-level (district) and the regional level, which contains within it the right to seek horizontal support and influence (Fig. 6.4). The fisheries management plan proposed a more detailed institutional framework but in principle, with the same three management levels.

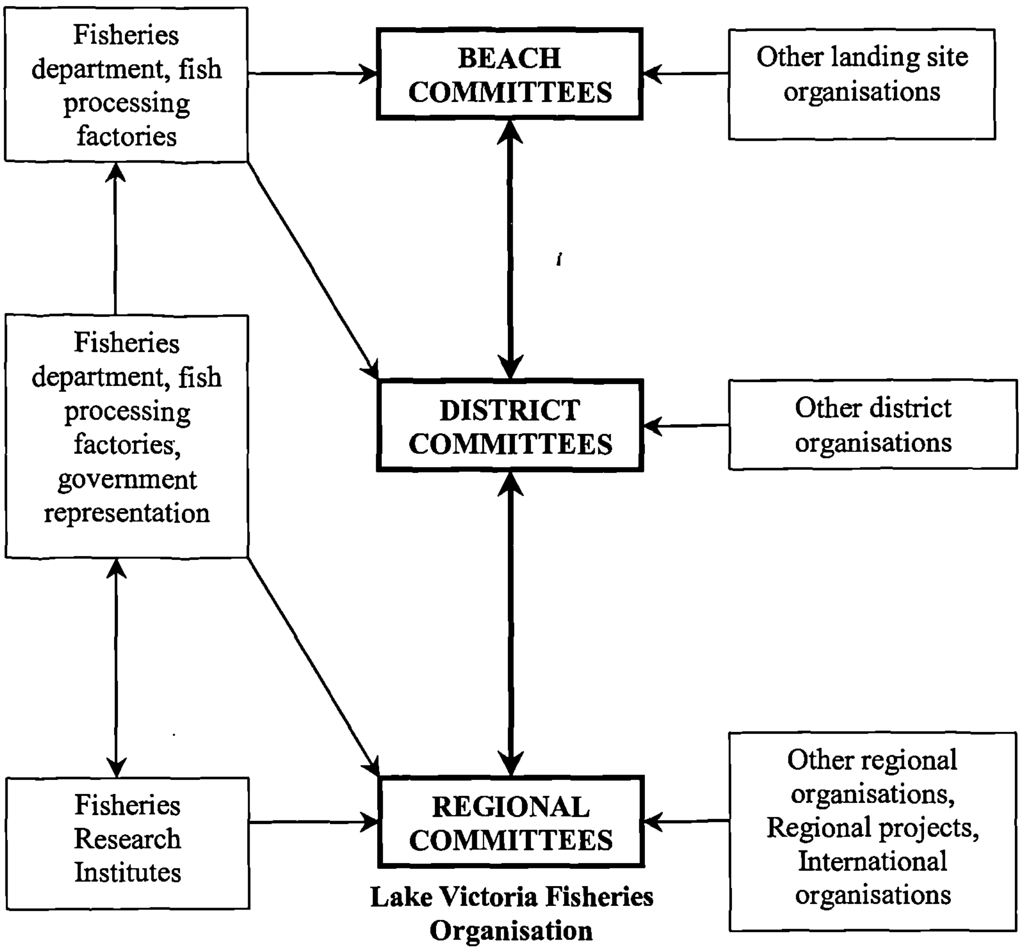


Figure 6.4 The framework of key institutions for administration of fisheries management in Lake Victoria within the co-management approach (modified from Geheb *et. al.*, 2002).

All landing sites on Lake Victoria have some kind of existing beach committee, which Geheb *et al.* (2002) proposed should form the backbone of Lake Victoria fisheries management. This is because communities already have experience with these beach committees and in addition to legitimising them, they would be put to maximum utilisation within the management framework. Geheb *et al.* (2002) emphasized, however, that the beach committees must be as representative as possible and all members of the landing community should contribute to the selection process.

At the regional level some progress has been made in the direction of institutional reforms that demonstrate some political will necessary for the rational management and sustainability of the fisheries of Lake Victoria. This was through the formation of the LVFO, which brings together institutions concerned with the development and management of Lake Victoria's fisheries, after recognising the need to manage Lake Victoria as one entity. Two technical committees of the LVFO, the scientific and fisheries management committees, are mandated to promote regional research activities to improve fisheries management.

In Uganda the constitution (Republic of Uganda, 1995) sets a new system of local governance that seeks to transfer central government powers to districts and lower levels of administration to ensure peoples participation in, and democratic control of, decision making. The roles and functions of local governments are further elaborated in the Local Governments Act (Republic of Uganda, 1997), which requires district councils to devolve certain powers to lower local government councils, including the control of fishing, markets and landing sites. The draft Fisheries Policy for Uganda (MAAIF, 2002) indicates the communities, under decentralisation policy, are expected to take a leading role in managing fisheries resources, especially in near shore waters. Under this arrangement, the central government retains direct responsibility of dealing with major issues and emergencies. The Department of Fisheries Resources (DFR), the fisheries arm of the central government, is mandated to promote, guide and support the sector, and also retains responsibility for setting and enforcing the standards and regulations for practices pertaining to fisheries. These are major steps towards empowering the fishing communities to take up management roles, although the scales of operations remain unclear because the communities are provided with duplicating and sometimes contradictory management roles (Geheb, 2000). Landing management committees (LMCs) originally set up, as task forces to combat fish poisoning in the Ugandan part of Lake Victoria have remained as permanent features (Kyangwa, 2000), providing community leadership, and if empowered they could spearhead fisheries management under co-management.

In Tanzania the organisation of the fisheries sector is generally similar to that in Uganda with Central Government and Regional/Local Government functions. The government at the district level has developed management partnerships involving fishing villages, known as Beach Management Units (BMUs) which are charged with enforcing and implementing the national fisheries regulations.

In Kenya the organisation of the fisheries sector is slightly different from that of Uganda and Tanzania with no clear central-local Government demarcation.

There is general consensus in the region that institutional set-up of fisheries management should change to accommodate the co-management strategy and operate a combined adaptive and precautionary approach. Therefore, LVFO and the relevant national institutions should immediately take up the challenge of identifying and defining the roles and responsibilities of stakeholders under co-management and lobbying for the political will of establishing a harmonised institutional framework around the whole lake.

Putting in place a new institutional framework requires protracted negotiations at the various levels of governance, and stakeholders and enacting appropriate legal instruments. This is a very slow process where tangible achievements can only be expected in the long term. However, the present status of the fisheries of Lake Victoria, especially those of Nile perch, requires immediate inception of regulatory mechanisms to avert collapse.

6.10 Strengthening monitoring of the commercial fisheries of Lake Victoria with emphasis on catch-effort sampling

The artisanal fisheries of large inland waters, including Lake Victoria, have been monitored by direct enumeration or frame surveys (Bazigos, 1974; Caddy and Bazigos, 1985). These involve direct enumeration of all or random sub-sampling of a high proportion of the fish landing sites on a regular or *ad hoc* basis and collecting as much information on the number of fishing boats, fishing gears, and fishermen as possible. Frame survey data do not truly represent the pattern over space and time because they are based on single sample and cannot be repeated often because of the generally excessive manpower and financial resources required to implement them, especially on large fisheries (Cowx, 1993). One of the main objectives of frame surveys has been to determine the structure of the fishery, which would then form the basis of designing a statistical fish catch assessment system. In the Ugandan part of Lake Victoria, the results of the frame survey of 1990, carried out under the FAO funded project for Fisheries Statistics and Information Systems, were used to design a catch assessment system in 1991, which became unsustainable and collapsed by the end of the project. The most recent lake wide frame survey in 2000 funded by two large projects on the lake, the Lake Victoria Environment Management Project (LVEMP) and the Lake Victoria Fisheries Research Project (LVFRP) and coordinated by the Lake Victoria Fisheries Organisation (LVFO), had as one of its primary objectives to provide baseline data for designing a regionally harmonised statistical fish catch assessment system for Lake Victoria. Two years later, this process has not been implemented.

The purposes of catch assessment

Decision-making in fisheries management should ideally be based on the scientific evaluation of fish stock characteristics. However, these high standards cannot be met in the management of inland fisheries, especially in the developing world where resources for carrying out appropriate research programmes are inadequate. Catch assessment is a simple mechanism, which can provide sufficient information about the status of the fishery to enhance decision-making at a minimal cost to the fishery manager (Cowx, 1993). Figure 6.5 provides a scheme representing inland fisheries management in which catch effort sampling is the prominent method of evaluation. A catch assessment programme can provide timely data for estimation of the total catch in weight of important commercial species and their length composition, which elucidate the performance of the fishery to guide management interventions.

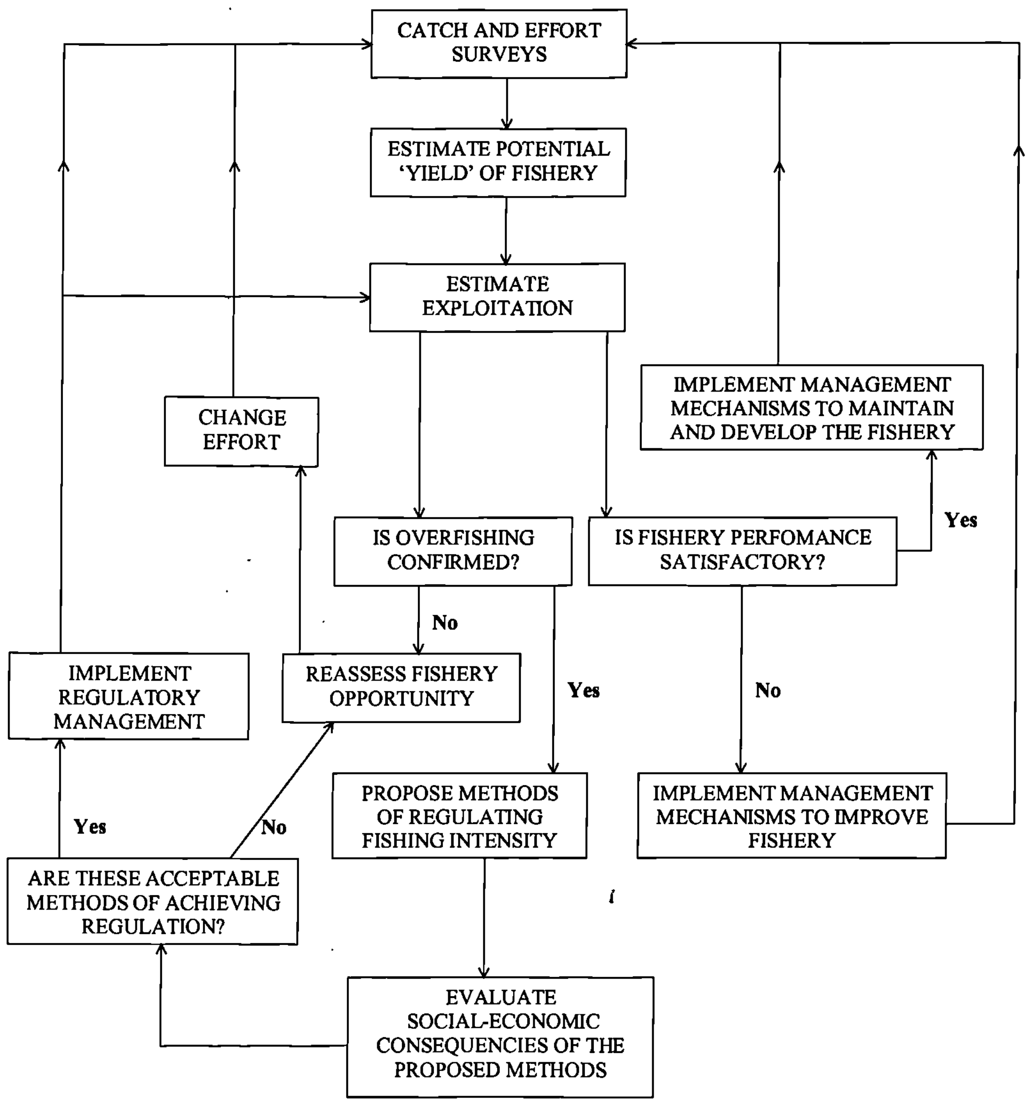


Figure 6.5 Flow chart for decision-making in the management of inland fisheries using catch effort sampling techniques as the method for evaluation (from Cowx, 1993).

The obstacles to catch assessment in Lake Victoria

The failure of catch assessment in the Ugandan waters of Lake Victoria can be largely blamed on the lack of the institutional mechanisms to run the programme. At present there are two prominent government institutions in the fisheries sector, the Fisheries Resources Research Institute (FIRRI) with the mandate to carry out research and provide guidelines for fisheries management, and the Fisheries Resources Department (FRD) with the mandate to implement fisheries management functions. Traditionally, catch assessment has been perceived as the responsibility of the Fisheries Resources Department. However, there has been lack of clear mandate to carry out catch assessment, which, coupled with decentralisation of fisheries management duties to local governments in the mid 1990s, is probably the overriding factor responsible for complete collapse of the system in Uganda. The present formal hierarchy of the fisheries sector established under the 1997 Local Government Act created fisheries regulation systems at district and sub-county and parish levels. At the lower levels nobody is clearly accountable for catch assessment. For any catch assessment design to succeed, it should be institutionalised in such a way that specific roles, responsibilities and accountability are clearly spelt out in the institutional framework governing the fisheries sector.

Rejuvenating catch assessment in Lake Victoria

In view of the need for long term accurate data on catches to guide management of the fisheries of Lake Victoria bold steps need to be urgently taken by LVFO and the individual governments of the countries sharing the lake to revive catch assessment surveys around the whole lake. To improve the quality of catch assessment data, the role of collecting these data needs to be separated from other fisheries duties. Therefore, catch assessment would probably be more successful if it were placed under the Fisheries Research Institutes throughout the lake. For instance, in Kenya, where the mandate of catch assessment is under the research institute, data collection has been more consistent. A centralised system of catch assessment under Fisheries Research institutes could probably have more capacity to guarantee high quality data compared with Fisheries departments, especially under the present decentralisation policy in Uganda and Tanzania. There is also potential to of utilise beach institutions under the co-management system of fisheries management when it becomes operational.

This study provides the benchmarks that should be considered in the future designs of catch effort data collection, prominent of which is the consideration of the variations in the types, sizes and propulsion of fishing boats, on which all other differences, e.g. fishing methods and fisheries, fishing methods and times, landing times and places, and diversity in fishing skills, are largely dependent. This implies that a design of a stratified random sampling programme based on types, sizes and propulsion of fishing boats could be largely representative of the major fisheries of Lake Victoria, and should probably be adopted when reviving catch assessment in the lake.

6.11 General conclusions

Huge increases in all aspects of fishing effort took place in the Ugandan part of Lake Victoria over the last decade following the establishment of Nile perch in the late 1980s.

The number of fishing boats approximately doubled, from 8000 to 15 462 boats, and the numbers of gillnets almost quadrupled, from 84 977 to 294 529 nets, in 1990 and 2000 respectively. The remarkable increase in numbers of gillnets was accompanied by substantial reductions of gillnet mesh sizes and adoption of more effective methods of gillnet operation, i.e. active and drifting modes of gillnet operation when targeting Nile tilapia in inshore areas and Nile perch in deep offshore waters, respectively, compared with the traditional method of operating gillnets as a stationary passive fishing gear. The use of all other fishing gears including the illegal ones, especially beach seines and undersized gillnets, which indiscriminately catch large quantities of juvenile fish, also increased considerably. This excessive fishing effort is leading to serious reduction in fish stocks as implied by the declining CPUE since the early 1990s. These are classic indicators of a declining fishery and suggest that the current level of fishing effort is not sustainable.

Fishing pressure, both the use of illegal destructive fishing gears and the overall fishing effort, is highest in the eastern zone in the Ugandan waters, and in the Kenyan waters at the regional level. Efforts to reduce overall fishing effort and to eradicate the use of destructive fishing gears should focus more on these parts of the lake, whereas the management programmes in other areas should concentrate more on preventing further increases in fishing pressure. The major problem identified in areas, which appear to have relatively less fishing pressure, i.e. the western part of the Ugandan waters, and the Tanzanian waters in general, is that motorised boats targeting Nile perch are concentrating fishing effort around the minimum legal gillnet mesh size of 127 mm. In the long term this could, through recruitment overfishing of Nile perch, erode the benefits of the apparently lower fishing pressure in those areas. This noticeable rush for small Nile perch is probably driven by the demand of fish factories because they buy the small fish caught. Enforcement of the slot size (50 – 85 cm TL) of Nile perch going into factories would probably discourage the lowering of mesh sizes of gillnets used in these areas.

The fishing strategies of boats, in terms of the habitats where they fish, the target fish species and/or size of fish targeted, vary with boat type especially in the gillnet fishery, which is the predominant fishery targeting Nile perch and Nile tilapia. Parachute/dugout boats are used to target Nile tilapia inshore with mainly actively operated gillnets; paddled Sesse boats are used, principally, to target juvenile Nile perch in shallow waters up to about 10 m depth with passively set gillnets; and motorised/sailed boats in which gillnets are predominantly operated as driftnets in mid-waters of deep offshore waters targeting large Nile perch. The operations of each category of gillnetting boats, therefore, have distinctive impacts in the fishery, thus management measures should be tailored to specific categories of boats. For instance, the current status of the fisheries suggests that the near shore areas where small manually powered boats (parachutes and paddled Sesse boats) operate are overfished to unsustainable levels. Therefore, to restore the fisheries in inshore waters, the numbers of boats operating in this zone should be urgently reduced and the legislation banning some fishing gears, e.g. beach seines and undersized gillnets, which are also exclusively operated in inshore areas and are known to be very destructive, should be enforced.

The present exploitation rates and fishing mortalities of Nile perch and Nile tilapia in the Ugandan waters are excessive and unsustainable requiring large reductions of the present fishing effort to achieve optimum yield. High fishing effort emanates from the open access policy of the fisheries, which should be regulated in a protracted process involving all stakeholders, because of the socio-economic and political complexities involved. In the short-term, substantial reduction in fishing mortality could be achieved through immediate enforcement of the ban on destructive fishing gears, like beach seines and under-sized gillnets.

The selection of Nile perch sizes within the slot size of 50 – 85 cm TL could be achieved from catches of drift gillnets with the minimum mesh size of 152 mm. The present Nile perch fishery with hooks is largely non-selective and should be discouraged. The type/size of bait is suspected to be the major factor controlling the Nile perch size selectivity of hooks rather than the size of hooks. Future studies should endeavour to identify the type of bait that can improve the selectivity characteristics of hooks if their use cannot be banned. In the Nile tilapia fishery, in addition to the use of undersize gillnets that crop juvenile fish, active fishing methods with both gillnets and cast nets, although illegal, are prevalent. These fishing methods are probably a sign that the fishery is heavily overfished and could lower the production potential of Nile tilapia further through disruption of breeding, consequently, they are considered not sustainable.

The present fishing effort for *R. argentea* in the Ugandan waters was achieving approximately the maximum sustainable yield, but this fishery is more or less limited to inshore areas using mosquito seines and would probably become unsustainable if fishing effort is allowed to exceed the present level. The 5-mm mesh size mosquito nets, which are the main fishing gear used in the Ugandan waters, catch predominantly juveniles in inshore sheltered waters, where the present fishery is concentrated, but appear to have little effect on juveniles when operated offshore. Expansion of fishing effort without endangering sustainability of the *R. argentea* fishery would probably be viable if fishing was reoriented to offshore stocks by motorisation of fishing boats and adoption of fishing gears like lift nets, which are appropriate for fishing in open waters. One issue associated with fishing far in the *R. argentea* fishery is getting the catch ashore before it rots. Sustainable exploitation of *R. argentea* in inshore areas would probably require increasing the mesh size mosquito seines used. Closed seasons/areas may be inappropriate to protect immature *R. argentea* in inshore waters because juveniles dominated the catches throughout the year and no distinct spawning season or areas were identified on which to base such measures.

6.12 The way forward

It is indisputable that the present fishing effort targeted to the major commercial fish species, Nile perch and Nile tilapia, is excessive and is not sustainable in the long term. This fishing effort is exacerbated by uncontrolled demand for fish, especially by the fish processing industry, operating within the existing open access policy framework that encourages unlimited entry of fishers, fishing boats and fishing gears. The fishery is characterised by wide scale use of illegal, destructive fishing gears and methods; capture of immature fish; capture of breeding fish and/or disruption of breeding activities, which are responses to declining fish catches, and demonstrate serious disregard of the existing fishing regulations. The following interventions are recommended for restoring fishing effort to sustainable levels.

There is need for rapid reduction of fishing mortality in the over utilised fisheries, especially Nile perch and to some extent Nile tilapia as a precautionary measure to guard against the dangers of overfishing, resource depletion and stock collapse. Immediate interventions should attempt to control the size of fish caught, giving priority to enforcing the existing legislation on fishing gears, especially those targeting the young stages of fish.

- **Controlling the fish processing industry**

The fish processing factories have been identified as the most obvious force driving exploitation of the Nile perch fishery and control of their activities could indirectly influence fishing operations in the lake. Two interventions in the fish processing industry could be appropriate for reducing overall fishing effort.

(i) Enforcing the slot size (50 to 85 cm TL) of Nile perch going into the factories could, indirectly, discourage the lowering of mesh sizes of gillnets, especially among motorised boats, which target this lucrative market. The compliance of the fish factories can be monitored easily at the major fish outlets and the factory premises compared with monitoring catches of individual fishing vessels at the numerous landing sites around the lake. Therefore, this intervention could be expected to register high levels of success in reversing the decline of gillnet mesh sizes in the short term. However, to achieve sustainable fisheries in the long term, additional efforts to regulate overall effort, i.e. the numbers of fishing boats and/or the numbers of gillnets, is necessary.

(ii) A mechanism to control the input and/or output of fish processing factories ought to be established to ensure that the quantities processed are consistent with the fishery production potential of the lake. This could be achieved by introducing a quota system to factories, in the long term, with adjustments following fisheries monitoring programmes.

- **Implementing the ban on illegal fishing gears and methods**

Attempts should be made at all levels of the existing fisheries administrative structures to implement the ban on destructive fishing gears, especially beach seines and undersized gillnets. This is because these fishing gears and methods are responsible for high fishing mortality, especially of juveniles, e.g. the results of Nile perch population analyses (Table 5.1) show that the fishing mortality caused by beach seines is more serious than all other gears targeting the species. To enhance compliance there is need for greater community involvement in the fight against the use of these gears. This could be achieved by sensitising the fishing communities about the dangers posed by these gears, through improved fisheries extension services.

- **Discouraging the long line fishery**

Long lining is one of the prominent fishing gears used to catch Nile perch and its popularity is increasing. This gear catches a high proportion of fish outside the limits of the slot size, e.g. in this study 57.8% of their Nile perch catches were <50 cm TL and 8% >85 cm TL. There is no evidence of selectivity according to hook size but bait type/size appeared to be more important in regulating the size of capture. In the short term therefore, long lining should be discouraged pending further scientific investigations of their selectivity characteristics.

- **Setting the minimum gillnet mesh size limits at two levels**

The present minimum gillnet mesh size limit at 127 mm (5 inch) is appropriate for the Nile tilapia fishery if operated passively but is too small with respect to harvesting Nile perch of sizes within the slot size of 50 – 85 cm TL. The latter requires gillnets in the gillnet mesh size range 152 to 254 mm. This study has demonstrated that motorised boats, in which huge quantities of gillnets are used and catch exclusively Nile perch, there is a tendency to lower gillnet mesh sizes in some parts of the lake to around 127 mm, which catch large quantities of juvenile fish. The minimum mesh size of gillnets used by motorised boats should be set at 152 mm, whereas the 127 mm minimum mesh size could be maintained for the paddled boats operating inshore. In addition reducing the overall pressure on juvenile Nile perch it would also reduce the competition between the large-scale operators with motorised boats and the small time operators with paddled boats, thus promoting social objectives of the fishery, like maximising employment and food security. This is because the fishery with paddled boats is relatively more labour intensive and supplies the local and regional demand compared with the motorised boats which target the market of fish factories.

- **Limiting access**

Fisheries resources are finite, and open access fisheries the world over, are not precautionary. The open access policy framework governing the fisheries of Lake Victoria is indisputably the overriding factor contributing to the present unsustainable status of the fisheries, which are characterised by heavy overexploitation. Immediate serious considerations of limiting access to avert overexploitation caused by excessive fishing effort in Lake Victoria should be undertaken. In the limited access regime, fishing licenses should be classified according to the type/size of boat, specifying the limits of fishing gears, i.e. type size and quantities, allowed to be operated on the boat and the target fish species. These strict rules would enable management to apportion fishing effort to different fisheries and would be clear targets of surveillance and enforcement efforts.

- **Improving monitoring of the fisheries**

One major setback for management of the Lake Victoria is the lack of reliable information on the performance of the fishery. It is vital to enhance information gathering and dissemination. There is therefore an immediate need to revive the fisheries statistical data collection in Uganda and Tanzania. Under the auspices of the LVFO, catch assessment surveys and fisheries data reporting systems should be harmonised around the whole lake.

- **Co-management**

Having realised that regulating fisheries under a centralised system is ineffective, there is need to speed up the process of streamlining institutional mechanisms and legal instruments under which a co-managerial arrangement of fisheries management could operate. This should include defining the stakeholders and their roles in fisheries management.

- **Sustainable funding**

Funding constraints are a major hindrance to sustainable management of the fisheries of Lake Victoria. Any institutional arrangement for the lake must address the issue of sustainable funding. This could be achieved through reasonable taxation of economic activities along the fish production chain, including licenses, penalties and fines, enhanced by budgetary allocations by the three states.

6.13 Future studies

1. There is no appropriate regulation governing the Nile perch fishery with long lines at present and there is no reliable scientific basis on which this fishery could be regulated. It is suspected that Nile perch selectivity of long lines is influenced by bait type/size rather than hook size. Studies should be conducted to determine the fishing conditions under which long lines would become more selective for the desirable sizes of fish.

2. In the *R. argentea* fishery, the 10 mm minimum mesh size regulation is probably unrealistic and is not scientifically proven to be the most appropriate for harvesting the species. The *R. argentea* size selectivity characteristics of a wide range of mesh sizes should be studied in both inshore and offshore habitats to determine the most appropriate mesh size for harvesting the species in Lake Victoria.

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8. APPENDICES

Appendix 2.1 The 1990 Frame survey forms

FRAFORM. A1

---------- FISHIN PROJECT UGA/87/007----------

QUESTIONNAIRE FOR FRAME SURVEY

NAME OF RECORDER____________________ DATE: ______________

TIME: ______________

1. Person (s) interviewed: Name Title

_____________________ __________________

_____________________ __________________

_____________________ __________________

2. Landing characteristics.

Name of landing:________________ Name of parish:______________

Subcounty county_______________ County ____________________

District ______________________ Map code________________

Nearest village km to main road_______ Km to main road_____________
(i.e. served by public transport)

Access to Landing: (tick)

Tarmac road_____ Murram road_____ Footpath_____ Only by water______

If landing is on island, specify island name:_____________________________

3. Staff establishment of landing:

(Name/Designation) ____________________, ____________________

____________________, ________________

If not permanently staffed, do fisheries staffs ever visit it?
(YES/NO) _________

If YES, how often? (✓) Once a week _________, Once a month______

Twice a month________, Other ____________

For what purpose? (✓) Fisheries statistics________, Extension work______

Other ________

4. In which year was this fish landing established (Since when in use)? __________

5. Is the landing used all year round? (YES/NO) __________

- If YES, do fishermen also use any other landing (s)? (YES/NO) _______
- If YES, which landing (s)? ______________ ______________

  ______________ ______________

- If NO, during which period (s) is it not used?

  (Month) from ____________ (Month) to ____________

  Reason: (✓) Floods ______, Scarcity of fish_______, Other______

  (Month) from ____________, (Month) to ____________

  Reason: (✓) Floods ______, Scarcity of fish_______ Other______

6. Is processed fish landed here? (YES/NO) _________

   If \YES;

   Type (s) (✓) Smoked ______, Sundried ______ Salted _________

   Place (s) of origin? ___________, ___________, _________,_____

   ___________, ___________, _________,_____

   How often? (✓) Daily_____, Once a week_____, Twice a week_____

   Other_____,

7. Number of disused boats: ________) TOTAL:_____

   Number of active boats: ________)

ACTIVE BOAT CHARACTERISTICS	PLANKED Powered	CANOÉ (No.) Non powered	DUG OUT No.	TRAWLER No.
TOTAL No.				
FISHING ONLY				
NO./CREW				Remarks
NO.OWNERS				
FISHING/TRANSP				
NO. CREW				
NO.OWNERS				
TRANSP.ONLY*				
NO.CREW				
NO.OWNERS				

* TRANSP. ONLY = FISH. TRANSP. _____ + NON FISH. TRANSP._____

8. Gears used (✓) Remarks:

Gillnets ____________ Beach-Seines ________________________

Long Line ____________ Mosquito-Seines______________________

Cast Nets ____________ Traps ________ ________________

Trawl Nets ___________ Others ________

9. Fish species (✓) Others

Lates ___________ Protop ________ ________________

Tilapia ___________ Mormy ________ ________________

Bagrus ____________ Rast ________ ________________

Clarias ____________ Hapl ________ ________________

10. Are the fisherfolk (operators and/or traders/processors) of this landing organised into any society/societies? (YES/NO) _______

If YES, Specify society name(s) and number of members:

Name: _______________No. _______ Name: ___________No. ______

Name: _______________No. _______ Name: ___________No. ______

11. Market destinations for Catch : Is there market at landing site?
(YES/NO) ______
Other markets (specify): __________________, ____________________

__________________, ____________________

__________________, ____________________

12. Facilities/Amenities at landing only (Number)

FEATURE/SERVICE	NO. UNITS	FEATURE/SERVICE	NO.UNITS
Bicycle	________	Frying unit	________
Pick-up	________	Boat repair/const.	________
Lorry	________	Fish display table	________
Bus	________	Fisheries office	________
Van	________	Petrol station	________
Wheelbarrow	________	Piped water	________
Weighing shed	________	Public latrine	________
Cleaning slab	________	Net repair	________
Drying rack	________	Oputboard repair	________
Smoking pit/kiln	________	Fishing equip.shop	________

13. Fishing risk at landing:

(a) During the calendar year 1990, were any fishing/transport boat from this landing involved in any capsizing or sinking accidents

(YES/NO) __________

(b) How many separate accidents occurred? ____________

How many boats from this landing were involved in each, per type of boat (P, D, F, T, N) and for what reason?

No. Acc .1 _____ No. & Type Boat (s)_________ Reason ____________

No. Acc .2 _____ No. & Type Boat (s)_________ Reason ____________

No. Acc .3 _____ No. & Type Boat (s)_________ Reason ____________

No. Acc .4 _____ No. & Type Boat (s)_________ Reason ____________

(c) Was there any loss of life ? (YES/NO) ______________________________

If YES, how many died (total for all accidents)? ________________________

(d) Was there any loss of property (boats, Equipment's, etc.)? (YES/NO)________

If YES, specify ____

____

____

____

General Remarks:

____

____

____

____

INDIVIDUAL BOAT PARTICULARS

NAME OF RECORDER____________________ DATE: ______________

WATER BODY __________________ NAME OF LANDING _______________

DISTRICT ______________________ COUNTY _______________________

SUB-COUNTY ___________________ MAP CODE _____________________

BOAT SERIAL No. ________________ LICENCE NO. __________________

NAME OF OWNER ____

ACTIVITY [ ] 1 = Part of crew 2 = Supervisor 3 = other

NUMBER OF CREW ____________ LENGTH OF BOAT (m) ______________

TYPE OF BOAT: [ ] 1 = Planked 2 = Dugout 3 = Fibreglass
4 = Trawler 5 = Not classified

ENGINE (Y/N) [ ] IF YES, WHICH HORSEPOWER: _______________HP

ACTIVITY [ ] 1 = Fishing only 2 = Transport only
3 = Fishing and transport

GEAR TYPE (S) USED [ ] [ ] [ ] [ ] [ ]

1 = GILLNETS MESH SIZE	NO.	2 = HOOKLINES	SIZE	NO.
_______	_____		_____	_____
_______	_____		_____	_____
_______	_____		_____	_____
_______	_____	3 = CAST NETS		_____
_______	_____	4 = BEACH SEINES		_____
_______	_____	5 = TRAPS		_____
_______	_____	6 = TRAWL NETS		_____
_______	_____	7 = NOT CLASSIFIED	_____	

REMARKS:____

Appendix 2.2 The 2000 Frame survey forms

FRAME SURVEY: LAKE VICTORIA FISHERIES, 2000
Fisheries departments and fisheries research Institutes of Kenya, Tanzania and Uganda.
LVEMP/LVFRP co-operative programme.

CODING GUIDE

SHEET 1
Notes on craft

Total craft	=	All craft at the beach
Derelict Craft	=	All damaged craft unlikely to be repaired in the next 3 months
Transport craft	=	Craft used for transport only and never for fishing

SHEET 2:

Craft type:
1. Sesse flat at one end
2. Sesse pointed at both ends
3. Parachute
4. Dugout
5. Other (specify)

Length:
Measured in metres (One long step is about a metre)

Prop. = Method of propulsion: State the main method
1. Inboard motor (state horsepower, e.g. 1(15) = inboard engine of 15HP)
2. Outboard motor (state horsepower, e.g. 2(15) = outboard engine of 15HP)
3. Paddles
4. Sails

#CREW = The number of crew that normally accompany the boat

Gear types

Gillnets:	State the number per mesh size
LL	Long lines: state the number of hooks
CN	Cast net: state the number
TR	Traps: state the number
MS	Mosquito seines (mosquito net for dagaa/omena/mukene); state number
Others	Other gears: state type and number

FRAME SURVEY: LAKE VICTORIA FISHERIES, 2000
Fisheries departments and fisheries research Institutes of Kenya, Tanzania and Uganda. LVEMP/LVFRP co-operative programme.

Sheet 1: Summary details of number of craft on beach and facilities

1. Name of recorder: ______________________

2. Status/rank of respondent: ______________________

3. Date: ______________________

4. District: ______________________

5. Sub-county/division: ______________________

6. Parish/location: ______________________

7. Name of landing: ______________________

1	
2	
3	
4	
5	
6	
7	

Craft summary

8. Total number of craft on beach: ______________________

9. Derelict craft: ______________________

10. Transport craft (non-fishing): ______________________

11. Fishing craft with outboard engine: ______________________

12. Fishing craft with inboard engine: ______________________

13. Fishing craft using paddles only: ______________________

14. Fishing craft using sails: ______________________

8	
9	
10	
11	
12	
13	
14	

Facilities summary

15. Banda (1) Yes (2) No

16. Cold room (1) working (2) not working (3) None

17. Pontoon/jetty (1) Yes (2) No

18. Fish store (1) Yes (2) No

19. All weather road (1) Yes (2) No

19a. If 'No' how far to the nearest all weather road (km)?
(1) <20 (2) 21-40 (3) 41-60 (4) >61

20. Boat repair facilities (1) Yes (2) No

21. Net repair facilities (1) Yes (2) No

22. Electricity supply (1) Yes (2) No
22a. If 'No' how far to the nearest supply (km)?
(1) <20 (2) 21-40 (3) 41-60 (4) >61

15	
16	
17	
18	
19	
19a	
20	
21	
22	
22a	

Fisheries department staffing

23. Is FD staff present? (1) Yes (2) No

24. If yes, how many?______________________

23	
24	

Additional information
25. Name of nearest market (designated by the local authority)
to the beach: ______________________

25	

26. Do fishermen land at this beach for

(1) <5 months of the year (2) >5 months of the year

26	

FRAME SURVEY: LAKE VICTORIA FISHERIES, 2000
Fisheries departments and fisheries research institutes of Kenya, Tanzania and Uganda. LVEMP/LVFRP co-operative programme.

Sheet 2: Details of fishing craft (ignoring transport craft) and fishing gears in use in each craft   Name of Landing ____________________

	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
CRAFT	CRAFT TYPE	LENGTH	PROP.	#CREW	GEAR TYPE																						
					GILLNET MESH SIZES (INCHES)																LL	BS	CN	HL	TR	MS	OTHERS
					<2.5	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	9	10	>10							
1																											
2																											
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Appendix 3.1 Summary of frame survey 2000 showing distribution of landing sites, crafts and gears between countries (LVFO, 2000)

Item	Kenya	Tanzania	Uganda	Total
Approximate area (km^2)	4080	34680	29240	68000
Landing sites	297	604	597	1498
fishers	33037	56443	34889	124369
fishing boats	10014	15533	15544*	41091
motorised boats	509	1526	2031	4066
gillnets by mesh size (mm)				
<64	4388	7095	675	12158
64	5176	3124	321	8621
76	8298	2943	3014	14255
89	6714	2300	9626	18640
102	5716	4082	20235	30033
114	2828	5679	20473	28980
127	8058	88370	51357	147785
140	10955	27095	16294	54344
152	29320	59334	94771	183425
165	8856	8804	8067	25727
178	22284	15157	52590	90031
191	1992	0	1398	3390
203	2404	1139	8014	11557
229	2502	198	1776	4476
254	3527	480	5709	9716
>254	3203	0	625	3828
Total Number of gillnets	126221	225800	294945*	646966
Long lines (hooks)	972087	2212571	254453	3439111
Beach seines	5245	1020	811	7076
Cast nets	4418	63	1276	5757
Hand lines	27789	14355	4585	46729
Traps	3192	2584	11349	17125
Mosquito seines	11265	3278	2452	16995
Other gears	1706	1146	71	2923

*The total numbers of fishing boats and gillnets above, for the Ugandan part of the lake, i.e. 15 544 boats and 294 945 are higher than 15 462 boats and 294 529 gillnets mentioned elsewhere in this thesis because they included 82 boats erroneously recorded along the River Nile in Jinja and Mukono districts.

Appendix 4.1 One-way ANOVA tests for differences in mean Nile tilapia catch rates of gillnetting parachute boats between quarters in eastern zone

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3572.633	6	595.4389	2.489425	0.023415	2.135099
Within Groups	59557.65	249	239.1874			
Total	63130.29	255				

Appendix 4.2 One-way ANOVA tests for differences in mean Nile tilapia catch rates of gillnetting parachute boats between quarters in western zone

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1959.484	6	326.5807	1.151341	0.336379	2.167425
Within Groups	37725.79	133	283.6525			
Total	39685.27	139				

Appendix 4.3 Multiple comparison tests of differences of mean Nile tilapia catch rates of parachute boats between zones and between quarters

Univariate Analysis of Variance

Tests of Between-Subjects Effects
Dependent Variable: Catch rates (kg boat^{-1} day^{-1})

Factor	**Sum of Squares**	**d.f.**	**Mean Square**	***F* ratio**	**Sig.**
ZONE	5.670	1	5.670	.022	0.881
QUARTER	3881.219	6	646.870	2.540	0.020
QUARTER * ZONE	1135.987	6	189.331	.743	0.615
Error	97283.437	382	254.669		
Total	242932.923	396			

Post Hoc Tests - quarter

Multiple Comparisons

Dependent Variable: CATCH
Gabriel

(I) QUARTER	(J) QUARTER	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	8.3407	3.8093	.429	-3.0925	19.7740
	3.00	6.1351	3.7565	.877	-5.0953	17.3655
	4.00	7.3351	3.6197	.539	-3.3368	18.0069
	5.00	13.2800*	3.7981	.009	1.8895	24.6705
	6.00	6.7364	3.6197	.689	-3.9355	17.4082
	7.00	12.0750*	3.8859	.037	.3577	23.7923
2.00	1.00	-8.3407	3.8093	.429	-19.7740	3.0925
	3.00	-2.2057	3.0054	1.000	-11.3699	6.9586
	4.00	-1.0057	2.8326	1.000	-9.6114	7.6000
	5.00	4.9393	3.0572	.903	-4.3850	14.2636
	6.00	-1.6044	2.8326	1.000	-10.2101	7.0013
	7.00	3.7343	3.1657	.996	-5.9169	13.3854
3.00	1.00	-6.1351	3.7565	.877	-17.3655	5.0953
	2.00	2.2057	3.0054	1.000	-6.9586	11.3699
	4.00	1.2000	2.7611	1.000	-7.2029	9.6028
	5.00	7.1449	2.9911	.305	-1.9765	16.2664
	6.00	.6013	2.7611	1.000	-7.8016	9.0041
	7.00	5.9399	3.1019	.696	-3.5084	15.3882
4.00	1.00	-7.3351	3.6197	.539	-18.0069	3.3368
	2.00	1.0057	2.8326	1.000	-7.6000	9.6114
	3.00	-1.2000	2.7611	1.000	-9.6028	7.2029
	5.00	5.9449	2.8174	.521	-2.6180	14.5079
	6.00	-.5987	2.5719	1.000	-8.4430	7.2456
	7.00	4.7399	2.9348	.898	-4.1499	13.6297
5.00	1.00	-13.2800*	3.7981	.009	-24.6705	-1.8895
	2.00	-4.9393	3.0572	.903	-14.2636	4.3850
	3.00	-7.1449	2.9911	.305	-16.2664	1.9765
	4.00	-5.9449	2.8174	.521	-14.5079	2.6180
	6.00	-6.5436	2.8174	.347	-15.1066	2.0193
	7.00	-1.2050	3.1521	1.000	-10.8134	8.4034
6.00	1.00	-6.7364	3.6197	.689	-17.4082	3.9355
	2.00	1.6044	2.8326	1.000	-7.0013	10.2101
	3.00	-.6013	2.7611	1.000	-9.0041	7.8016
	4.00	.5987	2.5719	1.000	-7.2456	8.4430
	5.00	6.5436	2.8174	.347	-2.0193	15.1066
	7.00	5.3386	2.9348	.766	-3.5512	14.2284
7.00	1.00	-12.0750*	3.8859	.037	-23.7923	-.3577
	2.00	-3.7343	3.1657	.996	-13.3854	5.9169
	3.00	-5.9399	3.1019	.696	-15.3882	3.5084
	4.00	-4.7399	2.9348	.898	-13.6297	4.1499
	5.00	1.2050	3.1521	1.000	-8.4034	10.8134
	6.00	-5.3386	2.9348	.766	-14.2284	3.5512

Based on observed means.

*. The mean difference is significant at the .05 level.

Homogeneous Subsets of Nile tilapia catch rates between quarters

Gabriel [a,b,c]

QUARTER	N	Subset 1	Subset 2
5.00	55	13.6200	
7.00	48	14.8250	
2.00	54	18.5593	18.5593
4.00	77	19.5649	19.5649
6.00	77	20.1636	20.1636
3.00	59	20.7649	20.7649
1.00	26		26.9000
Sig.		.411	.173

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 254.669.

a. Uses Harmonic Mean Sample Size = 50.389.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Appendix 4.4 One-way ANOVA tests for differences in mean Nile perch catch rates of gillnetting paddled Sesse boats between quarters in eastern zone

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12579.62		2096.603	3.999617	0.00089	2.151324
Within Groups	90686.77	17	524.201			
Total	103266.4	17				

Appendix 4.5 One-way ANOVA tests for differences in mean Nile perch catch rates of gillnetting paddled Sesse boats between quarters in central zone

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3451.92		575.321	1.753679	0.109873	2.139956
Within Groups	72174.41	220	328.065			
Total	75626.34	226				

Appendix 4.6 One-way ANOVA tests for differences in mean Nile perch catch rates of gillnetting paddled Sesse boats between quarters in western zone

ANOVA (log_{10} transformed data)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.15096		0.19182	1.393599	0.221296	2.163929
Within Groups	19.27079	140	0.13764			
Total	20.42175	146				

Appendix 4.7 Multiple comparison tests of differences of mean Nile perch catch rates of paddled Sesse boats between zones and between quarters

Univariate Analysis of Variance

Tests of Between-Subjects Effects
Dependent Variable: Catch rates (kg $boat^{-1}$ day^{-1})

Factor	Sum of Squares	df	Mean Square	*F* ratio	Sig.
ZONE	13904.052	2	6952.026	15.730	.000
QUARTER	8050.680	6	1341.780	3.036	.006
QUARTER * ZONE	12105.002	12	1008.750	2.282	.008
Error	235571.960	533	441.974		
Total	542228.149	554			

Post Hoc Tests – ZONE

Multiple Comparisons

Dependent Variable: CATCH
Gabriel

(I) ZONE	(J) ZONE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1.00	2.00	14.7017*	2.2257	.000	9.4011	20.0024
	3.00	9.0091*	2.3371	.000	3.4177	14.6004
2.00	1.00	-14.7017*	2.2257	.000	-20.0024	-9.4011
	3.00	-5.6927*	2.0982	.020	-10.7105	-.6749
3.00	1.00	-9.0091*	2.3371	.000	-14.6004	-3.4177
	2.00	5.6927*	2.0982	.020	.6749	10.7105

Based on observed means.
*. The mean difference is significant at the .05 level.

Homogeneous subsets of catch rates between zones

Gabriel[a,b,c]

ZONE	N	Subset 1	2	3
2.00	227	16.1901		
3.00	180		21.8828	
1.00	147			30.8918
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 441.974.

a. Uses Harmonic Mean Sample Size = 178.960.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Tests – QUARTER

Multiple Comparisons

Dependent Variable: CATCH
Gabriel

(I) QUARTER	(J) QUARTER	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-14.1003*	3.2748	.000	-24.0723	-4.1284
	3.00	-7.6919	3.3932	.392	-18.0134	2.6296
	4.00	-12.6912*	3.2442	.002	-22.5708	-2.8115
	5.00	-9.2906	3.3306	.108	-19.4286	.8474
	6.00	-8.1659	3.2442	.225	-18.0455	1.7138
	7.00	-2.6037	3.2964	1.000	-12.6401	7.4328
2.00	1.00	14.1003*	3.2748	.000	4.1284	24.0723
	3.00	6.4084	3.4407	.741	-4.0641	16.8810
	4.00	1.4092	3.2939	1.000	-8.6216	11.4400
	5.00	4.8097	3.3790	.970	-5.4794	15.0988
	6.00	5.9345	3.2939	.789	-4.0963	15.9653
	7.00	11.4967*	3.3453	.013	1.3091	21.6843
3.00	1.00	7.6919	3.3932	.392	-2.6296	18.0134
	2.00	-6.4084	3.4407	.741	-16.8810	4.0641
	4.00	-4.9993	3.4116	.959	-15.3795	5.3810
	5.00	-1.5987	3.4938	1.000	-12.2373	9.0399
	6.00	-.4740	3.4116	1.000	-10.8542	9.9063
	7.00	5.0882	3.4612	.958	-5.4488	15.6253
4.00	1.00	12.6912*	3.2442	.002	2.8115	22.5708
	2.00	-1.4092	3.2939	1.000	-11.4400	8.6216
	3.00	4.9993	3.4116	.959	-5.3810	15.3795
	5.00	3.4006	3.3493	1.000	-6.7962	13.5974
	6.00	4.5253	3.2634	.977	-5.4132	14.4638
	7.00	10.0875	3.3153	.050	-7.7567E-03	20.1828
5.00	1.00	9.2906	3.3306	.108	-.8474	19.4286
	2.00	-4.8097	3.3790	.970	-15.0988	5.4794
	3.00	1.5987	3.4938	1.000	-9.0399	12.2373
	4.00	-3.4006	3.3493	1.000	-13.5974	6.7962
	6.00	1.1247	3.3493	1.000	-9.0721	11.3215
	7.00	6.6870	3.3999	.653	-3.6666	17.0405
6.00	1.00	8.1659	3.2442	.225	-1.7138	18.0455
	2.00	-5.9345	3.2939	.789	-15.9653	4.0963
	3.00	.4740	3.4116	1.000	-9.9063	10.8542
	4.00	-4.5253	3.2634	.977	-14.4638	5.4132
	5.00	-1.1247	3.3493	1.000	-11.3215	9.0721
	7.00	5.5622	3.3153	.871	-4.5331	15.6575
7.00	1.00	2.6037	3.2964	1.000	-7.4328	12.6401
	2.00	-11.4967*	3.3453	.013	-21.6843	-1.3091
	3.00	-5.0882	3.4612	.958	-15.6253	5.4488
	4.00	-10.0875	3.3153	.050	-20.1828	7.757E-03
	5.00	-6.6870	3.3999	.653	-17.0405	3.6666
	6.00	-5.5622	3.3153	.871	-15.6575	4.5331

Based on observed means.

*. The mean difference is significant at the .05 level.

Homogeneous subsets of catch rates between quarters

Gabriel [a,b,c]

QUARTER	N	Subset 1	Subset 2
3.00	49	172.9694	
2.00	29	205.1552	
1.00	47	205.6255	
6.00	49	209.3622	
7.00	44	228.2955	228.2955
5.00	41	230.1098	230.1098
4.00	33		316.0303
Sig.		.844	.167

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 22216.457.

a. Uses Harmonic Mean Sample Size = 40.231.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Appendix 4.8 One-way ANOVA tests for differences in mean Nile perch catch rates of gillnetting motorised/sailed Sesse boats between quarters in eastern zone

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16235.9		2705.998	3.9516	0.000986	2.150415
Within Groups	120522.2	176	684.785			
Total	136758.2	182				

Appendix 4.9 One-way ANOVA tests for differences in mean Nile perch catch rates of gillnetting motorised/sailed Sesse boats between quarters in central zone

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	123639.2		20606.53	13.67049	5.55E-14	2.124068
Within Groups	536624.9	35	1507.373			
Total	660264.1	36				

Appendix 4.10 One-way ANOVA tests for differences in mean Nile perch catch rates of gillnetting motorised/sailed Sesse boats between quarters in western zone

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	23973.62	6	3995.604	4.047952	0.000771	2.147331
Within Groups	184581.7	187	987.068			
Total	208555.3	193				

Appendix 4.11 Multiple comparison tests of differences of mean Nile perch catch rates of motorised/sailed Sesse boats between zones and between quarters

Univariate Analysis of Variance

Tests of Between-Subjects Effects
Dependent Variable: Catch rates (kg boat^{-1} day^{-1})

Factor	d.f.	Sum of Squares	Mean Square	*F* ratio	Sig.
ZONE	2	34699.481	17349.741	14.643	.000
QUARTER	6	41996.975	6999.496	5.908	.000
QUARTER * ZONE	12	85073.152	7089.429	5.984	.000
Error	715	847144.353	1184.817		
Total	736	3209591.700			

Post Hoc Tests – ZONE

Multiple Comparisons

Dependent Variable: CATCH
Gabriel

(I) ZONE	(J) ZONE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	2.00	-2.5030	3.0613	.793	-9.7492	4.7432
	3.00	15.5821*	3.5674	.000	7.0382	24.1261
2.00	1.00	2.5030	3.0613	.793	-4.7432	9.7492
	3.00	18.0852*	3.1437	.000	10.6671	25.5032
3.00	1.00	-15.5821*	3.5674	.000	-24.1261	-7.0382
	2.00	-18.0852*	3.1437	.000	-25.5032	-10.6671

Based on observed means.

*. The mean difference is significant at the .05 level.

Homogeneous subsets of catch rates between zones

Gabriel [a,b,c]

ZONE	N	Subset 1	Subset 2
3.00	179	41.0575	
1.00	194		56.6397
2.00	363		59.1427
Sig.		1.000	.827

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 1184.817.

a. Uses Harmonic Mean Sample Size = 222.287.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Tests-QUARTER

Multiple Comparisons

Dependent Variable: CATCH
Gabriel

(I) QUARTER	(J) QUARTER	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1.00	2.00	9.1830	4.7508	.683	-5.2849	23.6510
	3.00	-2.6145	5.0495	1.000	-17.9705	12.7414
	4.00	-12.5865	4.7734	.164	-27.1234	1.9503
	5.00	-12.2404	4.7734	.199	-26.7772	2.2964
	6.00	-6.2558	4.6205	.982	-20.3191	7.8076
	7.00	19.5962*	4.6578	.001	5.4157	33.7767
2.00	1.00	-9.1830	4.7508	.683	-23.6510	5.2849
	3.00	-11.7976	5.0282	.331	-27.0846	3.4895
	4.00	-21.7696*	4.7508	.000	-36.2375	-7.3016
	5.00	-21.4234*	4.7508	.000	-35.8914	-6.9555
	6.00	-15.4388*	4.5972	.017	-29.4332	-1.4444
	7.00	10.4131	4.6347	.410	-3.6984	24.5247
3.00	1.00	2.6145	5.0495	1.000	-12.7414	17.9705
	2.00	11.7976	5.0282	.331	-3.4895	27.0846
	4.00	-9.9720	5.0495	.644	-25.3280	5.3839
	5.00	-9.6259	5.0495	.703	-24.9818	5.7301
	6.00	-3.6412	4.9052	1.000	-18.5237	11.2412
	7.00	22.2107*	4.9404	.000	7.2111	37.2103
4.00	1.00	12.5865	4.7734	.164	-1.9503	27.1234
	2.00	21.7696*	4.7508	.000	7.3016	36.2375
	3.00	9.9720	5.0495	.644	-5.3839	25.3280
	5.00	.3462	4.7734	1.000	-14.1907	14.8830
	6.00	6.3308	4.6205	.980	-7.7325	20.3941
	7.00	32.1827*	4.6578	.000	18.0022	46.3632
5.00	1.00	12.2404	4.7734	.199	-2.2964	26.7772
	2.00	21.4234*	4.7508	.000	6.9555	35.8914
	3.00	9.6259	5.0495	.703	-5.7301	24.9818
	4.00	-.3462	4.7734	1.000	-14.8830	14.1907
	6.00	5.9846	4.6205	.989	-8.0787	20.0479
	7.00	31.8366*	4.6578	.000	17.6561	46.0170
6.00	1.00	6.2558	4.6205	.982	-7.8076	20.3191
	2.00	15.4388*	4.5972	.017	1.4444	29.4332
	3.00	3.6412	4.9052	1.000	-11.2412	18.5237
	4.00	-6.3308	4.6205	.980	-20.3941	7.7325
	5.00	-5.9846	4.6205	.989	-20.0479	8.0787
	7.00	25.8519*	4.5010	.000	12.1450	39.5589
7.00	1.00	-19.5962*	4.6578	.001	-33.7767	-5.4157
	2.00	-10.4131	4.6347	.410	-24.5247	3.6984
	3.00	-22.2107*	4.9404	.000	-37.2103	-7.2111
	4.00	-32.1827*	4.6578	.000	-46.3632	-18.0022
	5.00	-31.8366*	4.6578	.000	-46.0170	-17.6561
	6.00	-25.8519*	4.5010	.000	-39.5589	-12.1450

Based on observed means.

*. The mean difference is significant at the .05 level.

Homogeneous Subsets of catch rates between quarters

Gabriel [a,b,c]

QUARTER	N	Subset 1	2	3
7.00	115	34.0548		
2.00	106	44.4679	44.4679	
1.00	104		53.6510	53.6510
3.00	84		56.2655	56.2655
6.00	119			59.9067
5.00	104			65.8913
4.00	104			66.2375
Sig.		.464	.250	.164

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 1184.817.

a. Uses Harmonic Mean Sample Size = 104.037.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Appendix 4.12 One-way ANOVA test for differences in mean Nile perch catch rates of motorised/sailed boats using passively operated gillnets, between eastern, central and western zones in the Ugandan part of Lake Victoria

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3016.105	2	1508.053	3.777738	0.036285	3.36901
Within Groups	10379.06	26	399.1946			
Total	13395.17	28				

Appendix 4.13 One-way ANOVA test for differences in mean Nile perch catch rates of motorised/sailed boats using drift gillnets, between eastern, central and western zones in the Ugandan part of Lake Victoria

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	47767.87	2	23883.94	19.34337	6.6E-09	3.008395
Within Groups	877896.4	711	1234.735			
Total	925664.2	713				

Appendix 4.14 One-way ANOVA test for differences in mean Nile perch catch rates of motorised/sailed boats using passively operated gillnets, between the central and western zones in the Ugandan part of Lake Victoria

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	824.3734	1	824.3734	1.676658	0.209425	4.324789
Within Groups	10325.21	21	491.6765			
Total	11149.58	22				

Appendix 4.15 One-way ANOVA test for differences in mean Nile perch catch rates of motorised/sailed boats using drift gillnets, between the central and western zones in the Ugandan part of Lake Victoria

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	18.81952	1	18.81952	0.013476	0.90763	3.859
Within Groups	742973.6	532	1396.567			
Total	742992.5	533				

Appendix 4.16 One-way ANOVA tests for differences in mean Nile perch catch rates of hand lining boats between quarters in the Ugandan part of Lake Victoria

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	853.6217	6	142.2703	1.031316	0.423362	2.399076
Within Groups	4414.408	32	137.9503			
Total	5268.03	38				

Appendix 4.17 One-way ANOVA tests for differences in mean Nile perch catch rates of long lining boats between quarters in the Ugandan part of Lake Victoria

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	17304.64	5	3460.929	2.060989	0.079252	2.331738
Within Groups	130982	78	1679.256			
Total	148286.6	83				

Appendix 4.18 One-way ANOVA tests for differences in mean *Rastrineobola argentea* catch rates of paddled boats between quarters in eastern zone

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	541264.9	6	90210.81	4.0112	0.001183	2.18699
Within Groups	2338917	104	22489.59			
Total	2880182	110				

Appendix 4.19 One-way ANOVA tests for differences in mean *Rastrineobola argentea* catch rates of paddled boats between quarters in central zone

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	68108.02	6	11351.34	0.4828	0.817505	2.31326
Within Groups	1034438	44	23509.95			
Total	1102546	50				

Appendix 4.20 One-way ANOVA tests for differences in mean *Rastrineobola argentea* catch rates of motorised boats between quarters in western zone

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	605837.5	5	121167.5	1.3811	0.242758	2.35380
Within Groups	5790267	66	87731.32			
Total	6396105	71				

Appendix 4.21 One-way ANOVA tests for differences in mean *Rastrineobola argentea* catch rates of paddled boats between quarters in western zone

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	221964.3	6	36994.06	1.7188	0.122046	2.17311
Within Groups	2647304	123	21522.8			
Total	2869269	129				

Appendix 4.22 Multiple comparison tests of differences of mean *Rastrineobola argentea* catch rates of paddled boats between zones and between quarters

Univariate Analysis of Variance

Tests of Between-Subjects Effects
Dependent Variable: Catch rates (kg $boat^{-1}$ day^{-1})

Factor	**Sum of Squares**	**d.f.**	**Mean Square**	***F* ratio**	**Sig.**
ZONE	3857.489	2	1928.744	.087	.917
QUARTER	244701.325	6	40783.554	1.836	.092
QUARTER * ZONE	397517.187	12	33126.432	1.491	.127
Error	6020659.804	271	22216.457		
Total	21002214.158	292			

Post Hoc Tests – ZONE

Multiple Comparisons

Dependent Variable: CATCH
Gabriel

		Mean Difference			95% Confidence Interval	
(I) ZONE	(J) ZONE	(I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
1.00	2.00	-2.3712	24.6275	1.000	-60.0260	55.2836
	3.00	-12.6538	19.2625	.883	-58.8876	33.5801
2.00	1.00	2.3712	24.6275	1.000	-55.2836	60.0260
	3.00	-10.2826	25.2144	.967	-69.7627	49.1976
3.00	1.00	12.6538	19.2625	.883	-33.5801	58.8876
	2.00	10.2826	25.2144	.967	-49.1976	69.7627

Based on observed means.

Homogeneous subsets of catch rates between zones

Gabriel [a,b,c]

		Subset
ZONE	N	1
1.00	130	214.8327
2.00	51	217.2039
3.00	111	227.4865
Sig.		.929

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 22216.457.

a. Uses Harmonic Mean Sample Size = 82.624.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Tests - QUARTER

Multiple Comparisons

Dependent Variable: CATCH
Gabriel

(I) QUARTER	(J) QUARTER	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1.00	2.00	.4704	35.1962	1.000	-106.3898	107.3305
	3.00	32.6561	30.4317	.999	-60.3975	125.7098
	4.00	-110.4048*	33.8514	.025	-213.5206	-7.2889
	5.00	-24.4842	31.8521	1.000	-121.8297	72.8613
	6.00	-3.7367	30.4317	1.000	-96.7903	89.3169
	7.00	-22.6699	31.2668	1.000	-118.2692	72.9294
2.00	1.00	-.4704	35.1962	1.000	-107.3305	106.3898
	3.00	32.1858	34.9211	1.000	-73.7049	138.0765
	4.00	-110.8751	37.9382	.075	-226.8281	5.0778
	5.00	-24.9546	36.1656	1.000	-135.1372	85.2280
	6.00	-4.2071	34.9211	1.000	-110.0978	101.6837
	7.00	-23.1403	35.6511	1.000	-131.5767	85.2961
3.00	1.00	-32.6561	30.4317	.999	-125.7098	60.3975
	2.00	-32.1858	34.9211	1.000	-138.0765	73.7049
	4.00	-143.0609*	33.5652	.001	-245.2073	-40.9145
	5.00	-57.1404	31.5478	.779	-153.5164	39.2357
	6.00	-36.3929	30.1130	.995	-128.4771	55.6913
	7.00	-55.3261	30.9567	.798	-149.9559	39.3038
4.00	1.00	110.4048*	33.8514	.025	7.2889	213.5206
	2.00	110.8751	37.9382	.075	-5.0778	226.8281
	3.00	143.0609*	33.5652	.001	40.9145	245.2073
	5.00	85.9205	34.8582	.256	-20.5177	192.3588
	6.00	106.6681*	33.5652	.032	4.5216	208.8145
	7.00	87.7348	34.3241	.204	-16.9572	192.4269
5.00	1.00	24.4842	31.8521	1.000	-72.8613	121.8297
	2.00	24.9546	36.1656	1.000	-85.2280	135.1372
	3.00	57.1404	31.5478	.779	-39.2357	153.5164
	4.00	-85.9205	34.8582	.256	-192.3588	20.5177
	6.00	20.7475	31.5478	1.000	-75.6286	117.1236
	7.00	1.8143	32.3540	1.000	-97.1074	100.7360
6.00	1.00	3.7367	30.4317	1.000	-89.3169	96.7903
	2.00	4.2071	34.9211	1.000	-101.6837	110.0978
	3.00	36.3929	30.1130	.995	-55.6913	128.4771
	4.00	-106.6681*	33.5652	.032	-208.8145	-4.5216
	5.00	-20.7475	31.5478	1.000	-117.1236	75.6286
	7.00	-18.9332	30.9567	1.000	-113.5631	75.6967
7.00	1.00	22.6699	31.2668	1.000	-72.9294	118.2692
	2.00	23.1403	35.6511	1.000	-85.2961	131.5767
	3.00	55.3261	30.9567	.798	-39.3038	149.9559
	4.00	-87.7348	34.3241	.204	-192.4269	16.9572
	5.00	-1.8143	32.3540	1.000	-100.7360	97.1074
	6.00	18.9332	30.9567	1.000	-75.6967	113.5631

Based on observed means.

*. The mean difference is significant at the .05 level.

Homogeneous Subsets of catch rates between quarters

Gabriel [a,b,c]

QUARTER	N	Subset 1	Subset 2
3.00	49	172.9694	
2.00	29	205.1552	
1.00	47	205.6255	
6.00	49	209.3622	
7.00	44	228.2955	228.2955
5.00	41	230.1098	230.1098
4.00	33		316.0303
Sig.		.844	.167

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 22216.457.

a. Uses Harmonic Mean Sample Size = 40.231.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.