Fish populations, gill net selectivity, and artisanal fisheries in the Okavango River, Namibia

Recommendations for a sustainable fishery

C.J. Hay, T.F. Næsje, J. Breistein, K. Hårsaker,
J. Kolding, O.T. Sandlund, and B. v. Zyl

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Preface

The White Paper «Responsible Management of the Inland Fisheries of Namibia» was finalised in December 1995, and forms the basis for a new law and regulations concerning fish resources management in the different freshwater systems in Namibia. The Okavango River is one of the most important of the perennial rivers, and freshwater fish are a very important food source for local inhabitants. Hence, the protection of this resource is of utmost importance to secure the future food availability of the riparian population in this region of Namibia. In this report management actions are recommended on the basis of eight years of biological studies in the river, including survey fishing on seven different localities every year from 1992-99. Later reports will give recommendations for regulations of fisheries in the other perennial rivers in Namibia.

Our main objective has been to develop applicable guidelines for regulations of the inland fisheries in the Okavango River. This report will further enable the Ministry of Fisheries and Marine Resources to implement the proposed law and regulations necessary for sustainable management of the fish resources in the river. The recommended guidelines are presented in the last chapter of the report.

In addition, a second goal of this report has been to identify critical aspects and needs for more knowledge that should be addressed in future studies, and give recommendations on how to obtain the necessary information needed for future management of the Okavango River.

The project is a collaboration between Freshwater Fish Institute of the Ministry of Fisheries and Marine Resources, and the Norwegian Institute for Nature Research (NINA). The work has received economic support from the Norwegian Agency for Development Cooperation (NORAD) through the Nansen Programme.

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Clinton Hay

Tor F. Næsje

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1 Executive Summary

Hay, C.J., Næsje, T.F., Breistein, J., Hårsaker, K., Kolding, J., Sandlund, O.T. & van Zyl, B. 2000. Fish populations, gill net selectivity, and artisanal fisheries in the Okavango River, Namibia. Recommendations for a sustainable fishery. – NINA-NIKU Project Report 010: 1-105.

Objective:
The objective of this report is to produce guidelines for a sustainable management of the fisheries in the Okavango River, Namibia, based on fish survey data for the years 1992-1999. Data were also collected regarding the subsistence fishery in the river. The rationale for the report is the 1995 White Paper "Responsible Management of the Inland Fisheries of Namibia" and the draft bill on inland fisheries. These have the objectives of ensuring a sustainable and optimal utilisation of the freshwater resources, and to favour utilisation of fish resources by subsistence households over commercialisation. The stated policy takes into consideration the large differences among water systems in Namibia and proposes adoption of separate management regimes for the various river systems.

Material and study area:
Fish were collected in seven main areas (Matava, Musese, Bunya, Rundu, Cuito, Mbambi, and Kwetze) with survey gill nets (22–150 mm stretched mesh) and 16 other sampling methods, such as seine nets, mosquito nets, cast nets, angling, electrofishing apparatus, rotenone and different traditional gears. These are later collectively called "other gears". The stations were selected to include all main habitats present in the Okavango River. The gill nets were mainly used in relatively deep water, whereas the other gears were mainly used in shallow and vegetated habitats. All seven localities were sampled at least once a year between 1992 and 1999. A total of 47438 fishes were sampled, 13559 in gill nets, and 33879 in other gears.

The Okavango River originates in the central highlands of Angola at approx. 1700 m a.s.l. and enters Namibia at Katwitwi. The river forms the border between Namibia and Angola before turning south towards Botswana. Along the Namibian section of the river, there are large floodplains with sandy substrates and rocky outcrops, and abundant aquatic vegetation. After a distance of 460 km within Namibia, the river enters Botswana where it evaporates in the swamps of the Okavango Delta.

The annual flood in the Namibian portion of the Okavango starts during December reaches its peak in March-April and recedes during May. The annual discharge of the Okavango at Rundu is between 5,000 and 6,000 million m^3. Below the confluence with the Cuito River, the annual discharge nearly doubles to over 10,000 million m^3.

More than 136,000 people live in the Okavango region. An estimated 90 % of the population live within 10 km of the river, and many of the economic and social activities in the region are connected to the river. More than 50 % of the human population along the river do fish, both with traditional gears such as baskets, funnel traps and fences constructed of plant material, and with some modern gears such as gill nets, seines, hook and line, and mosquito-nets. For more than 90 % of the households fish is a source of subsistence, and sales of fish provide some income for approximately 45 % of the households. The highest population density is at Rundu, whereas no people live at Kwetze, which is within the Mahongo Game Park. It is assumed that the fishing pressure is correlated to the riparian population density.

Results:
Data on local fishing activities were collected through a survey of the gears (modern and traditional) used in the subsistence fishery and interviews with fisherfolk attending their gear in June 1994. This survey revealed that the peak fishing time is during the receding phase of the flood and during low water periods when the fish are concentrated, i.e. from May onwards. There is reduced fishing activity during the flood when large areas along the river become inaccessible for the subsistence fishers. A diversity of traditional gears include, e.g., baited traps, corral traps, fish fences, scoop baskets, fish funnel, bow and arrow, and fish spear. Modern gears are mainly restricted to gill nets, used most often by men, and mosquito nets, a method used by women. Casts nets were rarely used. A comparison with earlier surveys reveals that there is an overall decline in catches in subsistence fisheries from 1987 to 1992. A socio-economic survey in 1994 indicated that 56,000 people along the Namibian portion of the Okavango River were fishing an average of 60 days per year catching 1,045 tonnes.

In the survey catches in this investigation a total of 76 fish species were recorded. Gill nets caught 47 of these species, whereas all species were recorded in the other gears used mainly in shallow waters. These figures include seven *Synodontis* species which are not easily separated and therfore have been pooled in the results. In gill nets the ten most important species constituted between 70 and 80 % of the catches both by numbers and weight. The three most important species in gill net catches according to an index of relative importance (IRI) were silver catfish (*Schilbe intermedius*), bulldog (*Marcusenius macrolepidotus*) and tigerfish (*Hydrocynus vittatus*). In the other gears, the ten most important species constituted approximately 54 % and 37 % of the total catch by numbers and weight, respectively. The lower proportion of the dominant species reflects the higher species diversity in catches with other gears. The three most important species in these gears, according

to the IRI, were all cichlids; southern mouthbrooder (*Pseudocrenilabrus philander*), banded tilapia (*Tilapia sparrmanii*), and redbreast tilapia (*T. rendalli*). The *Synodontis* group of species was important both in gill nets and other gears.

The body length of fish caught in gill nets was generally larger than fish caught in other gears. This is evident both in the combined catches of all species and when comparing individual species. Fish caught in gill nets were between 4 and 79 cm in length, with fish between 7 and 17 cm constituting 82.9 % of the catches. Modal length was 9.0-9.9 cm. Fish caught in other gears were between 1 and 75 cm, with fish between 2 and 8 cm constituting 88.0 % of the catches. Modal length in this group was 4.0-4.9 cm.

The highest proportion of sexually mature fish was found during the period January-March, i.e. during the peak of the rainy season. This is before the main thrust of the local fisheries. Most of the important species (according to IRI) mature and spawn during this period. The smallest size of sexually mature fish varies among the different species. The overall smallest size at maturity was found in the cichlid southern mouthbrooder (*P. philander*), being a mature female of 3 cm. The largest size at maturity was found in sharptooth catfish (*C. gariepinus*), with minimum size of males and females at 40 and 38 cm, respectively.

Based on their importance according to number of fish caught and IRI in gill nets, other gears, and local subsistence fisheries, 21 species were selected for a closer description in terms of basic ecology and gill net selectivity. In addition, 16 species with the potential of being important for anglers are also described in these terms.

The results concerning gill net selectivity show that for most of the 21 important species (in local fisheries and in the survey fishing), the highest number of fish per setting were caught in small mesh sizes (22-45 mm, 15 species). Only two species are most efficiently caught in larger mesh sizes (73 and 93 mm). In terms of weight of fish per setting, 11 species were most efficiently caught in the 22-45 mm mesh sizes, two species in 57 mm, and four species in 93-118 mm. These results reflect that the fish community in the Okavango River is dominated by relatively small species and individuals. Among the species that are important in local fisheries or in our survey catches, only six out of 21 species have a minimum mature length above 10 cm or are on average above 15 cm in the gill net catches. Only two out of 21 species have mean lengths above 20 cm in our survey catches. Moreover, only seven out of the additional 16 species that are considered attractive angling species, have mean lengths above 20 cm in the gill net catches. This indicates that there presently is no firm basis for a commercial fishery for large fish in the Namibian part of the Okavango River.

Comparison of fish catches between the seven sampling localities revealed that there was a correlation between human population density and catches, both by weight and number of fish. The largest catches were taken in the areas with the lowest population densities. This correlation is highly significant for catches in kilograms. For catches in number of fish, the trend was similar, although not significant. The total gill net catches by weight at Kwetze (3.76 kg per setting) were nearly five times as high as at Rundu, Bunya and Musese (0.61-0.68 kg per setting). Catches at Cuito, Matava and Mbambi were intermediate, but considerably lower than at Kwetze (1.02-1.30 kg per setting). This indicates that the fish stocks at Kwetze are relatively unexploited. These differences between stations were more pronounced in the backwaters than in the main stream habitats. It is important to note, when evaluating the fish populations as a resource for subsistence fisheries, that the most important factor is the biomass (weight) of fish caught. In subsistence fisheries, the size of the individual fish is of less importance. In commercial or recreational fisheri-es, on the other hand, the size of the individual fish may be of great importance.

Between the different stations, differences were larger when comparing catches in the larger gill net mesh sizes than in the smaller ones. Catches in small mesh sizes (22 and 28 mm) at Kwetze (1.12 kg and 56.8 fish per setting) were not very different from the other stations (0.80-1.17 kg and 70.6-72.8 fish per setting). However, the mean weight of the fish caught in 22 and 28 mm mesh size at Kwetze were on average larger, 20 g compared with 10–13 g at the other stations. In the larger meshed gill nets (35-150 mm), differences were more pronounced. Kwetze had the highest catch both in weight and number of fish (4.35 kg and 39.9 fish per setting), whereas Rundu had the lowest catch (0.57 kg and 7.9 fish per setting).

Based on population densities, Rundu and Kwetze may represent the extremes in fishing intensity in the Okavango River, with close to no fishing at Kwetze and probably high exploitation rates at Rundu. These two sampling localities may therefore be used to exemplify possible differences in catches due to fishing intensity. In the smallest mesh sizes (22–28 mm) there were no significant differences in catches by weight between Rundu and Kwetze (0.8 and 1.1 kg, respectively). However, in larger mesh sizes (35–150 mm) catches were several times higher at Kwetze than at Rundu. In the largest mesh size (150 mm) there was no catch at all at Rundu, whereas the catch at Kwetze was 2.6 kg per setting.

Intensive fishing and exploitation of fish populations may reduce the overall number of individuals within a species. However, the result of selective fishing aiming at relatively large fish is often that the average size of species are reduced due to an increasing proportion of smaller fish. For most of the relatively large species in the Okavango River, catches in weight were largest at Kwetze compared with the other stations. No such tendency was observed for the small species. In terms of number of fish per setting, there was no systematic difference between Kwetze and the other stations, neither for large or small species. Thus, mean size of fish is larger at Kwetze than at the other stations.

The gill net mesh sizes used in this investigation were chosen to obtain a representative catch and size distribution of the fish populations. On average a larger proportion of large fish were caught in gill nets at Kwetze than at the other sampling localities. This was shown both in the total catches, and for many of the individual species sampled. Three examples are the common species silver catfish, bulldog and tigerfish. The largest fish were caught at Kwetze, where mean fish length in total gill net catches was 16.3 cm. The smallest fish were caught at Rundu, with a mean length of 10.7 cm. The two numerically dominant species in the gill net catches, silver catfish and bulldog, showed a similar pattern in length distribution among localities. Both species are largest at Kwetze and smallest at Rundu. These differences are reflected in the mean weight of fish, which was highest at Kwetze and lowest at Rundu (92 and 33 g respectively).

Two species, silver catfish and bulldog, are among the three most important species at all localities when ranging the ten most important species at each locality in terms of the index of relative importance (IRI) in gill net catches. Several species, which were important or common at the unexploited locality of Kwetze, were of little importance at the heavily fished locality of Rundu. These are in particular African pike (*Hepsetus odoe*), spotted squeaker (*Synodontis nigromaculatus*) and dashtail barb (*Barbus poechii*). One large cichlid species, threespot tilapia (*Oreocromis andersonii*) is only found in any significant number at Kwetze.

The recommended management actions are summarised as follows:

- The fish community consists of 76 species each with their specific ecology, forming an integral part of a complex and dynamic ecosystem. The exploitation of such a multi-species fish resource should preferably be performed non-selectively, i.e.; fish from all trophic levels should be caught in proportion to their occurrence in the aquatic ecosystem. This principle of proportional exploitation forms the basis of our management recommendations.
- The Okavango River is shared between Namibia, Angola and Botswana. The present collaboration with neighbouring countries on management issues is limited, and the available biological data from the sections of the river in Angola and Botswana is very restricted. The future aim should be to establish a management regime in close collaboration with neighbouring countries.
- Commercialisation of the fish resources in the Okavango is not an economically and ecologically viable option. The limited fish resource should be regarded strictly as a source for a sustainable subsistence fishery utilised by the population along the Okavango River. All traditional gears may be allowed. These gears are an important part of the traditional life of local inhabitants. Gill nets and angling equipment (rods and reels) should be the only modern gear allowed.
- Regulation of the artisanal fishery by means of a quota system is logistically impractical. A more practical system based on effort restrictions by means of gear regulations is therefore recommended. Recreational and trophy fishing, however, may be regulated through both quotas and gear restrictions.
- Our results clearly show the value of sanctuaries where fishing is prohibited. Depending on their size and position, sanctuaries may protect breeding and/or feeding habitats for different species. The protected areas may also serve as source areas, where fish production provides a surplus that migrates out of the protected area and reinforce the exploited fish populations. In addition, given the appropriate regulations, sanctuaries may provide excellent trophy fishing (e.g., catch-and-release) attracting exclusive fishing safaris creating economic activities to benefit local communities.
- No activities or gears should be allowed which may potentially pollute the environment. This includes also explosives, noxious substances, poison or electrical devices should be allowed. Artificial light during any fishing activities should not be allowed.
- The recreational fishery should be licensed, and specific regulations developed. Organisers of angling competitions must seek permission from the Ministry.

Management actions for future consideration: Actions may depend on further scientific research, and collaboration with local communities and neighbouring countries.

- The establishment of fish sanctuaries in addition to the Mahango Game Park should be considered. In this context, investigations about the habitat use and migration patterns of riverine fish species are needed. Fish sanctuaries could be included in the already present community conservancies.
- Closed fishing seasons could be implemented to protect the fish population during vulnerable periods, for example when fish are congregated during spawning at low water discharge or during seasonal migrations.
- Defined areas for specific activities, such as areas for fishing safaris and fishing competitions should be considered.
- The initiation of a community data collection programme should be considered to increase the fish database.

- Continuous international collaboration with neighbouring countries should be given high priority.

In future research programmes, the following is recommended:

- It is imperative that a modified monitoring programme of the river continues so that changes in the fish community may be identified and management actions taken to reverse possible future adverse effects.
- The collection of data by the community for research purposes have been done successfully elsewhere in Africa and should be considered in the Okavango to increase the database for future stock assessment studies.
- The knowledge of fish behaviour, migration, and area and habitat use, is limited. Resources should be allocated to conduct such studies. This is important for the establishment of fish sanctuaries and to dissolve conflicts between the recreational and subsistence fishermen.
- The socio-economic role of fish in the region should be subject to ongoing studies to complement the fishery and experimental data.
- Namibia has very little control over the management of the Okavango watershed as the catchment area falls within neighbouring countries. The Okavango River must be managed as an entity and collaboration with neighbouring countries is essential for further improved management of the fish resources.
- Where possible, comparable data sets from neighbouring countries should be included in future analysis.

2 Introduction

Floodplain rivers are among the most endangered ecosystems, and their faunas are especially under threat of species extinction and population disturbance (Halls et al. 1999). Multi-species multi-gear floodplain and river fisheries have complex interactions between the environment, the fish communities and the fishers.

As human populations and levels of income rise, so does the demand for water for various purposes, and water is a commodity which limits development and human well-being in many parts of the world. With increasing demand for water for human activities, such as irrigation, drinking water, power production, and flood control, floodplains are increasingly being modified on both a large and small scale. Floodplain fish production, however, is dependent on the maintenance of the natural functions of the floodplain system. Both the "Code of Conduct for Responsible Fisheries" adopted by FAO Committee of Fisheries (1995) and the Convention on Biological Diversity (UNEP 1992) (ratified by more than 170 countries, including Namibia and Norway) are concerned about the need for countries to manage their aquatic environment to maintain biodiversity and sustainable fisheries.

The high species and habitat diversity of floodplains is reflected in the complexity of the fishery where many different types of gears are used, both traditional and modern. Often there are competitive interactions between different fishing gears. The various gears impact fish communities differently, and influence the distribution of catches between fishers. A management approach including, e.g., gear closures and restrictions, closed seasons, and mesh or fish size limits may increase catches in some gears, and reduce catches in others. It will also influence the distribution of catches and income among the fishers and in the local communities. Hence, when implementing management regulations in a fishery, it is important to identify those who have an interest or stake in the fishery. A description of stakeholders is essential as management of a fishery means managing human activities. Knowledge about stakeholders and relationships between different interest groups, such as subsistence, commercial, and sport fishers, is important to facilitate analysis of the effects of the implemented regulations. Acceptance of regulations among stakeholders is essential to achieve a successful management.

The highly variable ecological and social characteristics of floodplain rivers often demand locally adapted management regimes. Such careful management of the river systems must be based on scientific and traditional knowledge, and include an active and important role of local communities. It is important to maintain the cultural, economic and social importance of riverine life and traditions, in addition to securing stable fish yields as an essential food source for the riparian human population. Adaptive management will include monitoring programmes designed to ensure the local effectiveness of the chosen management strategies.

In a perennial floodplain system, like the Namibian portion of the Okavango River, the main river might be regarded as containing the capital of the fishery, while the seasonal production in the floodplains and the harvest of fish in the main river constitutes the interest of that capital. Too heavy exploitation of the fish populations in the main river might reduce the overall fish capital and thereby the interest and returns from that capital. As long as the capital of fish is good, the fish populations will provide a relatively stable food supply. Therefore, reliable assessment and monitoring of the status of the fish populations in the river are necessary for sustainable management of the resources and a stable and optimal yield of fish.

Changes in the ecosystem, including destruction of fish habitats, reduced floods, and new fishing methods, are altering the fishery in the Okavango River. Management regimes have changed from traditional and local to more centralised, accompanied by an erosion of local checks and controls. Modern, more effective and destructive gears have been introduced, and the human population along the river has increased. These elements all pose a threat to the fish resources.

Previous estimates of maximum sustainable yield (MSY) for the Okavango River in Namibia based on different methods have given figures between 840 and 3000 metric tonnes. The basis for these calculations is dubious, as the available data and knowledge on complex floodplain systems are not at all sufficient to allow proper application of any MSY model (Sandlund and Tvedten 1992). Hence, neither the minimum nor maximum figure might be the correct one. Moreover, the MSY concept itself has recently been rejected as a useful tool in fisheries management (Hilborn & Walters 1992). The main reason is that MSY gives the false impression that a fixed and stable maximum output can be calculated for any fishery. In fact, a relatively correct MSY value can only be calculated when serious overfishing has already occurred (Hilborn & Walters 1992). It, therefore, is necessary to develop adaptive management systems (Martin 1999) for fish stocks in rivers and floodplains, based on monitoring data with important parameters such as community and stock structures, life histories of important species, and so on.

In Namibia freshwater fish is a key food item for poor people in the northern region of the country (Sandlund and Tvedten 1992, Tvedten et al. 1994). As population growth and fishing activities increase, conflicts arise between subsistence fishery, commercial fisheries, and recreational fishery. In addition, the perennial rivers of Namibia, including the Okavango River, are shared with other countries, and the activities of foreign fishermen are also the reason for conflicts in certain areas.

The objective of this report is to produce guidelines for a sustainable management of the fisheries in the Okavango River, Namibia, based on monitoring data for the years 1992-99. Fish were collected in seven main areas with survey gill nets and 16 other sampling methods. The rationale for this report is the White Paper "Responsible Management of the Inland Fisheries of Namibia" (MFMR 1995) and the draft bill on inland fisheries, which have the objectives of ensuring a sustainable and optimal utilisation of the freshwater resources, and to favour utilisation by subsistence households over commercialisation. The stated policy takes into consideration the large differences among water systems and proposes different management systems. In this report we give recommendations on how to implement important parts of the new legislation.

3 Study area

3.1 General features

The Okavango River originates in the central highlands (approx. 1700 m a.s.l.) of Angola , where it is known as Rio Cubango (Smit 1991). It flows in a south-easterly direction, entering Namibia at Katwitwi **(Figure 3.1)**. The river forms the border between Namibia and Angola before turning south towards Botswana. The steepest gradient is in the upper reaches, levelling off as the river enters Namibia, where it creates large floodplains with sandy substrates and rocky outcrops, with abundant aquatic vegetation. After a distance of 460 km within Namibia, the river enters Botswana where it evaporates in the swamps of the Okavango Delta. We have sampled seven localities in the Namibian portion of the Okavango **(Figure 3.1)**.

The Okavango floodplain system in Namibia consists of the main river, standing backwaters, swamps and floodplains covered by water only parts of the year **(Figure 3.2)**. The water-covered areas vary considerably between the dry and rainy seasons. The floodplains are complicated ecosystems where terrestrial and aquatic elements are closely interlinked. The fish communities are usually diverse, and their population dynamics, migration patterns, habitat use and production rates are poorly known.

Hocutt et al. (1994) divided the river into four zones according to habitat. Zone 1, from Katwitwi to Kasivi is characterised by shallow water with sandy and rocky substrates. Zone 2, which stretches from Kasivi to Mbambi, is characterised by developed floodplains with large oxbow lakes and backwater habitats. Zone 3, from Mbambi to Popa Falls, is characterised by many rapids and a substratum of sand and gravel with large boulders. Zone 4, which stretches from Popa Falls to the Namibia/Botswana border, forms the beginning of the Okavango Delta panhandle and features large floodplains.

Several tributaries join the Okavango from the north. The Cuito River is the major tributary entering Okavango at Katere, approximately 100 km from Rundu. The water flow of the Cuito nearly doubles the annual flow of the Okavango, thus playing a major role for the fish population downstream. The only southern tributary of any significance is the Omuramba Omatako, which drains the northeastern parts of Namibia. Although certain sections of this system sometimes are water filled, it only rarely reaches the Okavango River.

The annual flood in the Namibian portion of the Okavango starts during December, reaches its peak in March - April and recedes during May (**Figure 3.3**). However, the intensity, timing and duration of the flood depend on the rainfall in Angola. Summer rainfall in the catchment area (an estimated 115,000 km^2) is the primary source of inflow into the river. The annual discharge of the Okavango at Rundu is between 5,000 and 6,000 million m^3. This runoff is increased by the inflow from the Cuito River so that the annual discharge in the Okavango at Mukwe has nearly doubled to over 10,000 million m^3. The water discharge in cubic meters per second is also nearly two times higher at Mukwe than at Rundu (**Figure 3.4**). The water discharge is largest in April, both at Rundu and at Mukwe.

Water quality in the Okavango River has been monitored since 1992 at the stations Kakuru, Matava, Musese, Bunya, Rundu, Cuito, Mbambi, Popa Falls and Kwetze (**Table 3.1–3.9**). pH was lowest (6.0) at Cuito during the spring of 1993 and highest (9.5) at Bunya during the winter of 1994. The majority of the measurements were between 6.6 and 7.1. Conductivity was lowest (2.9 mS/m) at Popa Falls during winter 1995 and highest (11.2 mS/m) at Cuito during spring 1996. The concentrations of total dissolved solids (TDS) correlated closely with the conductivity. The highest nitrate and nitrite concentrations were measured at Cuito (4.84 mg/l) during winter 1993 and Musese (2.31 mg/l) during spring 1993, respectively. The concentration of nitrate and nitrite tended to be higher in winter and spring, respectively. The concentrations of organic ortho-phosphate were higher during the spring survey in 1993 than during the other surveys, but the highest concentration (1.38 mg/l) was measured at Rundu during the winter 1994.

The fish sampling localities were selected to be representative of each of the four zones mentioned above **(Figure 3.1)**. The first two sampling localities Matava and Musese are found in zone 1, from Katwitwi to Kasivi. The next three localities, Bunya, Rundu and Cuito are found in zone 2, from Kasivi to Mbambi. Mbambi is located in zone 3, between Mbambi and Popa Falls. The last locality, Kwetze, is located in zone 4, between Popa Falls and the Namibia/Botswana border.

More than 136,000 people live in the Okavango region, and the population is increasing with an annual growth rate of approximately 3 % (Tvedten et al. 1994). An estimated 90 % of the population live within 10 km of the river and approximately 80 % within 5 km. The social structure is mainly rurally based, and many of the economic and social activities in the region are connected to the river. Fishing is an integral part of this tradition as more than 50 % of the human population along the river do fish (Tvedten et al. 1994). Many of the people still use traditional gears such as baskets, funnel traps and fences constructed of plant material (**Table 3.10**). However, more modern gears such as gill nets, seines, hook and line, and mosquito-nets have lately been increasing in numbers. Fishing is an important part in the multiple income strategy of riverine households. For more than 90 % of the households fish

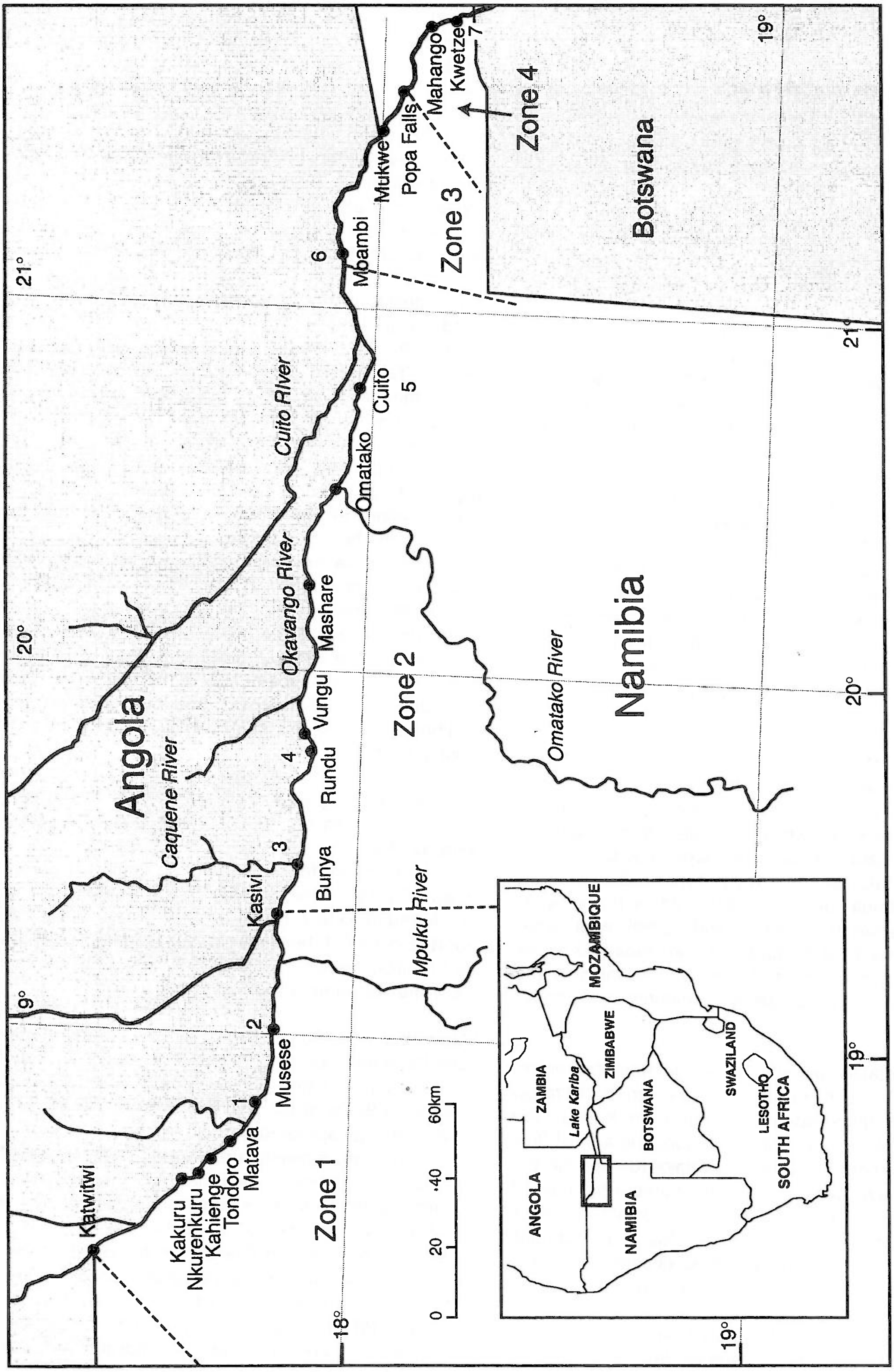


Figure 3.1. *The Okavango River with the four zones (according to Hocutt et al. 1994) and the seven main sampling localities.*

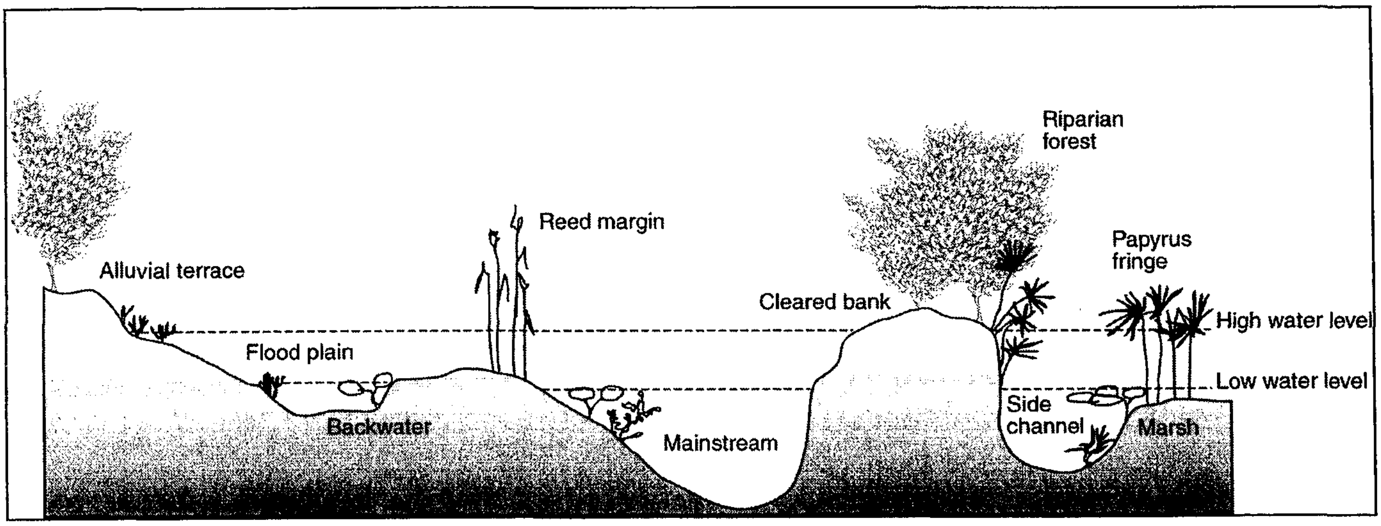
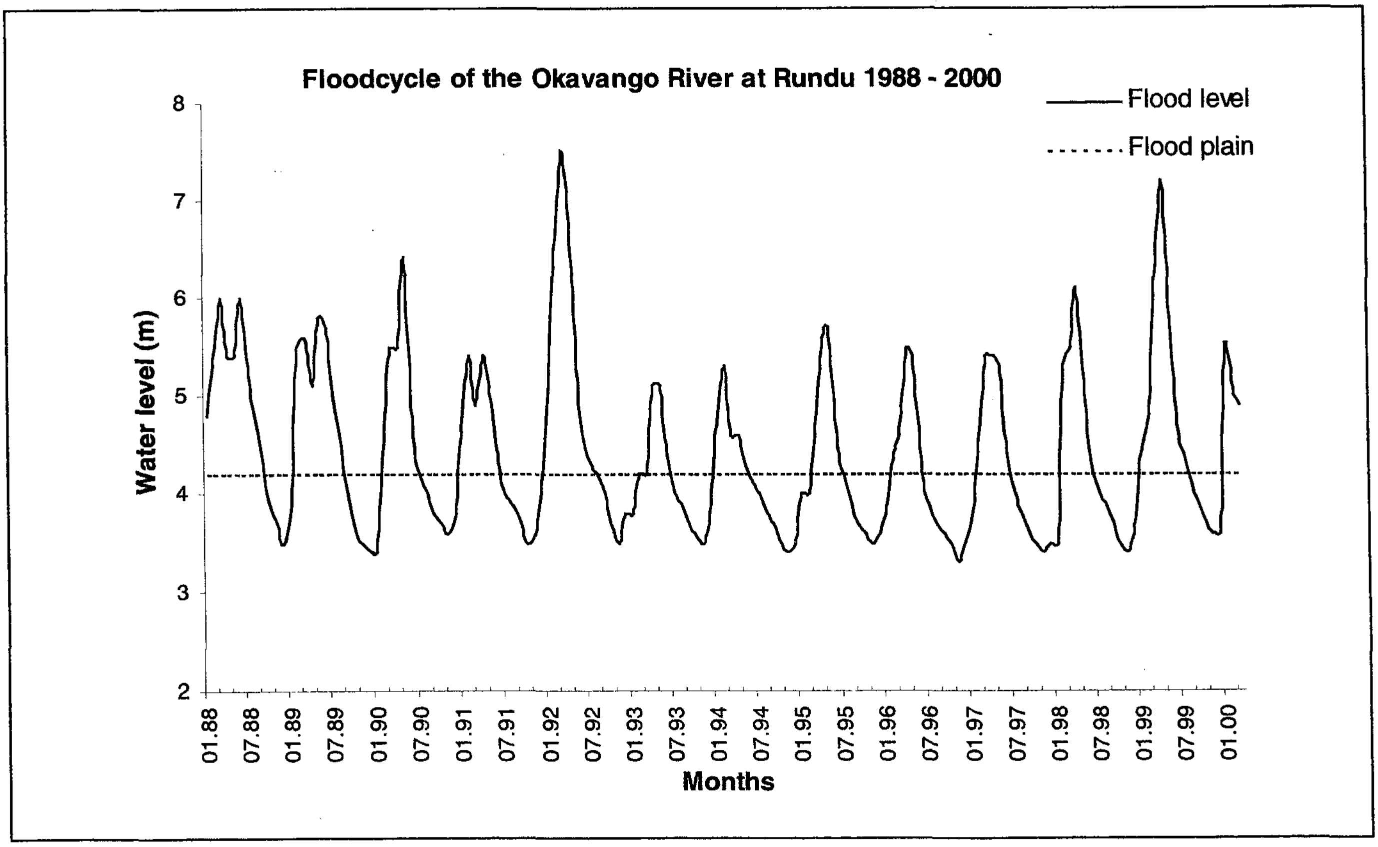


Figure 3.2. *Schematic profile of the habitats in the Okavango River (after Bethune 1991).*



Figur 3.3. *Water level of the Okavango River at Rundu 1988-2000.*

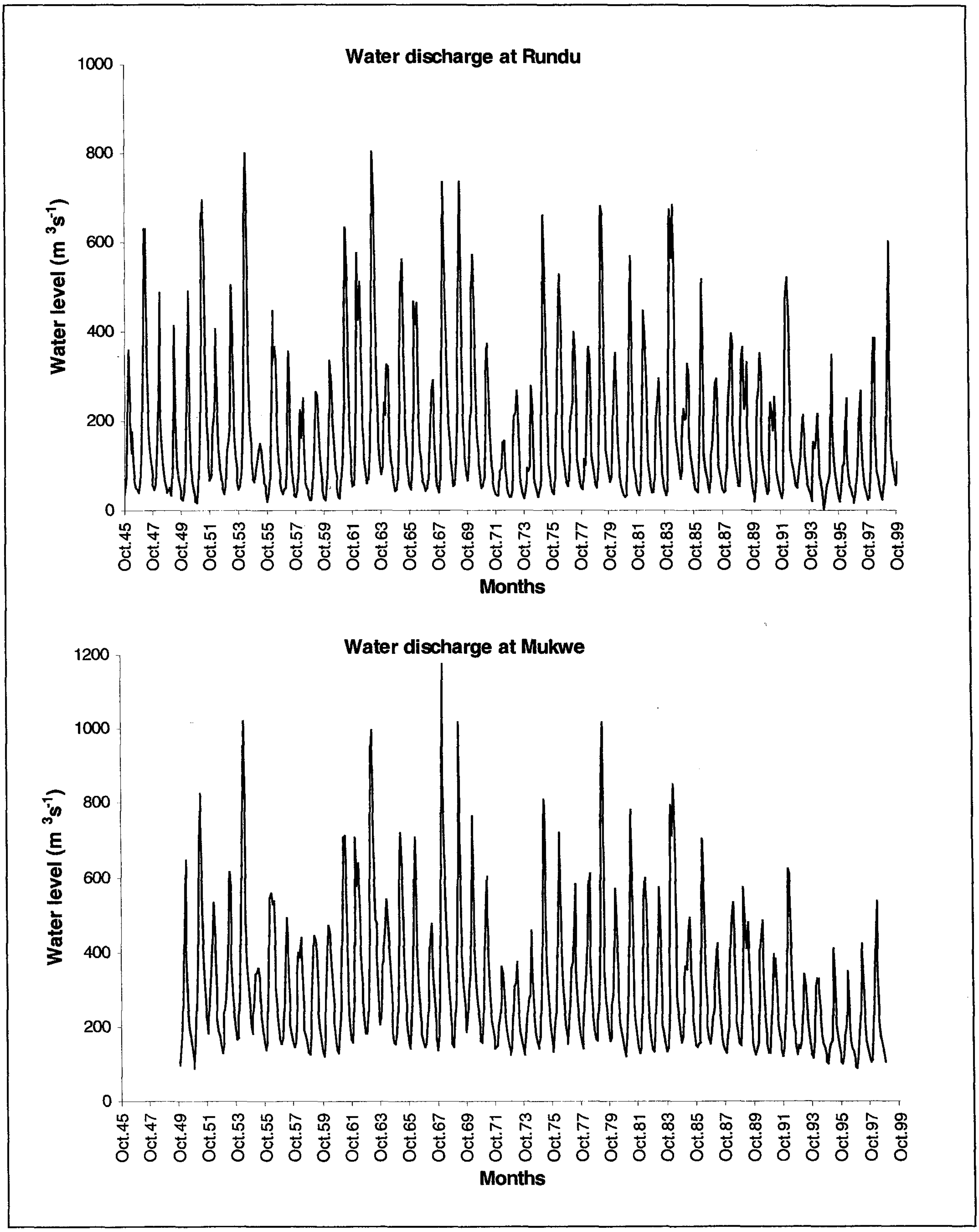


Figure 3.4. *Average water discharge in the Okavango River at Rundu and Mukwe in the period 1945–99 as cubic meters per second. The water discharge is estimated from monthly total water discharge.*

Table 3.1. *Water chemistry, temperature and oxygen in the Okavango River at Kakuru.*

Parameter	Aut 92	Aut 93	Win 93	Spr 93	Sum 94	Aut 94	Win 94	Aut 95*	Win 95*	Spr 96**	Win 97**
PH		6.40	6.80	6.30	6.80	6.90	7.20	6.8	6.8	6.7	6.6
Conductivity mS/m		9.80	5.70	7.80	5.30	4.40	3.70	4	4.9	6.1	4.5
TDS mg/l		65.00	38.00	51.00	35.00	29.00	24.00	26	32	40	30
Nitrate N mg/l		0.00	0.80	0.02	<0.01	0.00	0.00	<0.5	<0.5	<0.5	<0.5
Nitrite N mg/l		0.00	<0.01	0.00	<0.01	<0.01	0.00	<0.1	<0.1	<0.1	<0.1
Phosphorus P mg/l		0.163	0.026	0.147	0.029	0.023	0.020	0.254	<0.001	0.003	
Chloride mg/l		1.00	4.00	2.00	2.00	2.00	1.00	2	<1	2	1
Sodium mg/l		6.00	8.00	5.00	5.00	4.00	4.00	3	5	5	3
Potassium mg/l		6.00	1.00	2.00	3.00	4.00	3.00	3	2	3	2
Calcium mg/l		12.00	7.00	30.00	10.00	12.00	7.00	2.8	2.8	4.8	3.2
Total Hardness mg/l		21.00	12.00	34.00	14.00	21.00	12.00	12	12	21	16
Turbidity NTU		25.00	13.00	45.00	12.00	50.00	0.80		0.6	12.1	57.9
Oxygen mg/l		3.20	8.60	7.52	5.83	6.63	4.55				
Min. Air Temp. •C		22.90	15.10	15.20	17.00	16.00	14.00				
Max. Air Temp. •C		23.50	26.60	28.80	31.00	25.10	24.00				
Min. Water Temp. •C		23.00	16.00	20.00	22.00	17.00	15.00				
Max. Water Temp •C		25.00	19:80	28.20	27.60	24.20	18.50				

* Backwater
** Sidestream

Table 3.2. *Water chemistry, temperature and oxygen in the Okavango River at Matava.*

Parameter	Aut 92	Aut 93	Win 93	Spr 93	Sum 94	Aut 94	Win 94	Aut 95*	Win 95*	Spr 96**	Win 97*
PH		6.70	6.90	6.30	6.70	6.70	7.30	6.7	6.7	6.6	6.6
Conductivity mS/m		6.20	4.30	6.00	4.10	4.70	4.50	4.2	4.6	5.6	6
TDS mg/l		41.00	28.00	40.00	27.00	31.00	30.00	28	30	37	40
Nitrate N mg/l		0.50	0.80	0.00	0.34	0.30	0.25	<0.5	<0.5	<0.5	<0.5
Nitrite N mg/l		<0.01	<0.01	0.60	<0.01	0.00	<0.01	<0.1	<0.1	<0.1	<0.1
Phosphorus P mg/l		0.075	0.020	0.029	0.098	0.065	0.010	0.277	<0.001	0.018	
Chloride mg/l		1.00	1.00	2.00	1.00	2.00	1.00	<1	<1	<1	1
Sodium mg/l		2.00	6.00	4.00	0.00	4.00	5.00	3	6	4	4
Potassium mg/l		3.00	2.00	2.00	5.00	3.00	4.00	2	3	2	2
Calcium mg/l		7.00	10.00	12.00	10.00	17.00	7.00	4	2.8	2.8	5.2
Total Hardness mg/l		16.00	14.00	17.00	14.00	30.00	12.00	18	12	16	21
Turbidity NTU		0.50	0.90	4.50	3.40	20.00	0.40		3	1.3	2.4
Oxygen mg/l		6.60	6.53	8.60	6.12	5.90	4.54				
Min. Air Temp. •C		18.00	12.40	25.20	16.00	17.50	7.50				
Max. Air Temp. •C		25.30	26.30	30.00	29.20	22.40	17.90				
Min. Water Temp. •C		24.50	15.40	25.50	19.50	18.30	13.60				
Max. Water Temp •C		28.80	22.00	30.60	28.80	23.80	18.20				

* Backwater
** Mainstream

Table 3.3. *Water chemistry, temperature and oxygen in the Okavango River at Musese.*

Parameter	Aut 92*	Aut 93	Win 93	Spr 93	Sum 94	Aut 94	Win 94	Aut 95**	Win 95**	Spr 96**	Win 97**
PH	7	6.20	7.00	6.10	6.70	7.70	7.60	6.8	7	6.6	7
Conductivity mS/m	5.6	9.50	3.70	5.50	4.10	5.50	4.40	4.3	4.2	5.5	4.6
TDS mg/l	37	63.00	24.00	36.00	27.00	36.00	29.00	28	28	36	31
Nitrate N mg/l	<0.5	0.33	0.60	<0.01	0.31	0.30	0.65	<0.5	<0.5	<0.5	<0.5
Nitrite N mg/l	0.1	<0.01	0.00	0.70	<0.01	0.00	<0.01	<0.1	<0.1	<0.1	<0.1
Phosphorus P mg/l		0.026	0.026	0.401	0.046	0.042	0.062	0.011	<0.001	0.01	
Chloride mg/l	4	6.00	2.00	2.00	1.00	1.00	1.00	2	<1	3	1
Sodium mg/l	3	3.00	5.00	3.00	0.00	4.00	3.00	4	6	4	3
Potassium mg/l	5	6.00	2.00	2.00	5.00	3.00	3.00	1	2	2	1
Calcium mg/l	4	7.00	10.00	15.00	10.00	17.00	10.00	2.8	2.8	2.8	4
Total Hardness mg/l	18	16.00	14.00	19.00	14.00	22.00	14.00	12	12	16	18
Turbidity NTU	16	0.50	0.30	5.00	3.40	15.00	0.80		0.4	0.4	0.25
Oxygen mg/l		8.30	7.70	9.14	5.60	7.90	4.52				
Min. Air Temp. •C		20.00	13.20	24.90	15.50	17.80	7.00				
Max. Air Temp. •C		26.00	26.20	31.00	29.80	23.30	18.50				
Min. Water Temp. •C		26.00	17.40	25.30	21.20	21.50	14.50				
Max. Water Temp •C		28.10	23.50	27.60	28.00	24.60	16.80				

*Backwater
** Mainstream

Table 3.4. *Water chemistry, temperature and oxygen in the Okavango River at Bunya.*

parameter	Aut 92	Aut 93	Win 93	Spr 93	Sum 94	Aut 94	Win 94	Aut 95**	Win 95**	Spr 96**	Win 97**
PH		6.30	6.20	6.50	6.60	8.20	9.50	6.6	6.8	6.5	6.7
Conductivity mS/m		5.40	3.90	5.00	6.00	6.20	6.30	4.1	4.4	6.3	4.8
TDS mg/l		36.00	26.00	33.00	45.00	41.00	42.00	27	29	42	32
Nitrate N mg/l		0.20	0.80	<0.01	0.57	0.70	0.70	<0.5	<0.5	<0.5	<0.5
Nitrite N mg/l		0.00	<0.01	0.40	0.02	<0.01	<0.01	<0.1	<0.1	<0.1	<0.1
Phosphorus P mg/l		0.026	0.016	0.189	0.026	0.023	0.010	0.016	<0.001	0.017	
Chloride mg/l		6.00	4.00	2.00	2.00	1.00	1.00	2	<1	3	1
Sodium mg/l		3.00	7.00	4.00	4.00	4.00	5.00	4	5	4	3
Potassium mg/l		5.00	1.00	2.00	2.00	3.00	3.00	2	3	3	2
Calcium mg/l		7.00	10.00	12.00	15.00	22.00	17.00	2.8	2	2.8	4
Total Hardness mg/l		16.00	14.00	17.00	25.00	35.00	22.00	12	9	16	18
Turbidity NTU		0.30	0.40	0.08	0.80	30.00	0.80		0.3	1.5	0.4
Oxygen mg/l		6.60	7.54	8.32	7.50	8.90	4.43				
Min. Air Temp. •C		23.10	6.80	16.50	15.50	20.20	11.90				
Max. Air Temp. •C		28.00	24.90	30.80	32.00	22.80	20.00				
Min. Water Temp. •C		26.50	15.10	21.00	22.50	20.80	14.60				
Max. Water Temp •C		29.00	19.70	30.10	31.50	24.00	16.20				

* Backwater
** Mainstream

Table 3.5. *Water chemistry, temperature and oxygen in the Okavango River at Rundu.*

Parameter	Aut 92**	Aut 93	Win 93	Spr 93	Sum 94	Aut 94	Win 94	Aut 95**	Win 95**	Spr 96**	Win 97**
PH	7.3	6.60	7.10	6.60	7.00	6.70	9.00	6.8	6.8	6.8	7
Conductivity mS/m	4.9	6.50	6.60	8.20	5.80	5.10	7.20	4.9	7	9.9	5.1
TDS mg/l	32	43.00	44.00	54.00	38.00	34.00	48.00	32	46	65	34
Nitrate N mg/l	<0.5	0.40	0.60	0.00	0.11	0.10	0.60	<0,5	<0.5	<0.5	<0.5
Nitrite N mg/l	<0.1	<0.01	<0.01	0.30	0.06	0.00	0.00	<0.1	<0.1	<0.1	<0.1
Phosphorus P mg/l		0.065	0.45	0.055	0.023	0.029	0.013	0.391	<0.001		0.02
Chloride mg/l	1	4.00	7.00	2.00	2.00	3.00	1.00	1	<1	5	<1
Sodium mg/l	2	3.00	5.00	4.00	5.00	5.00	4.00	4	6	8	3
Potassium mg/l	9	4.00	7.00	1.00	4.00	3.00	2.00	3	3	2	3
Calcium mg/l	2.8	7.00	10.00	4.00	12.00	10.00	22.00	4	2.8	4.8	3.2
Total Hardness mg/l	7	16.00	14.00	29.00	17.00	18.00	27.00	18	16	21	16
Turbidity NTU	11	3.10	0.90	0.90	6.40	20.00	0.60		0.3		2.8
Oxygen mg/l		8.70	8.95	5.00	5.50	8.60	3.91				
Min. Air Temp. •C		21.00	13.50	22.70	18.50	19.80	13.50				
Max. Air Temp. •C		33.00	23.60	31.80	32.50	21.10	17.40				
Min. Water Temp. •C		25.00	17.50	24.80	21.50	20.60	15.00				
Max. Water Temp •C		26.50	18.60	30.90	30.00	22.90	17.10				

* Backwater
** Mainstream

Table 3.6. *Water chemistry, temperature and oxygen in the Okavango River at Cuito.*

parameter	Aut 92	Aut 93	Win 93	Spr 93	Sum 94	Aut 94	Win 94	Aut 95**	Win 95**	Spr 96*	Win 97**
PH		7.00	6.90	6.00	6.90	6.80	6.70	6.6	6.6	7.7	6.7
Conductivity mS/m		7.50	4.10	5.10	6.00	5.20	4.60	4.4	3.1	11.2	5.3
TDS mg/l		50.00	27.00	34.00	30.00	34.00	30.00	29	20	74	36
Nitrate N mg/l		0.35	1.10	<0.01	0.57	0.68	1.10	<0.5	<0.5	<0.5	<0.5
Nitrite N mg/l		<0.01	<0.01	0.20	0.03	0.02	<0.01	<0.1	<0.1	<0.1	<0.1
Phosphorus P mg/l		0.016	0.013	0.082	0.098	0.026	0.023	0.095	<0.001	0.013	
Chloride mg/l		1.00	1.00	2.00	1.00	1.00	1.00	2	<1	4	1
Sodium mg/l		3.00	5.00	4.00	5.00	4.00	4.00	3	4	5	3
Potassium mg/l		3.00	2.00	4.00	3.00	3.00	2.00	4	3	2	3
Calcium mg/l		7.00	10.00	10.00	8.00	15.00	7.00	2.8	2	14	5.2
Total Hardness mg/l		16.00	14.00	14.00	14.00	27.00	12.00	12	9	43	17
Turbidity NTU		1.20	0.90	2.50	0.90	16.00	0.80		28	6.2	0.83
Oxygen mg/l		7.80	7.79	6.00	5.00	10.20	3.61				
Min. Air Temp. •C		26.20	7.00	16.00	18.50	20.30	14.80				
Max. Air Temp. •C		30.30	28.30	30.50	32.00	23.60	23.50				
Min. Water Temp. •C		26.90	15.10	19.00	20.50	20.90	16.50				
Max. Water Temp •C		28.10	19.50	29.00	31.00	23.30	20.50				

* Backwater
** Mainstream

Table 3.7. *Water chemistry, temperature and oxygen in the Okavango River at Mbambi.*

Parameter	Aut 92**	Aut 93	Win 93	Spr 93	Sum 94	Aut 94	Win 94	Aut 95**	Win 95**	Spr 96**	Win 97**
PH	7.1	6.70	6.70	7.80	6.60	8.20	7.10	6.6	8.2	6.7	6.6
Conductivity mS/m	4.4	6.10	3.00	8.00	4.50	6.30	3.00	4.7	8.8	6.5	3.5
TDS mg/l	29	40.00	20.00	53.00	30.00	42.00	20.00	31	58	43	23
Nitrate N mg/l	<0.5	0.30	0.70	<0.01	0.57	0.34	0.30	<0.5	<0.5	<0.5	<0.5
Nitrite N mg/l	<0.1	0.00	<0.01	0.50	<0.01	<0.01	<0.01	<0.1	<0.1	<0.1	<0.1
Phosphorus P mg/l		0.033	0.033	0.072	0.065	0.065	0.007	0.139	<0.001	0.009	
Chloride mg/l	3	3.00	2.00	2.00	1.00	1.00	1.00	<1	<1	3	1
Sodium mg/l	2	2.00	3.00	2.00	4.00	3.00	2.00	3	5	3	1
Potassium mg/l	9	3.00	2.00	4.00	4.00	3.00	3.00	3	3	2	3
Calcium mg/l	2.8	12.00	7.00	30.00	10.00	25.00	7.00	2.8	12.8	8	3.2
Total Hardness mg/l	12	21.00	12.00	34.00	14.00	37.00	12.00	12	37	24	12
Turbidity NTU	0.3	2.30	0.40	4.30	4.70	20.00	0.50		0.4	2.6	1.5
Oxygen mg/l		8.30	7.74	7.37	8.00	10.40	3.32				
Min. Air Temp. •C		20.00	5.00	27.50	19.50	17.70	14.00				
Max. Air Temp. •C		27.80	22.90	30.50	28.50	23.80	27.50				
Min. Water Temp. •C		25.50	15.40	26.20	24.50	19.20	16.50				
Max. Water Temp •C		27.80	18.70	30.50	29.00	23.40	18.50				

* Backwater
** Mainstream

Table 3.8. *Water chemistry, temperature and oxygen in the Okavango River at Popa Falls.*

Parameter	Aut 92**	Aut 93	Win 93	Spr 93	Sum 94	Aut 94	Win 94	Aut 95*	Win 95*	Spr 96*	Win 97*
PH	7.2	7.00	7.00	7.70	6.80	6.90	7.40	6.8	6.8	6.7	6.8
Conductivity mS/m	4.2	9.50	3.20	6.90	5.10	4.00	3.00	4.8	2.9	4.3	3.3
TDS mg/l	28	63.00	21.00	46.00	34.00	26.00	20.00	32	19	28	22
Nitrate N mg/l	<0.5	0.18	<0.01	<0.01	<0.01	0.45	0.50	<0.5	<0.5	<0.5	<0.5
Nitrite N mg/l	<0.1	0.46	<0.01	0.30	<0.01	<0.01	<0.01	<0.1	0.2	<0.1	<0.1
Phosphorus P mg/l		0.13	0.007	0.173	0.016	0.13	0.01	0.026	<0.001	0.015	
Chloride mg/l	3	4.00	4.00	2.00	1.00	1.00	1.00	2	<1	5	1
Sodium mg/l	2	2.00	6.00	2.00	4.00	2.00	2.00	3	4	3	1
Potassium mg/l	10	6.00	2.00	4.00	5.00	4.00	3.00	3	3	2	4
Calcium mg/l	2	10.00	7.00	25.00	7.00	10.00	7.00	2.8	2	2.8	3.2
Total Hardness mg/l	9	18.00	12.00	29.00	12.00	14.00	12.00	16	9	12	12
Turbidity NTU	0.2	0.90	0.60	1.50	18.00	30.00	0.80		1.2	6.4	1.7
Oxygen mg/l		8.10	7.45	9.00	10.50	11.88	3.31				
Min. Air Temp. •C		19.50	8.60	22.50	20.00	20.30	12.00				
Max. Air Temp. •C		23.10	23.60	28.20	32.00	23.30	24.60				
Min. Water Temp. •C		25.10	15.40	24.40	19.00	20.20	16.80				
Max. Water Temp •C		27.10	18.70	28.60	28.90	22.90	18.20				

* Side stream
** Main stream

Table 3.9. *Water chemistry, temperature and oxygen in the Okavango River at Kwetze.*

Parameter	Aut 92*	Aut 93	Win 93	Spr 93	Sum 94	Aut 94	Win 94	Aut 95*	Win 95**	Spr 96*	Win 97*
PH	7.4	6.90	6.70	8.60	6.80	6.30	7.50	6.6	7.1	6.1	6.6
Conductivity mS/m	5.2	7.50	4.00	10.10	5.20	3.80	4.10	5.3	4.6	3.8	3.5
TDS mg/l	34	50.00	26.00	67.00	34.00	25.00	27.00	35	30	25	23
Nitrate N mg/l	<0.5	0.30	0.27	0.00	0.05	0.07	0.05	<0.5	<0.5	<0.5	<0.5
Nitrite N mg/l	<0.1	0.06	<0.01	0.00	<0.01	<0.01	<0.01	<0.1	<0.1	<0.1	<0.1
Phosphorus P mg/l		0.020	0.098	0.098	0.026	0.026	0.020	0	<0.001	0.034	
Chloride mg/l	3	4.00	3.00	2.00	1.00	0.00	1.00	2	<1	4	1
Sodium mg/l	2	2.00	2.00	2.00	4.00	2.00	2.00	3	6	3	1
Potassium mg/l	10	4.00	4.00	4.00	4.00	4.00	4.00	4	3	2	4
Calcium mg/l	2.8	7.00	10.00	57.00	10.00	10.00	10.00	4.8	4	2	2
Total Hardness mg/l	12	16.00	14.00	62.00	14.00	14.00	14.00	17	14	9	13
Turbidity NTU	1.5	4.10	2.20	20.00	2.30	35.00	0.80		2.5	24.8	35.2
Oxygen mg/l		6.70	2.50	7.79	6.50	6.60	3.09				
Min. Air Temp. •C		26.50	10.70	25.40	19.50	20.00	14.50				
Max. Air Temp. •C		28.50	27.80	27.70	33.00	22.80	26.50				
Min. Water Temp. •C		26.50	15.30	26.10	22.50	20.60	17.80				
Max. Water Temp •C		27.00	20.90	28.80	29.00	22.80	18.50				

* Backwater
** Floodplain

Table 3.10. *Main characteristics of the freshwater fishery in the Okavango River (after Tvedten et al. 1994).*

Estimated fishing population	56,000 persons
Households using traditional gears	100 %
Households using modern gears	43 %
Proportion of women among fishing population	55 %
Proportion of households marketing fish	42 %
Proportion of households marketing fish	42 %
Local perception of open access to fishing grounds	92 %
Proportion catching > 15 kg per fishing trip	0 %
Proportion catching < 15 kg per fishing trip	91 %
Households in favour of regulating fishery	91 %

is a source of subsistence, and sales of fish provide some income for approximately 45 % of the households (Tvedten et al. 1994). The highest density of people live near Rundu (**Table 3.11**) and the highest utilisation of fish will also be at this place. No subsistence fishing is taking place at Kwetze, which is within a game reserve.

Population estimates and density at the main sampling stations in the Okavango River in 1991 ranges from 38 people per square kilometre at Musese to 1937 people per square kilometre at Rundu (**Table 3.11**). Rundu is the major population centre in the Okavango region. It differs from the other stations in having a population density about 17 times higher than the second highest population density at Bunya.

3.2 Gill net stations

A description of the habitats at the seven main sampling localities **(Figure 3.1)** is given below.

3.2.1 Matava

Matava (17°47' S 18°50' E) has a relatively large floodplain area during the high water season. A backwater channel is formed with aquatic vegetation, reeds and grass on the banks (**Figure 3.5**). The water is either stagnant or slow flowing depending on the river level. The substrate is sandy with little silt/clay present. The channel opens up into the main river where large rock boulders are present. The depth in the channel varies between 0.8 m and 2 m. There is no aquatic vegetation in the main stream with only reeds near the banks and some larger trees on the riverbank. The depth in the main stream is between 1 and 3 m.

Gill nets

Gill nets were set in the middle of the floodplain channel with some aquatic vegetation present. The substrate was silt to clay with little or no water flow. Gill nets were also set in the main stream near the banks with no aquatic vegetation present. The substrate in the main stream was sand.

Table 3.11. *Population densities at the main sampling localities in the Okavango River, 1991. * = Population density at Rundu in 1999.*

Station	No. of people		Approx. area	People/km^2	
Matava	965		20 km^2	48.3	
Musese	568		15 km^2	37.9	
Bunya	2 905		25 km^2	116.2	
Rundu	19 366	(43789*)	10 km^2	1936.6	(4378.9*)
Katere (Cuito)	546		9 km^2	60.7	
Mbambi	401		9 km^2	44.6	

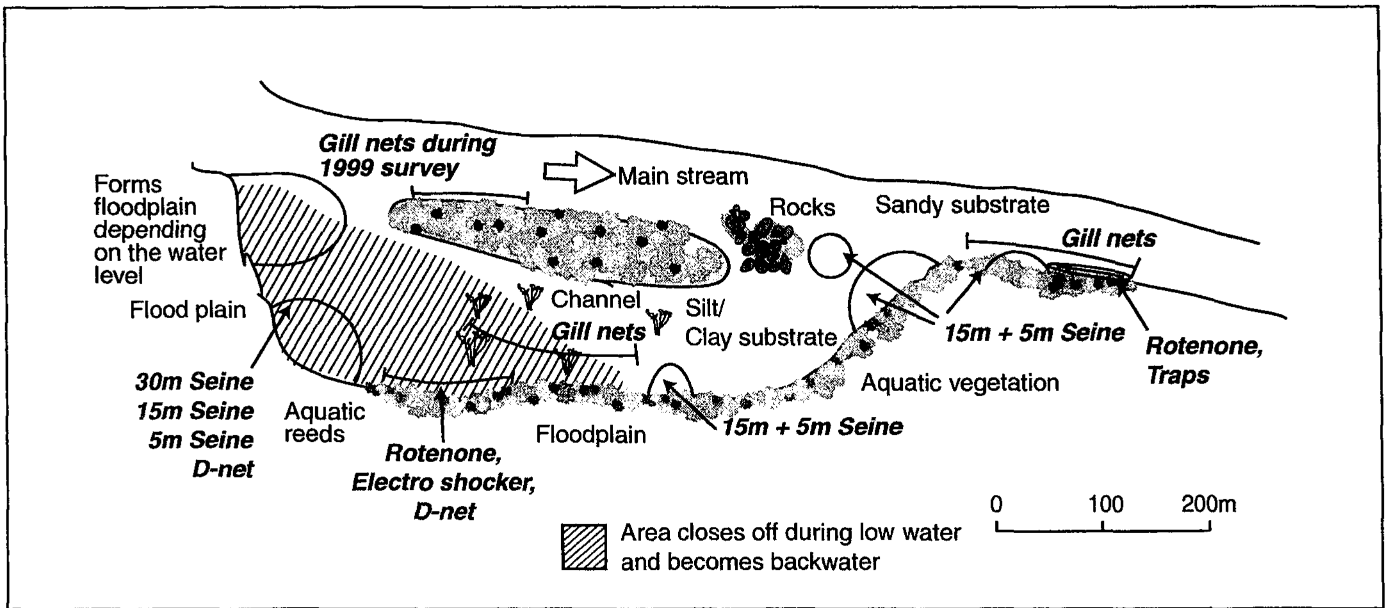


Figure 3.5. *Schematic map of the sampling station at Matava in the Okavango River. The fishing sites and vegetation cover are indicated.*

Other gears
Seine setting was done in the mainstream near the riverbanks, where no vegetation is present, as well as in the backwater channel. Rotenone and traps were used in the marginal vegetation along the banks of the main stream, and also in the backwater channel. Electro fishing was done in the vegetated areas of the channel. A D-net was used to sample between the reeds and aquatic vegetation.

3.2.2 Musese

Musese (17°49′ S 18°55′ E) is primarily a main stream habitat with a relatively small floodplain that varies with the water level. The small floodplain has aquatic vegetation and reeds, but can also form an isolated pool with shallow, murky water (**Figure 3.6**). The substrate in the main stream is sandy and clay in the floodplain. The water on the floodplain is either stagnant or slow flowing depending on the flood level. The main stream is clear, with flowing water with no aquatic vegetation. Reeds are present on the riverbank. The depth varies between 0.3 m and 3 m.

A stagnant backwater with reeds was also sampled approximately 2 km down stream from the previous site. This, however, was sampled irregularly, because it was difficult to access during low water periods.

Gill nets
The gill nets were set in the main stream near the riverbank. No aquatic vegetation was present with only reeds near the riverbanks. The water current was low to medium depending on the flood level. Gill nets were also set at Musese 2 in a backwater habitat with no water flow and within aquatic vegetation.

Other gears
Rotenone, electro fishing and seine netting were done at the floodplain/backwater in the aquatic vegetation. The vegetated habitats were also sampled using an electro shocker and a D-net. This was done in the main stream along the shore and in the floodplain/back water habitats. Sampling was done in the shallower habitats in the main stream between the reeds and the riverbank with seine net, rotenone and traps.

3.2.3 Bunya

At Bunya (17°51′ S 19°21′ E) the main stream has clear, flowing water with a sandy substrate. Reeds are present near the riverbank (**Figure 3.7**). No other aquatic vegetation is present. The depth varies between 1 and 3.5 m. The stagnant backwaters with a sand and clay substrate were also sampled. The depth in the backwaters is between 1 and 2 m. Some aquatic vegetation was present in these back waters. There are also rocky

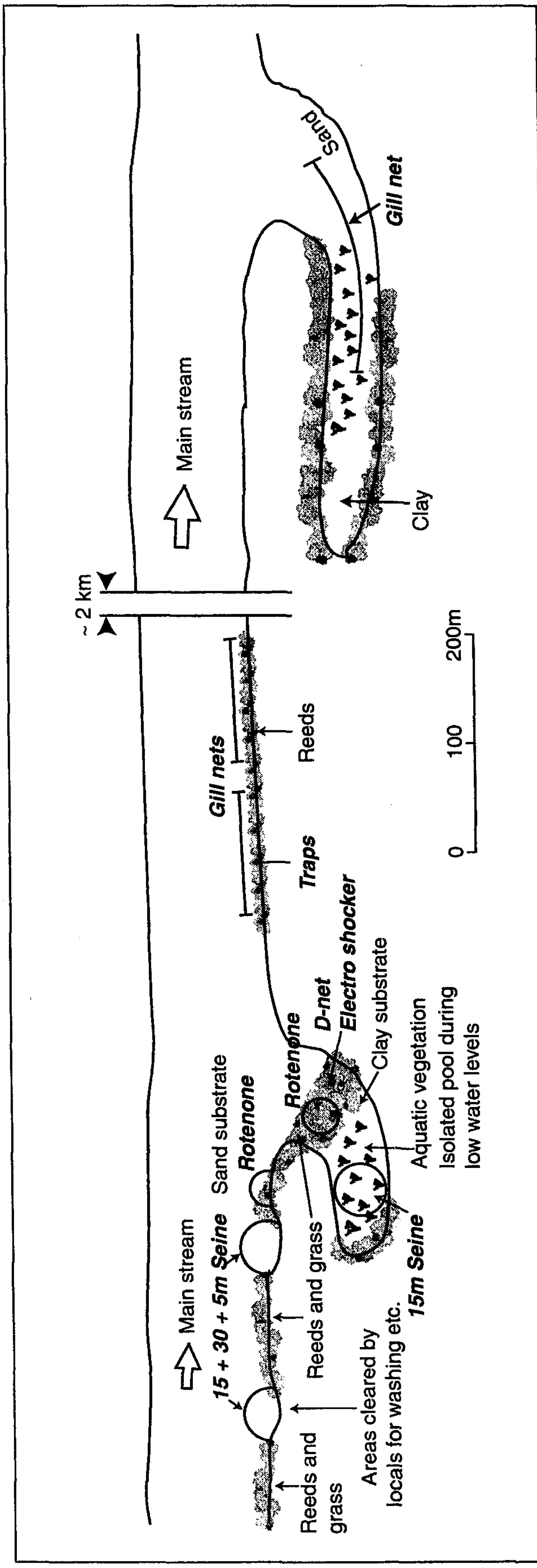


Figure 3.6. Schematic map of the sampling station at Musese in the Okavango River. The fishing sites and vegetation cover are indicated.

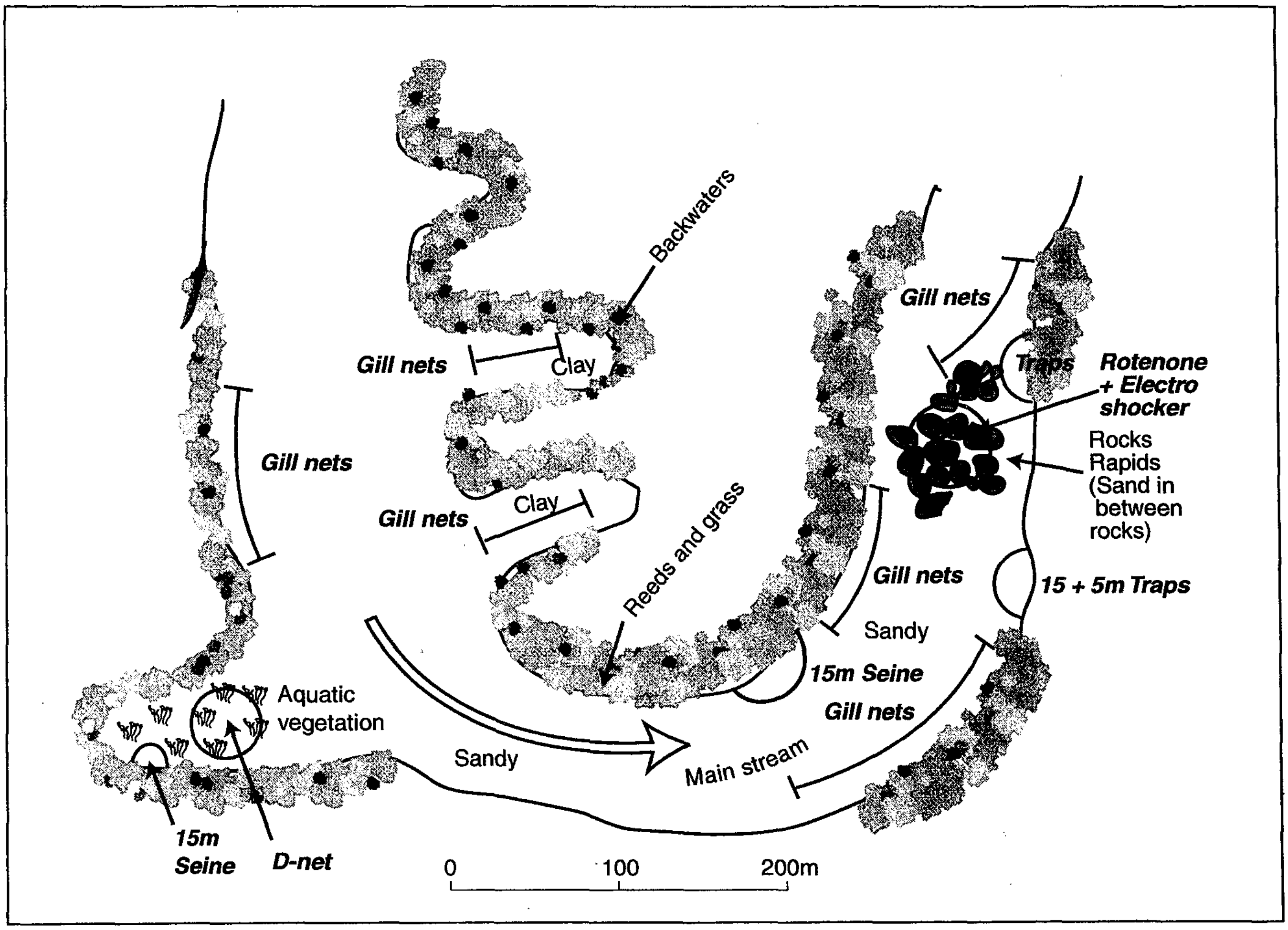


Figure 3.7. Schematic map of the sampling station at Bunya in the Okavango River. The fishing sites and vegetation cover are indicated.

habitats with depths between 0.2 and 1 m in the main stream, with water velocities depending of the flood level. In the rocky area there is a sandy substrate with some reeds between the rocks, and no other vegetation.

Gill nets
Gill nets were set in the main stream near reeds on the riverbanks and in the back waters. The gill nets in the main stream sampled open, flowing water habitats with a sandy substrate while those in the back waters sampled stagnant areas with some vegetation present.

Other gears
Rotenone and electro fishing were done between the rocks in the main stream. Seine netting was also done along the shore in the main stream in open water and also in the backwater within aquatic vegetation. The D-net was used to sample within the aquatic vegetation in the backwater. Traps were set along the side in the main stream.

3.2.4 Rundu

At Rundu (17°53' S 19°46' E) the main stream runs through a large floodplain area, and has a sandy substrate with some reeds near the shore (**Figure 3.8**). Some additional aquatic plants were also present. The water velocity was medium flowing and the depth varied between 1 and 2 m. Water depth at the floodplain varied between 0.2 and 1 m over a clay substrate. Aquatic vegetation was present on the floodplain habitats. Backwater habitats were also sampled and consisted of marginal vegetation, stagnant water and a clay substrate. Rocky habitats were present in the main stream, but only during low water periods.

Gill nets
Gill nets were set in the main stream near the riverbank and along the island. These gill nets sampled open water habitats while those that were set in the backwater sampled habitats with marginal vegetation (mainly reeds) and with no water current.

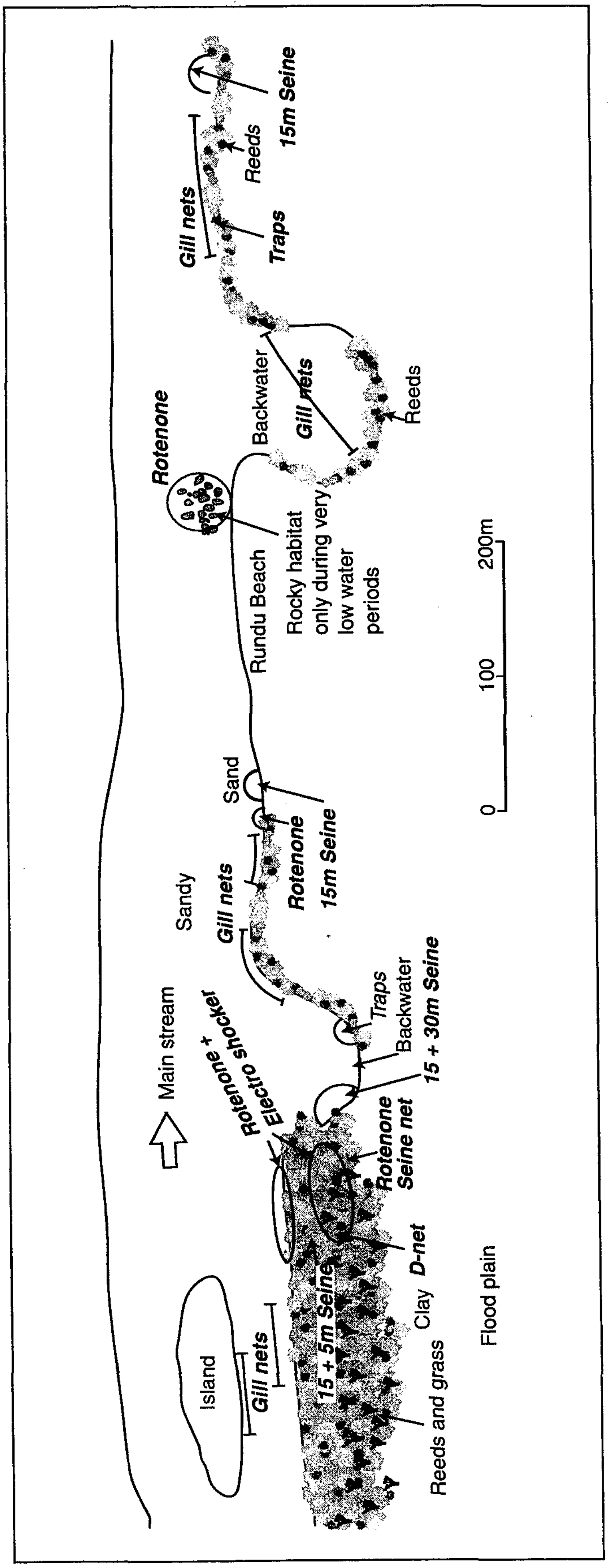


Figure 3.8. *Schematic map of the sampling station at Rundu in the Okavango River. The fishing sites and vegetation cover are indicated.*

Other gears

The floodplain habitat was surveyed using rotenone, electro shocker, seine nets and a D-net. Grass and aquatic vegetation characterised these habitats. In the main stream along the edges between the reeds, rotenone, electro shocker and traps were used to sample fish. Rotenone was also used between the rocks in the main stream during low water levels. Seine netting was done in the backwater, as well as the main stream in open water areas.

3.2.5 Cuito

At Cuito (18°01′ S 20°47′ E) the main stream had a depth of 0.5 to 3.5 m and a sandy substrate with reeds along the riverbank (**Figure 3.9**). Some large boulders were present in the main stream. The water velocity was slow to medium. There was no aquatic vegetation in the deeper parts, but some in the shallower areas. The floodplain was shallow (0.2 to 0.5 m) with a clay substrate. Aquatic vegetation was present and includes reeds and grasses. Rocks were present in the main stream, at depths between 0.2 and 0.5 m. The stagnant backwater had some aquatic vegetation, depths between 1 and 2 m, and a clay substrate.

Gill nets

The gill nets were set in the backwater along the edge and in the middle of the water body. Aquatic vegetated areas were sampled within the backwater. The open, main stream habitats were surveyed by placing gill nets along the riverbank.

Other gears

Rotenone and electro fishing were used on the floodplains and in the main stream near the riverbank between the reeds. Rocky habitats were similarly sampled using rotenone. Seine netting was performed in the main stream in shallow, open water habitats. The backwater was sampled using a scoop net between the aquatic vegetation consisting mainly of lilies. Apart from gill nets and seine nets in the main stream, traps were set on the edges near the reed banks.

3.2.6 Mbambi

At Mbambi (17°57′ S 21°00′ E) the main stream had a sandy substrate with marginal vegetation of mainly reeds (**Figure 3.10**). The water current depended on flood levels. Water depth varies between 1 and 2.5 m. Rocks were present in the main stream together with some vegetation. The shallow floodplain (0.2-1 m) had stagnant waters with grass and aquatic vegetation and a clay substrate. The stagnant backwater had a clay substrate, some aquatic vegetation and a depth of 1 m. Reeds were present in the backwater, mainly on the edges. There was also a stagnant isolated pool with a depth of 1-2 m.

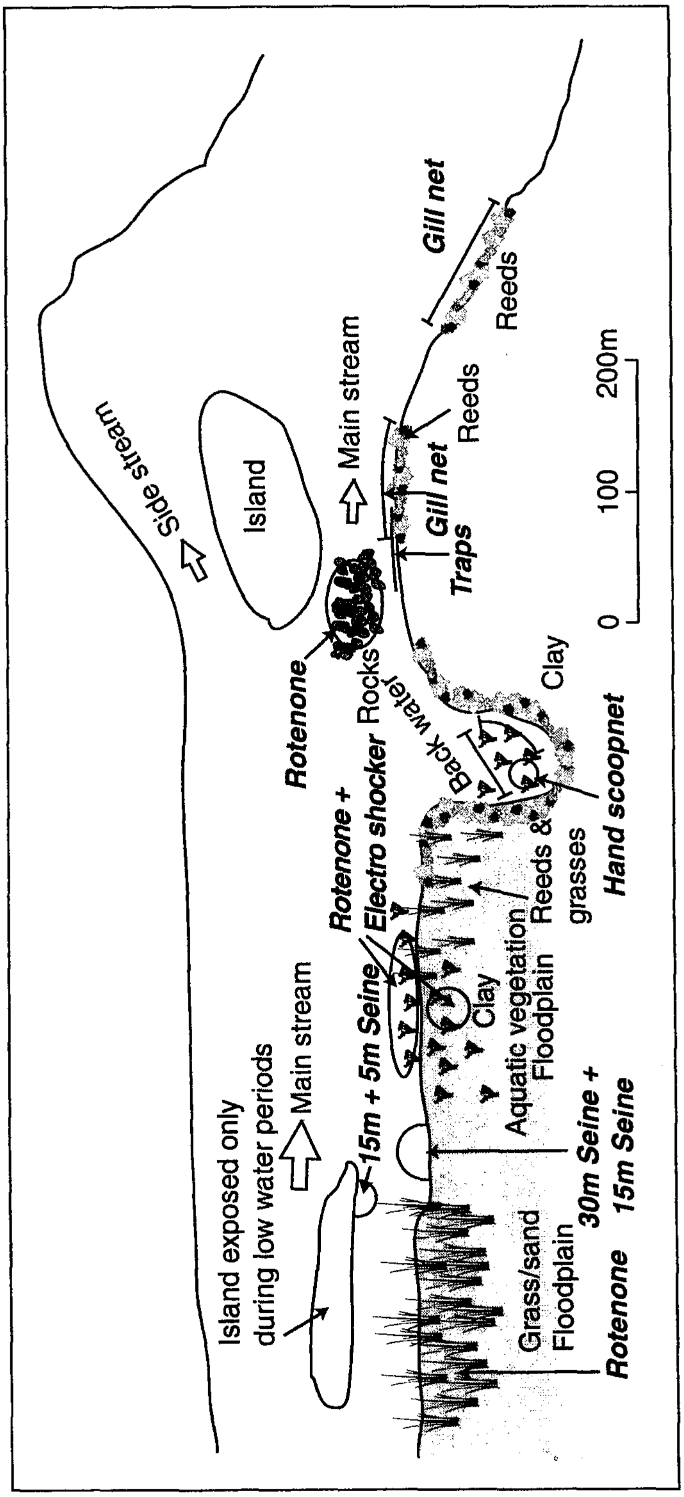


Figure 3.9. *Schematic map of the sampling station at Cuito in the Okavango River. The fishing sites and vegetation cover are indicated.*

Gill nets
Gill nets were set in the main stream along the riverbanks to sample open water habitats. The depth of these habitats varied between one and 2.5 m. Few aquatic plants were present.

Other gears
The rocky habitat in the main stream was surveyed using only rotenone. The backwater habitats were similarly surveyed. This habitat was also sampled using an electro shocker and a D-net. Seine netting was performed in the shallow, open water habitats in the main stream and in the backwater. The isolated pool was also surveyed with a seine net. Traps were set along the riverbanks near the gill nets.

3.2.7 Kwetze.

Kwetze (18°13' S 21°45' E) is situated within the Mahondo Game Park. At the sampling site, the main stream had clear flowing water with a depth of 1 to 2.5 m and a sandy substrate, with reeds along the shoreline.

There were large nearly stagnant backwaters (2-3.5 m deep) with reeds along the shore (**Figure 3.11**). Some aquatic plants were present in the backwater bays. The backwater substrate was clay. There were shallow (0.2-0.5 m), nearly stagnant floodplains with murky waters, grass and aquatic vegetation, and a clay substrate.

Gill nets
Gill nets were set in the main stream near the reed beds sampling open water habitats and in the backwater. Some gill nets were set between aquatic vegetation in the backwater.

Other gears

Seine nets were used for sampling in the backwater habitats and in the main stream in clear, flowing habitats. Traps were set near some of the gill nets in the backwater.

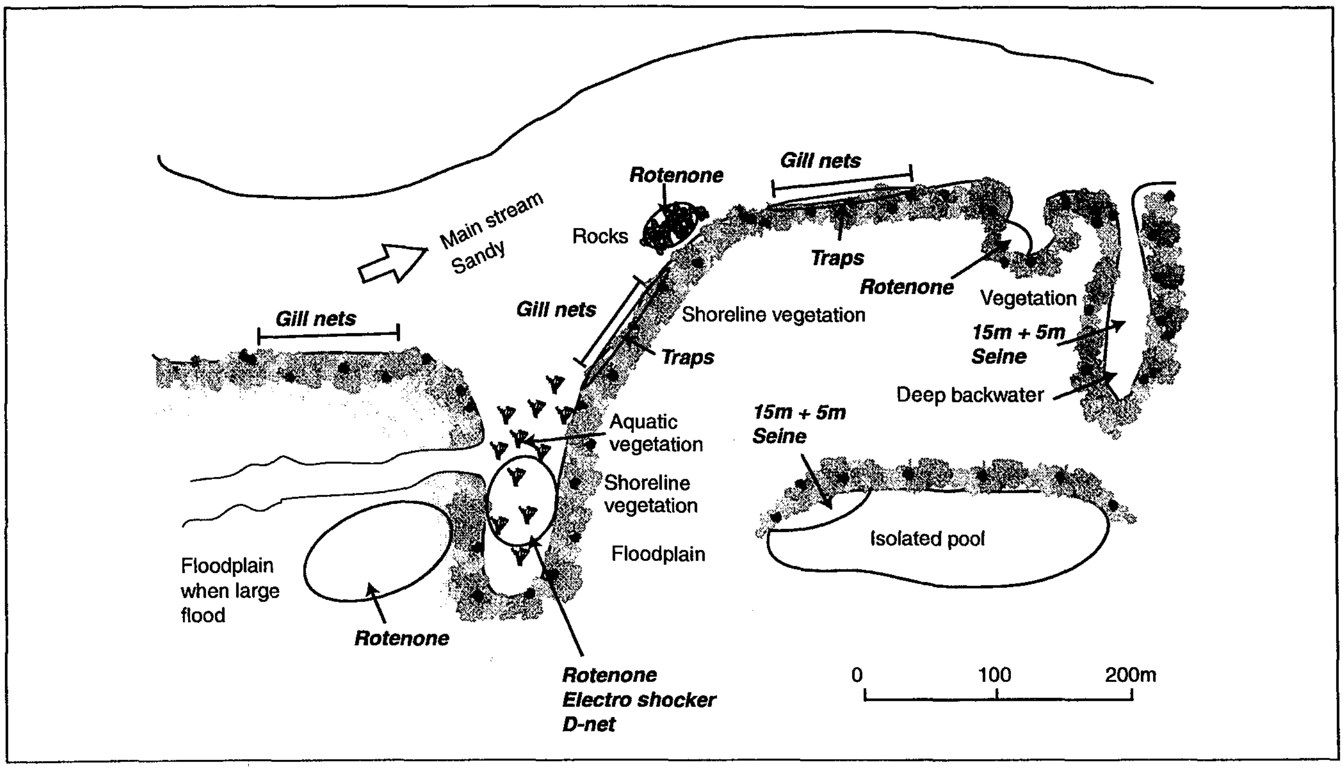


Figure 3.10. *Schematic map of the sampling station at Mbambi in the Okavango River. The fishing sites and vegetation cover are indicated.*

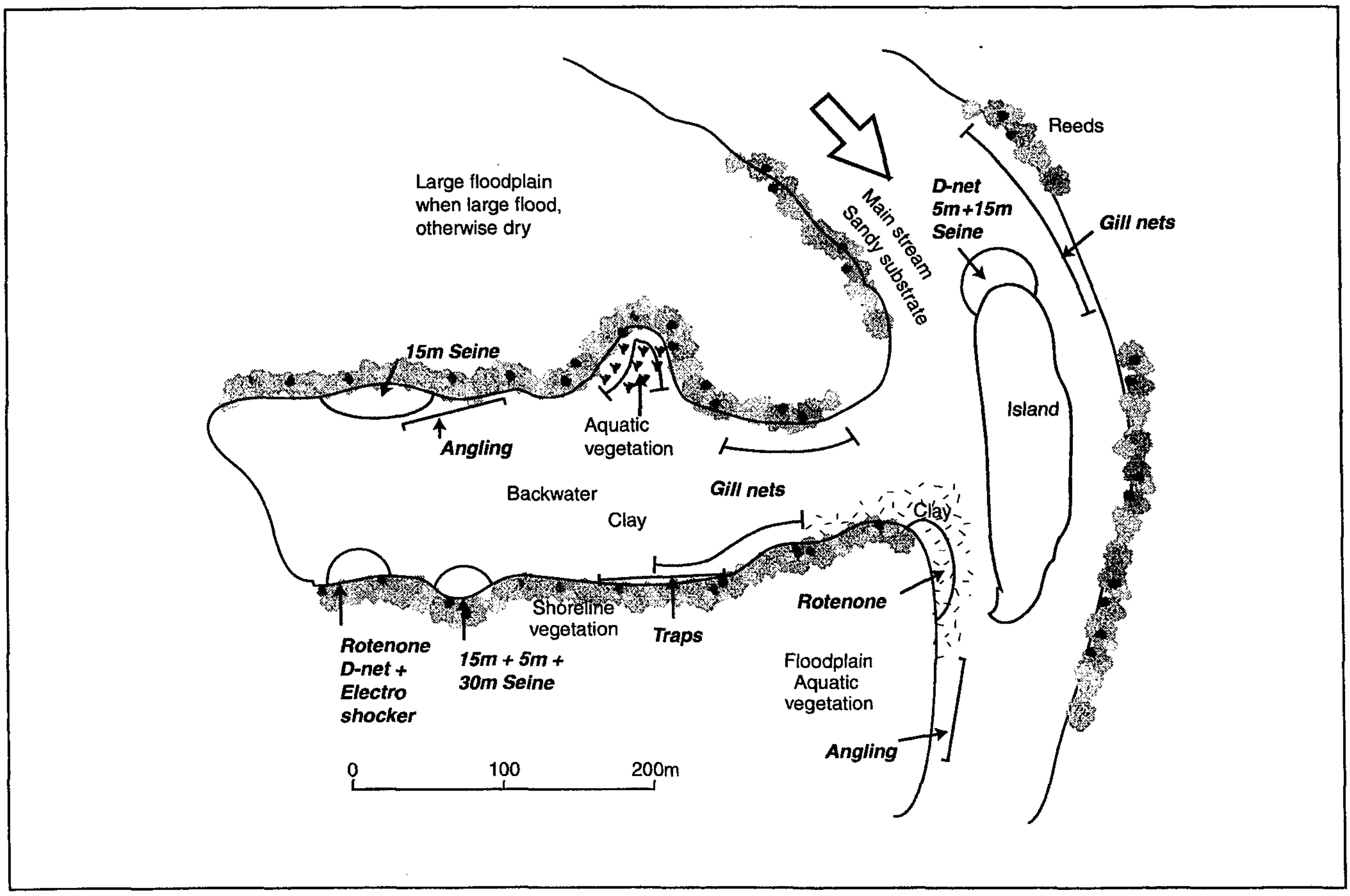


Figure 3.11. *Schematic map of the sampling station at Kwetze in the Okavango River. The fishing sites and vegetation cover are indicated.*

4 Local fisheries

4.1 Background

The exploitation of the fishes of the Okavango River has received attention in the past (Gilmore 1976; van der Waal 1977, 1991; van Zyl 1992). With the increase in the human population (approximately 110 000 people within five kilometres of the river, according to Tvedten et al. 1994), the subsistence fishery became an important aspect to consider for future sustainable utilisation in the Okavango Region. With 53 % of the riverine people catching fish and 91 % who see fish as a source of subsistence, it is clear that the fishery of the Okavango River forms an integral part of these people's daily requirements (Tvedten *et al.* 1994).

4.2 Surveys on catch in local fisheries

4.2.1 Material and methods

The data for this chapter were collected through a survey of the gear (modern and traditional) used in the subsistence fishery. Approximately 230 km from Matava to Omatako were travelled by boat on the Okavango River during June 1994 to survey the subsistence fishery. Some areas were surveyed more than once, so that the total surveyed river length was 400 km. Data were collected from the fisherfolk attending to their gear. All other gear were counted and its position noted in relation to the Angolan or Namibian river bank. The following information was noted during these surveys for each gear used in the subsistence fishery:

- the gender of the fisher
- the gear used
- the total mass of the fish sampled
- the species composition and number of individuals
- a sub-sample for length frequency
- the time spent fishing for that particular catch
- the number and method used on the Angolan side of the river

4.2.2 Fishing seasons and gears in local fisheries

The peak fishing time is during the receding phase of the flood and low water periods when the fish are concentrated, while there is reduced fishing activity during the flood when large areas along the river become inaccessible for the subsistence fishers. People prepare their fishing gear during September/October as the peak fishing period approaches. During the low water period, fish traps placed in mud pools in the shallow parts of the stream become a favourite method of fishing. The fish are lured into these traps with mango or any type of food. During the flooding season when the water becomes deep and the currents strong, the preferred method is fish corral traps (*sintunga*) which are placed in shallow habitats on the floodplains. This is a favourite fishing method during summer when people also need to attend to their fields, because it does not need constant attention. The hook and line is also a favourite gear, especially for the boys after school or during weekends.

During the receding phase, fish fences (*masasa*) are used to prevent fish from moving from the floodplains back to the main stream. Fish corral traps are then placed in these areas where the fish concentrations are high. The women also to a limited extent use scoop baskets (*tambi*). This is an oval shaped basket with handles and is used as a drag net. Mosquito nets were effectively used during the receding flood as well as the *shikuku* or fish funnel. Other traditional fishing methods were also seen along the river, these are the push basket (*sididi*), fishing basket (*runkinda*), bow and arrow (*ngumba*) and fish spear (*muho*).

The use of modern gear is restricted to gill nets, which are used mainly by the men, and mosquito nets, a method used by the women. The gill nets are usually in poor condition and are not very effective. Van Zyl (1992) also observed this during his surveys. Casts nets were also seen, although this method is considered to be rare, as it requires certain technical skills.

It is unfortunate that systematic monitoring of the Okavango River did not start before 1989, which would have given a better picture of the present state and development of the fish resource in the Okavango River. Tendencies recorded over extensive time periods are important for management purposes of such a complex aquatic system.

4.2.3 Catches in local fisheries

These results only describe the artisanal fishery during a limited period of time in parts of the river and should be treated accordingly. Total catch in the local fishery, measured as mean CPUE multiplied with total number of that gear observed in the river, was largest for hook and line, followed by cast net and mosquito nets (**Table 4.1**). For gears used by subsistence fishers, the CPUE (g/hour) was the highest for cast net, followed by spear. It should be noted, however, that only a small number were recorded, which could have influenced the results. Fish corral trap was the most common gear used, followed by hook and line. The low percentage of the corral traps seen on the Angolan side is probably due to the difficulty of observing them from a distance. One section of the river was monitored both during a weekend and a weekday to compare the difference in

Table 4.1. *Mass per unit effort (CPUE, g/hour) for the different gear used by the people fishing in the Okavango River as well as the number of gear seen along a 230 km section of surveyed river. The numbers in brackets are the numbers used when calculating the CPUE for the specific gear. Tot. catch = Mean CPUE*total no of gears.*

Fishing gear	Tot. catch (g)	Mean cpue (g/h)	Max. cpue (g/h)	Tot. no of gear	No (%) on angolan side
Hook and line	36,600	244 (31)	1,500	150	56 (37%)
Cast net	15,094	7,547 (1)	7,547	2	1 (50%)
Mosquito net	14,200	284 (19)	1,180	50	12 (24%)
Funnel	10,528	112 (47)	480	94	14 (15%)
Fish corral trap	7,236	36 (12)	85	201	4 (2%)
Spear	6,420	2,140 (2)	2,310	3	1 (33%)
Gill nets 40-90 mm (15 m long)	4,416	138 (1)	138	32	8 (25%)
Seine net 50 mm (15 m long)	3,516	1,758 (1)	1758	2	-
Scoop basket	912	456 (2)	658	2	-
Bow and arrow	?			1	-
Fish fence	?			4	-

fishing effort. There appears to be more effort during the weekend by people using hook and line as well as the fish corral traps. During the week, however, more mosquito nets were observed.

The local people using funnels (shikuku), followed by mosquito net sampled most species (37 and 33 respectively) (**Table 4.2**). The most common species sampled was *P. philander* followed by the *Synodontis* spp. The hook and line (mainly *P. philander* and juvenile cichlids) as well as the traps (mainly *P. philander* and *T. sparrmanii*) targeted the Cichlidae. The dominant family collected was the Cichlidae.

There is an overall decline in the CPUE (g/hour) of the gear used by the local people since the survey by van der Waal (1991) (**Table 4.3**). The only exception is the hook and line, which increased since 1987 to 1992, but decreased again to the present study performed in 1994. The greatest decline was with the fish corral trap and the mosquito net.

4.3 Questionaire on fisheries

As a background study for the White Paper "Responsible Management of the Inland Fisheries of Namibia 1995", Tvedten et al. (1994) made a general assessment of the socio-economic aspects of freshwater fisheries in the Okavango River. This chapter summarises some of his results.

Tilapia species are the most common fish caught according to 240 fishers asked (**Table 4.4**). Thereafter catfishes, barbs and tigerfish were caught in similar frequency.

Van der Waal (1991) (see Tvedten et al. 1994) calculated that 35,000 residents were fishing an average of 40 days annually resulting in an annual catch of 840 tonnes. Tvedten et al. (1994) suggested that a higher number of people were fishing with greater frequency. They found that approximately 41 % of the population in Okavango, 56,000 residents, fish 60 days annually with an rather low average catch of 300 g per unit effort, resulting in a total annual catch of 1,045 tonnes. However, their results indicate that catch per unit effort appeared to be declining. Few people fish full time, and peak fishing activities (3-4 weeks) were performed during low water in September, October and November. The normal catch per fishing trip (> 90 %) was 1–5 kg, and 1 % or less caught more than 10 kg.

"Traditional" fishing methods are widespread in the Okavango River (Tvedten et al. 1994) (**Table 4.5**). All the respondents in their study indicate that they use traditional gears, and 88.5 % said they prefer traditional gears to modern gear. However, the distinction between traditional and modern gear was not clear. In the Okavango area, however, there is a growing awareness of the increased efficiency, potential for commercialisation as well as possible destructive effects of modern gears. There are regional variations in fishing methods reflecting the four different ecological zones of the river. In areas with lakes, floodplains and streams fishers use the whole range of gears, while people in rocky faster flowing areas use hook and line and nets. However, fishing methods, locations and time do also vary according to gender and generation of the fishers. Tvedten et al. (1994) characterised the fishery in Okavango as increased use of modern gear and fishing effort, which reflect an "incipient commercialisation". This is especially evident in the area around and west of Rundu.

Table 4.2. Composition of species (%) harvested by the local people with different gear during June 1994

Species	Funnel	Hook & line	Mosquito net	Traps	Basket (tambl)	Seine net	Total
Hippopotamyrus ansorgii	-	-	0.05	-	-	-	0.03
H. discorhynchus	3.12	-	8.29	-	4.23	-	6.11
Marcusenius macrolepidotus	10.79	-	1.96	-	5.69	-	4.19
Mormyrus lacerda	-	-	0.09	-	0.15	-	0.08
Pollimyrus castelnaui	2.84	-	2.10	-	3.80	-	2.43
Petrocephalus catostoma	1.14	-	4.24	-	2.63	-	3.12
Brycinus lateralis	0.43	-	3.12	-	0.15	-	1.90
Micralestes acutidens	3.98	0.66	7.69	-	0.44	-	5.26
Hemigrammocharax machadoi	-	-	0.09	-	-	-	0.05
H. multifasciatus	1.85	-	4.33	-	6.28	-	3.98
Barbus barnardi	0.14	-	-	1.96	-	-	0.55
B. barotseensis	-	-	0.28	-	-	-	0.16
B. bifrenatus	0.14	-	-	-	-	-	0.03
B. cf. Eutaenia	0.43	-	0.19	-	1.02	-	0.37
B. fasciolatus	0.71	-	0.28	-	1.17	-	0.51
B. haasianus	0.28	-	-	-	-	-	0.05
B. paludinosus	1.70	-	0.23	-	0.44	-	0.53
B. poechii	0.43	1.32	0.84	7.84	0.73	-	0.85
B. radiatus	1.28	-	0.14	-	-	-	0.32
B. thamalakanensis	0.57	-	9.41	-	5.40	-	6.49
B. unitaeniatus	0.14	-	2.33	-	0.88	-	1.52
Labeo cylindricus	0.85	0.30	2.28	1.96	0.44	-	1.58
Parauchenoglanis ngamensis	0.28	-	0.05	-	0.29	-	0.13
Schilbe intermedius	5.54	-	3.26	-	5.99	-	4.01
Clarias gariepinus	0.14	0.66	-	-	-	-	0.05
C. ngamensis	0.43	-	0.09	-	0.15	-	0.16
C. theodorae	0.85	-	-	-	0.88	-	0.32
Synodontis spp.	5.82	3.11	15.70	-	7.30	-	11.56
S. macrostigma	0.54	-	-	-	-	-	0.11
Aplocheilichthys johnstoni	1.42	-	0.23	-	1.31	-	0.64
Pharyngochromis acuticeps	4.97	-	5.22	1.96	7.01	-	6.03
Pseudocrenilabrus philander	35.93	17.87	11.70	47.04	31.39	-	20.56
S. angusticeps	0.71	-	0.28	-	1.02	-	0.48
S. macrocephalus	0.71	4.63	0.61	1.96	1.02	-	0.88
S. robustus	0.14	1.99	0.09	1.96	0.15	-	0.21
S. codringtonii	-	1.99	-	-	-	-	0.08
S. giardi	0.14	3.31	-	-	-	-	0.16
Tilapia rendalli	1.42	7.28	3.08	9.80	3.50	85.74	3.26
T. sparrmanii	7.95	1.99	1.58	21.56	6.42	-	3.95
Oreochromis andersonii	-	2.65	-	-	-	-	0.11
O. macrochir	0.14	3.31	0.09	-	0.15	14.29	0.27
Cichlidae juveniles	1.56	29.13	9.93	1.96	-	-	7.18
C. multispine	0.14	-	-	1.96	0.15	-	0.08
Aethiomastacembelus vanderwaali	0.28	-	0.09	-	-	-	0.11
Tot. no. of species	37	14	33	10	30	2	43
Tot. no. of individuals	705	151	2145	51	686	7	3745

Table 4.3. Catch per unit effort (CPUE, g/hour) in the subsistence fishery in the Okavango River.

Gear	Present study 1994	1992[1]	1987[2]
Funnel	112	133	193
Fish corral trap	36	66	97
Gill net	138	180	
Mosquito net	284	2 200	
Hook and line	244	461	242

[1] Van Zyl (1992)
[2] Van der Waal (1991)

Further away, however, the fishing is still predominantly subsistence oriented. No formal fish market is present in Rundu with only marine fish (mainly horse mackerel) available at the local shops in and around Rundu. Some fresh water fish are available along the main road to Nkurenkuru west of Rundu and to a lesser degree east of Rundu towards Popa Falls. These fish are usually larger individuals (mainly tilapia and catfish) collected by young people using hook and line. During 1999 dried fish (tilapia and catfish) from the Caprivi were observed at the newly build market in Rundu. This may be the start of an influx of fish from the Caprivi indicative of a depleting resource in the Okavango River.

Table 4.4. *Most common fish species (%) caught in the Okavango River. The informants in three areas (Ndonga, Rupara, and Kangongo) were asked to list the three most common species caught in order of frequency. The percentages given are an outcome of a point system where the first listed species is given three points, the second two points and the third one point. (After Tvedten et al. 1994).*

Fish species	Ndonga (Rundu-Mbambi)	Rupara (Musese)	Kangongo (Mbambi)	Mean
Tilapia	29	27	31	29
Catfish	14	15	25	19
Barb	20	25	2	16
Tigerfish	12	6	23	14
Squeakers	6	8	2	6
Others	19	19	17	16
Persons asked	81	83	83	

Table 4.5. *Frequency (%) of fishing methods used in the Okavango River. The informants in three areas (Ndonga, Rupara, and Kangongo) were asked to name their fishing gear. The frequencies are the result of a point system where the most important gear is given 3 points, the second 2 points and the third two points. (After Tvedten et al. 1994).*

Fishing method	Ndonga	Rupara	Kangongo	Total
Modern gears				
No modern gear	48	88	13	45
Hook and line	40	8	66	42
Nets	12	4	21	14
No persons	25	26	38	89
Traditional gears				
No traditional gears	0	0	0	0
Fish funnel	33	34	32	33
Fish trap or kraal	32	33	31	32
Hook and line	23	15	31	23
Scoop or push basket	5	16	4	9
Spear or bow and arrow	4	1	1	2
Others	3	2	1	1
No persons	92	98	85	275

5 Fish survey

5.1 Sampling design and methods

A total of 13 surveys were conducted between 1992 and 1999 with a minimum of one survey per season (**Table 5.1**). All years included a winter survey except for 1996. The rationale for doing comparative surveys for the winter is that the high natural mortality experienced during the breeding season would have levelled off and will not affect the analysis. Surveys were also done during the other seasons to investigate the effect of the flood cycle on the fish resource.

Table 5.1. *Different surveys (including season) performed between 1992 and 1999 in the Okavango River.*

Survey	Seasons			
year	Summer (Dec.–Feb.)	Autumn (Mar.–May)	Winter (Jun.–Aug.)	Spring (Sep.–Nov.)
1992			X	
1993		X	X	X
1994	X	X	X	
1995		X	X	
1996				X
1997			X	
1998			X	
1999			X	

A large range of different gears was used to limit the effect of gear selectivity. Brown multi-filament nets with stretch mesh sizes from 22 mm to 150 mm were used for sampling during the study period (**Table 5.2**). The 22 mm and 28 mm mesh sizes were included in the survey from the spring 1993 survey to sample the smaller individuals in the open, deeper water habitats. The length of each gill net mesh panel was 30 m, but was reduced to 10 m from the winter 1994 survey. The reason for this change was that the total net length became difficult to handle and the net was too long to survey several backwaters. Rather than surveying one area with 30 m panels, two or three sites were surveyed with 10 m panels. This made it possible to survey smaller water bodies and to increase the effort to a wider range of different habitats. The nets were set from 18:00 in the evening to 06:00 the next morning.

The gill nets were set at seven different stations at the same site whenever possible during each survey. However, the variable water level caused sites to change with time at a particular station. At some of the stations gill nets could not be set during low water periods. The gill nets were used to survey open, deep-water habitats in the main stream near the shore and in deeper backwater areas with some aquatic vegetation. Nets were set either in the middle of a water-body or near marginal vegetation.

Table 5.2. *Twine and mesh depth of each stretched mesh size used during the surveys in the Okavango River.*

Mesh size	Twine	Mesh depth
22 mm	210D/4	158.5
28 mm	210D/4	124.5
35 mm	210D/4	99.5
45 mm	210D/4	74.5
57 mm	210D/6	59.5
73 mm	210D/6	49.5
93 mm	210D/9	42.5
118 mm	210D/9	29.5
150 mm	210D/9	24.5

Several other types of gear were used during the sampling to ensure that all habitats, all sizes of fish and all species were sampled as effectively as possible. The other gears were used at 18 different stations at and close to the seven gill net stations. These gears targeted mainly small species and juveniles of long-lived species in shallow, vegetated and rocky habitats. The top layer of sandy substrates was also surveyed for several unique species. The following gears were used:

- A 15 m seine net (made from 30 % black shade cloth; with a depth of 1.5 m). This was used to sample shallower habitats, such as backwater, bays and also in the main stream, usually with a sandy or muddy substrate. It was occasionally used within aquatic vegetation.
- Rocky habitats were predominantly surveyed using rotenone. This was also the method used to collect fish from aquatic vegetated habitats.
- A 30 m seine net (made from anchovy net, green, 1.5 m deep, twine of 1.5 mm flat, a stretched mesh of 12 mm). This net was operated in large open water bodies with very little water flow. The substrate was usually sandy.
- The D-net was operated in vegetated habitats and also in sandy substrates. The top 5 cm of the sand was excavated using the D-net to survey for *Leptoglanis* spp.
- A two-meter cast net was used to collect fish from deep-water habitats. This was in backwaters and within the main stream. The water was either slow or fast flowing.
- Rocky and vegetated habitats were surveyed with a pulsed electrofishing apparatus.
- A rod and reel was put to use to sample fish from deep-water habitats.

- A hand scoopnet was used to sample fish within floating aquatic plants.
- The 5 m seine net was made from green, 80 % shade cloth. It had a depth of 1.5 m and sampled areas along the river edges. The substrate was predominantly sandy with occasional mud.
- Conical-shaped traps made from wire with approx. 2 mm mesh size. They were placed near the shore, in shallow, strong water currents and within aquatic vegetation.

The stations were selected to include all possible habitats present in the Okavango River (Hay et al. 1996). The different gears used at each station depended on the range of habitats present at that specific station. This was to ensure that a reliable representative sample was collected.

A total of 47438 fishes were caught with different gears in the Okavango River between 1992 and 1999 (**Table 5.3** and **appendix**). Of these, 13559 fishes were caught in gillnets ranging from 22 to 150 mm stretch mesh. The rest (33879 fishes) were caught with other gears, such as seine nets, mosquito nets, cast nets, angling, electrofishing apparatus, rotenone and different traditional gears.

There are seven *Synodontis* species listed for the Okavango River (Hay et al. 1999), but only one species, *S. nigromaculatus*, is easily identified morphologically. The other six species, *S. leopardinus*, *S. macrostoma*, *S. thamalakanensis*, *S. vanderwaali*, *S. woosnami*, and *S. macrostigma*, therefore, are grouped together for this report. A total of 76 species were represented in the total catch, including the seven *Synodontis* species (**appendix**).

5.2 Data collection and treatment

5.2.1 Biological data

Fish smaller than approximately 100 mm in length were measured to the closest mm while fish larger than approximately 100 mm were measured to the closest cm. Fork length was measured on fish with a forked caudal fin, while total length was measured on fish with a rounded caudal fin. Fish weight was measured in the field as wet weight with balances with different accuracy and weight ranges. All fish caught in gill nets were weighed to the nearest gram. Fish caught with other gears smaller than approximately 50 g were weighed to the nearest 0.1 g, while larger fish were weighed to the nearest 1 g. After weighing several individuals (often 50 or more) the remaining fish have been counted, pooled and weighed. When necessary figures have been adjusted upwards when measurements were between 5-9, 0.5–0.9 or 0.05–0.09.

From the total catch, length – weight relationships of 17 species had to be obtained from other studies or morphologically similar species due to low numbers or small sizes (< 0.1 g). These species are *Barbus codringtonii*, *Barbus haasianus*, *Barbus kerstenii*, *Barbus multilineatus*, *Coptostomabarbus wittei*, *Mesobola brevianalis*, *Hemigrammocharax machadoi*, *Rhabdalestes maunensis*, *Leptoglanis* cf *dorae*, *Clarias liocephalus*, *Chiloglanis fasciatus*, *Aplocheilichthys hutereaui*, *Aplocheilichthys johnstoni*, *Aplocheilichthys katangae*, *Serranochromis thumbergi*, *Microctenopoma intermedium*, and *Aethiomastacembelus frenatus*.

Table 5.3. *Gill net catches, other gears used in the sampling, catches in other gears and total catches at the seven stations sampled in the Okavango River from 1992 to 1999. All catches in number of fish. 1 =15 m seine net, 2 = rotenone, 3 = 30 m seine net, 4 = fish corral trap, 5 = mosquito net, 6 = D-net, 7 = traps, 8 = spear, 9 = funnel, 10 = hook and line, 11 = 2 m cast net, 12 = electro shocker, 13 = angling, 14 = hand scoopnet and 15 = 5 m seine net.*

Station	Catches in gill nets	Other gears	Catches in other gears	Total catches
Kwetze	4055	1-3, 6, 7, 12, 13, 15	1396	5451
Cuito	2547	1-3, 6, 7, 12, 14, 15	3838	6385
Matava	2161	1-3, 6, 7, 9, 12, 15	2949	5110
Musese	1585	1-4, 6-9, 12, 15	1593	3178
Mbambi	1193	1-3, 5-7, 10, 12, 15	5009	6202
Bunya	976	1, 2, 6, 7, 12, 15	4341	5317
Rundu	1042	1-7, 12, 15	4456	5498
Other	0	1-7, 9-13, 15	10297	10297
Total	13559	1-15	33879	47438

From 1992 to 1998 sexual maturity was classified on a scale from 1 to 4 where 1 is immature or gonads not developed (resting fish), 2 is maturing gonads, 3 is mature gonads and 4 is spent fish. In 1999 immature fish and resting mature fish were divided and classified as 1 or 5, respectively. From 1992 to 1998 all resting mature fish were classified as immature fish. This makes it difficult to calculate a length at 50 % maturity for each species. To calculate length at 50 % maturity for the 21 selected species, all fish above a specified length for each species were given a maturity value 6 to classify them as resting mature fish. This was done on fish caught outside of the breeding season in the period 1992-1998. **Table 5.4** gives the specified lengths and periods where fish were re-coded from immature fish to resting mature fish. After re-coding the fish, length at 50 % maturity was calculated for all fish caught from 1992 to 1999.

5.2.2 Catch per unit effort

When standard fishing gear is used, the catch per unit of effort may be used as a rough indicator of the density of fish in the fished area. For a standard series of gill nets, catch per unit effort (CPUE) is defined as the number or weight of fish caught in a unit of time in certain panel size of gill nets and during a specific setting is a gill net panel of 50 m^2, with a standard fishing time of 12 hours.

Measuring catch in number or weight of fish may give very different results. We have generally presented the results in both units, but with an emphasis on weight, as this unit is more important to fishermen and managers.

5.2.3 Species dominance in survey catches

An "index of relative importance", IRI, (1) (Pinkas et al. 1971, Caddy & Sharp 1986, Kolding 1989, 1999) is used to find the most important species in the catches from different sampling localities. This index is a measure of relative abundance or commonness of the different species in the catch, and is calculated as:

$$\mathrm{IRI} = \frac{(\%\mathrm{N}_i + \mathrm{W}_i)\times \mathrm{F}_i}{(\%\mathrm{N}_j + \%\mathrm{W}_j)\times \mathrm{F}_j}\times 100 \qquad (1)$$

where j = 1–S, $\%N_j$ and $\%W_j$ is percentage number and weight, respectively, of each species in the total catch, $\%F_j$ is percentage frequency of occurrence of each species in the total number of settings, and S is the total number of species.

Table 5.4. *Body lengths above which fish were re-coded from immature fish to resting but mature fish, and the periods in which these re-codings were done. - = No mature fish recorded in the catches.*

Species	Specified lengths (cm) Males	Females	Periods
Pseudocrenilabris philander	5	4	1.1.92-31.8.93, 1.3.94-31.8.95, 1.3.97-31.8.98
Barbus thamalakanensis	-	-	
Hippopotamyrus discorhynchus	10	9	1.1.92-31.11.93, 1.3.94-31.11.98,
Pharyngochromis acuticeps	9	8	1.1.92-31.8.93, 1.3.94-31.8.95, 1.3.97-31.8.98
Micralestes acutidens			
Marcusenius macrolepidotus	14	13	1.1.92-31.11.93, 1.3.94-31.11.98,
Schilbe intermedius	12	11	1.1.92-31.11.93, 1.3.94-31.11.98,
Hemigrammocharax machadoi	-	-	
Tilapia sparrmanii	7	7	1.1.92-31.8.93, 1.3.94-31.8.95, 1.3.97-31.8.98
Tilapia rendalli	16	17	1.1.92-31.8.93, 1.3.94-31.8.95, 1.3.97-31.8.98
Hydrocynus vittatus	30	40	1.1.92-31.11.93, 1.3.94-31.11.98,
Synodontis nigromaculatus	16	17	1.1.92-31.11.93, 1.3.94-31.11.98,
Brycinus lateralis	9	10	1.1.92-31.11.93, 1.3.94-31.11.98,
Clarias gariepinus	54	49	1.1.92-31.8.93, 1.3.94-31.8.95, 1.3.97-31.8.98
Hepsetus odoe	28	28	1.1.92-31.8.93, 1.3.94-31.8.95, 1.3.97-31.8.98
Barbus poechii	9	10	1.1.92-31.8.93, 1.3.94-31.8.95, 1.3.97-31.8.98
Serranochromis macrocephalus	20	20	1.1.92-31.8.93, 1.3.94-31.8.95, 1.3.97-31.8.98
Barbus paludinosis	7	8	1.1.92-31.11.93, 1.3.94-31.11.98,
Labeo cylindricus	14	15	1.1.92-31.11.93, 1.3.94-31.11.98,
Aplocheilichthys johnstoni	-	-	
Petrocephalus catostoma	8	7	1.1.92-31.8.93, 1.3.94-31.8.95, 1.3.97-31.8.98

Due to the large number of species caught in this study in the Okavango River (76), we have selected 21 species for detailed analysis. The main criteria for selecting these species were a) their importance expressed by the index of relative importance (IRI) in survey catches in gill nets and other gears, b) their importance expressed by the numeral importance in survey catches in gill nets and other gears or c) their numeric importance in a survey on artisanal fishery performed in June 1994. The selected species represent a large variety in habitat use, distribution, trophic status, body size and ecology in general. These species contributed approximately 75 % and 59 % of the biomass of fish caught in survey gill net and other gears, respectively.

In addition to the 21 selected species, the most important and potential angling species in the Okavango River were also selected for a more detailed analysis. The main criteria for selecting these species was their size. A total of 25 species were defined as potential angling species and nine of these 25 species are among the 21 selected species.

5.2.4 Gill net selectivity

Gill nets are selective gears, meaning that a certain mesh size of net catches fish mainly of a certain size interval (body length). This length varies from species to species depending on, e.g. body form, the presence of spines, etc. It is important to understand the selectivity of various gill net mesh sizes in relation to the fish species present for two major purposes: to facilitate the development of gear regulations, and to interpret the gill net survey results. The length frequency of fish in the different gill net mesh sizes is the simplest way to express and compare the gill net selectivity of different mesh sizes. However, for management purposes it is necessary to calculate the gill net selectivity curve, which is an expression of the probability of capturing a certain size group of fish in a specific gill net mesh size. The general statistical model and its application are described in Millar (1992) and Millar and Holst (1997). When the actual distribution of fish in the sampled area is unknown, as in this study, selectivity estimates are based on the assumption that all fish have the same probability of encountering the gear. This may not always be true as small individuals within a species may have different behaviour compared with larger ones. This uncertainty cannot be quantified without independent information on population structure. This information, however, is rarely available and hard to obtain in natural fish populations. A further assumption is that all mesh sizes have the same efficiency on their optimal length class (the so-called "modal length"). This may also be erroneous due to different behaviour of small and large individuals. Often, the fishing efficiency may increase with mesh size. Finally, there are several statistical methods developed to represent the selection curves. Basically two functions are used. The standard normal function is applied for species that are mainly entangled by their gills, whereas a skewed normal function (Helser et al. 1991, 1994) is used for species that also to some extent are caught in other body structures e.g. fin rays or spines. The selection curves have been standardised to unit height by dividing by the number of fish in the modal length class.

5.2.5 Databases and software

All recorded data have been stored in PASGEAR (Kolding 1995), which is a customised data base package intended for experimental fishery data from passive gears. The package is primarily developed to facilitate the entering, storage and analysis of large amounts of experimental data. The program makes data input, manipulation and checking data records easy. PASGEAR also contains predefined extraction, condensing and calculation programmes to facilitate data exploration and analysis from survey fisheries. Most of the calculations and statistical analysis in this report were performed by PASGEAR (version May 2000) or SPSS for Windows (version 9.0).

5.3 Results

5.3.1 Species in gill net catches

A total of 47 fish species, including the seven species in the *Synodontis* group, have been identified from the gill net catches in the Okavango River during this study from 1992 to 1999 (**Table 5.5**). Excluding the *Synodontis* species, the ten most important species in the gill net catches (as shown by the IRI index) accounted for 77.6 % of the total catch by numbers and 72.9 % by weight (**Figure 5.1**). Silver catfish (*Schilbe intermedius*) was the single most important species in gill net catches, both by numbers and weight, and also by frequency of occurrence (25.5 %, 19.5 % and 31.6 %, respectively) (**Figure 5.1**). Bulldog (*Marcusenius macrolepidotus*) was the second most important species by numbers and frequency of occurrence (17.4 % and 24.9 %, respectively), while sharptooth catfish (*Clarias gariepinus*) was the second most important species by weight (14.4 %). Striped robber (*Brycinus lateralis*) was the third most important species by numbers (10.2 %), while tigerfish (*Hydrocynus vittatus*) was the third most important species both by weight and by frequency of occurrence (10.0 % and 18.8 %, respectively).

***Table 5.5.** Relative importance of the different species from gill net catches in the Okavango River caught from 1992 to 1999, measured as total number (No), weight, frequency of occurrence (Freq) and index of relative importance (IRI) of each species. All measures are given both in absolute values and in percentage values (%).*

Species	No	%	Weight	%	Freq	%	IRI	%
Schilbe intermedius	3 451	25.5	152.847	19.5	340	31.6	1 421	39.5
Marcusenius macrolepidotus	2 354	17.4	67.968	8.7	268	24.9	649	18.0
Synodontis spp.	1 506	11.1	69.638	8.9	263	24.4	489	13.6
Hydrocynus vittatus	567	4.2	78.027	10.0	202	18.8	266	7.4
Synodontis nigromaculatus	1 165	8.6	60.382	7.7	137	12.7	208	5.8
Brycinus lateralis	1 388	10.2	17.093	2.2	146	13.6	169	4.7
Clarias gariepinus	110	0.8	113.072	14.4	74	6.9	105	2.9
Hepsetus odoe	417	3.1	49.957	6.4	100	9.3	88	2.4
Tilapia sparrmanii	595	4.4	10.427	1.3	121	11.2	64	1.8
Barbus poechii	340	2.5	3.753	0.5	88	8.2	24	0.7
Serranochromis macrocephalus	121	0.9	17.334	2.2	76	7.1	22	0.6
Petrocephalus catostoma	483	3.6	3.491	0.4	56	5.2	21	0.6
Hippotamyrus discorhynchus	239	1.8	4.998	0.6	64	5.9	14	0.4
Labeo lunatus	102	0.8	15.230	1.9	48	4.5	12	0.3
Clarias ngamensis	44	0.3	27.885	3.6	28	2.6	10	0.3
Serranochromis angusticeps	55	0.4	11.797	1.5	41	3.8	7	0.2
Oreochromis andersonii	33	0.2	19.428	2.5	22	2.0	6	0.2
Serranochromis robustus	47	0.3	10.951	1.4	29	2.7	5	0.1
Sargochromis giardi	36	0.3	12.073	1.5	28	2.6	5	0.1
Sargochromis codringtonii	78	0.6	5.071	0.6	38	3.5	4	0.1
Mormyrus lacerda	36	0.3	8.926	1.1	27	2.5	4	0.1
Sargochromis carlottae	52	0.4	4.467	0.6	37	3.4	3	0.1
Serranochromis altus	25	0.2	5.675	0.7	20	1.9	2	0.0
Labeo cylindricus	48	0.4	1.557	0.2	26	2.4	1	0.0
Tilapia rendalli	16	0.1	5.717	0.7	15	1.4	1	0.0
Pharyngochromis acuticeps	38	0.3	0.372	0.0	31	2.9	1	0.0
Barbus paludinosis	89	0.7	0.550	0.1	9	0.8	1	0.0
Parauchenoglanis ngamensis	28	0.2	1.093	0.1	16	1.5	1	0.0
Barbus radiatus	31	0.2	0.209	0.0	9	0.8	0	0.0
Oreochromis macrochir	8	0.1	1.001	0.1	7	0.7	0	0.0
Clarias theodorae	15	0.1	1.030	0.1	4	0.4	0	0.0
Hippopotamyrus ansorgii	8	0.1	0.153	0.0	7	0.7	0	0.0
Pseudocrenilabrus philander	5	0.0	0.021	0.0	5	0.5	0	0.0
Barbus unitaeniatus	11	0.1	0.084	0.0	1	0.1	0	0.0
Micralestes acutidens	8	0.1	0.043	0.0	1	0.1	0	0.0
Clarias stappersii	1	0.0	0.179	0.0	1	0.1	0	0.0
Serranochromis thumbergi	2	0.0	0.098	0.0	1	0.1	0	0.0
Barbus kerstenii	2	0.0	0.002	0.0	1	0.1	0	0.0
Tilapia ruweti	1	0.0	0.033	0.0	1	0.1	0	0.0
Ctenopoma multispine	1	0.0	0.023	0.0	1	0.1	0	0.0
Cichlidae	1	0.0	0.022	0.0	1	0.1	0	0.0
Barbus bifrenatus	1	0.0	0.007	0.0	1	0.1	0	0.0
Pollimyrus castelnaui	1	0.0	0.002	0.0	1	0.1	0	0.0
Sum	13 559	100	7682 688	100			3 602	100

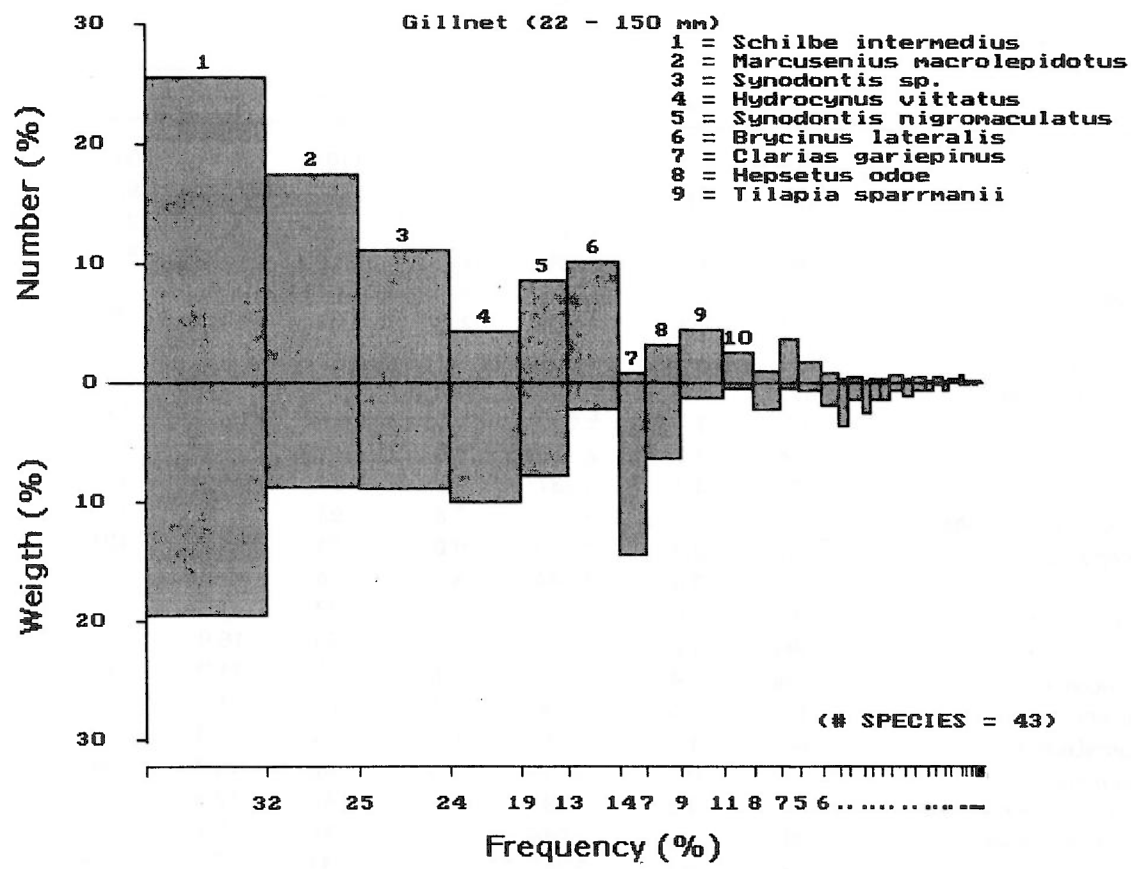


***Figure 5.1**. Index of relative importance (IRI) as a measure of the most important species in total gill net catches of fish from all localities (7 stations) sampled from 1992 to 1999. % F = frequency of occurrence, % W = percentage weight, % N = the numeric proportion of a species.*

5.3.2 Species in catches with other gears

Altogether 15 types of other gears were used in habitats and areas not easily accessible with gill nets. Species composition in the catches with other gears were more diverse than in gill net catches, and 76 identified species, including the seven *Synodontis* species, were recorded (**Table 5.6**). The ten most important species in these catches (as shown by the IRI index) constituted 53.9 % of the total catch by numbers and 37.2 % by weight (**Figure 5.2**). The three most important species by numbers were the cichlids *Pseudocrenilabrus philander* and *Tilapia sparrmanii*, and the dashtail barb (*Barbus poechii*) (10.6 %, 7.4 % and 6.1 %, respectively). The three most important species by weight were the redbreast tilapia (*T. rendalli*), sharptooth catfish (*C. gariepinus*) and redeye labeo (*Labeo cylindricus*) (12.1 %, 9.0 % and 7.4 %, respectively). The three most important species by frequency of occurrence were the cichlids *P. philander, T. sparrmanii* and *Pharyngochromis acuticeps* (70.5 %, 62.2 % and 46.8 %, respectively). The *Synodontis* group of species, which was important in gill net catches, was also prominent in these catches, constituting 14.1 % and 13.2 % by numbers and weight, respectively.

5.3.3 Survey catches vs. local fishery

The ten most important species in gill net catches, in catches with other fishing gears and in the artisanal fisheries were only partly the same (**Table 5.7**). In the artisanal fisheries, southern mouthbrooder (*P. philander*), Thamalakane barb (*Barbus thamalakanensis*), and Zambezi parrotfish (*Hippopotamyrus discorhynchus*) dominated by number, representing three different families; Cichlidae, Cyprinidae and Mormyridae. As in the artisanal fisheries, *P. philander* dominated in catches with other gears, while the cichlids, *T. sparrmanii* and *T. rendalli,* were the second and third most important. The gill net catches differed more from the artisanal fisheries, as *S. intermedius* (Schilbeidae), *M. macrolepidotus* (Mormyridae) and *B. lateralis* (Characidae) were the most important species. Altogether 21 fish species

***Table 5.6.** Relative importance of the different species from catches with other gears at seven sampling localities in the Okavango River between 1992 and 1999, measured as total number (No), weight, frequency of occurrence (Freq) and index of relative importance (IRI) of each species. All measures are given both in absolute values and in percentage. Continued on next page.*

Species	No	%	Weight	%	Freq	%	IRI	%
Synodontis spp.	4 781	14.1	25.544	13.2	119	38.1	1 043	17.8
Pseudocrenilabrus philander	3 594	10.6	4.733	2.5	220	70.5	921	15.7
Tilapia sparrmanii	2 504	7.4	8.187	4.2	194	62.2	724	12.3
Tilapia rendalli	1 580	4.7	23.396	12.1	113	36.2	608	10.4
Barbus poechii	2 052	6.1	5.536	2.9	121	38.8	346	5.9
Pharyngochromis acuticeps	1 407	4.2	3.966	2.1	146	46.8	291	4.9
Labeo cylindricus	1 510	4.5	14.247	7.4	69	22.1	262	4.5
Aplocheilichthys johnstoni	1 655	4.9	0.484	0.3	132	42.3	217	3.7
Schilbe intermedius	1 045	3.1	5.015	2.6	84	26.9	153	2.6
Brycinus lateralis	1 264	3.7	2.751	1.4	76	24.4	126	2.1
Barbus paludinosis	1 603	4.7	3.287	1.7	59	18.9	122	2.1
Serranochromis macrocephalus	385	1.1	5.361	2.8	93	29.8	117	2.0
Clarias gariepinus	97	0.3	17.410	9.0	34	10.9	101	1.7
Hydrocynus vittatus	267	0.8	7.484	3.9	54	17.3	81	1.4
Petrocephalus catostoma	665	2.0	2.557	1.3	72	23.1	76	1.3
Oreochromis macrochir	391	1.2	6.710	3.5	50	16.0	74	1.3
Mormyrus lacerda	134	0.4	8.965	4.6	37	11.9	60	1.0
Serranochromis robustus	190	0.6	4.006	2.1	67	21.5	57	1.0
Barbus thamalakanensis	641	1.9	0.241	0.1	54	17.3	35	0.6
Clarias ngamensis	121	0.4	5.639	2.9	32	10.3	34	0.6
Opsaridium zambezense	642	1.9	1.091	0.6	40	12.8	32	0.5
Oreochromis andersonii	322	1.0	8.044	4.2	18	5.8	30	0.5
Marcusenius macrolepidotus	151	0.4	3.465	1.8	41	13.1	29	0.5
Hemigrammoch. multifasciatus	411	1.2	0.125	0.1	70	22.4	29	0.5
Pollimyrus castelnaui	329	1.0	0.509	0.3	72	23.1	28	0.5
Micralestes acutidens	457	1.3	0.325	0.2	50	16.0	24	0.4
Barbus barnardi	440	1.3	0.086	0.0	56	17.9	24	0.4
Barbus radiatus	399	1.2	0.398	0.2	52	16.7	23	0.4
Sargochromis codringtonii	167	0.5	3.434	1.8	29	9.3	21	0.4
Hemigrammocharax machadoi	446	1.3	0.071	0.0	40	12.8	17	0.3
Barbus eutaenia	470	1.4	0.972	0.5	28	9.0	17	0.3
Barbus bifrenatus	287	0.8	0.102	0.1	49	15.7	14	0.2
Barbus fasciolatus	272	0.8	0.119	0.1	48	15.4	13	0.2
Synodontis nigromaculatus	196	0.6	1.926	1.0	26	8.3	13	0.2
Barbus cf. *eutaenia*	249	0.7	0.186	0.1	38	12.2	10	0.2
Ctenopoma multispine	206	0.6	0.879	0.5	28	9.0	10	0.2
Aethiomastacemb. vanderwaali	235	0.7	0.792	0.4	25	8.0	9	0.2
Barbus unitaeniatus	167	0.5	0.253	0.1	35	11.2	7	0.1
Parauchenoglanis ngamensis	66	0.2	1.068	0.6	29	9.3	7	0.1
Clarias stappersii	22	0.1	2.319	1.2	16	5.1	7	0.1
Hippotamyrus discorhynchus	137	0.4	1.275	0.7	19	6.1	6	0.1
Clarias theodorae	86	0.3	0.692	0.4	30	9.6	6	0.1
Barbus multilineatus	217	0.6	0.082	0.0	26	8.3	6	0.1
Hepsetus odoe	28	0.1	1.583	0.8	17	5.4	5	0.1
Barbus afrovernayi	159	0.5	0.039	0.0	30	9.6	5	0.1
Barbus haasianus	177	0.5	0.014	0.0	27	8.7	5	0.1
Aplocheilichthys katangae	145	0.4	0.033	0.0	30	9.6	4	0.1
Clariallabes platyprosopos	33	0.1	1.731	0.9	12	3.8	4	0.1
Cichlidae	237	0.7	0.128	0.1	15	4.8	4	0.1

Table 5.6. continued

Species	No	%	Weight	%	Freq	%	IRI	%
Serranochromis angusticeps	51	0.2	0.450	0.2	29	9.3	4	0.1
Tilapia ruweti	119	0.4	0.325	0.2	18	5.8	3	0.1
Sargochromis carlottae	27	0.1	1.162	0.6	10	3.2	2	0.0
Coptostomabarbus wittei	119	0.4	0.006	0.0	14	4.5	2	0.0
Microctenopoma intermedium	138	0.4	0.120	0.1	10	3.2	2	0.0
Sargochromis giardi	14	0.0	1.314	0.7	5	1.6	1	0.0
Amphilius uranoscopus	59	0.2	0.227	0.1	10	3.2	1	0.0
Clarias sp.	49	0.1	0.278	0.1	8	2.6	1	0.0
Labeo lunatus	9	0.0	0.574	0.3	6	1.9	1	0.0
Barbus barotseensis	38	0.1	0.024	0.0	15	4.8	1	0.0
Serranochromis altus	6	0.0	0.513	0.3	5	1.6	0	0.0
Clarias liocephalus	17	0.1	0.205	0.1	8	2.6	0	0.0
Hippopotamyrus ansorgii	25	0.1	0.111	0.1	9	2.9	0	0.0
Aethiomastacembelus frenatus	11	0.0	0.078	0.0	10	3.2	0	0.0
Chiloglanis fasciatus	26	0.1	0.006	0.0	9	2.9	0	0.0
Barbus kerstenii	15	0.0	0.007	0.0	10	3.2	0	0.0
Nannocharax macropterus	50	0.1	0.010	0.0	3	1.0	0	0.0
Hemichromis elongatus	8	0.0	0.047	0.0	8	2.6	0	0.0
Barbus sp.	9	0.0	0.013	0.0	7	2.2	0	0.0
Serranochromis sp.	13	0.0	0.016	0.0	5	1.6	0	0.0
Serranochromis thumbergi	5	0.0	0.023	0.0	5	1.6	0	0.0
Barbus codringtonii	4	0.0	0.081	0.0	2	0.6	0	0.0
Leptoglanis cf. *dorae*	12	0.0	0.002	0.0	2	0.6	0	0.0
Mesobola brevianalis	6	0.0	0.001	0.0	3	1.0	0	0.0
Aplocheilichthys hutereaui	6	0.0	0.000	0.0	2	0.6	0	0.0
Rhabdalestes maunensis	4	0.0	0.001	0.0	2	0.6	0	0.0
Sum	33 879	100	192.853	100			5 874	100

were among the 10 most important species in catches from the three types of fisheries studied (**Table 5.7**). These differences in catches clearly reflect the differences in habitat use of the fishes, the different areas sampled during the survey and by artisanal fisheries, and the selectivity of the gears used.

5.3.4 Body length distributions in gears

The body length of fish caught in gill nets was generally larger than fish caught in other gears. This is evident both in the combined catches of all species (**Figure 5.3**) and when comparing individual species (**Figure 5.4**). Fish caught in gill nets were between 4 and 79 cm in length, with the majority between 7 and 17 cm (82.9 % of the catches, **Figure 5.3**). Modal length was 9.0-9.9 cm. Fish caught in other gears were between 1 and 75 cm, with most fish having lengths between 2 and 8 cm (88.0 % of the catches). Modal length in this group was 4.0-4.9 cm.

The difference in length of fish caught in gill nets and other gears is also reflected when we compare the length distributions of fifteen selected species (**Figure 5.4**). Fish caught in gill nets were on average larger than in catches with other gears. The reason for this is mainly the difference in selectivity of the two groups of gears, and that they were used in different habitats. Gill nets is a size selective gear, i.e. gill nets with different mesh sizes select different length groups of fish. Due to the different morphology of the individual species this selection curve varies among fish species (see chapter 5.3.6 and 5.3.7). Most of the other gears used, e.g. seines and rotenone, are less size selective. The less selective gears were also mainly used in shallow and vegetated habitats, most often associated with small and/or juvenile fish.

5.3.5 Body length of mature fish

Information about the main spawning season of the different species is obtained by recording the proportion of sexually mature fish in the catches. Generally, the highest proportion of sexually mature fish was found in

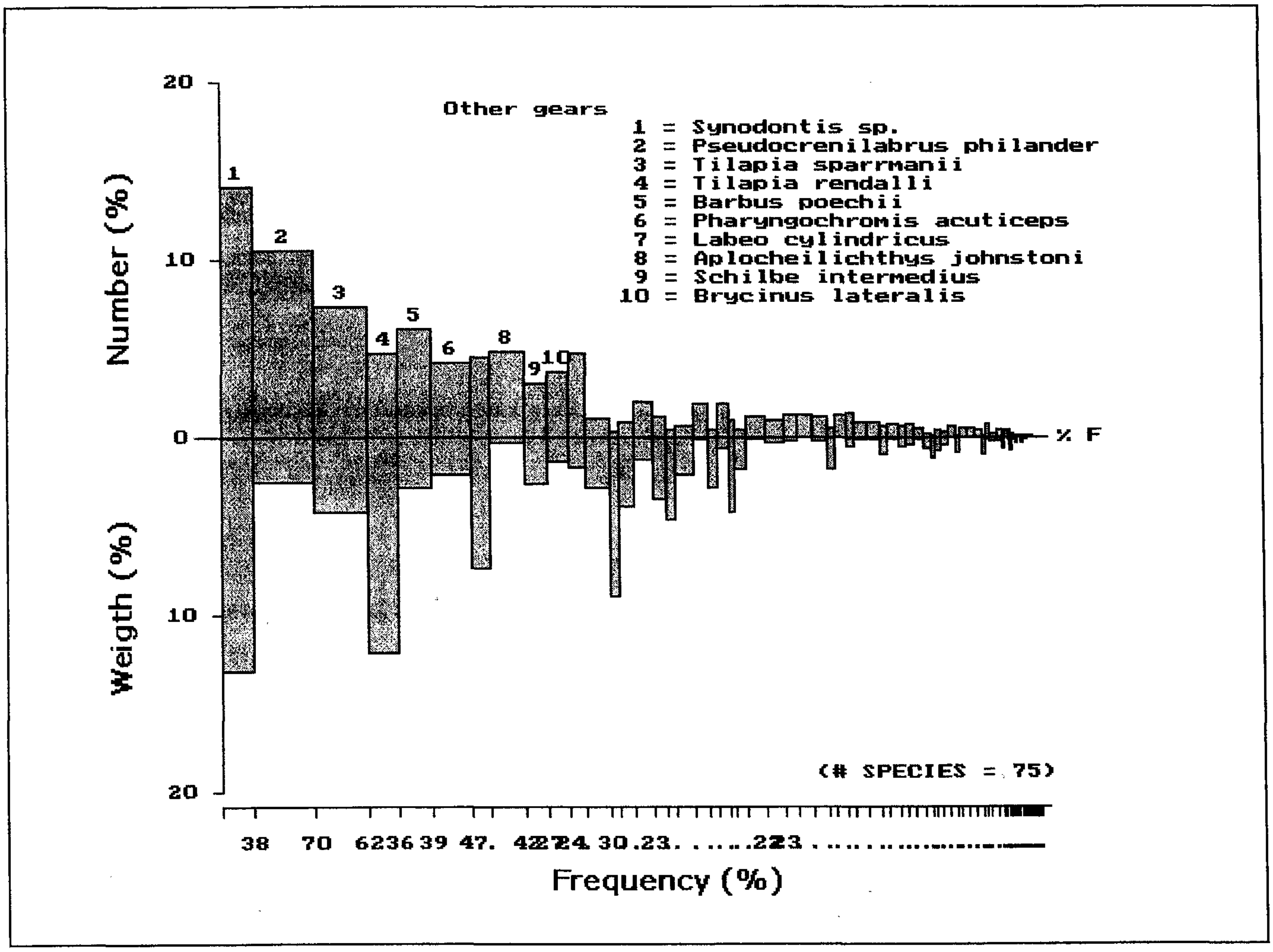


Figure 5.2. Index of relative importance (IRI) as a measure of the most important species in catches with other gears of fish from all localities (7 stations) sampled from 1992 to 1999. % F = frequency of occurrence, % W = percentage weight, % N = the numeric proportion of a species.

Okavango during the period January-March, i.e. during the peak of the rainy season. Most of the important species (according to IRI) mature and spawn during this period. Accordingly, the highest proportion of spawned fish was found in April-May.

The smallest size of sexually mature fish varies among the different species (**Table 5.8**). The overall smallest size at maturity was found in the cichlid southern mouthbrooder (*P. philander*), being a mature female of 3 cm. The largest size at maturity was found in sharptooth catfish (*C. gariepinus*), with minimum size of males and females at 40 and 38 cm, respectively.

Among the 21 selected species the minimum size at maturity varies greatly (**Table 5.8**). Ten species have a minimum size at maturity smaller than 10 cm, five species have a minimum size at maturity between 10 and 20 cm, two species have a minimum mature size larger than 20 cm, and in four species no mature fish were recorded. Silver catfish (*S. intermedius*) and bulldog (*M. macrolepidotus*) were both found to mature at a minimum of approximately 10 cm body length. Spotted squeaker (*S. nigromaculatus*) and redbreast tilapia (*T. rendalli*) demonstrate only slightly larger size at maturity (minimum 11 cm). Purpleface largemouth (*S. macrocephalus*) is somewhat larger with a minimum size at maturity of 14 cm. Tigerfish (*H. vittatus*) is significantly larger, as the smallest mature individual caught was 18 cm. Sharptooth catfish (*C. gariepinus*) and African pike (*H. odoe*) have minimum mature size of 38 cm and 27 cm, respectively. The rest of the species have minimum mature size between 5 and 8 cm, except the southern mouthbrooder (*P. philander*), with a minimum of 3 cm.

In most species, the smallest size of mature fish was similar in gill net catches and in other gear (**Table 5.8**). This indicates that the minimum sizes recorded probably are representative of these species in the Okavango River.

Table 5.7. *List of the ten most important species in each of the three fisheries: local fisheries, survey gill net and other survey gears, from 1992 to 1999. The species are ranked in accordance with their importance in the different types of fisheries. 1 is the most important species either by IRI or by number (No).*

Species	Local fisheries	Gill net		Other gear	
	No	IRI	No	IRI	No
Pseudocrenilabris philander	1			1	1
Barbus thamalakanensis	2				
Hippopotamyrus discorhynchus	3		10		
Pharyngochromis acuticeps	4			5	8
Micralestes acutidens	5				
Marcusenius macrolepidotus	6	2	2		
Schilbe intermedius	7	1	1	8	10
Hemigrammocharax machadoi	8				
Tilapia sparrmanii	9	8	5	2	2
Tilapia rendalli	10			3	6
Hydrocynus vittatus		3	6		
Synodontis nigromaculatus		4	4		
Brycinus lateralis		5	3	9	9
Clarias gariepinus		6			
Hepsetus odoe		7	8		
Barbus poechii		9	9	4	3
Serranochromis macrochephalus		10			
Barbus paludinosis				10	5
Labeo cylindricus				6	7
Aplocheilichthys johnstoni				7	4
Petrocephalus catostoma			7		

5.3.6 Life history and gill net selectivity for selected species

Based on the ranking of the 10 most important species by IRI or number in either local fisheries, gill nets, or other gears, 21 species were selected for a more thorough study of body length distribution in gears, body length of mature fish, and gill net selectivity (**Table 5.7**). In addition, a brief general information on the distribution and biology of the 21 species is included. This information is mainly in accordance with Skelton (1993). Of the 21 species, three species were not caught in gill nets. By numbers, the 18 species contributed 83.7 % of gill net catches, while the 21 species contributed 64.0 % of catches with other gears. They represent a large variation in biology, distribution and sizes.

Gill nets are selective gears, i.e. a certain mesh size of net catches fish mainly of a certain size interval (body length), and most effectively fish within a narrow range, the modal fish length. This length varies from species to species depending on e.g., body form, the presence of spines, etc. To evaluate the effect of gill nets on populations of various fish species, it is important to compare the modal fish lengths for the mesh sizes used and the fish size at sexual maturity. It may be expected that significant exploitation of juvenile fish negatively affects the sustainability of the fishery.

Cichlidae

Southern mouthbrooder (*Pseudocrenilabrus philander*)
Southern mouthbrooder is widespread in Southern Africa from the Orange River northwards to Malawi and the southern tributaries of the Congo River. It may reach a length of 13 cm and breeds from early spring to late summer. The female protects the eggs, larvae and juveniles until they can fend for themselves. Several broods may be raised in one season. The species lives in a wide variety of habitats, but prefers vegetated areas, feeding on insects, shrimps and even small fish. It is an aquarium species. It is the most important species in the subsistence fisheries in Okavango (**Table 5.7**), and the minimum mature lengths observed were 5 and 3 cm for males and females, respectively (**Table 5.8**). The length at 50 % maturation in males was 5.7 cm. This length could not be determined for females.

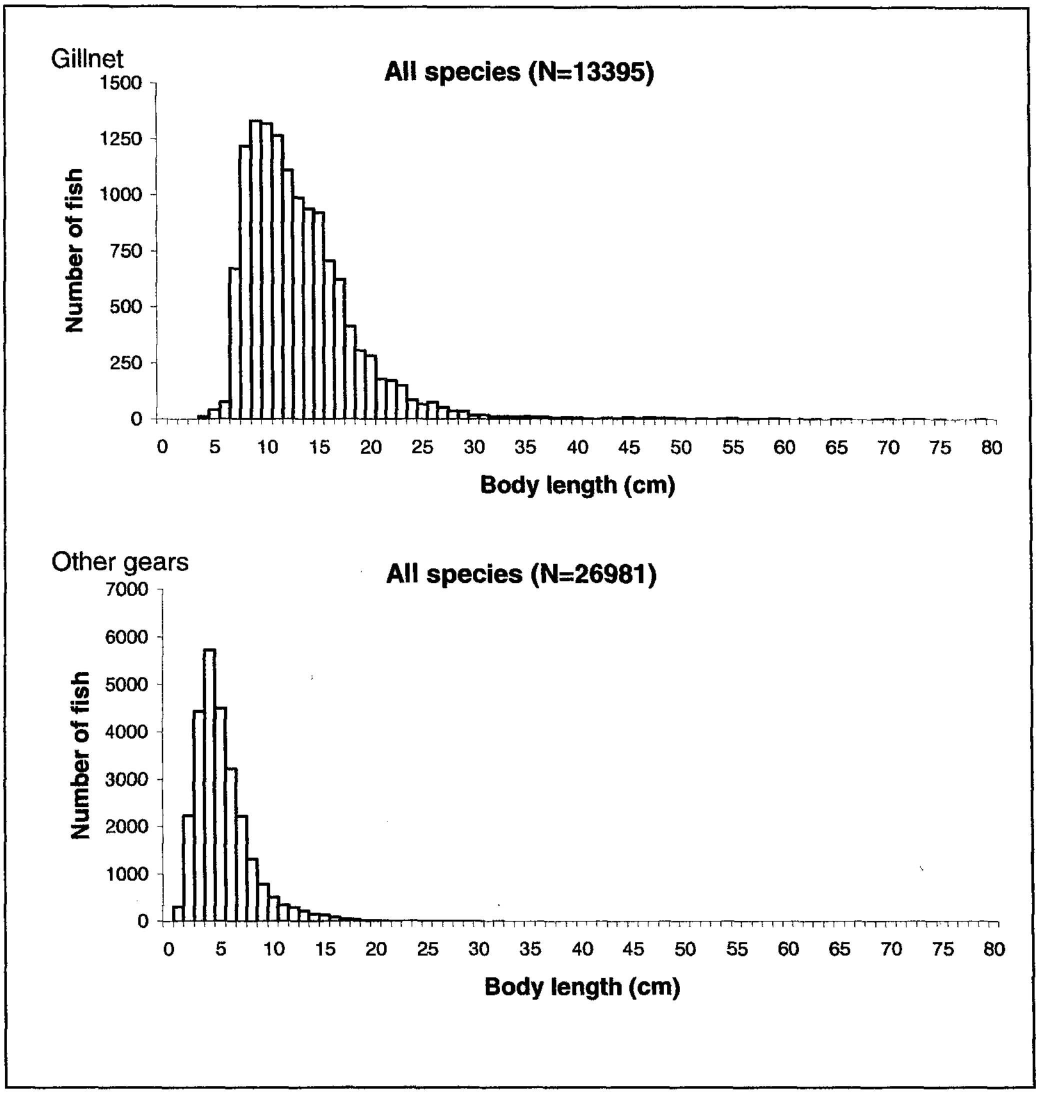


Figure 5.3. *Length distribution of all fish caught with gill nets (22–150 mm stretch mesh) and with other gears in the Okavango River 1992-99. Notice the different scales on y-axis.*

In the Okavango, only five fishes were caught in gill nets during the survey, while a total of 3010 fishes between 1 and 11 cm (mean 3.8 cm, modal length 4.0–4.9 cm) were caught in other gears (**Figure 5.4**). The modal length is about the same as the minimum length at maturity found in the total catches (3-5 cm) (**Table 5.8**). Only 22 mm gill nets caught this species, and these fishes were between 6 and 7 cm (mean 6.4 cm) (**Figure 5.4**).

Zambezi happy (*Pharyngochromis acuticeps*)
Zambezi happy occurs in the Okavango and Zambezi Rivers. It may grow to 22 cm, but is usually less than 10 cm. It is a mouthbrooder (females) and breeds in the summer. It occurs in a wide range of habitats, but needs cover such as vegetation, tree roots, etc. It preys on insects, shrimps, small fish, and eggs and larvae of nesting fishes. It is a potential aquarium species. It is the fourth most important species in the subsistence fisheries in the Okavango (**Table 5.7**). The minimum mature lengths of this species observed in our material were 7 and 6 cm for males and females, respectively (**Table 5.8**). The corresponding lengths at 50 % maturation were 7.9 cm and 6.5 cm.

In the Okavango, only 38 Zambezi happy individuals were caught in gill nets, whereas 1 380 fishes were caught in other gears (**Figure 5.4**). The body length of fish caught in gill nets was between 6 and 13 cm (mean 8.6 cm; modal length 9.0–9.9 cm), which is longer than the minimum length at maturity found in total catches (6-7 cm) (**Table 5.8**). The length of fish caught in other gears was 2 to 12 cm (mean 5.3 cm; modal length 4.0–4.9 cm).

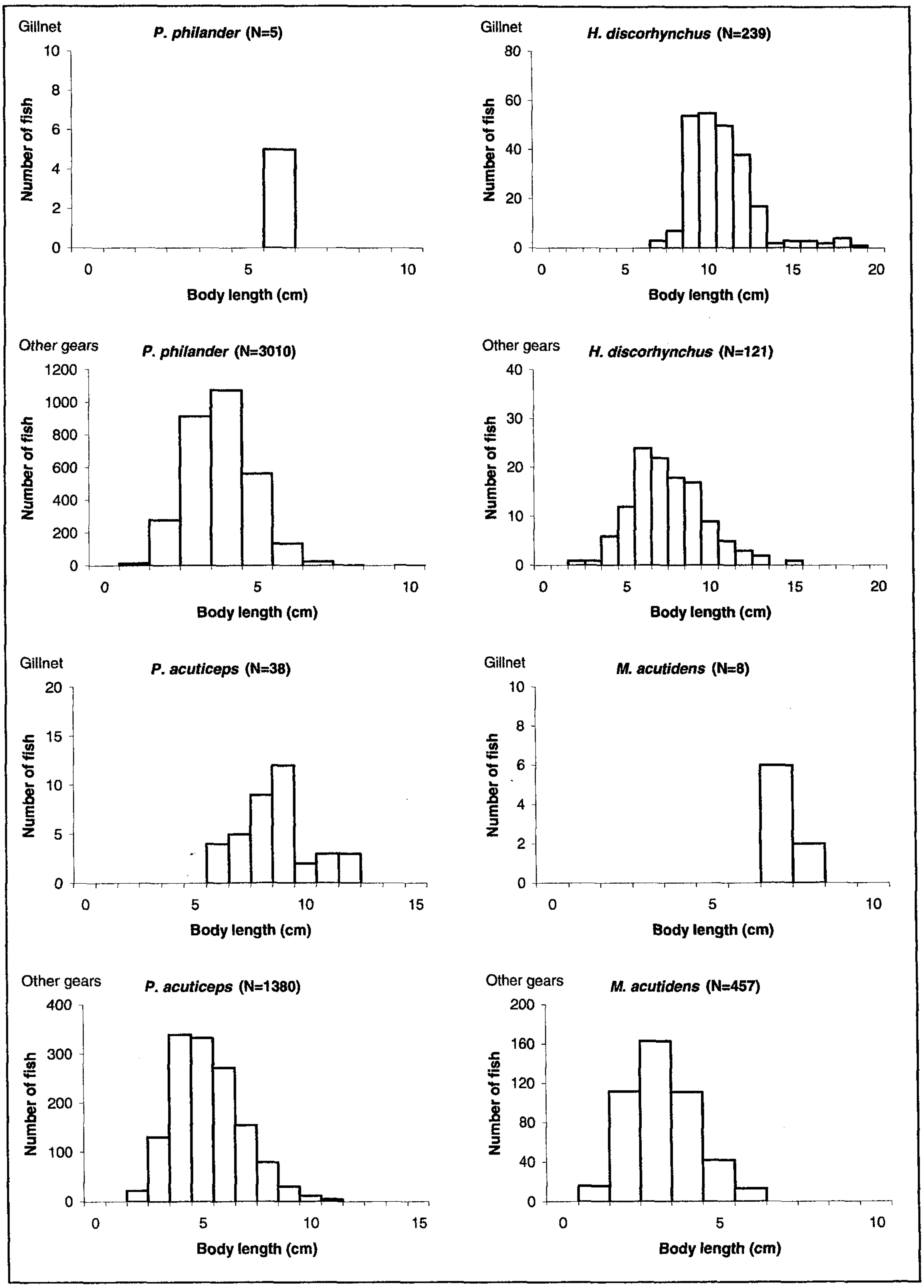


***Figure 5.4**. Length distribution of* P. philander, H. discorhynchus, P. acuticeps, M. acutidens, M. macrolepidotus, S. intermedius, T. sparrmanii, T. rendalli, H. vittatus, S. nigromaculatus, B. lateralis, C. gariepinus, H. odoe, B. poechii, S. macrocephalus, B. paludinosis, L. cylindricus,P. catostoma, B. thamalakanensis, H. machadoi *and* A. johnstoni *caught with gill nets and with other gears in the Okavango River 1992-99.* B. thamalakanensis, H. machadoi *and* A. johnstoni *were not caught with gill nets, only with other gears. Notice the different scales on x and y-axis. Continued on next pages.*

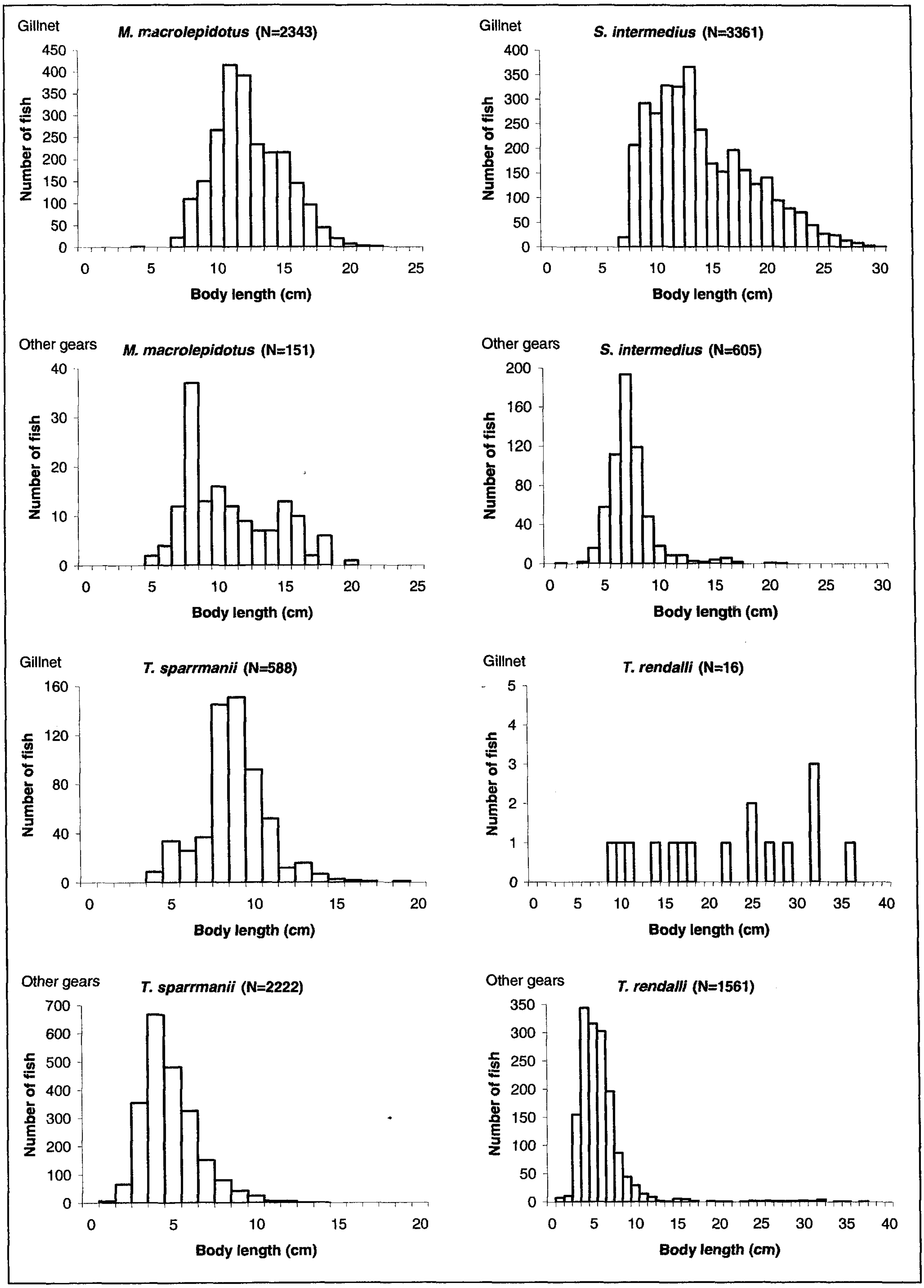


Figure 5.4 continued. *Continued on next page.*

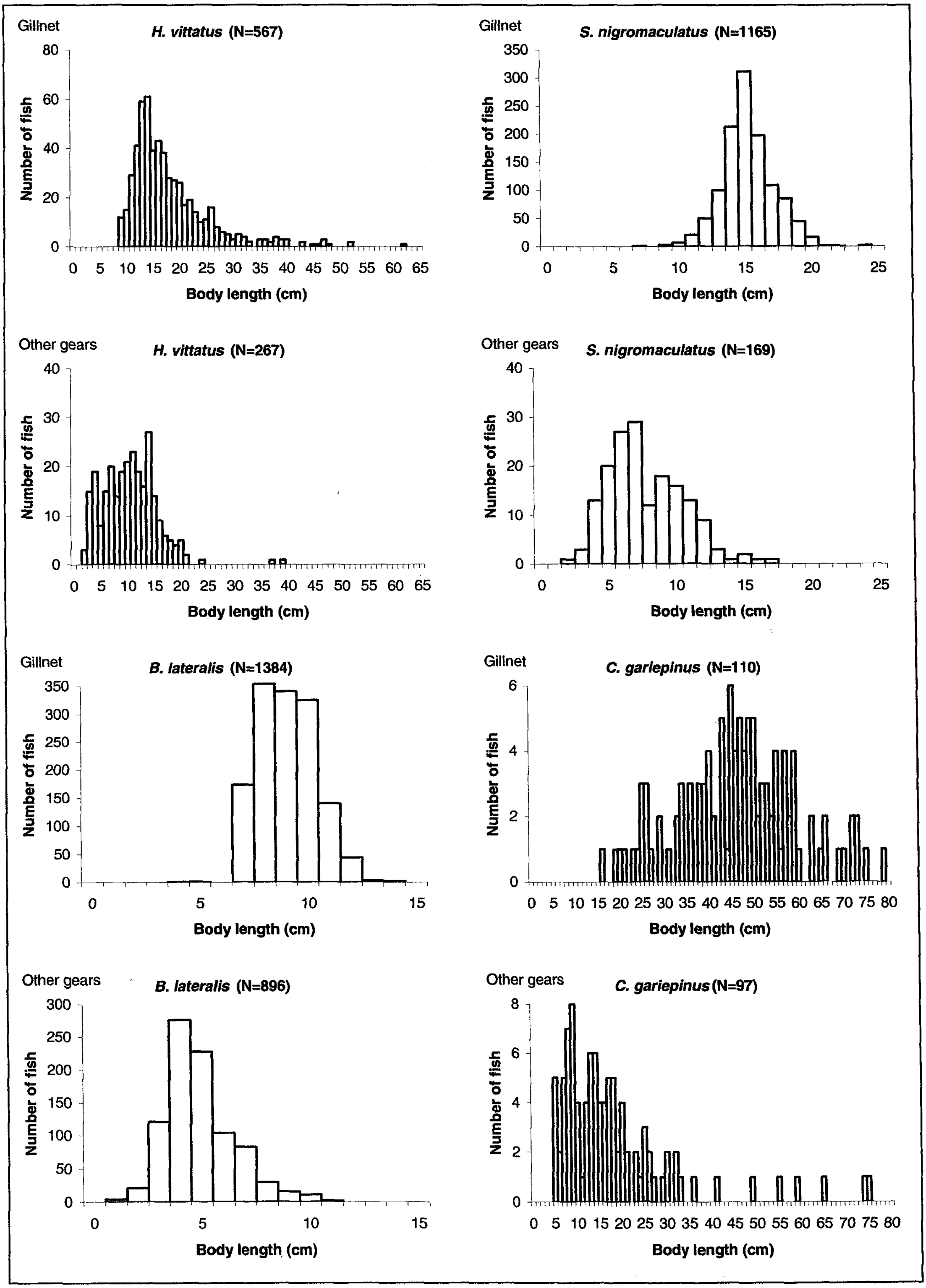
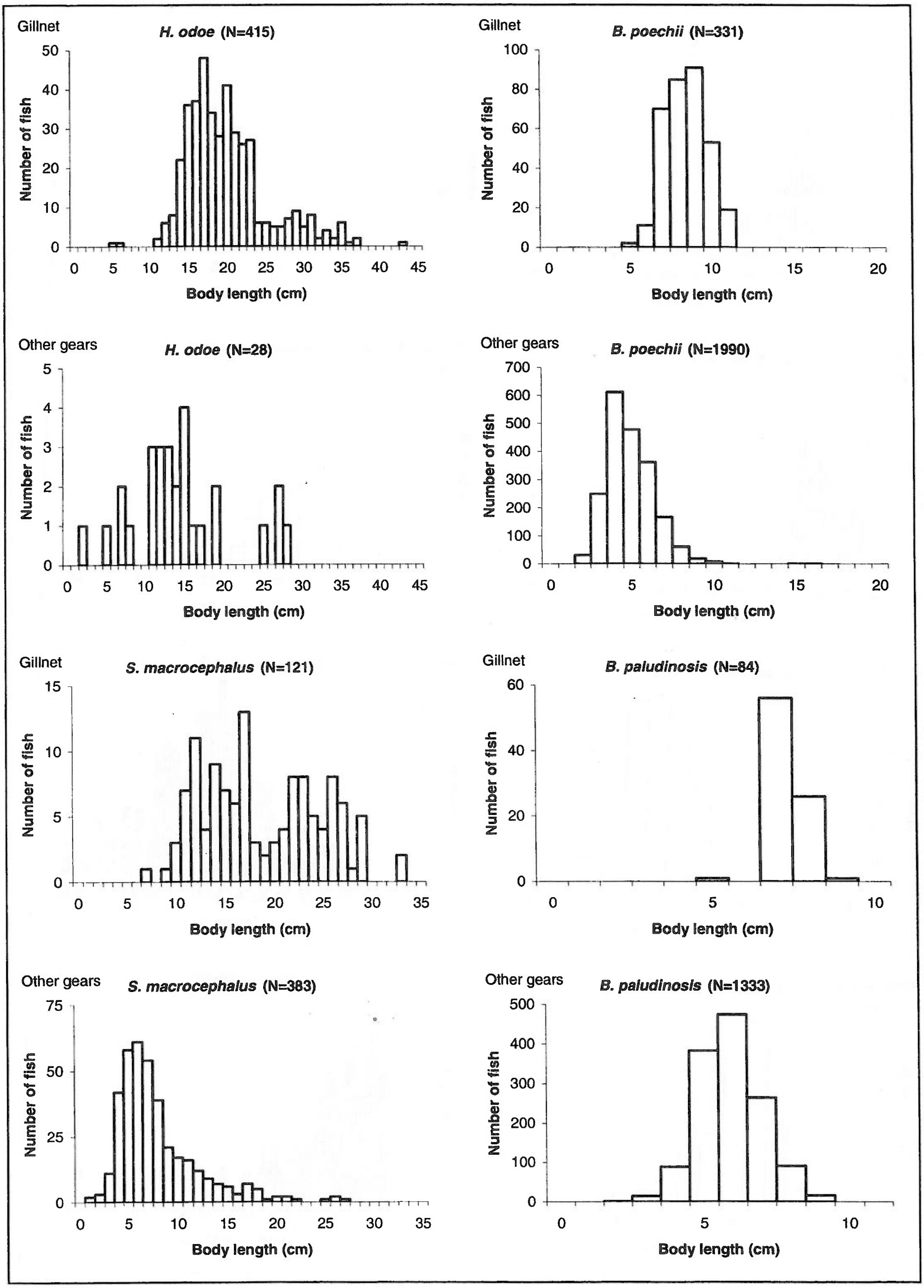


Figure 5.4 continued. *Continued on next page.*



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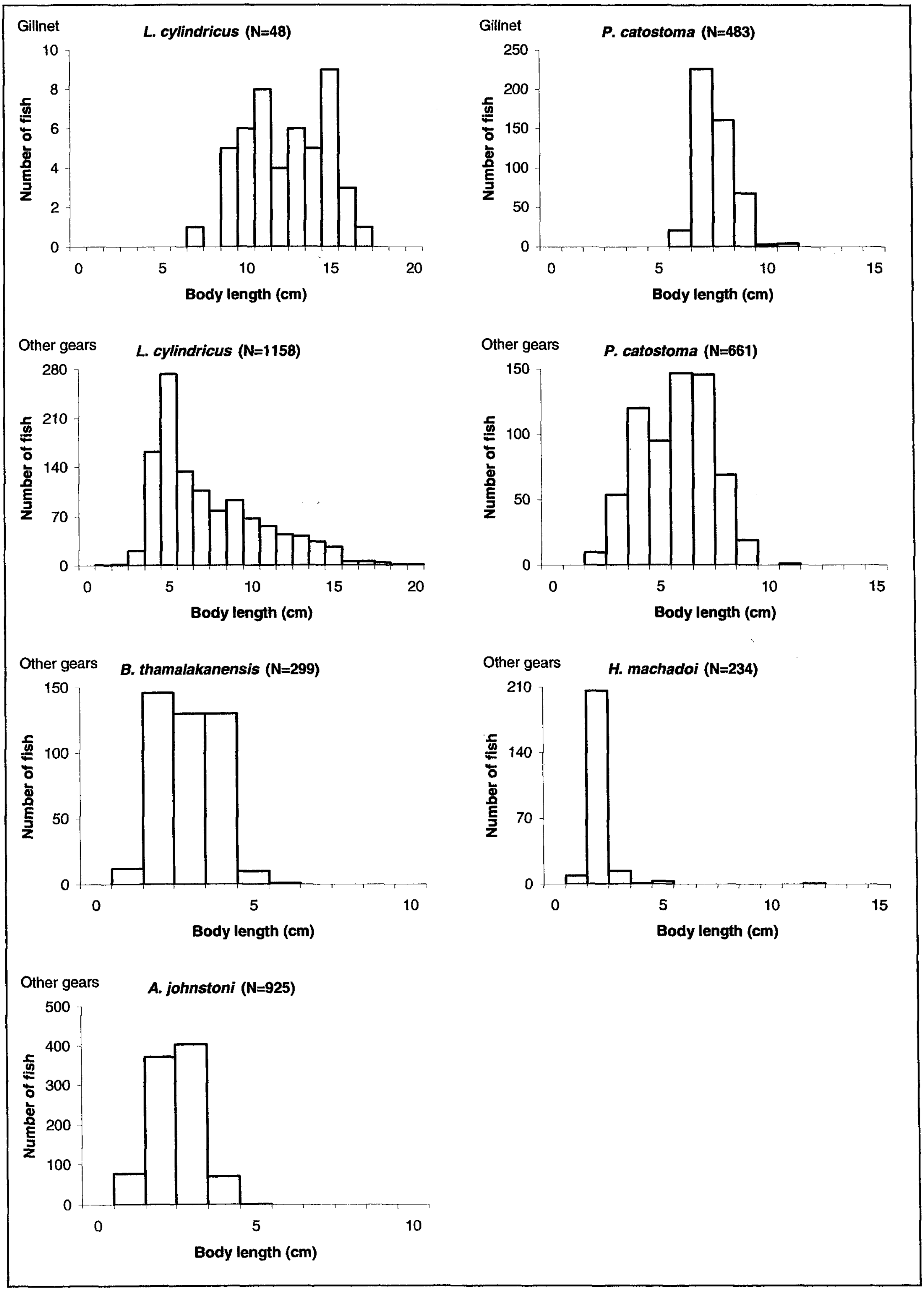

Figure 5.4 continued.

Table 5.8. *Minimum mature length and length at 50 % maturation of fish caught in the fish survey (all gears) in the Okavango River during 1992-1999 (selected species). --- = no mature fish recorded. () = smallest size in gill net catches.*

Species	Minimum size at maturation (cm)		Length at 50 % maturation (cm)	
	Males	Females	Males	Females
Pseudocrenilabris philander	5	3	5.7	
Barbus thamalakanensis	-	-		
Hippopotamyrus discorhynchus	8 (9)	7 (8)	9.7	8.5
Pharyngochromis acuticeps	7 (9)	6 (8)	7.9	6.5
Micralestes acutidens	-	-		
Marcusenius macrolepidotus	10 (10)	10 (10)	14.7	13.6
Schilbe intermedius	9 (10)	10 (11)	12.4	11.2
Hemigrammocharax machadoi	-	-		
Tilapia sparrmanii	7 (8)	5 (6)	6.7	6.1
Tilapia rendalli	11 (16)	14 (25)	11.7	13.7
Hydrocynus vittatus	18 (19)	27 (27)	20.0	28.0
Synodontis nigromaculatus	12 (12)	11 (11)	13.3	16.0
Brycinus lateralis	5 (5)	6 (7)	7.0	7.4
Clarias gariepinus	40 (40)	38 (38)	43.7	40.5
Hepsetus odoe	28 (28)	27 (27)	27.7	27.7
Barbus poechii	7 (7)	7 (7)	7.6	9.2
Serranochromis macrocephalus	17 (21)	14 (15)	17.7	16.2
Barbus paludinosis	5 (7)	6 (7)		6.5
Labeo cylindricus	8 (10)	11 (11)	10.3	11.5
Aplocheilichthys johnstoni	-	-		
Petrocephalus catostoma	7 (7)	6 (6)		

The mesh size catching the highest number of Zambezi happy per setting is 28 mm (**Table 5.9**). Fish caught with this mesh size have an average length of 8.9 cm, which is longer than the minimum mature size of 6-7 cm (**Table 5.8**). The 28 mm nets also have the highest catch in terms of weight per setting, i.e. 0.006 kg. The gill net mesh sizes used in this investigation efficiently catch Zambezi happy between 7 and 12 cm in length (**Figure 5.5**). Gill nets from 22 to 35 mm are most efficient. Larger mesh sizes do not catch any fish. A mesh size of 22 mm is most efficient (maximum catchability) for fish with a length of approximately 7.5 cm, which is about the same as minimum size at maturity in this species. Mesh sizes of 28 mm and 35 mm are most efficient for fish with lengths of approximately 9.5 cm and 11.5 cm, respectively.

Banded tilapia (*Tilapia sparrmanii*)
Banded tilapia is widespread in Southern Africa, with a similar distribution as the southern mouthbrooder, and it has been extensively translocated south of the Orange River in the Cape. It attains a length of approximately 23 cm, and weighs up to 0.5 kg. It is tolerant of a wide range of habitats, but prefers quiet or stagnant waters with vegetation where it feeds on algae, soft plants, invertebrates and small fish. It is common in subsistence fisheries and occasionally in angling. It is the ninth most important species in the subsistence fisheries in Okavango (**Table 5.7**), and the minimum mature lengths were found to be 7 cm for males and 5 cm for females (**Table 5.8**). The corresponding lengths at 50 % maturation were 6.7 and 6.1 cm.

In the Okavango, this species is frequently caught both in gill nets (588 fishes) and other gears (2 222 fishes) (**Figure 5.4**). The body lengths in gill net catches were 4 to 20 cm (mean 8.8 cm, modal length 9.0–9.9 cm). The modal length is longer than the minimum length at maturity found in total catches (5-7 cm) (**Table 5.8**). The lengths of fish caught in other gears were 1 to 15 cm (mean 4.8 cm, modal length 4.0–4.9 cm).

The most effective gill net mesh size for banded tilapia in terms of number of fish per setting is 35 mm (**Table 5.10**). Fish caught with this mesh-size have an average length of 9.0 cm, which is slightly larger than minimum mature size (5-7 cm) (**Table 5.8**). The 35 mm nets also have the highest catches in terms of weight per setting, estimated to 0.05 kg. The gill net mesh sizes used in this investigation efficiently catch banded tilapia between approximately 6 and 18 cm (**Figure 5.6**). Gill nets from 22 to 73 mm are most efficient. Larger mesh sizes do not catch any fish. The 28 mm mesh size catches fish between 4.5 and 11.5 cm, and maximum catchability is

Table 5.9. *Gill net selectivity for Zambezi happy* (P. acuticeps) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	10	7.5	0.25	0.001
28	22	8.9	0.66	0.006
35	6	11.4	0.14	0.003
Total	38		0.10	0.001

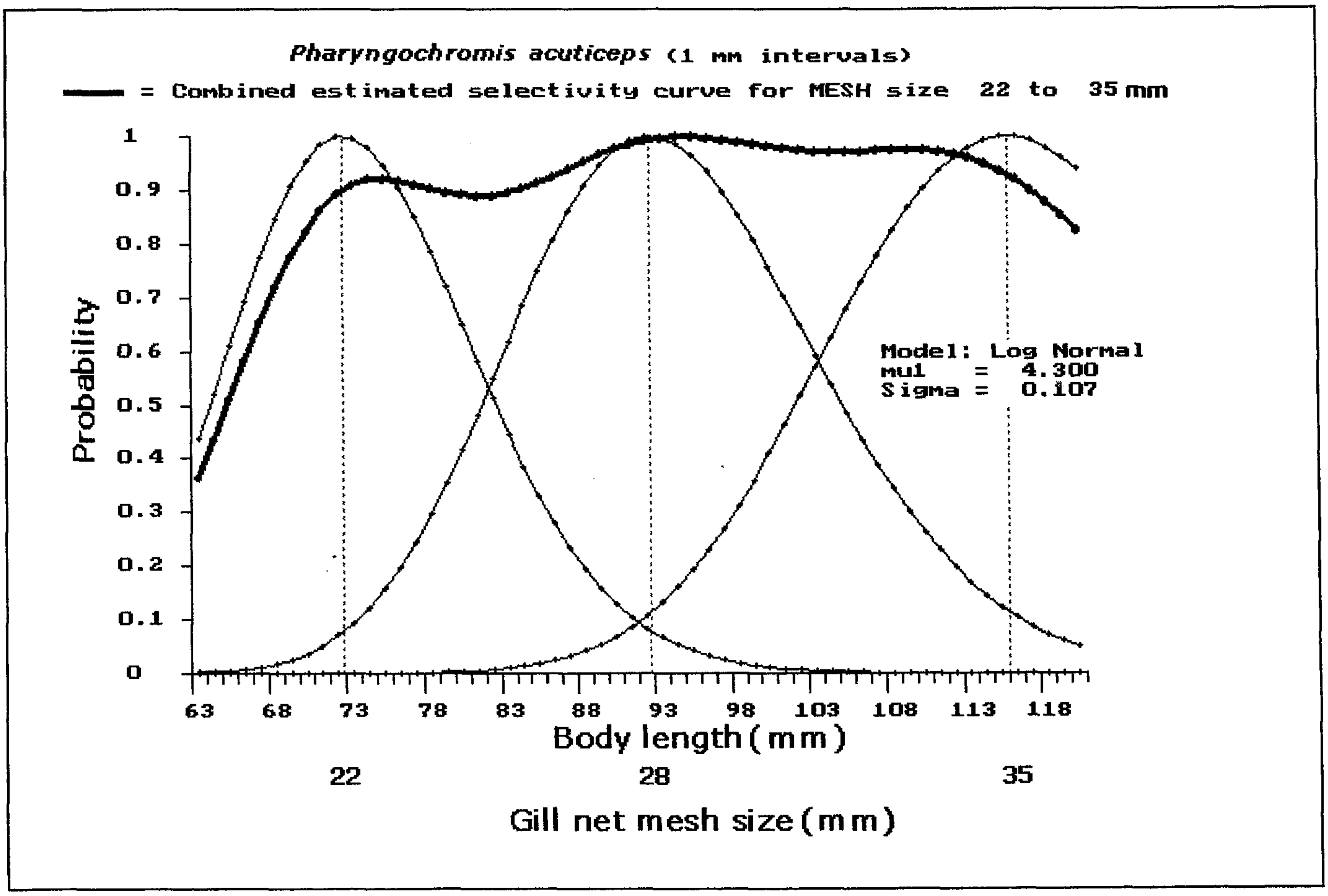

***Figure 5.5**. Gill net selectivity curves for Zambezi happy* (P. acuticeps) *for each mesh size from 22 mm to 35 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.10. *Gill net selectivity for banded tilapia* (T. sparrmanii) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	72	5.8	2.27	0.009
28	46	7.5	1.48	0.010
35	323	9.0	3.57	0.054
45	129	10.8	1.54	0.043
57	15	13.1	0.26	0.013
73	3	16.3	0.03	0.003
Total	588		0.97	0.015

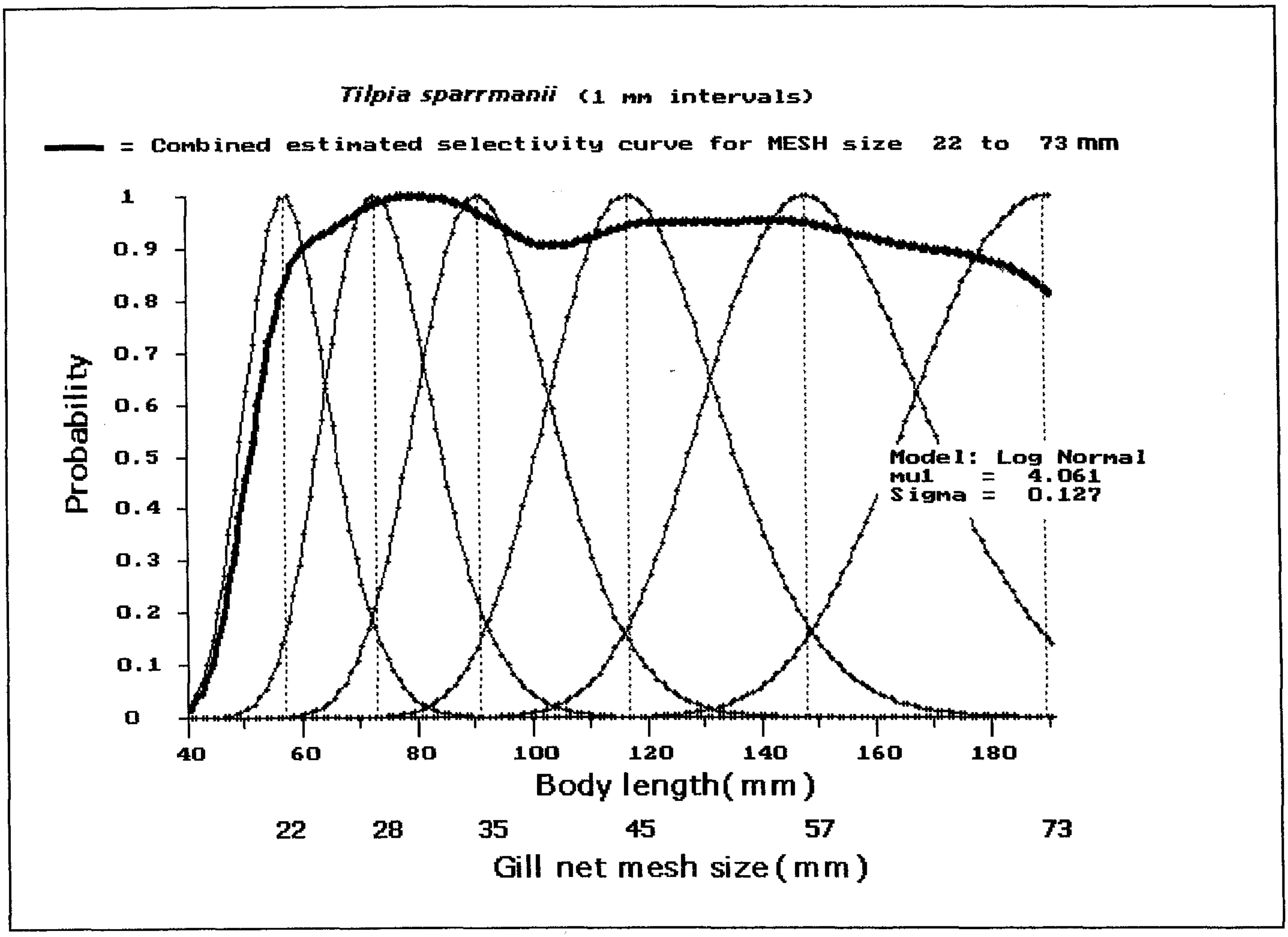

Figure 5.6*. Gill net selectivity curves for banded tilapia* (T. sparrmanii) *for each mesh size from 22 mm to 73 mm and combined estimated selectivity curve for all mesh sizes.*

for a fish length of approximately 7.5 cm, which is about the same as minimum size at maturity in this species. The 35 mm nets catch fish between 6.0 to 14.0 cm, with maximum catchability for a length of approximately 9.0 cm. Thus, 35 mm mesh size catches practically no immature fish.

Redbreast tilapia (*Tilapia rendalli*)
Redbreast tilapia is widespread in Southern Africa where it occurs in the Cunene, Okavango and Zambezi river systems, in the eastern Congo basin and coastal rivers south of the Zambezi. It is also translocated to many catchments in southern Africa. It grows to about 40 cm and 2 kg, and breeds and raises several broods each summer. It prefers quiet, vegetated waters along river littorals or backwaters, floodplains and swamps and feeds mainly on plant material, but may also feed on invertebrates and even small fish. It is an attractive angling species and is the tenth most important species in the subsistence fisheries in Okavango (**Table 5.7**). The minimum mature lengths observed were 11 and 14 cm for males and females, respectively (**Table 5.8**). The corresponding lengths at 50 % maturation were 11.7 and 13.7 cm.

Redbreast tilapia is rarely caught in gill nets. The 16 fishes caught in gill nets were between 9 and 37 cm (mean 22.2 cm), whereas the 1561 fishes caught in other gears were between 1 and 38 cm (mean 5.9 cm) (**Figure 5.4**). The modal length of fish caught in gill nets was 32.0–32.9 cm, which is longer than the minimum length at maturity found in total catches (11-14 cm) (**Table 5.8**). The modal length of fish caught in other gears was 4.0–4.9 cm.

The mesh size catching the highest number of redbreast tilapia per setting is 73 mm (**Table 5.11**). Fish caught with this mesh-size have an average length of 25.0 cm, which is longer than the minimum mature size of 11-14 cm (**Table 5.8**). The 118 mm nets have the highest catch in terms of weight per setting, at 0.04 kg. This species is efficiently caught with gill net mesh sizes from 57 to 118 mm, whereas 45 mm nets are somewhat less efficient (**Figure 5.7**). Smaller mesh sizes (22 and 28 mm) very rarely catch this species, but all mesh sizes used in this investigation may catch some redbreast tilapia.

Purpleface largemouth (*Serranochromis macrocephalus*)
Purpleface largemouth occurs in the Cunene, Okavango and upper parts of the Zambezi down to Kariba, and is also found in the southern tributaries of the Congo system. It may reach lengths over 35 cm and weights of more than 1.5 kg. It lives in a wide range of habitats, from mainstream margins to backwaters and floodplain lagoons, and feeds on insects and small fish. It is an important species in subsistence and commercial fisheries and an attractive angling species. The minimum mature length of this species in Okavango was 17 and 14 cm for males and females, respectively (**Table 5.8**). The corresponding lengths at 50 % maturation was 17.7 and 16.2 cm.

The largemouth was common in both gill net and other gear catches. The 121 fishes caught in gill nets were between 7 and 34 cm (mean 18.8 cm), with a modal length of 17.0–17.9 cm, which is about the same as the minimum length at maturity found in total catches (14-17 cm) (**Table 5.8**). The 383 fishes caught in other gears were between 1 and 28 cm (mean 7.9 cm), with a modal length of 6.0–6.9 cm.

The mesh size that catches the highest number of purpleface largemouth per setting is 45 mm (**Table 5.12**). Fish caught with this mesh-size have an average length of 15.1 cm, which is about the same as the minimum mature size of 14-17 cm (**Table 5.8**). The 93 mm nets have the highest catch in terms of weight per setting, estimated to 0.132 kg. Fish caught with this mesh-size has an average length of 27.6 cm, which is longer than the minimum mature size.

Purpleface largemouth is efficiently caught with gill net mesh sizes from 35 to 93 mm, whereas 22 mm, 28 mm and 118 mm nets are less efficient (**Table 5.12**). Mesh sizes from 73 mm and larger only catch purpleface largemouth longer than the minimum mature size. The 57 mm net catches fish between 10.0 and 31.0 cm, 73 mm net catches fish longer than 13.0 cm and 93 mm net catches fish longer than 17.0 cm (**Figure 5.8**), with maximum catchability for fish lengths of approximately 18.5 cm, 23.5 cm and 30.0 cm, respectively.

Cyprinidae

Thamalakane barb (*Barbus thamalakanensis*)
Thamalakane barb occurs in the Okavango and upper Zambezi. It grows to 4 cm and breeds in the summer. It prefers vegetated margins of rivers and lagoons, floodplain pools and backwaters where it feeds on insects and periphyton (algae living on plants). It is an attractive aquarium species, and is the second most important species in the subsistence fisheries in the Okavango (**Table 5.7**). However, it was not caught in gill nets. A total of 299 fishes with body lengths from 1 to 6 cm (mean 3.0 cm) and modal length of 2.0–2.9 cm were caught in other gears. No mature fish were recorded of this species (**Table 5.8**).

Dashtail barb (*Barbus poechii*)
Dashtail barb occurs in the Cunene, Okavango and Zambezi Rivers. It grows to 11 cm and is common in riverine and floodplain habitats, where it feeds on insects and other small organisms. It is used as bait for tigerfish and kept in larger aquariums and ponds. The minimum mature length observed in the Okavango was 7 cm for both males and females (**Table 5.8**). The corresponding lengths at 50 % maturation were 7.6 and 9.2 cm.

Table 5.11. Gill net selectivity for redbreast tilapia (T. rendallii) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the fish series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
45	3	10.5	0.06	0.002
57	3	18.8	0.04	0.010
73	4	25.0	0.09	0.023
93	2	12.5	0.05	0.018
118	3	18.8	0.06	0.042
150	1	6.3	0.01	0.010
Total	16		0.04	0.012

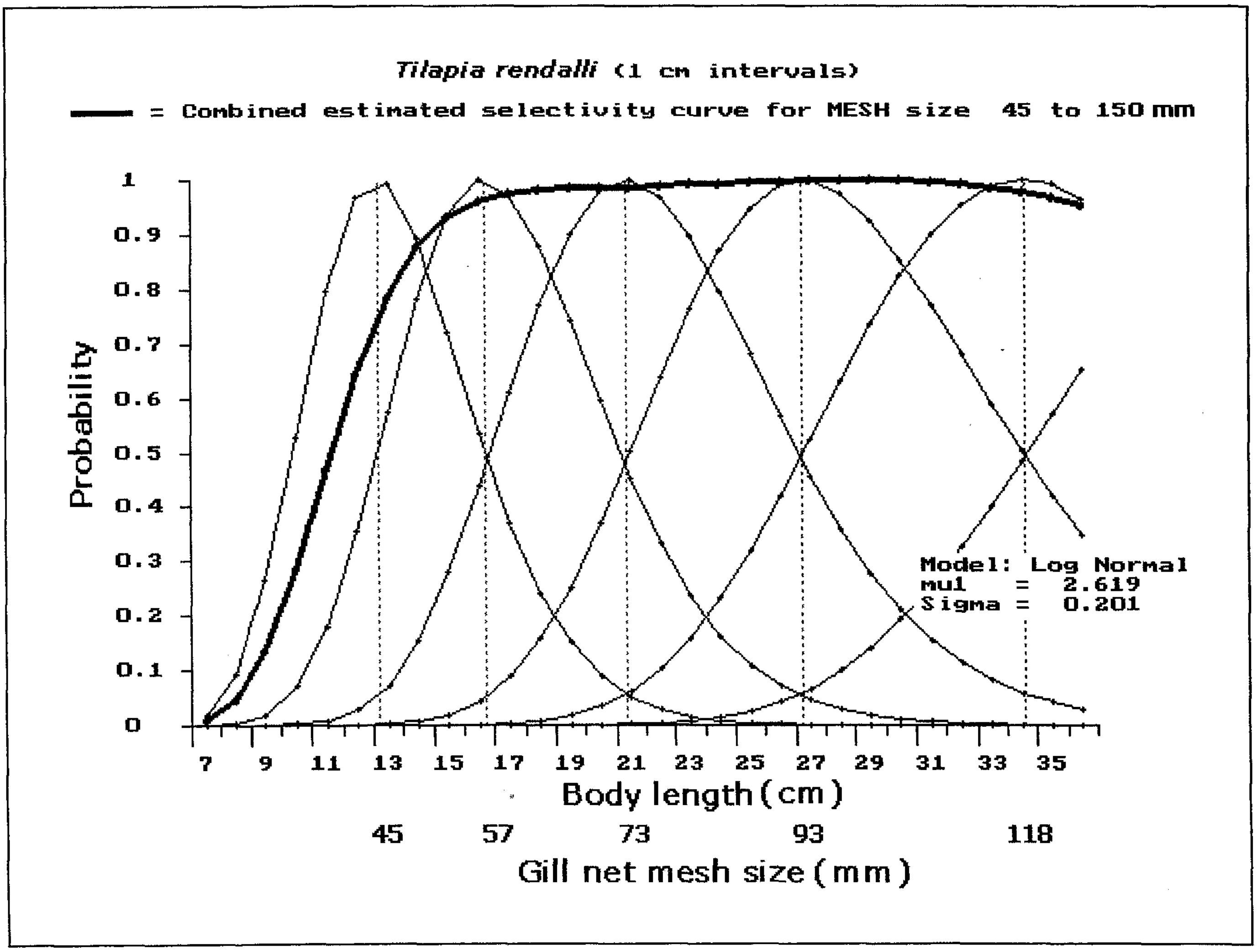

Figure 5.7. Gill net selectivity curves for redbreast tilapia (T. rendalli) *for each mesh size from 45 mm to 150 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.12. *Gill net selectivity for purpleface largemouth* (S. macrocephalus) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the fish series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	1	7.3	0.01	<0.001
28	3	9.7	0.08	0.001
35	22	12.5	0.42	0.014
45	24	15.1	0.46	0.024
57	24	18.7	0.39	0.042
73	20	22.6	0.42	0.075
93	20	27.6	0.37	0.132
118	7	25.0	0.11	0.033
Total	121		0.26	0.038

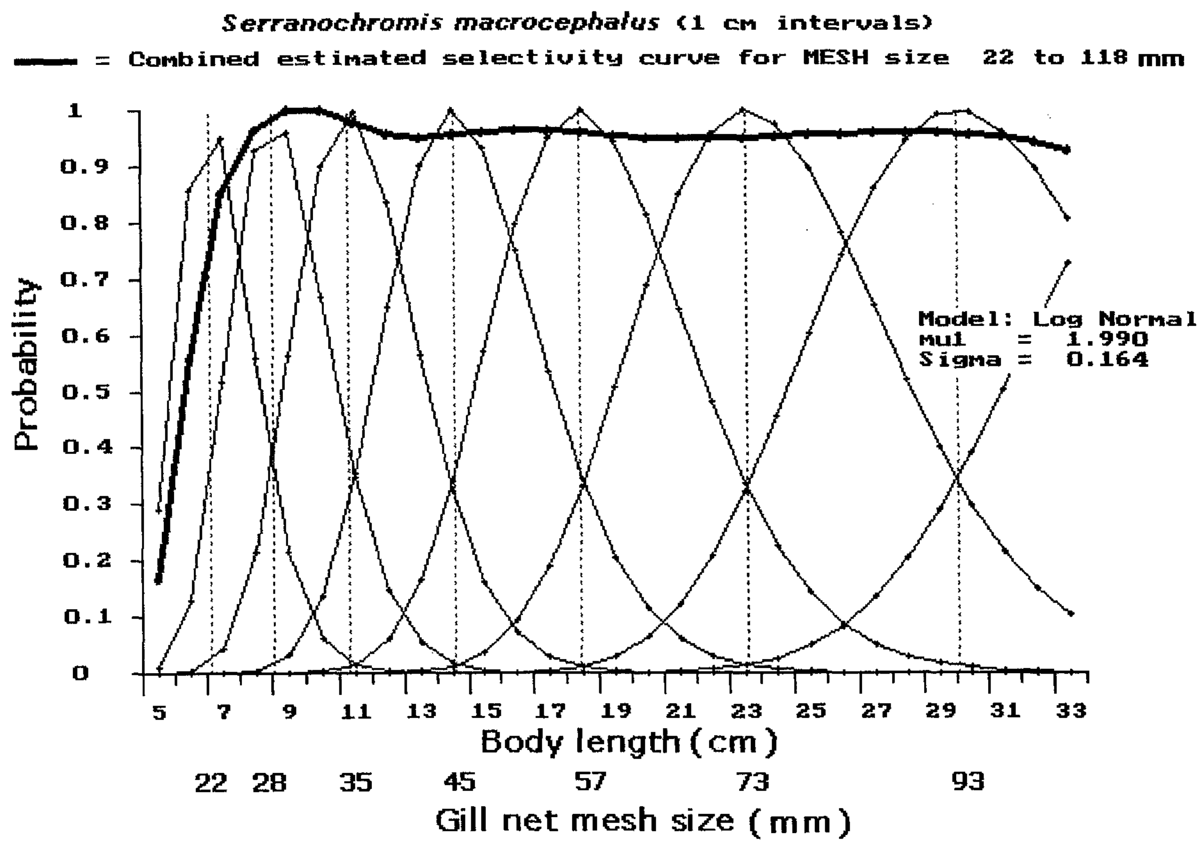

Figure 5.8. *Gill net selectivity curves for purpleface largemouth* (S. macrocephalus) *for each mesh size from 22 mm to 118 mm and combined estimated selectivity curve for all mesh sizes.*

The dashtail barb is quite common in gill net catches. A total of 331 fishes were caught in gill nets, with lengths between 5 and 12 cm (mean 8.5 cm) and a modal length of 9.0–9.9 cm. In other gears, 1990 fishes were caught with body lengths from 2 to 17 cm (mean 4.9 cm) and a modal length of 4.0–4.9 cm (**Figure 5.4**). Dashtail barb is most efficiently caught in terms of number of fish per setting in 22 mm nets (**Table 5.13**). Fish caught with this mesh size have an average length of 7.9 cm, which is about the same as minimum length at maturity (**Table 5.8**). Maximum catch in terms of weight per setting was obtained with 28 mm nets, estimated to 0.06 kg. Average length of fish in this mesh size was 9.5 cm.

The catchability curve for dashtail barb shows that the gill net series used is not very efficient for this species. Catchability values of 0.9 or higher are only reached for fish lengths of approximately 8–10 cm (**Figure 5.9**). Both 22 and 28 mm nets mainly catch fish larger than minimum length at maturity (7 cm). The 22 mm net catches fish between 5.5 and 10.5 cm, whereas 28 mm net catches fish between 7.5 and 12 cm.

Straightfin barb (*Barbus paludinosis*)
Straightfin barb is widespread in Southern Africa from east-coastal rivers in East-Africa south to the Vungu, Natal, and from the southern Congo tributaries and the Quanza in Angola to the Orange. It grows to 15 cm. Females are multiple spawners, which breed during the summer. It prefers quiet, vegetated waters in lakes, swamps and marshes or marginal areas of larger rivers and slow-flowing streams, where it feeds on a wide variety of small organisms such as insects, snails, crustaceans, and algae, as well as detritus. The minimum mature lengths of this species in the Okavango were found to be 5 cm for males and 6 cm for females (**Table 5.8**). The length at 50 % maturation for females was 6.5 cm. This could not be determined for males.

This species was only caught in gill nets with mesh size of 22 mm. The 84 fishes caught in gill nets ranged from 5 to 10 cm in length (mean 7.3 cm), and the modal length was 7.0–7.9 cm. This is longer than the minimum length at maturity found in total catches (5-6 cm) (**Table 5.8**). The 1333 fishes caught in other gears had body lengths between 1 and 9 cm (mean 4.9 cm), and a modal length of 5.0–5.9 cm (**Figure 5.4**).

Redeye labeo (*Labeo cylindricus*)
Redeye labeo is widespread from East African rivers southwards through the Zambezi system and east coastal drainages to northern Natal, and is also reported in the Congo basin. It may reach lengths of 23 cm and weights of 0.9 kg. It prefers clear, running waters in rocky habitats of small and large rivers where it feeds on algae on rocks and other firm surfaces. It is used as an algal grazer in aquariums. The minimum mature lengths observed in the Okavango were 8 and 11 cm for males and females, respectively (**Table 5.8**). The corresponding lengths at 50 % maturation were 10.3 and 11.5 cm.

The gill nets caught 48 fishes between 7 and 18 cm (mean 12.4 cm) in length, with a modal length of 15.0–15.9 cm. In other gears, 1158 fishes were caught, with body lengths from 1 to 21 cm (mean 7.5 cm), and the modal length was 5.0–5.9 cm.

Redeye labeo is most efficiently caught in terms of number of fish per setting in 28 mm nets (**Table 5.14**). Fish caught with this mesh size have an average length of 11.1 cm, which is about the same as minimum length at maturity (**Table 5.8**). Maximum catches in terms of weight per setting were obtained with 35 mm and 45 mm nets, both estimated at 0.013 kg. Average lengths of fish in these mesh sizes were 14.0 cm and 15.6 cm, which are larger than the minimum mature size. Maximum catchabilities for 35 and 45 mm nets are for fish lengths of approximately 14 cm and 17.5 cm, respectively. Both 22 and 28 mm nets mainly catch fish smaller than 11 cm (**Figure 5.10**). Maximum catchabilities are for fish lengths of approximately 8.5 cm and 11 cm, respectively.

Mormyridae

Zambezi parrotfish (*Hippopotamyrus discorhynchus*)
Zambezi parrotfish occurs in the Cunene, Okavango, Zambezi, Buzi and Pungwe Rivers and in the upper Congo and Lakes Tanganyika and Malawi. It grows to 31 cm in length and 1.1 kg in weight and breeds during the summer rainy season. It prefers large river channels with a soft bottom and fringing vegetation, where it feeds on bottom-living invertebrates such as chironomid larvae. It is occasionally caught on rod and line. It is the third most important species in the subsistence fisheries in Okavango (**Table 5.7**), where the minimum mature lengths observed were 8 and 7 cm for males and females, respectively (**Table 5.8**). The corresponding lengths at 50 % maturation were 9.7 and 8.5 cm.

This species was more common in gill nets than in other gears. In gill nets, 239 fishes were caught, measuring from 7 to 20 cm (mean 10.8 cm) with a modal length of 10.0–10.9 cm (**Figure 5.4**). In other gears, the 121 fishes caught measured from 2 to 16 cm in length (mean 7.5 cm) with a modal length of 6.0–6.9 cm.

The highest number of Zambezi parrotfish per setting are caught in mesh size 28 mm (**Table 5.15**). Fish caught with this mesh size have an average length of 9.9 cm, which is longer than the minimum mature size of 7-8 cm (**Table 5.8**). The 35 mm nets have the highest catch in terms of weight per setting, estimated to 0.04 kg. Maximum catchabilities for 28 mm and 35 mm gill nets are for fish lengths of approximately 10 cm and 12 cm, respectively. The gill net mesh sizes used in this investigation efficiently catch Zambezi parrotfish be-

Table 5.13. *Gill net selectivity for dashtail barb* (B. poechii) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	166	7.9	4.95	0.034
28	143	9.5	4.72	0.063
35	21	10.8	0,38	0.008
45	1	9.1	0.03	0.000
Total	331		0.92	0.010

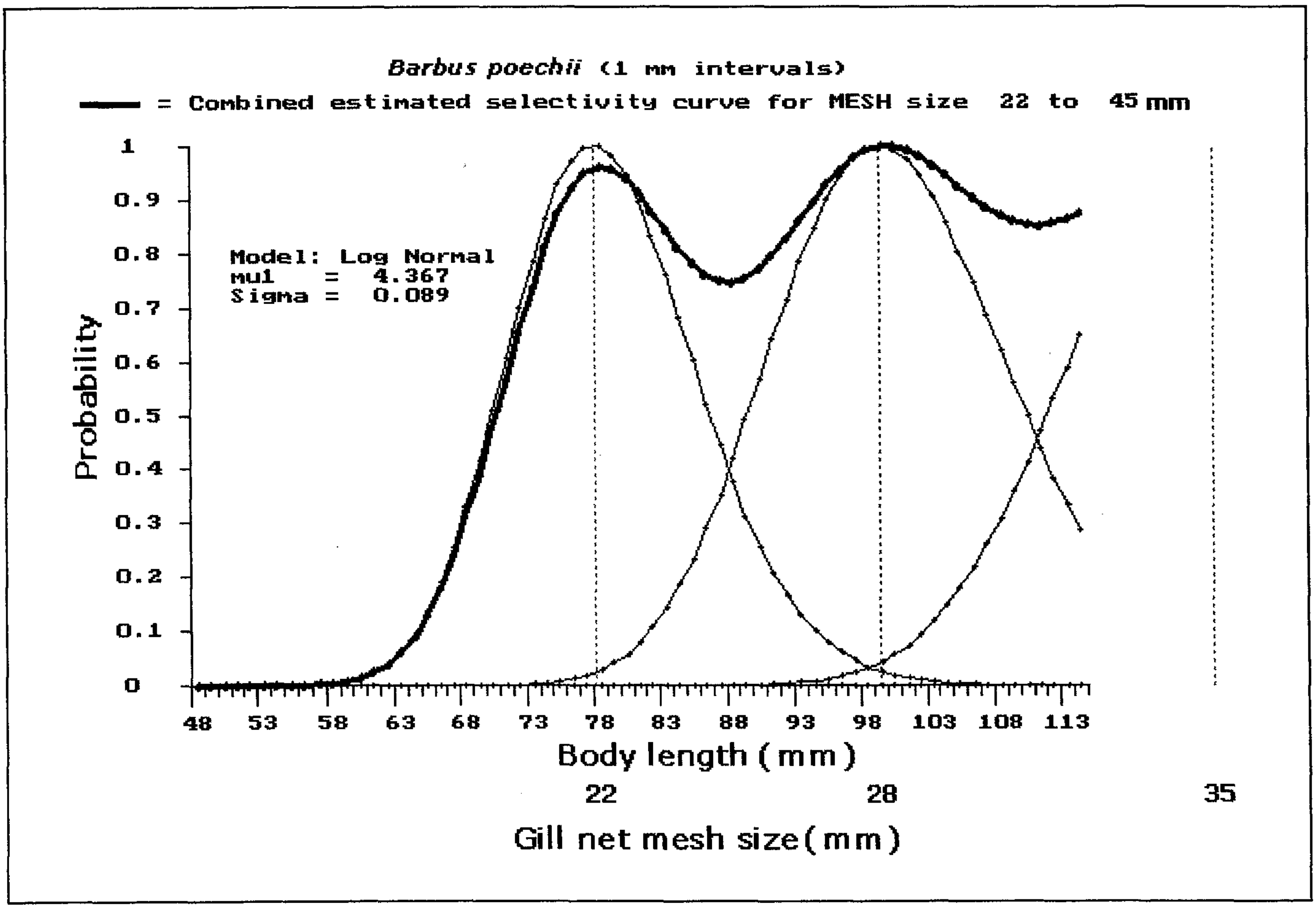

Figure 5.9. *Gill net selectivity curves for dashtail barb* (B. poechii) *for each mesh size from 22 mm to 45 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.14. Gill net selectivity for redeye labeo (L. cylindricus) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	5	8.9	0.17	0.002
28	17	11.1	0.56	0.012
35	16	14.0	0.35	0.013
45	10	15.6	0.23	0.013
Total	48		0.13	0.004

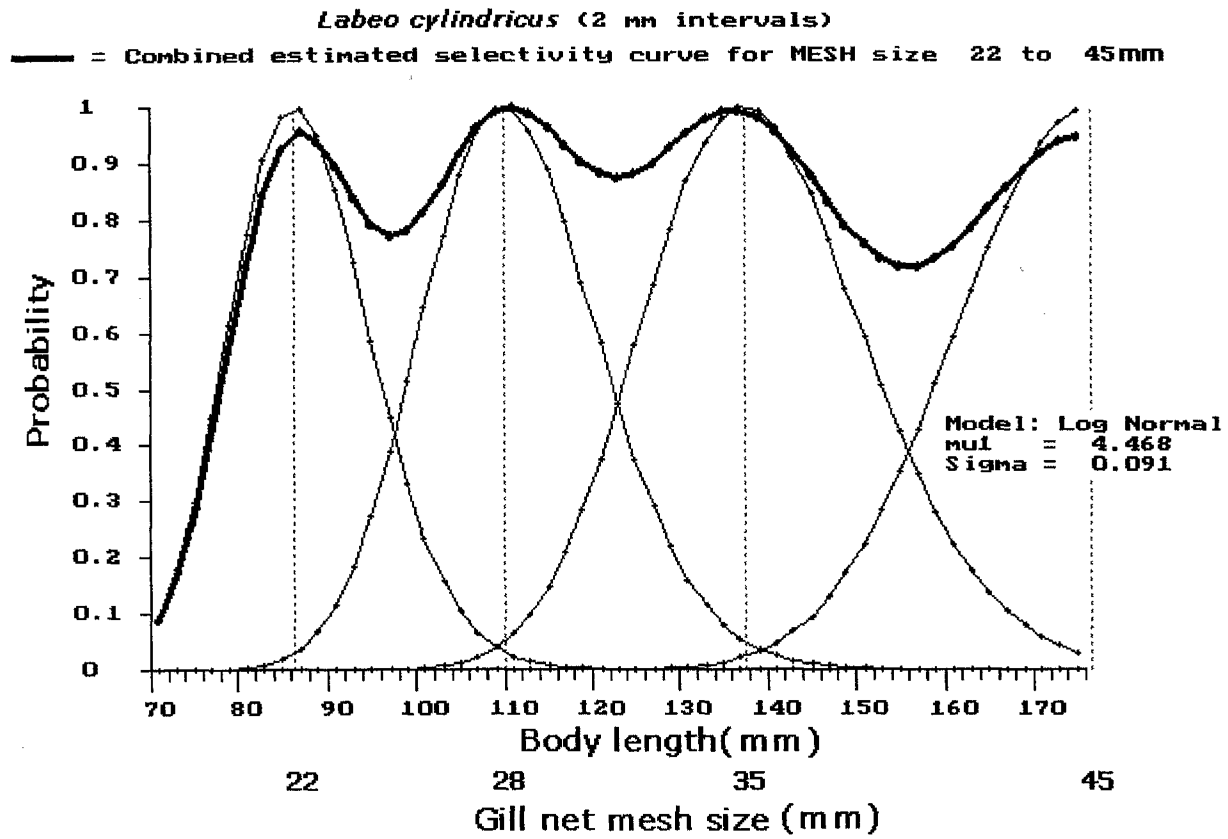

***Figure 5.10**. Gill net selectivity curves for redeye labeo* (L. cylindricus) *for each mesh size from 22 mm to 45 mm and combined estimated selectivity curve for all mesh sizes.*

tween 7 and 20 cm. Gill nets from 28 to 45 mm are most efficient. Gill nets with mesh size 22 mm, and 73 mm or larger, catch few fish of this species (**Figure 5.11**).

Bulldog (*Marcusenius macrolepidotus*)
Bulldog is widespread in Central and Southern Africa in the Cunene, Okavango and Zambezi Rivers and in east coastal rivers and lakes from Tanzania to Natal, and also in the upper Congo. It grows to 30 cm and 0.5 kg, and breeds during the rainy season. Bulldog shoals in vege-

Table 5.15. *Gill net selectivity for Zambezi parrotfish* (H. discorhynchus) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (2- 150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	5	7.7	0.13	0.001
28	115	9.9	2.07	0.027
35	92	11.7	1.57	0.036
45	15	14.5	0.24	0.010
57	9	15.1	0.20	0.011
73	3	18.3	0.08	0.007
Total	239		0.44	0.010

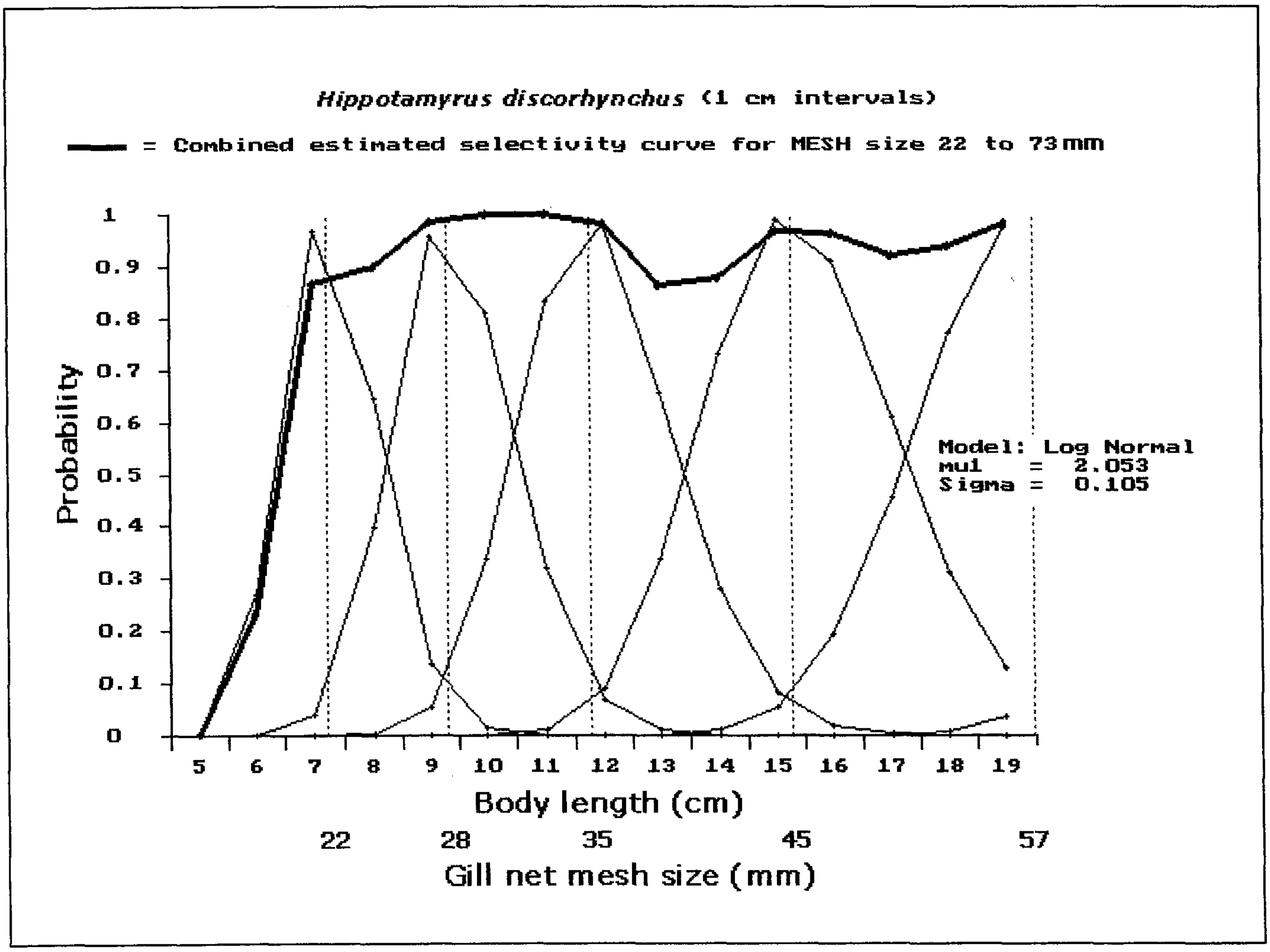

Figure 5.11*. Gill net selectivity curves for Zambezi parrotfish* (H. discorhynchus) *for each mesh size from 22 mm to 73 mm and combined estimated selectivity curve for all mesh sizes.*

tated and shallow waters where it feeds on invertebrates found on the bottom or on vegetation. It is occasionally caught on rod and line and is an interesting aquarium species. It is the sixth most important species in the subsistence fisheries in the Okavango (**Table 5.7**), where the minimum mature lengths were found to be 10 cm for both sexes (**Table 5.8**). The length of 50 % maturation was 14.7 and 13.6 cm for males and females, respectively.

The bulldog is the second most important species in gill net catches in the Okavango. A total of 2 343 fishes were caught in gill nets with body lengths from 4 to 23 cm (mean 12.4 cm), and a modal length of 11.0–11.9 cm (**Figure 5.4**). The 151 fishes caught in other gears were between 5 and 21 cm (mean 10.8 cm), with a modal length of 8.0–8.9 cm. The most effective gill net mesh size in terms of number of fish per setting is 35 mm (**Table 5.16**). Fish caught with this mesh size have an average length of 12.4 cm, which is longer than minimum mature size (10 cm; **Table 5.8**). Gill nets with a mesh size of 45 mm have the highest catches in weight per setting, estimated at 0.47 kg, with an average length of 15.8 cm. The gill nets with mesh size 22-57 mm show a high efficiency in catching fish between 8.5 and 22 cm (**Figure 5.12**), i.e. for these mesh sizes and fish lengths, catchability is close to 1. The smallest mesh size that only catches bulldog equal to or larger than minimum mature size is 45 mm.

Churchill (*Petrocephalus* *catostoma*)
Churchill is widespread from the Cunene, Okavango and Zambezi Rivers to Congo and the lakes Malawi, Tanganyika and Victoria. It grows to 13 cm and breeds during the summer rainy season. It prefers quiet reaches of rivers and floodplains, where it feeds on insect larvae and other small invertebrates. It is a potentially attractive aquarium species and is caught in subsistence fisheries. In the Okavango, the minimum lengths at maturity were 7 cm for males and 6 cm females (**Table 5.8**). Corresponding lengths at 50 % maturation could not be determined, because only a few mature fish were sampled. A total of 483 fishes with body lengths from 6 to 12 cm (mean 7.6 cm) and a modal length of 7.0–7.9 cm were caught in gill nets. In other gears, 661 fishes were caught, with lengths from 2 to 12 cm (mean 5.7 cm) and a modal length of 6.0–6.9 cm. Thus, the modal lengths in both types of gear are equal to or larger than the minimum length at maturity (6-7 cm).

The most effective gill net mesh size to catch the highest number of churchill per setting is 22 mm (**Table 5.17**). The catches are between 5.5 and 9.5 cm in length, with a mean length of 7.5 cm, which is above minimum mature size. 28 mm gill nets have the highest catches in weight per setting, estimated at 0.053 kg. This mesh size catch fish between 7 and 12 cm in length, with an average of 8.7 cm. The smallest mesh size that only catches fish equal to or larger than minimum mature size in churchill is 35 mm, which catches fish longer than 9 cm (**Figure 5.13**). Maximum catchabilities in mesh sizes 22, 28 and 35 mm are for fish lengths of approximately 7.5 cm, 9.5 and 11.5 cm, respectively.

Characidae

Silver robber (*Micralestes acutidens*)
Silver robber occurs in the Cunene, Okavango and Zambezi Rivers, in the east coastal rivers, and is also widespread in the Congo system. It grows to about 8 cm and breeds throughout the summer months. It shoals in clear, flowing or standing, open water where it feeds on surface insects and zooplankton. It is an attractive aquarium species and is used as a forage fish and as bait for tigerfish and African pike. It is the fifth most important species in the subsistence fisheries in Okavango (**Table 5.7**).

Only 8 silver robbers with body lengths from 7 to 9 cm (mean 7.5 cm) were caught in gill nets during this survey. Only 22 mm mesh size caught this species. In other gears, 457 fishes from 1 to 7 cm (mean 3.2 cm) were caught, with a modal length of 3.0–3.9 cm (**Figure 5.4**). No mature fish of this species were recorded (**Table 5.8**).

Tigerfish (*Hydrocynus vittatus*)
Tigerfish is widespread in Africa. It grows to 70 cm (females), 50 cm (males) and to over 10 kg. Tigerfish breed during summer and spawn in shallow flooded areas. Fish larger than approximately 10 cm prey on other fish, while smaller fish eat invertebrates. Adults prefer open waters in rivers or lakes. It is a popular fish both commercially and for angling. In the Okavango, the minimum lengths at maturity were found to be 18 cm for males and 27 cm for females (**Table 5.8**). The corresponding lengths at 50 % maturation were 20.0 and 28.0 cm.

The 567 tigerfish caught in gill nets were between 9 and 63 cm in length (mean 18.3 cm), with a modal length of 14.0–14.9 cm. In other gears, 267 fishes were caught with lengths between 2 and 40 cm (mean 10.6 cm), also with a modal length of 14.0–14.9 cm (**Figure 5.4**). The modal length was considerably shorter than the minimum length at maturity (18-27 cm). The highest number of fish per setting was caught in 28 mm mesh size (**Table 5.18**). With an average length of 13.3 cm, they were smaller than the minimum mature size (**Table 5.8**). Gill nets with a mesh size of 93 mm had highest catches in weight per setting, estimated to 0.28 kg. With a mean length of 38.0 cm, tigerfish caught in this mesh size were well above minimum mature size.

The gill net mesh sizes used in this investigation efficiently catch tigerfish between 10 and 45 cm. Gill nets from 22 to 93 mm are most efficient (**Figure 5.14**). The smallest mesh size that most efficiently catch tigerfish

Table 5.16. Gill net selectivity for bulldog (M. macrolepidotus) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	189	8.5	5.35	0.036
28	445	10.5	13.77	0.177
35	1 157	12.4	15.88	0.397
45	471	15.8	8.90	0.472
57	78	17.9	1.45	0.114
73	3	18.3	0.08	0.007
93				
Total	2 343		4.80	0.135

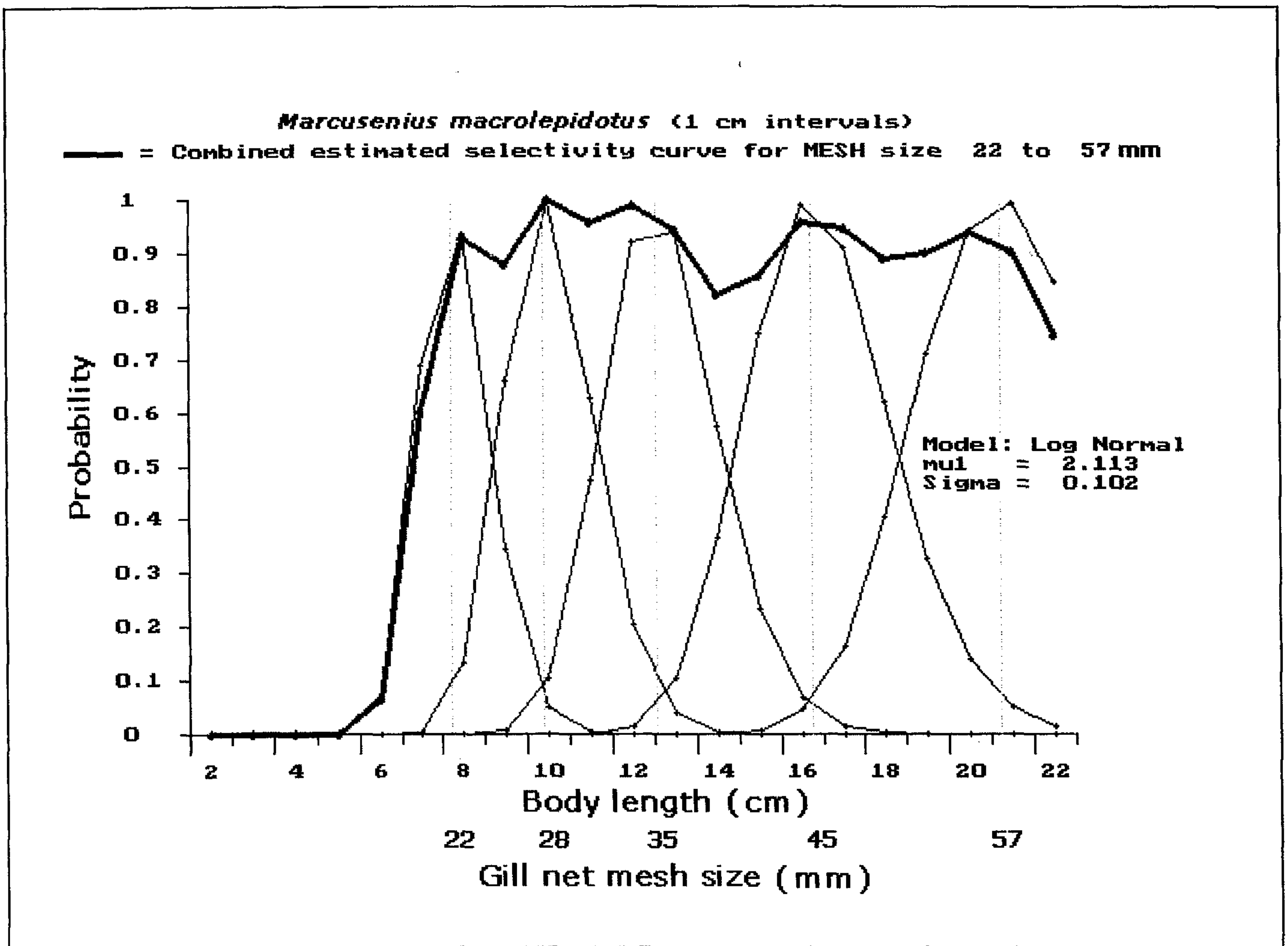

Figure 5.12. Gill net selectivity curves for bulldog (M. macrolepidotus) *for each mesh size from 22 mm to 57 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.17. *Gill net selectivity for churchill* (P. catostoma) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	291	7.5	5.51	0.028
28	188	8.7	5.27	0.053
35	4	10.6	0.11	0.002
Total	483		0.98	0.007

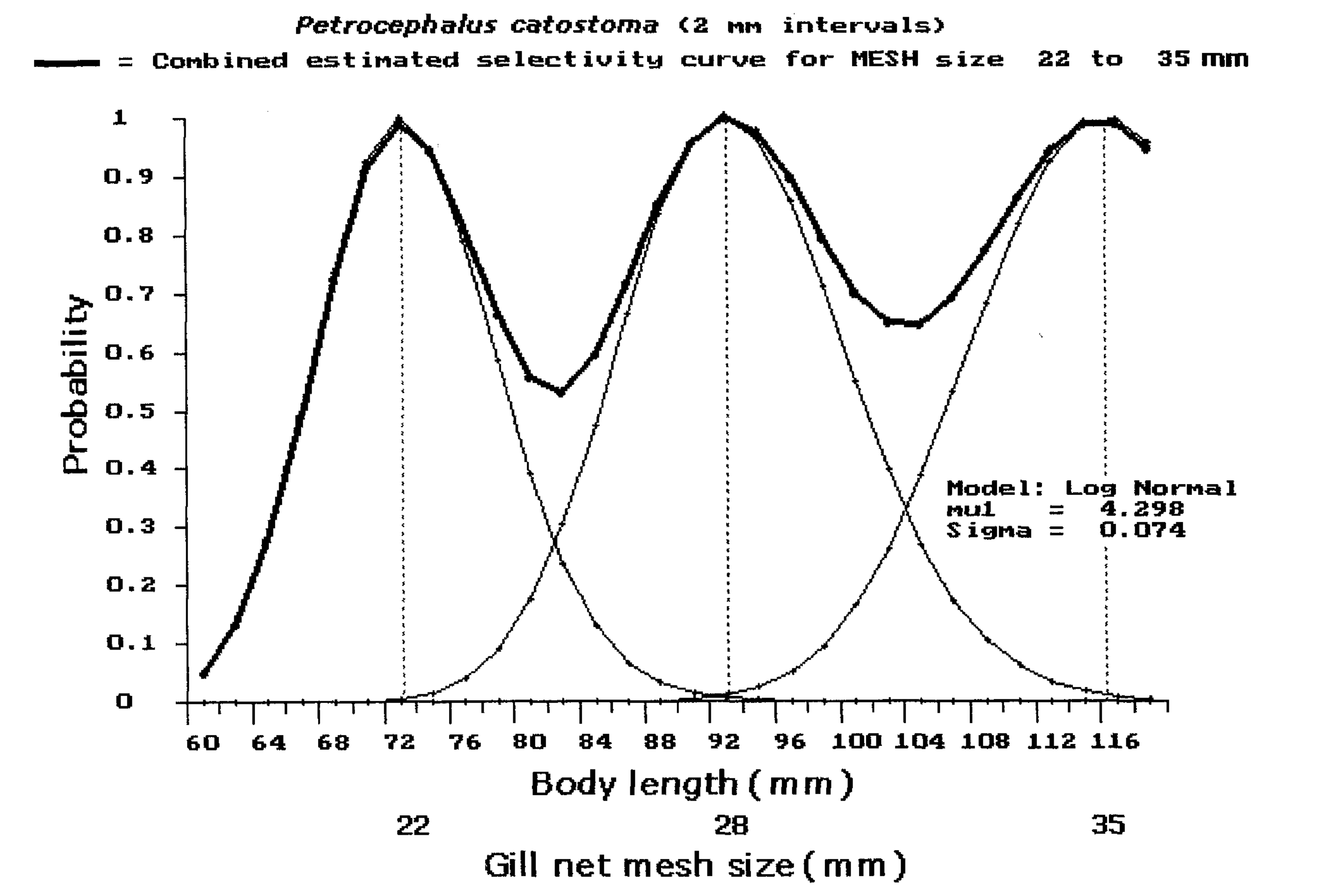

Figure 5.13*. Gill net selectivity curves for churchill* (P. catostoma) *for each mesh size from 22 mm to 35 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.18. *Gill net selectivity for tigerfish* (H. vittatus) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	32	10.2	0.85	0.010
28	121	13.3	3.83	0.108
35	209	16.2	3.34	0.197
45	101	20.1	1.40	0.145
57	59	24.9	0.80	0.171
73	19	30.2	0.20	0.080
93	19	38.0	0.33	0.283
118	4	47.8	0.05	0.101
150	3	52.4	0.04	0.116
Total	567		1.10	0.139

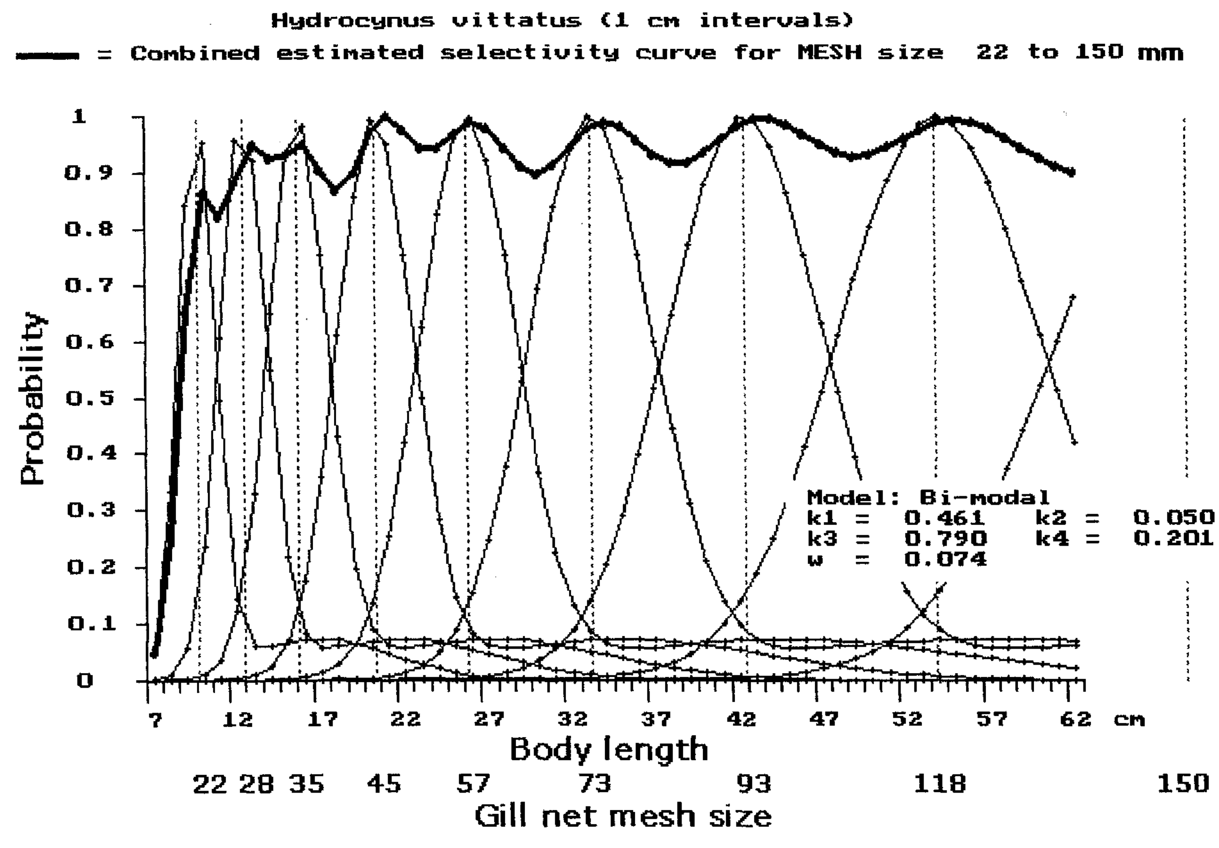

Figure 5.14. *Gill net selectivity curves for tigerfish* (H. vittatus) *for each mesh size from 22 mm to 150 mm and combined estimated selectivity curve for all mesh sizes.*

larger than minimum mature size is 45 mm. This mesh size has maximum catchability at a fish length of approximately 21 cm, while fish between 13 to 57 cm are also caught (**Figure 5.14**). To avoid catching a large proportion of immature tigerfish, a mesh size of 93 mm should be used. This mesh size catches fish between 27 and 62 cm and has highest catchability on fish with a length of approximately 43 cm.

Striped robber (*Brycinus lateralis*)
Striped robber occurs in the Okavango, Zambezi and Cunene Rivers. It grows to 14 cm, and migrates upstream and possibly spawns in rainy season. It shoals in slow flowing or quiet, vegetated waters. It is caught in subsistence fisheries and is also used as bait for tigerfish. In the Okavango, the minimum lengths at maturity were found to be 5 cm for males and 6 cm for females (**Table 5.8**). Corresponding lengths at 50 % maturation were 7.0 and 7.4 cm.

This species is very common in gill net catches in the Okavango. A total of 1384 fishes between 4 to 15 cm (mean 9.0 cm) were caught during this investigation (**Figure 5.4**). The modal length of fish caught in gill nets was 8.0–8.9 cm, which is well above minimum length at maturity. Eight hundred and ninety-six fishes between 1 and 12 cm (mean 4.9 cm), with a modal length of 4.0–4.9 cm, were caught in other gears. The highest number of striped robber per setting was caught in gill net mesh size 22 mm (**Table 5.19**). Fish caught with this mesh size has an average length of 8.4 cm, which is longer than minimum mature size and length at maturity (**Table 5.8**). Gill nets with a mesh size of 28 mm have highest catches in weight per setting, estimated to 0.25 kg. Average length of fish on this mesh size is 10.1 cm.

Striped robber is a small-bodied fish (**Figure 5.4**), and only the 22 and 28 mm mesh sizes catch them in any number. However, catchability of this species is also quite high in 35 mm nets (**Figure 5.15**). With a minimum mature size of 5-6 cm, even the 22 mm nets mainly catch mature striped robber. The 22 mm nets catch fish from 6 to 12 cm, with maximum catchability on a fish length of approximately 8.5 cm. The 28 mm nets catch fish from 7.5 to 14 cm, with maximum catchability on a fish length of approximately 10.5 cm. This mesh size only catches mature striped robber. The 35 mm nets catch fish from approximately 10 cm, with maximum catchability on a fish length of approximately 13.5 cm.

Schilbeidae

Silver catfish (*Schilbe intermedius*)
Silver catfish is widely distributed in Sub-Saharan Africa. It may reach 30 cm in length and weigh 1.3 kg. Generally it is found to mature sexually at approximately16 cm, and it breeds in the rainy season. It may live to 6-7 yrs. It lives in standing or slow flowing waters, often shoaling. The varied diet may include fish, invertebrates, plant seeds and fruits. The silver catfish is important in subsistence fisheries and is also subject to angling. It is the seventh most important species in the subsistence fisheries in the Okavango (**Table 5.7**). In this investigation, the minimum lengths at maturity for silver catfish were found to be 9 cm for males and 10 cm for females (**Table 5.8**). Corresponding lengths at 50 % maturation were 12.4 and 11.2 cm.

Silver catfish is the most important species in gill net catches in the Okavango. A total of 3 361 fishes with body lengths between 7 and 31 cm (mean 14.2 cm), and a modal length of 13.0–13.9 cm were caught during our survey (**Figure 5.4**). In other gears, 605 fishes between 1 and 22 cm (mean 7.4 cm) and a modal length of 7.0–7.9 cm were caught. The most effective gill net mesh size for this species in terms of number of fish per setting is 28 mm (**Table 5.20**). Mean length of fish caught in this mesh size is 11.6 cm, which is larger than the minimum length at maturity for this species (**Table 5.8**). CPUE in terms of weight of fish per gill net setting, however, is highest (0.67 kg) in mesh size 57 mm. Mean length of fish caught in this mesh size is 21.3 cm, which is well above minimum mature size. Mesh sizes of 35 mm and 45 mm are most efficient for fish with a length of approximately 14.5 cm and 18.5 cm, respectively.

Figure 5.16 shows that the gill net series used here (mesh sizes from 22 mm to 150 mm) efficiently catch silver catfish above approximately 9 cm in length. Few fish longer than 23-24 cm were caught, and mesh sizes of 93 mm and larger rarely catch this species, mainly because this species rarely reaches this size.

Mochokidae

Spotted squeaker (*Synodontis nigromaculatus*)
Spotted squeaker lives in the Okavango and Zambezi Rivers as well as in the Congo Basin and Lake Tanganyika. It grows to 30 cm and 0.3 kg, and breeds during the rainy season. Spotted squeaker lives in rocky areas or marginal vegetated habitats in running water where it feeds on detritus, plants, invertebrates and fish. It is caught in subsistence fisheries. In the Okavango, the minimum lengths at maturity were found to be 12 cm for males and 11 cm for females (**Table 5.8**). Corresponding lengths at 50 % maturation were 13.3 and 16.0 cm.

A total of 1165 fishes with body lengths from 7 to 25 cm (mean 15.2 cm) were caught in gill nets (**Figure 5.4**). The modal length in gill net catches was 15.0–15.9 cm, which is longer than the minimum length at maturity (11-12 cm). In other gears, 169 fishes from 2 to 18 cm in length (mean 7.8 cm) and modal length 7.0–7.9 cm were caught.

Table 5.19. *Gill net selectivity for striped robber* (B. lateralis) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	674	8.4	19.63	0.157
28	600	10.1	16.70	0.249
35	107	11.4	1.77	0.044
45	1	14.0	0.01	0.000
57	2	10.2	0.04	0.001
Total	1 384		3.49	0.042

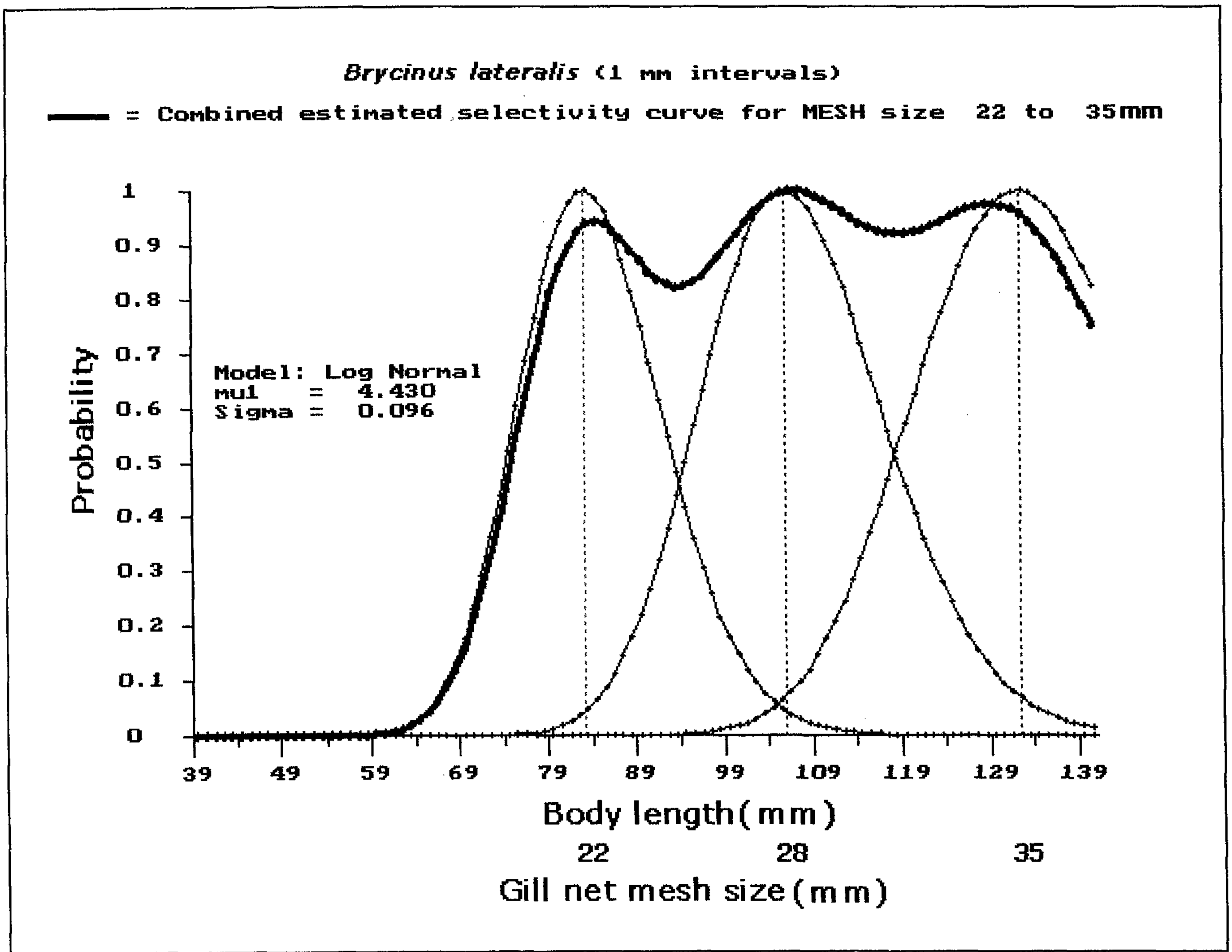

Figure 5.15. *Gill net selectivity curves for striped robber* (B. lateralis) *for each mesh size from 22 mm to 35 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.20. *Gill net selectivity for silver catfish* (S. intermedius) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	523	9.4	19.76	0.160
28	713	11.6	22.94	0.393
35	1 106	14,1	16.07	0.562
45	627	17.9	8.70	0.618
57	328	21.4	5.56	0.672
73	50	24.9	0.86	0.166
93	4	22.8	0.07	0.011
Total	3 361		7.51	0.288

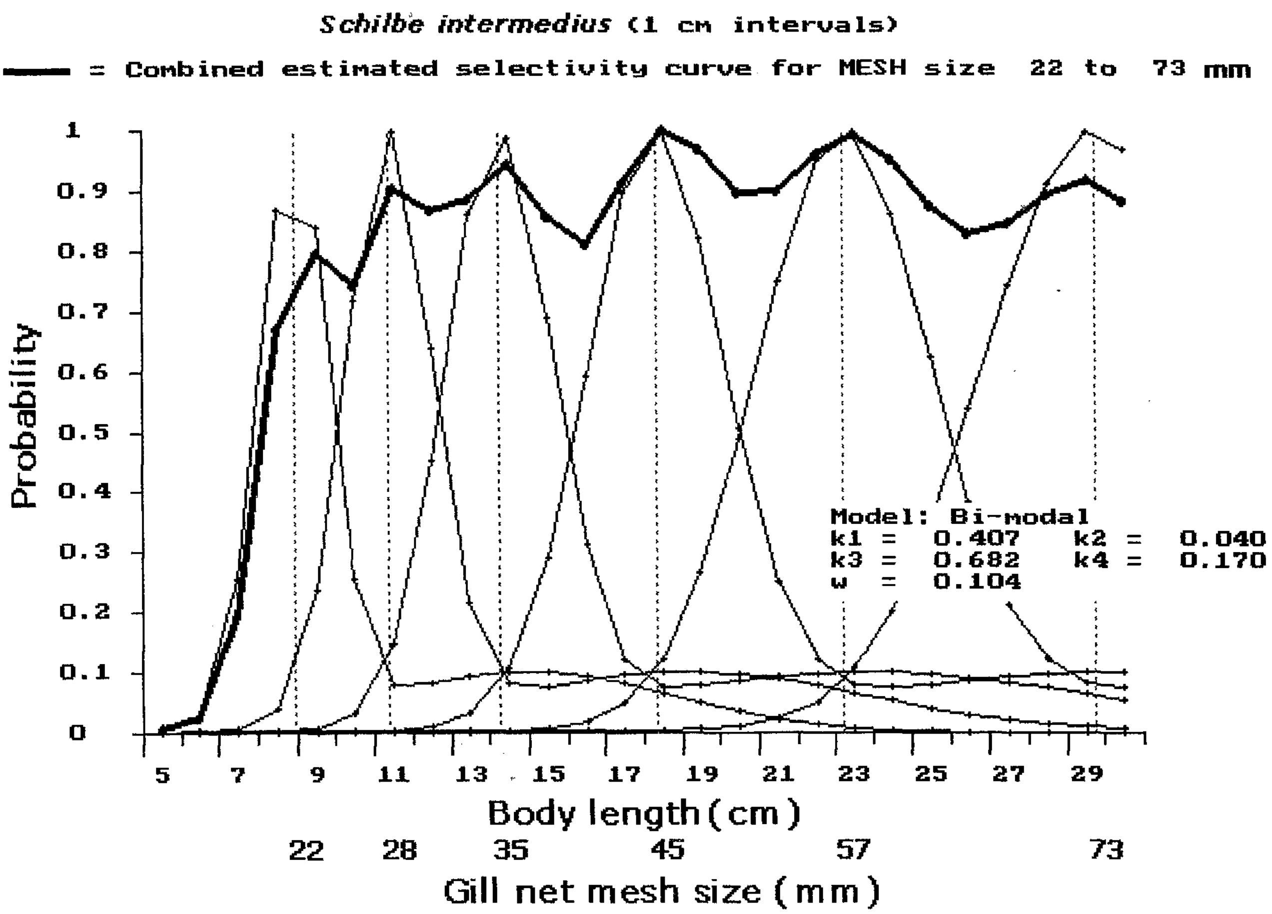

Figure 5.16*. Gill net selectivity curves for silver catfish* (S. intermedius) *for each mesh size from 22 mm to 73 mm and combined estimated selectivity curve for all mesh sizes*

The highest number of spotted squeakers per setting was caught in 45 mm mesh size (**Table 5.21**). These fish have an average length of 15.9 cm, which is well above minimum length at maturity (**Table 5.8**). This mesh size also has the highest catch in weight per setting, estimated to 0.31 kg. This species is efficiently caught only in the mesh sizes 35-57 mm (**Figure 5.17**). The fact that the smaller mesh sizes (22 and 28 mm) has a somewhat lower catchability is probably due to the body form of the fish. To ensure that the majority of fish caught are mature (i.e. larger than 11–12 cm), a mesh size of mimimum 35 mm should be used. This mesh size catches fish between 6 and 25 cm with maximum catchability on a fish length of approximately 13.5 cm.

Cyprinodontidae

Johnston's topminnow (*Aplocheilichthys johnstoni*)
Johnston's topminnow occurs in the Cunene, Okavango and Zambezi Rivers. It grows to about 5 cm. It prefers standing or slow flowing waters in river backwaters, floodplains or swamps with vegetated areas, often in very shallow waters, feeding on small invertebrates. It is an aquarium species and is also used in mosquito control. In the Okavango, this species was only caught in other gears. A total of 925 fishes with body lengths from 1 to 6 cm and average length of 2.5 cm were caught. The modal length of these fishes was 3.0–3.9 cm. No mature fish of this species were recorded (**Table 5.8**).

Distichodontidae

Dwarf citharine (*Hemigrammocharax machadoi*)
Dwarf citharine occurs in the Cunene, Okavango and Zambezi Rivers. It grows to about 4 cm and breeds during the summer. It lives in clear, quiet, vegetated areas where it feeds on periphyton and small invertebrates on water plants. It is an attractive aquarium species. It is the eighth most important species in the subsistence fisheries in Okavango (**Table 5.7**). This species was only caught in other gears. A total of 234 fishes with body lengths from 1 to 13 cm and average length of 2.1 cm were caught. The modal length of these fishes was 2.0–2.9 cm. No mature fish were recorded (**Table 5.8**).

Clariidae

Sharptooth catfish (*Clarias gariepinus*)
Sharptooth catfish is probably the most widespread fish species in Africa. It may reach 1.4 m in length and 59 kg in weight and occurs in almost any habitat, but prefers floodplains, large sluggish rivers, lakes and dams where it feeds on virtually any available organic food source. It is an important angling and food fish species. In the Okavango, the minimum lengths at maturity were 40 cm for males and 38 cm for females (**Table 5.8**). Corresponding lengths at 50 % maturation were 43.7 and 40.5 cm.

In gill nets, 110 fishes from 16 to 80 cm (mean 46.6 cm) and a modal length of 45.0–45.9 cm were caught. In other gears, the total catch was 97 fishes with body lengths between 5 and 76 cm (mean 18.4 cm) and a modal length of 9.0–9.9 cm. This shows that the small and juvenile sharptooth catfish live in shallow and vegetated habitats, whereas the larger fish live in deeper waters. The gill nets catch a large proportion of mature fish. The mesh size catching the highest number of sharptooth catfish per setting is 93 mm (**Table 5.22**). Fish caught with this mesh-size have an average length of 48.7 cm, which is longer than the minimum mature size of 38-40 cm (**Table 5.8**). The 93 mm nets also have the highest catch in terms of weight per setting, estimated to 0.70 kg. Sharptooth catfish is efficiently caught with gill net mesh sizes from 45 to 118 mm, whereas 35 and 150 mm nets are somewhat less efficient (**Figure 5.18**). Twenty-two and 28 mm nets only very rarely catch this species. All mesh sizes used in this investigation will catch some immature sharptooth catfish.

Hepsetidae

African pike (*Hepsetus odoè*)
African pike occurs in the Cunene, Okavango and Zambezi Rivers and is also widespread through central Congo and West Africa. It may reach 47 cm and about 2.0 kg and breeds during the summer months. It prefers quiet, deep water in channels and lagoons of large floodplains where it feeds on fish. Juveniles inhabit vegetated marginal habitats where they feed on small invertebrates and fish. It is an angling species and is also taken in subsistence fisheries. In the Okavango, the minimum mature lengths of this species were 28 cm for males and 27 cm for females (**Table 5.8**). The length at 50 % maturation was 27.7 cm for both males and females.

A total of 415 African pike were caught in gill nets during this investigation. The length varied between 5 and 44 cm (mean 19.9 cm), and the modal length was 17.0–17.9 cm. Only 28 fishes were caught in other gears. These fish were smaller, with body lengths from 2 to 29 cm (mean 14.4 cm) and modal length of 15.0–15.9 cm, respectively. Both gear types catch a large proportion of fish smaller than the minimum length at maturity (27-28 cm) (**Table 5.8**).

The gill net mesh sizes used here efficiently catch African pike between approximately 11 and 33 cm in length (**Figure 5.19**). The most effective gill net mesh size for African pike in terms of number of fish per setting is 35 mm (**Table 5.23**). Fish caught with this mesh size have an average length of 17.4 cm, which is smaller than minimum length at maturity (27-28 cm)

Table 5.21. *Gill net selectivity for spotted squeaker* (S. nigromaculatus) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	22	15.8	0.32	0.018
28	71	15.2	1.07	0.055
35	474	14.8	5.24	0.241
45	486	15.9	5.87	0.305
57	75	18.0	1.19	0.096
73	21	17.6	0.24	0.019
93	5	15.5	0.04	0.003
118	10	15.1	0.09	0.004
150	1	19.2	0.01	0.001
Total	1 165		1.61	0.085

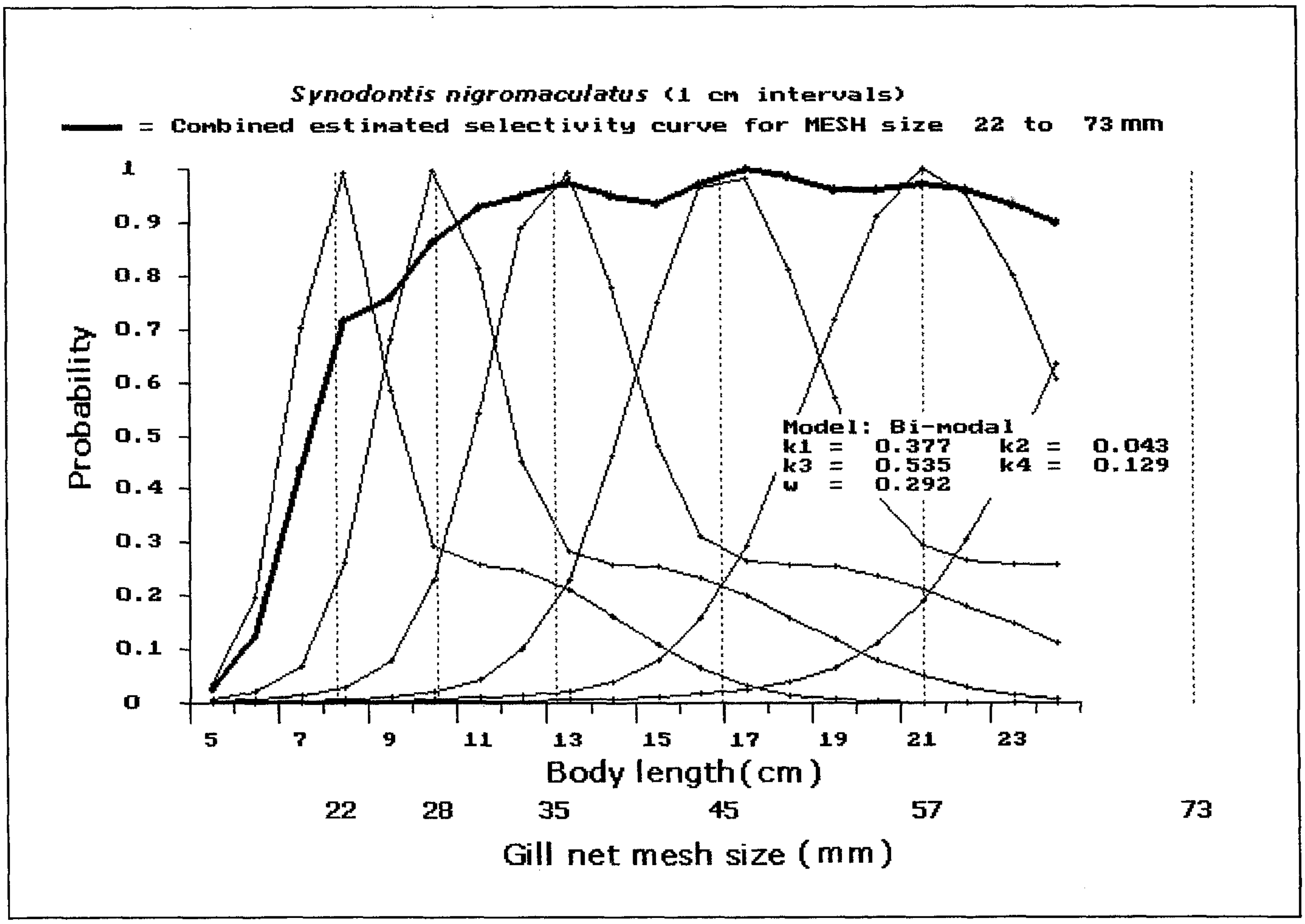

Figure 5.17. *Gill net selectivity curves for spotted squeaker* (S. nigromaculatus) *for each mesh size from 22 mm to 73 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.22. *Gill net selectivity for sharptooth catfish* (C. gariepinus) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	1	16.5	0.03	0.001
28				
35	2	20.0	0.04	0.002
45	5	24.4	0.13	0.016
57	7	28.2	0.13	0.026
73	22	40.3	0.42	0.269
93	42	48.7	0.69	0.702
118	23	54.2	0.33	0.470
150	8	72.2	0.09	0.229
Total	110		0.22	0.201

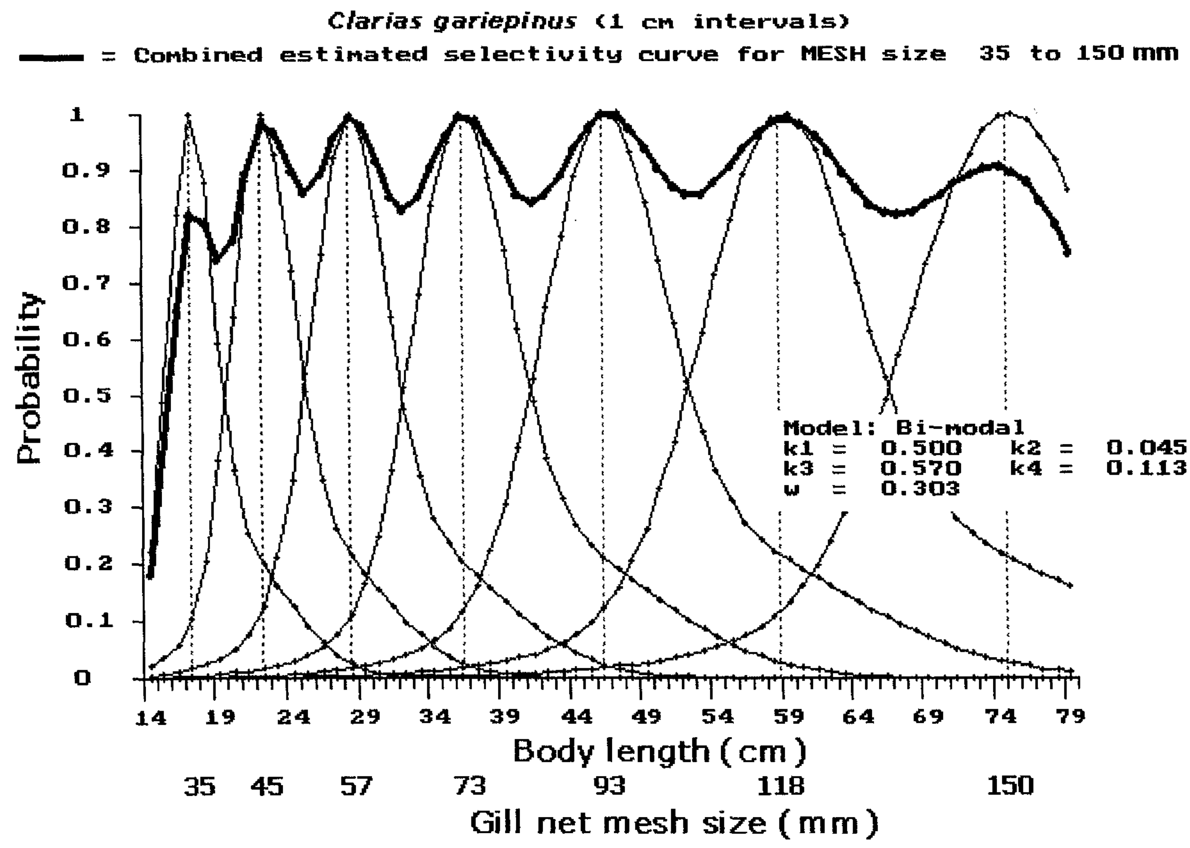

Figure 5.18. *Gill net selectivity curves for sharptooth catfish* (C. gariepinus) *for each mesh size from 35 mm to 150 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.23. *Gill net selectivity for African pike* (H. odoe) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	9	11.8	0.31	0.007
28	46	15.1	1.53	0.070
35	164	17.4	2.26	0.140
45	108	20.9	1.16	0.132
57	66	25.8	0.97	0.223
73	20	32.5	0.32	0.143
93	2	31.0	0.04	0.016
118				
Total	415		0.72	0.083

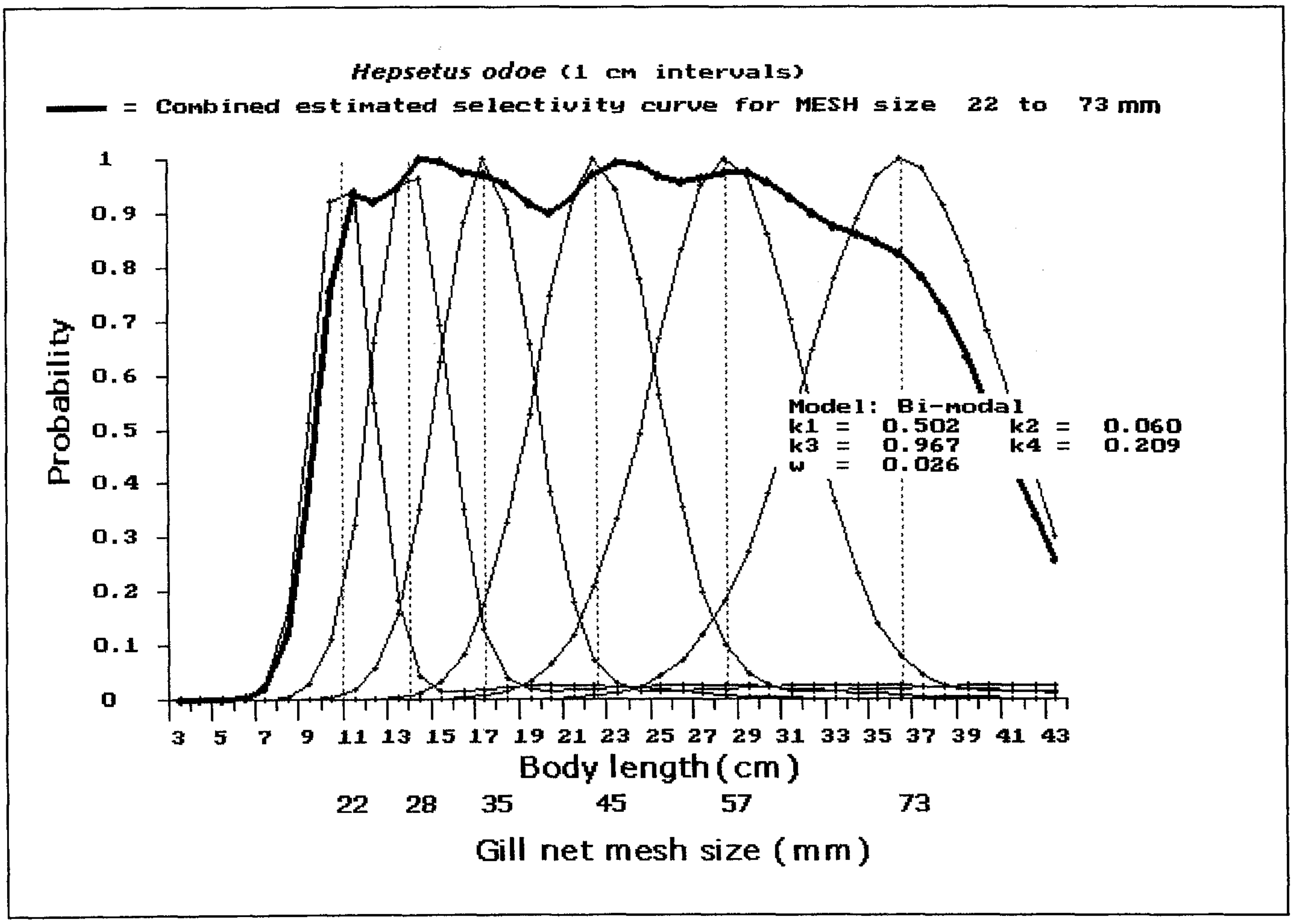

Figure 5.19. *Gill net selectivity curves for African pike* (H. odoe) *for each mesh size from 22 mm to 73 mm and combined estimated selectivity curve for all mesh sizes.*

(**Table 5.8**). Gill nets with a mesh size of 57 mm have highest catches in weight per setting, estimated to 0.22 kg. Average length of fish on this mesh size is 25.8 cm. This is also smaller than observed minimum mature size in our material, but larger than the mature size given by Skelton (1993), i.e. 20 cm in males and 25 cm in females.

5.3.7 Angling species in the Okavango River: life history and gill net selectivity

In the Okavango River, 25 species have been defined as potential angling species, mainly due to their body size (**Table 5.24**). The maximum size of these species range from 10 cm (*Hemichromis elongatus*) to 79 cm (*Clarias gariepinus*) and the average size ranges from 13 cm (*Labeo cylindricus*) to 47 cm (*Clarias gariepinus*) in gill net catches and 6 cm (*Tilapia rendalli*) to 19 cm (*Clarias gariepinus*) in catches with other gears. Nine of the 25 angling species are among the 21 selected species listed in **Table 5.7**.

Cyprinidae

Upper Zambezi yellowfish (*Barbus codringtonii*)
Upper Zambezi yellowfish occurs in the Okavango and upper Zambezi Rivers. It may reach 39 cm and about 3.2 kg and breeds in spring and summer. It prefers flowing water where it feeds on a wide variety of food items as algae, larvae of aquatic insects, small fishes, snails, freshwater mussels and drifting organisms. In the Okavango, this species was not caught in gill nets. Only four fishes with body lengths from 9 to 13 cm (mean 11.2 cm) were caught in other gears. No mature fish of this species were recorded (**Table 5.24**).

Table 5.24. *Potential angling species from the Okavango River, and the size of these species caught in gill nets and other gears during the period 1992-99.*

Species	Total number caught	Average size Gill nets	Average size Other gear	Size range in all gears min	Size range in all gears max	Minimum size at maturity min	Minimum size at maturity max
Barbus codringtonii	4	-	112	93	125	-	-
Labeo cylindricus	1 558	128	78	10	200	8	11
Labeo lunatus	111	191	137	38	475	31	21
Hydrocynus vittatus	834	184	108	20	620	18	27
Marcusenius macrolepidotus	2 505	126	111	42	225	10	10
Mormyrus lacerda	170	273	174	45	360	16	23
Hepsetus odoe	445	201	147	20	430	28	27
Parauchenoglanis ngamensis	94	147	109	50	185	13	11
Schilbe intermedius	4 496	144	75	17	300	9	10
Clariallabes platyprosopos	33	-	164	40	300	27	21
Clarias gariepinus	207	467	186	50	790	40	38
Clarias ngamensis	165	399	155	76	730	34	47
Synodontis sp.	6 287	133	63	10	250	12	9
Synodontis nigromaculatus	1 361	156	80	25	240	12	11
Hemichromis elongatus	8	-	68	37	97	-	-
Oreochromis andersonii	355	293	95	28	500	13	26
Oreochromis macrochir	399	140	85	10	325	-	8
Serranochromis altus	31	205	148	72	441	15	28
Serranochromis angusticeps	106	212	78	30	462	16	20
Serranochromis macrocephalus	506	190	81	10	335	17	15
Serranochromis robustus	237	207	89	30	480	27	19
Serranochromis thumbergi	7	125	68	58	130	-	-
Sargochromis carlottae	79	151	127	80	300	10	12
Sargochromis codringtonii	245	136	97	30	270	15	10
Sargochromis giardi	50	210	121	60	450	-	22
Tilapia rendalli	1 596	224	62	11	375	11	14

Upper Zambezi labeo (*Labeo lunatus*)
Upper Zambezi labeo occurs in the Okavango and upper Zambezi Rivers. It may reach 40 cm and about 2.5 kg and breeds during the summer months. It occurs among rocks in the mainstream and in large softbottom floodplain lagoons where it grazes on algae and detritus. It is a shoaling species and is also taken in subsistence fisheries. In the Okavango, minimum mature lengths for this species were 31 cm for males and 21 cm for females (**Table 5.24**). A total of 102 fishes with body lengths from 11 to 48 cm (mean 19.1 cm) and a modal length of 16.0–16.9 cm were caught in gill nets. Only nine fishes from 3 to 25 cm (mean 13.7 cm) in length were caught in other gears.

The most effective gill net mesh size for Upper Zambezi labeo in terms of number of fish per setting is 45 mm (**Table 5.25**). Fish caught with this mesh size have an average length of 17.3 cm, which is smaller than minimum length at maturity (**Table 5.24**). Gill nets with a mesh size of 45 mm also have the highest catches in weight per setting, estimated to 0.063 kg. The gill net mesh sizes used in this invesitgation efficiently catch Upper Zambezi labeo between approximately 15 and 36 cm in length (**Figure 5.20**). The 73 and 93 mm nets catch mainly mature fish (larger than 21 cm), with maximum catchability at approximately 29 and 37 cm, respectively.

Mormyridae

Western bottlenose (*Mormyrus lacerda*)
Western bottlenose occurs in the Cunene, Okavango, upper Zambezi and Kafue Rivers. It may reach 50 cm and about 2.0 kg and breeds during the summer months. It prefers quiet stretches of river channels, deep pools and floodplain lagoons with aquatic vegetation where it feeds mainly on insect larvae, shrimps, small snails and small fish. It may form small shoals and is caught in subsistence fisheries and by anglers. In the Okavango, the minimum mature lengths of this species were 16 cm for males and 23 cm for females (**Table 5.24**). In gill nets, 36 fishes ranging in length from 15 to 37 cm (mean 27.3 cm), with modal length 27.0–27.9 cm, were caught. In other gears, 134 fishes from 4 to 30 cm (mean 17.4 cm), with modal length 14.0–14.9 cm, were caught.

The most effective gill net mesh size for western bottlenose in terms number of fish per setting is 73 mm (**Table 5.26**). Fish caught with this mesh size have an average length of 29.9 cm, which is larger than minimum length at maturity (**Table 5.24**). Gill nets with a mesh size of 73 mm also have the highest catches in weight per setting, estimated to 0.096 kg. The gill net mesh sizes used here efficiently catch western bottlenose from approximately 19 cm in length (**Figure 5.21**). The 57, 73 and 93 mm nets catch mainly mature fish (larger than 16 cm), with maximum catchability at approximately 19, 24 and 31 cm, respectively.

Claroteidae

Zambezi grunter (*Parauchenoglanis ngamensis*)
Zambezi grunter occurs in the Okavango and upper Zambezi Rivers and also the Kasai River in the Congo system. It may reach 38 cm. It produces relatively few large eggs, suggesting parental care, but no details are known. It prefers rocky habitat or marginal vegetation in slow flowing rivers and lagoons, often sheltering under trees. It feeds on small fishes and invertebrates such as snails, shrimps and insects. It is a potential aquarium species.

In the Okavango, the minimum mature lengths were 13 cm for males and 11 cm for females (**Table 5.24**). In gill nets, 28 fishes with body lengths from 8 to 19 cm (mean 14.7 cm) and a modal length of 13.0–13.9 cm were caught. In other gears, 66 fishes from 5 to 17 cm (mean 10.9 cm) and the same modal length were caught. The most effective gill net mesh size for western bottlenose in terms of number of fish per setting is 28 mm (**Table 5.27**). Fish caught with this mesh size have an average length of 13.5 cm, which is larger than minimum length at maturity (**Table 5.24**). Gill nets with a mesh size of 28 mm also have the highest catches in weight per setting, estimated to 0.011 kg. The gill net mesh sizes used here efficiently catch western bottlenose from approximately 12 cm in length (**Figure 5.22**). The 35 and 45 mm nets catch mainly mature fish (larger than 13 cm). These nets catch fish larger than 8 cm, with maximum catchability at approximately 15 cm in the 35 mm net. No fish were caught in gill nets with larger mesh sizes.

Clariidae

Broadhead catfish (*Clariallabes platyprosopos*)
Broadhead catfish occurs in the Okavango and upper Zambezi Rivers. It may reach 28 cm and the angling record in Zimbabwe is 0.128 kg. It occurs in rocky rapids of large rivers and is known to feed on fish. It is occasionally caught by anglers. In the Okavango, this species was not caught in gill nets. A total of 33 fishes with body lengths from 4 to 31 cm and average length of 16.4 cm were caught in other gears. The modal length of these fishes were 10.0–10.9 cm. The minimum lengths at which this species matured were found to be 27 and 21 cm for the males and females, respectively (**Table 5.24**).

Blunttooth catfish (*Clarias ngamensis*)
Blunttooth catfish occurs in the Cunene, Okavango, Zambezi, Kafue, Save, Limpopo and Phongolo Rivers. It also occurs in the Zambian Congo system and the Cuanza in Angola. It may reach 73 cm and about 4.0 kg

Table 5.25. *Gill net selectivity for Upper Zambezi labeo* (L. lunatus) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
28	1	11.0	0.01	0.0002
35	29	14.6	0.31	0.018
45	42	17.3	0.71	0.063
57	13	23.0	0.20	0.041
73	12	25.1	0.12	0.036
93	5	36.8	0.04	0.036
Total	102		0.16	0.023

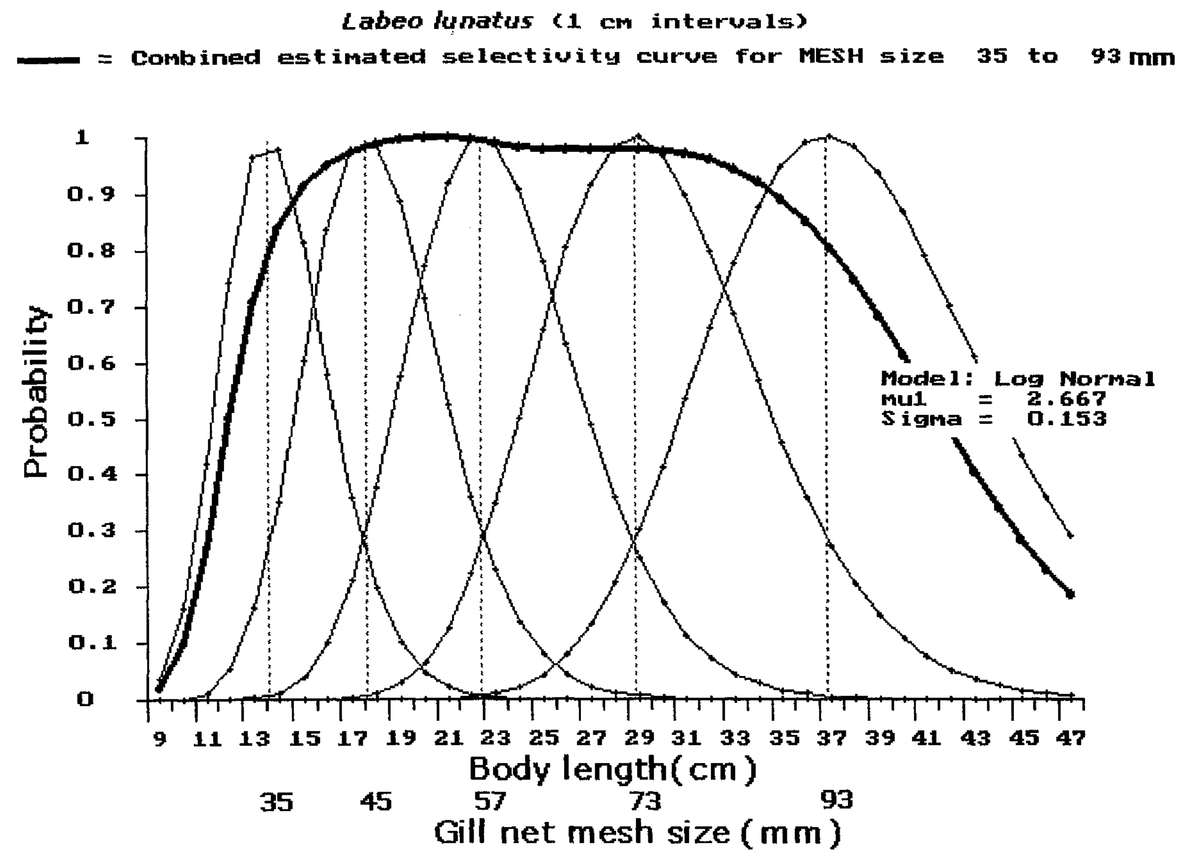

Figure 5.20*. Gill net selectivity curves for Upper Zambezi labeo* (L. lunatus) *for each mesh size from 35 mm to 93 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.26. *Gill net selectivity for western bottlenose* (M. lacerda) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
35	1	15.0	0.01	0.0003
45	6	19.2	0.07	0.007
57	7	24.5	0.17	0.024
73	18	29.9	0.34	0.096
93	4	35.4	0.05	0.030
Total	36		0.07	0.018

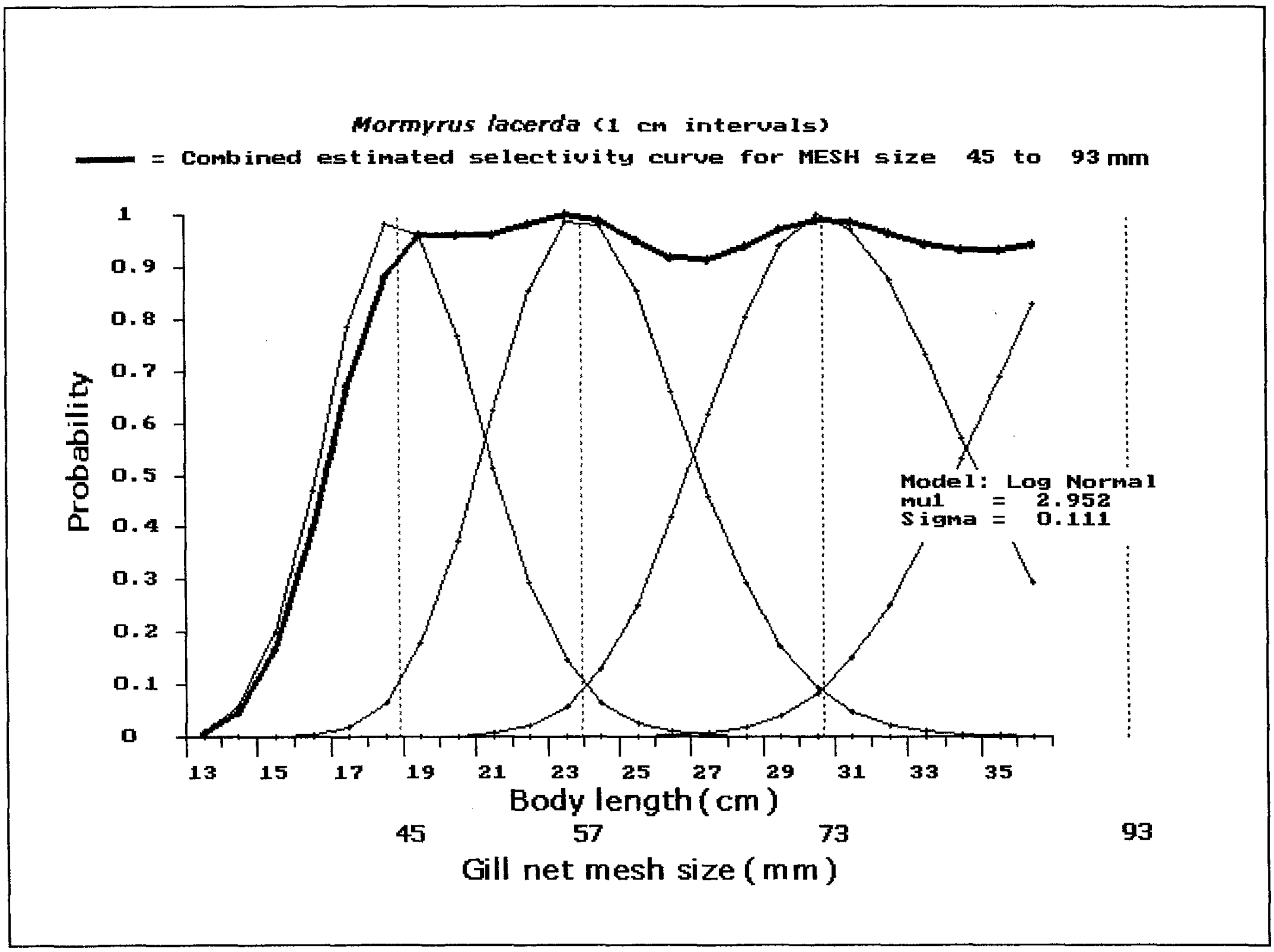

***Figure 5.21**. Gill net selectivity curves for western bottlenose* (M. lacerda) *for each mesh size from 45 mm to 93 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.27. *Gill net selectivity for Zambezi grunter* (P. ngamensis) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	3	12.0	0.08	0.003
28	11	13.5	0.38	0.011
35	6	15.8	0.12	0.006
45	8	16.5	0.09	0.004
Total	28		0.07	0.002

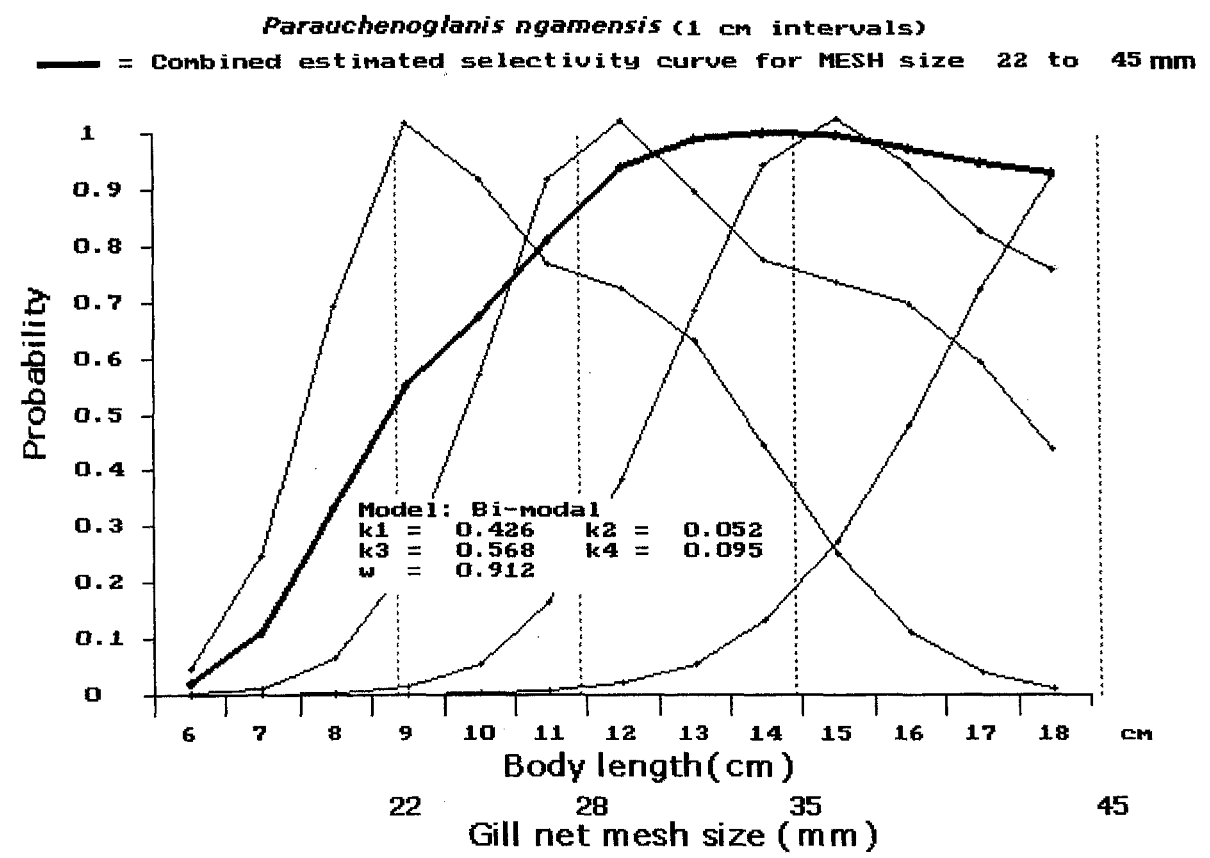

Figure 5.22. *Gill net selectivity curves for Zambezi grunter* (P. ngamensis) *for each mesh size from 22 mm to 45 mm and combined estimated selectivity curve for all mesh sizes.*

and breeds during the summer rainy season. It prefers vegetated habitats in swamps and riverine floodplains and is often found together with the sharptooth catfish. It feeds on molluscs, terrestrial and aquatic insects, shrimps, crabs and snails. It is an important species in subsistence and commercial floodplain fisheries.

In the Okavango, the minimum mature lengths were 34 cm for males and 47 cm for females (**Table 5.24**). The gill net catches of 44 fishes ranged from 20 to 74 cm (mean 39.9 cm), with a modal length of 26.0–26.9 cm. In other gears, 121 fishes from 7 to 48 cm (mean 15.5 cm) and modal length 11.0–11.9 cm, were caught. The most effective gill net mesh size for blunttooth catfish in terms of number of fish per setting is 73 mm (**Table 5.28**). Fish caught with this mesh size have an average length of 37.6 cm, which is about the same as minimum length at maturity (**Table 5.24**). Gill nets with a mesh size of 93 mm have the highest catches in weight per setting, estimated to 0.139 kg. The gill net mesh sizes used here efficiently catch blunttooth catfish from approximately 22 cm in length (**Figure 5.23**). The 93 and 118 mm nets catch mainly mature fish. These nets catch fish larger than 22 cm, with maximum catchability at approximately 49 and 62 cm, respectively.

Cichlidae

Banded jewelfish (*Hemichromis elongatus*)
Banded jewelfish occurs in the Okavango and upper Zambezi Rivers and is also widespread through the Congo basin to tropical West Africa. It may reach 19 cm and breeds in early summer. It occurs in littoral riverine habitats and permanent floodplain lagoons with clear water and is known to feed on shrimps, insects and small fishes. It is an occasional aquarium fish and is also taken in small numbers in subsistence fisheries. In the Okavango, this species was not caught in gill nets. A total of 8 fishes with body lengths from 3 to 10 cm and average length of 6.8 cm were caught in other gears. None of these fish were sexually mature (**Table 5.24**).

Threespot tilapia (*Oreochromis andersonii*)
Threespot tilapia occurs in the Cunene, Okavango, upper Zambezi and Kafue Rivers and is occasionally recorded from the middle Zambezi. It may reach 45 cm and about 3.2 kg, and multiple broods are raised during the warmer months. It prefers slow-flowing or standing water such as in pools, backwaters and floodplain lagoons. Adults occupy deep open waters, while juveniles remain inshore among vegetation. It feeds on detritus, diatoms and zooplankton. It is an important species in aquaculture and fisheries, and it is also a popular angling species.

In the Okavango, the minimum mature lengths were 13 cm for males and 26 cm for females (**Table 5.24**). The gill net catches of 33 fishes ranged from 10 to 45 cm (mean 29.3 cm) in length, with a modal value of 22.0–22.9 cm. In other gears, 322 fishes with body lengths from 2 to 51 cm (mean 9.5 cm) and a modal length of 7.0–7.9 cm were caught. The most effective gill net mesh size for threespot tilapia in terms of number of fish per setting is 93 mm (**Table 5.29**). Fish caught with this mesh size average 23.3 cm in length, which is about the same as minimum length at maturity (**Table 5.24**). Gill nets with a mesh size of 150 mm have the highest catches in weight per setting, estimated to 0.178 kg. Fish caught with this mesh size have an average length of 39.0 cm. The gill net mesh sizes used in this investigation efficiently catch threespot tilapia from approximately 12 cm in length (**Figure 5.24**). The 118 and 150 mm nets catch mainly mature fish, i.e. larger than 16 cm, with maximum catchability at approximately 30 and 38 cm, respectively.

Greenhead tilapia (*Oreochromis macrochir*)
Greenhead tilapia occurs in the Cunene, Okavango, upper Zambezi and Kafue Rivers, as well as Lake Kariba, the Busi River and in the Zambian Congo system and southern tributaries of the Congo. It may reach 40 cm, and the angling record in Zimbabwe is 2.6 kg. It breeds in summer. It prefers quiet waters along river margins and backwaters, in floodplain habitats and impoundments where it feeds on microscopic foods, such as algae and detritus taken from the bottom. Juveniles live close inshore in shallow water and feed more on zooplankton and insect larvae. It is an important species in aquaculture and fisheries, and it is also a popular angling species.

The minimum mature lengths in the Okavango were 8 cm for females; no mature males were recorded (**Table 5.24**). Only eight fishes ranging from 5 to 28 cm (mean 14.0 cm, modal length 8.0–8.9 cm) were caught in gill nets. A total of 391 fishes with body lengths from 1 to 33 cm (mean 8.5 cm; modal length 8.0–8.9 cm) were caught in other gears. The number of greenhead tilapia caught is too few to say anything specific about gill net selectivity for this species.

Humpback largemouth (*Serranochromis altus*)
Humpback largemouth occurs in the Okavango, upper Zambezi and Kafue Rivers. It may reach 41 cm and about 2.0 kg and breeds in early summer before rains. It is found close to marginal vegetation of river channels or deep connected lagoons where it primarily preys on fish such as mormyrids and butter barbels. It is an angling species.

In the Okavango, the minimum mature lengths were 15 cm for males and 28 cm for females (**Table 5.24**). The gill net catches of 25 fishes ranged from 9 to 45 cm (mean 20.5 cm, modal length 16.0–16.9 cm). Only 6 fishes with body lengths 7–31 cm (mean 14.8 cm) were caught in other gears. The most effective gill net mesh size for humpback largemouth in terms of number of fish per setting is 57 mm (**Table 5.30**). Fish caught with this mesh size have an average length of 18.2 cm, which is longer than minimum length at maturity for males (**Table 5.24**). Gill nets with a mesh size of 93 mm have the highest catches in weight per setting, estimated to 0.025 kg. Fish caught with this mesh size have an average length of 27.9 cm, which is the same as the minimum length at maturity for females. The gill net mesh sizes used here efficiently catch humpback largemouth from approximately 11 cm in length (**Figure 5.25**). The 118 and 150 mm nets catch mainly mature

Table 5.28. *Gill net selectivity for blunttooth catfish* (C. ngamensis) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
35	2	28.5	0.04	0.006
45	1	56.1	0.03	0.058
57	11	28.3	0.11	0.020
73	14	37.6	0.23	0.101
93	11	47.3	0.17	0.139
118	5	56.8	0.08	0.123
Total	44		0.08	0.052

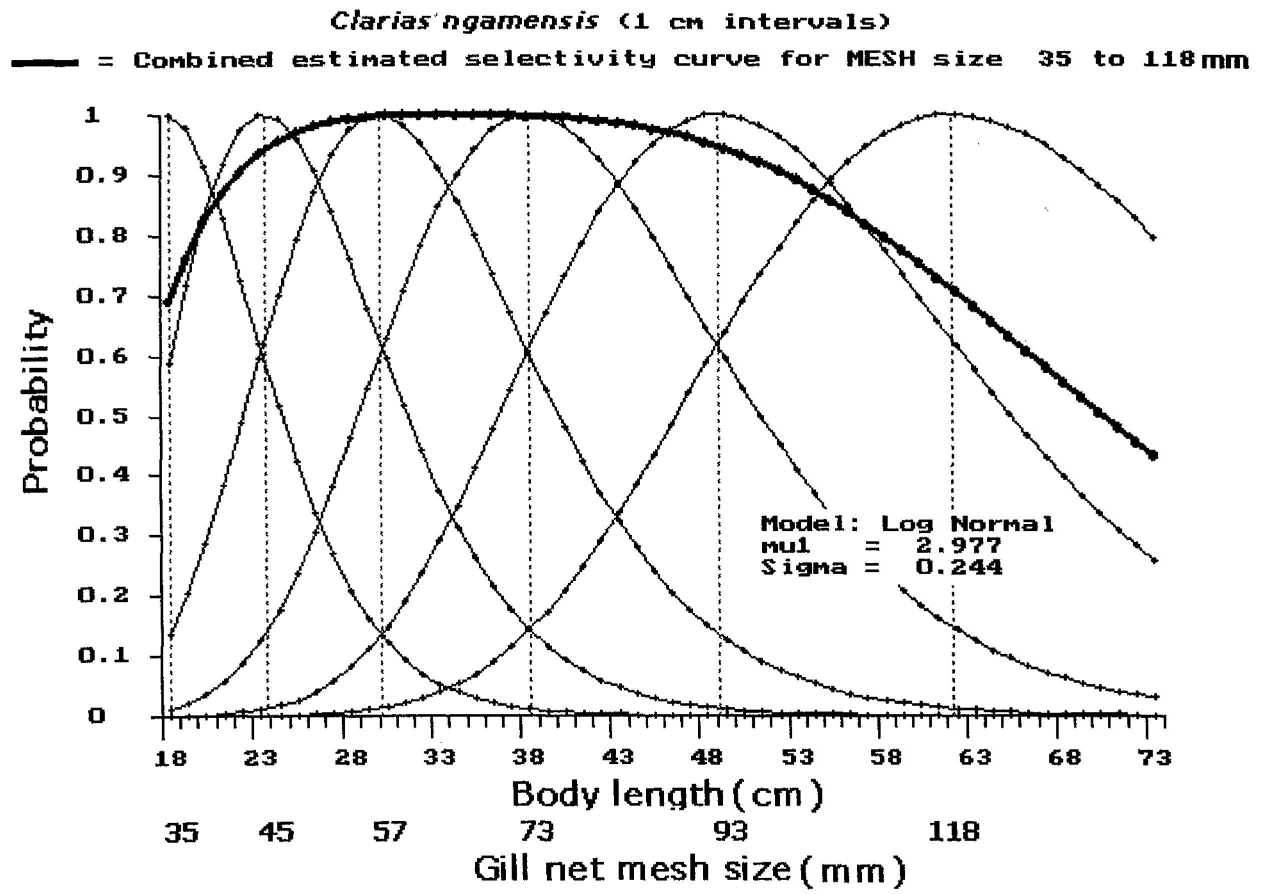

Figure 5.23. *Gill net selectivity curves for blunttooth catfish* (C. ngamensis) *for each mesh size from 35 mm to 118 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.29. Gill net selectivity for threespot tilapia (O. andersonii) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
45	2	10.9	0.04	0.0007
57	2	12.8	0.04	0.001
73	1	41.0	0.03	0.026
93	8	23.3	0.21	0.050
118	9	29.1	0.19	0.093
150	11	39.0	0.17	0.178
Total	33		0.08	0.041

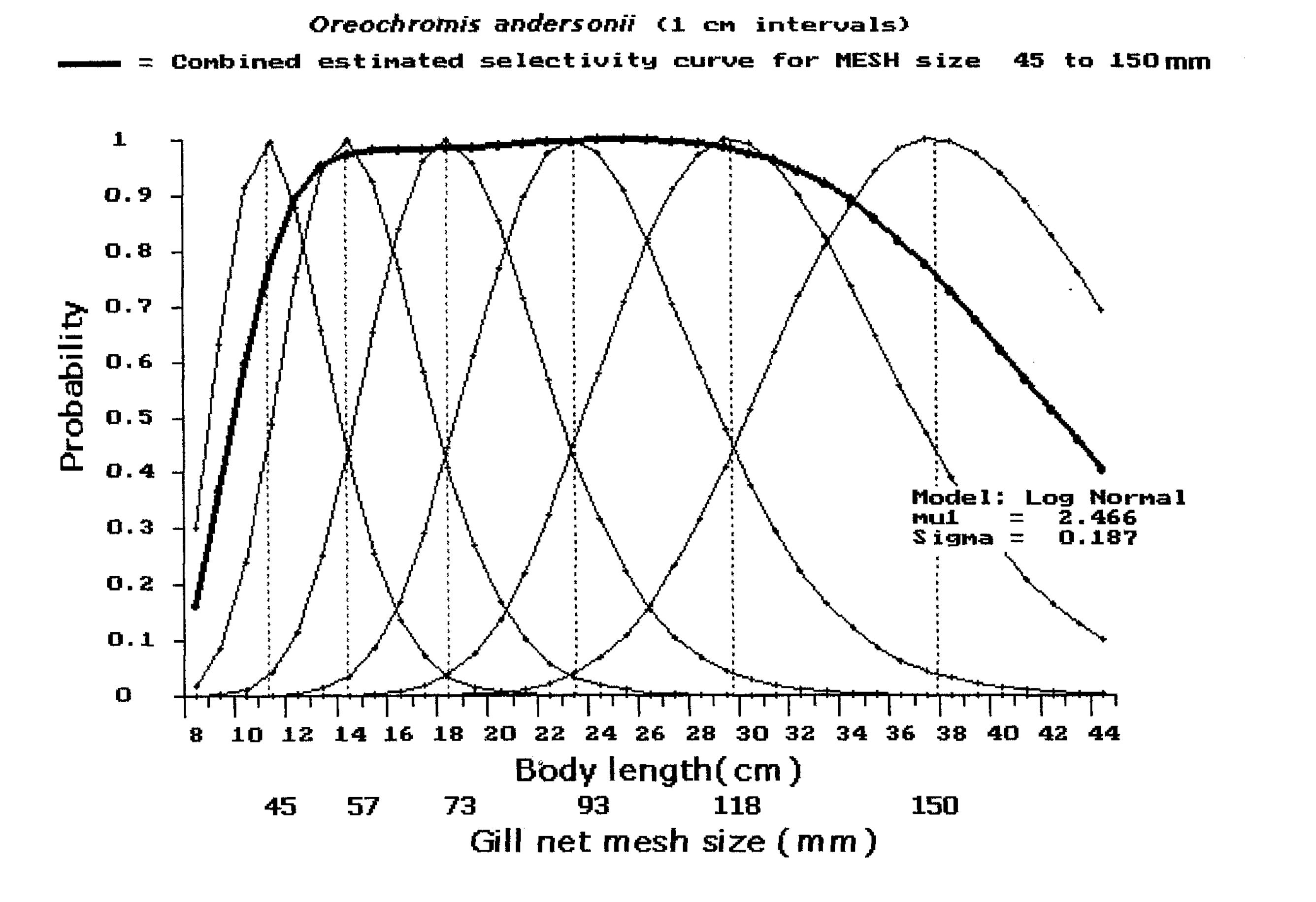

Figure 5.24. Gill net selectivity curves for threespot tilapia (O. andersonii) *for each mesh size from 45 mm to 150 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.30. Gill net selectivity for humpback largemouth (S. altus) in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
28	2	11.1	0.07	0.001
35	5	14.6	0.13	0.007
45	3	14.2	0.08	0.003
57	6	18.2	0.16	0.014
73	3	23.6	0.06	0.018
93	4	27.9	0.07	0.025
118	1	39.5	0.03	0.024
150	1	44.1	0.01	0.012
Total	25		0.07	0.012

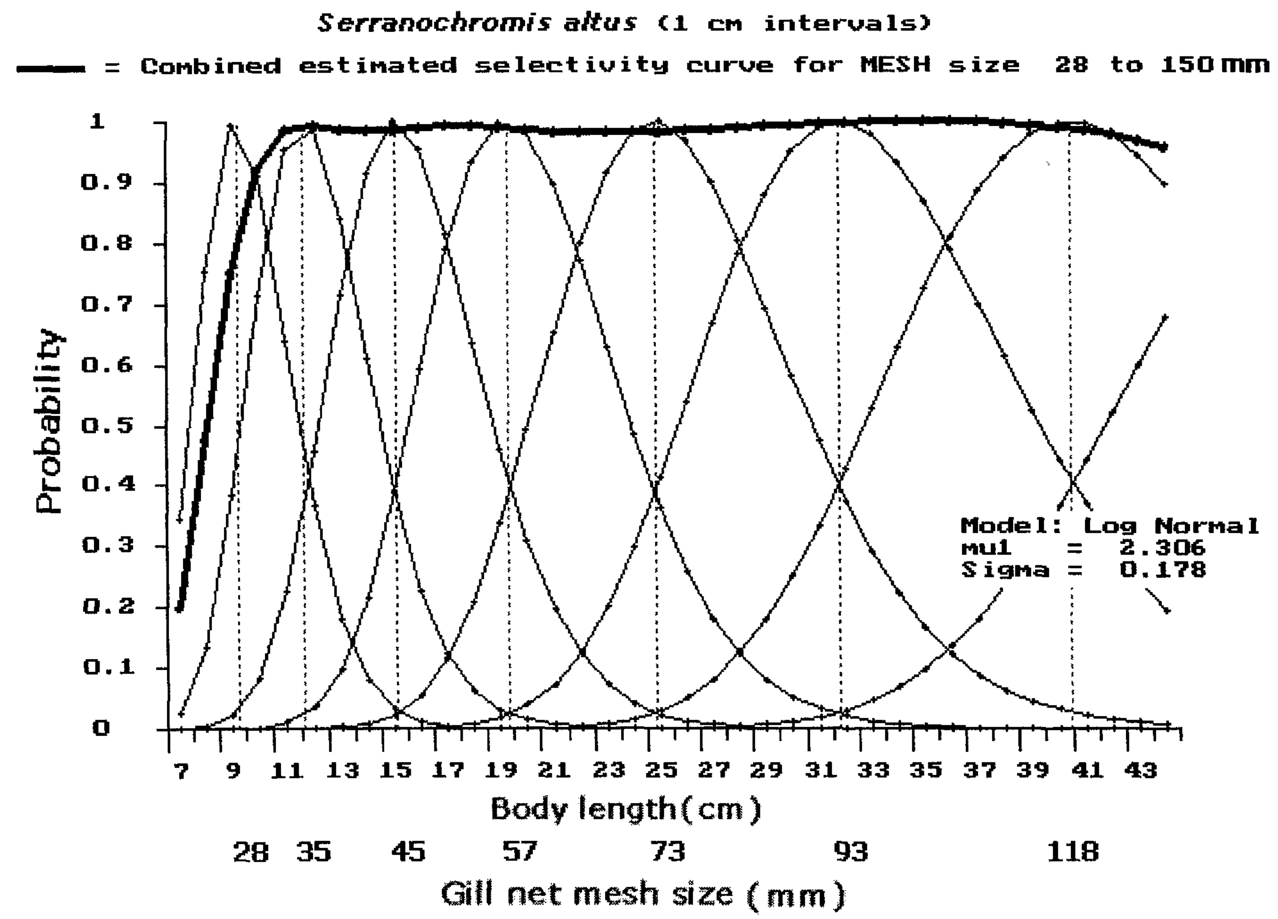

Figure 5.25. Gill net selectivity curves for humpback largemouth (S. altus) for each mesh size from 28 mm to 150 mm and combined estimated selectivity curve for all mesh sizes.

fish, i.e. larger than 22 cm, with maximum catchability at approximately 41 cm for the 118 mm mesh size.

Thinface largemouth (*Serranochromis angusticeps*)
Thinface largemouth occurs in the Cunene, Okavango, upper Zambezi, Kafue and Zambian Congo systems, and possibly also in coastal rivers north of the Cunene in Angola. It may reach 41 cm and the angling record in Zimbabwe is 2.2 kg. It breeds throughout the summer. It prefers lagoons and quiet backwaters with dense vegetation where it feeds on small fishes such as robbers and barbs. Growth is rapid, and it generally matures at 17.5 and 25.0 cm for females and males, respectively. It is a popular angling species, and is also important in subsistence and commercial fisheries.

In the Okavango, the minimum mature lengths were 16 cm for males and 20 cm for females (**Table 5.24**). In gill nets, 55 fishes between 8 and 47 cm (mean 21.2 cm) and modal length 11.0–11.9 cm were caught. Fifty fishes between 3 and 19 cm (mean 7.8 cm; modal length 5.0–5.9 cm) were caught in other gears. The most effective gill net mesh size for thinface largemouth in terms of number of fish per setting is 93 mm (**Table 5.31**). Fish caught with this mesh size have an average length of 29.3 cm, which is longer than minimum length at maturity (**Table 5.24**). Gill nets with a mesh size of 93 mm also have the highest catches in weight per setting, estimated to 0.054 kg. The gill net mesh sizes used here efficiently catch thinface largemouth from approximately 8 cm in length (**Figure 5.26**). Gill nets with mesh size 57 mm and larger catch mainly mature fish, i.e. larger than 11 cm, with maximum catchability at approximately 19 and 25 cm for the 57 and 73 mm, respectively.

Nembwe (*Serranochromis robustus*)
Nembwe occurs in the Okavango, upper Zambezi, Kafue and Zambian Congo systems. It may reach 45 cm and about 3.5 kg and breeds in the summer. Larger fishes prefer deep main channels and permanent lagoons, whereas smaller fishes occur mainly in lagoons and secondary channels. It is a fish predator. Juveniles prefer minnows, while adults prefer squeakers. It is a major angling species, and it is an important species in commercial and subsistence fisheries.

In the Okavango, the minimum mature lengths were 27 cm for males and 19 cm for females (**Table 5.24**). The gill net catch of 47 fishes ranged from 11 to 49 cm (mean 20.7 cm) in length. The modal length was 14.0–14.9 cm. In other gears, 190 fishes with body lengths between 3 and 31 cm (mean 8.9 cm; modal length 8.0–8.9 cm) were caught. The most effective gill net mesh size for nembwe in terms of number of fish per setting is 45 mm (**Table 5.32**). Fish caught with this mesh size have an average length of 14.9 cm, which is shorter than the minimum length at maturity (**Table 5.24**). Gill nets with a mesh size of 118 mm have the highest catches in weight per setting, estimated to 0.114 kg. Fish caught with this mesh size have an average length of 36.1 cm, which is considerably longer than the minimum length at maturity. The gill net mesh sizes used here efficiently catch nembwe from approximately 12 cm in length (**Figure 5.27**). The 93 and 118 mm nets catch mainly mature fish, i.e. larger than 19 cm, with maximum catchability at approximately 30 and 38 cm, respectively.

Brownspot largemouth (*Serranochromis thumbergi*)
Brownspot largemouth occurs in the Cunene, Okavango, upper Zambezi, Kafue, Lufira-Lualaba and Zambian Congo systems. It may reach 33 cm and about 1.2 kg. It occurs in floodplain channels and lagoons and favours open water. It preys on insects, shrimps, crabs and fish. It is an angling species and is also caught in subsistence fisheries.

No mature fish of this species were recorded in our catches from the Okavango (**Table 5.24**). Only two fishes between 12 and 13 cm were caught in gill nets, while a total of 5 fishes between 5 and 10 cm were caught in other gears. Average size of fish caught in gill nets and in other gears was 12.5 cm and 6.8 cm, respectively. This species was only caught in gill nets with mesh size 45 mm.

Rainbow happy (*Sargochromis carlottae*)
Rainbow happy occurs in the Okavango, upper Zambezi and Kafue systems, and also in Lake Kariba. It may reach 26 cm and about 1.4 kg. It prefers deeper permanent floodplain channels and lagoons with sandy bottom and vegetation. It feeds on aquatic insects, crustacea and snails. It is an angling species, and it is an important species in commercial and subsistence fisheries. It is also useful as a control agent for snails.

In the Okavango, the minimum mature lengths were 10 cm for males and 12 cm for females (**Table 5.24**). In gill nets, 52 fishes with body lengths from 8 to 31 cm (mean 15.1 cm; modal length 10.0–10.9 cm) were caught. In other gears, 27 fishes from 8 to 26 cm (mean 12.7 cm; modal length 12.0–12.9 cm) were caught. The most effective gill net mesh size for rainbow happy in terms of number of fish per setting is 35 mm (**Table 5.33**). Fish caught with this mesh size have an average length of 10.4 cm, which is about the same as the minimum length at maturity for males (**Table 5.24**). Gill nets with a mesh size of 73 mm have the highest catches in weight per setting, estimated to 0.029 kg. Fish caught with this mesh size have an average length of 19.5 cm. The gill net mesh sizes used here efficiently catch rainbow happy from approximately 10 cm in length (**Figure 5.28**). The 45 mm and nets with larger mesh size catch mainly mature fish, i.e. fish larger than 8 cm, with maximum catchability at approximately 13 cm for the 45 mm net.

Table 5.31. *Gill net selectivity for thinface largemouth* (S. angusticeps) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	1	8.0	0.03	0.0002
28	2	10.5	0.7	0.0001
35	9	12.1	0.10	0.002
45	11	16.7	0.13	0.011
57	6	19.1	0.11	0.010
73	10	23.8	0.12	0.029
93	9	29.3	0.15	0.054
118	6	30.2	0.09	0.040
150	1	46.2	0.01	0.015
Total	55		0.09	0.019

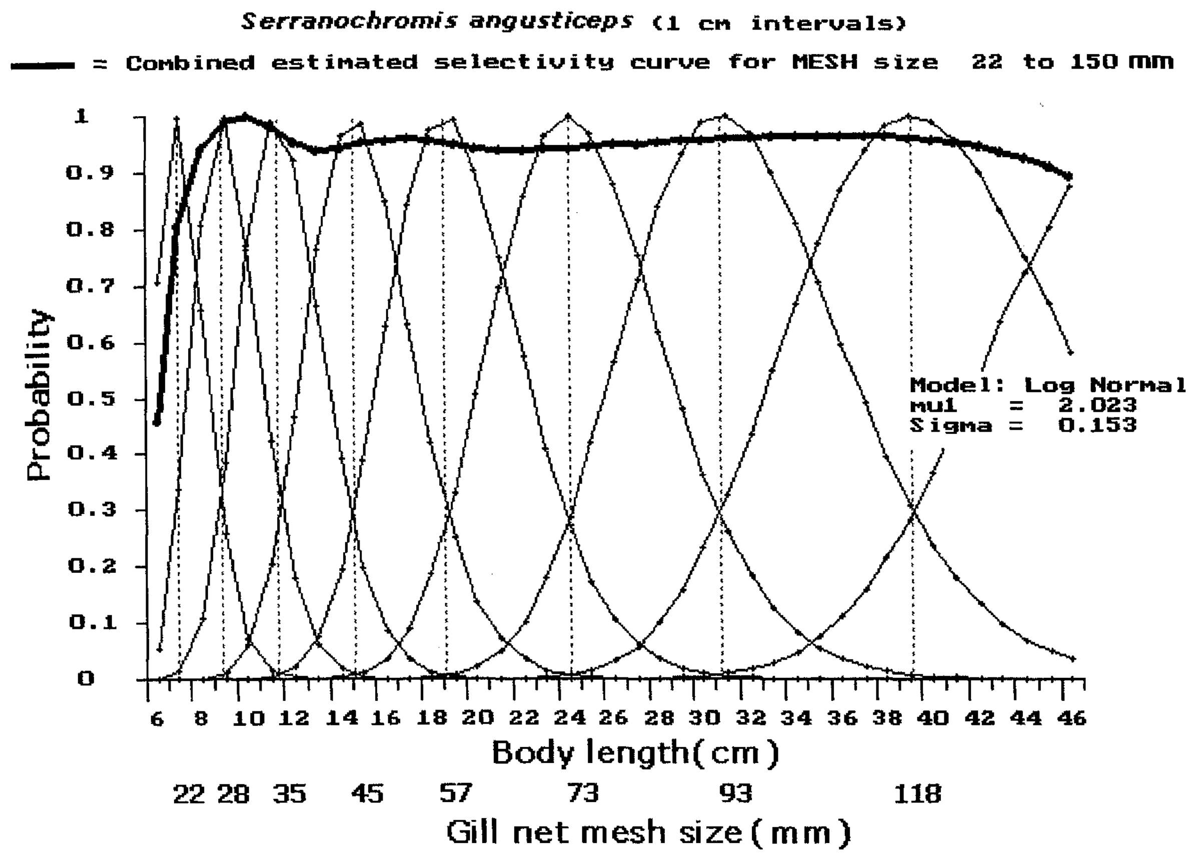

Figure 5.26. *Gill net selectivity curves for thinface largemouth* (S. angusticeps) *for each mesh size from 22 mm to 150 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.32. *Gill net selectivity for nembwe* (S. robustus) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	1	14.9	0.03	0.001
	0			
35	08	11.4	0.09	0.002
45	14	14.9	0.35	0.019
57	7	18.6	0.15	0.014
73	4	24.6	0.07	0.016
93	6	29.1	0.12	0,054
118	7	36.1	0.13	0.114
Total	47		0.11	0.026

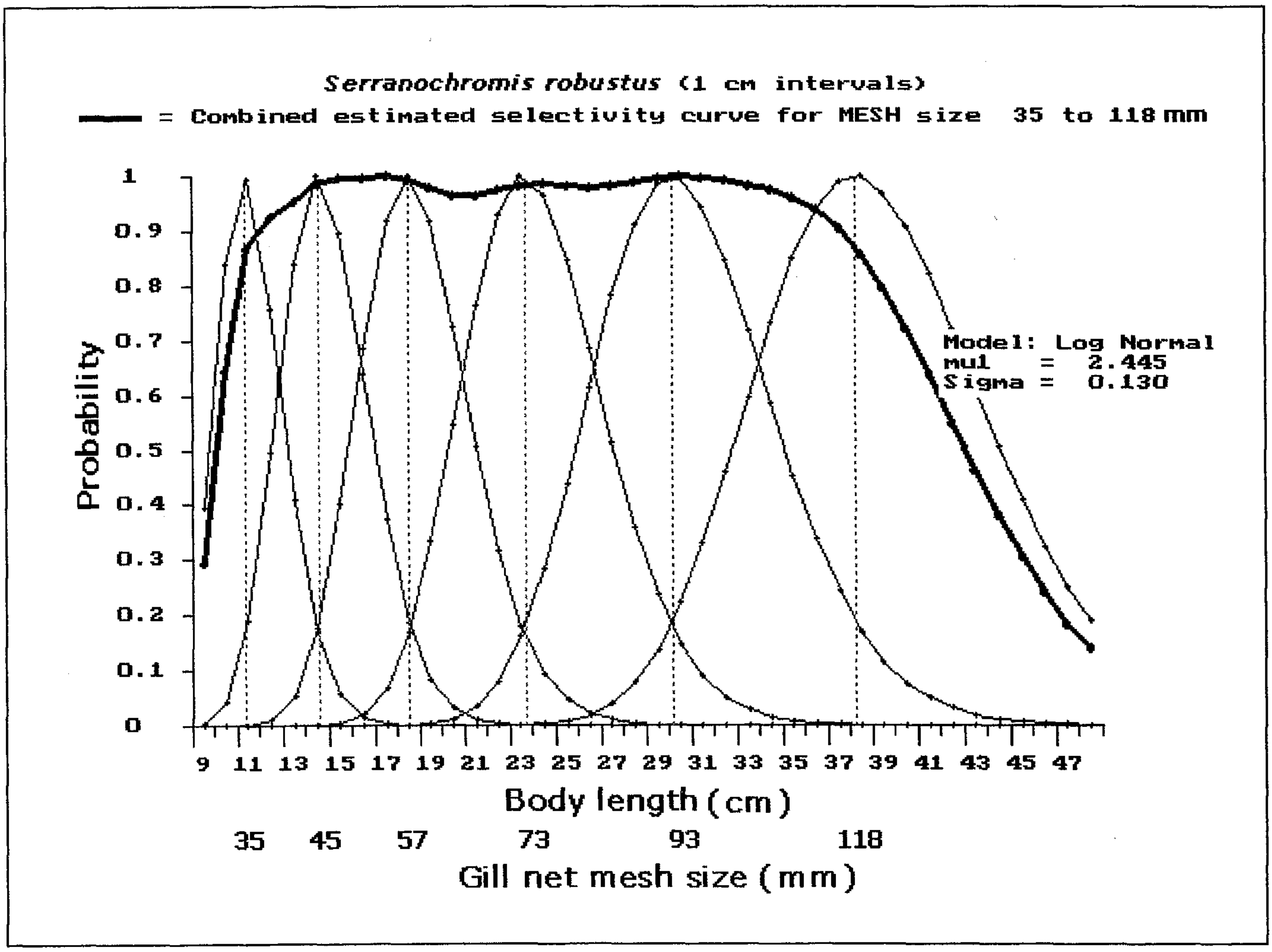

***Figure 5.27**. Gill net selectivity curves for nembwe* (S. robustus) *for each mesh size from 35 mm to 118 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.33. Gill net selectivity for rainbow happy (S. carlottae) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
28	1	8.8	0.01	0.00007
35	18	10.4	0.21	0.004
45	9	12.9	0.11	0.004
57	8	15.9	0.11	0.008
73	11	19.5	0.20	0.029
93	4	24.9	0.07	0.022
118	1	30.0	0.01	0,004
Total	52		0.08	0.008

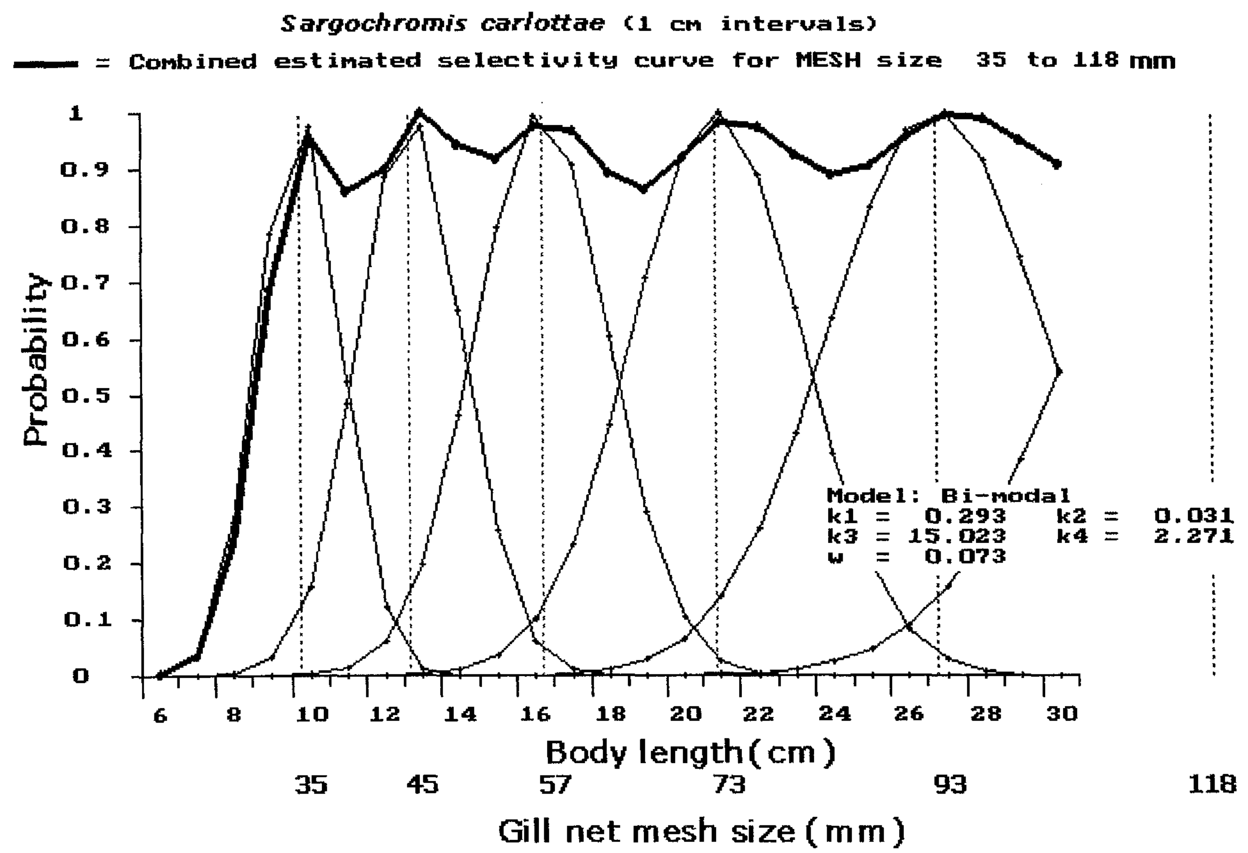

Figure 5.28. Gill net selectivity curves for rainbow happy (S. carlottae) *for each mesh size from 35 mm to 118 mm and combined estimated selectivity curve for all mesh sizes.*

Green happy (*Sargochromis codringtonii*)
Green happy occurs in the Okavango, upper Zambezi and Kafue systems, and also in Lake Kariba. It may reach 29 cm and the angling record in Zimbabwe is 2.21 kg. Generally, it matures at about 15 cm for males and 12.5 to 15 cm for females. It prefers deep, quiet water, slow flowing channels and floodplain lagoons. It feeds on waterlily seeds, small snails, bivalves and aquatic insects. It is an angling species, and it is an important species in commercial and subsistence fisheries. It is also useful as a control agent for snails.

In the Okavango, the minimum mature lengths were 15 cm for males and 10 cm for females (**Table 5.24**). A total of 78 fishes were caught in gill nets. Their lengths were between 7 and 28 cm (mean 13.6 cm; modal length 10.0–10.9 cm). In other gears, 167 fishes from 3 to 19 cm (mean 9.7 cm; modal length 9.0–9.9 cm) were caught. The most effective gill net mesh size for green happy in terms of number of fish per setting is 35 mm (**Table 5.34**). Fish caught with this mesh size has a mean length of 10.1 cm, which is about the same as the minimum length at maturity for females (**Table 5.24**). Gill nets with a mesh size of 73 mm have the highest catches in weight per setting, estimated to 0.018 kg. Fish caught with this mesh size have a mean length of 19.1 cm. The gill net mesh sizes used here efficiently catch green happy from approximately 7 cm in length (**Figure 5.29**). The 57 mm and nets with larger mesh size catch mainly mature fish, i.e. larger than 11 cm, with maximum catchability at approximately 17 cm for the 57 mm net.

Pink happy (*Sargochromis giardi*)
Pink happy occurs in the Cunene, Okavango, upper Zambezi and Kafue systems and also in Lake Kariba. It may reach 48 cm and about 2.9 kg and breeds in early summer. It matures at about 15-18 cm. It prefers deep main river channels and floodplain lagoons with sandy bottoms. It feeds primarily on snails, bivalves and insect larvae. It is an angling species and an important species in commercial and subsistence fisheries. It is also useful as a control agent for snails.

The minimum mature length found in the Okavango was 22 cm for females (**Table 5.24**). In gill nets, 36 fishes ranging from 10 to 46 cm (mean 21.0 cm; modal length 12.0–12.9 cm), were caught. In other gears, 14 fishes with body lengths from 6 to 31 cm (mean 12.1 cm; modal length 6.0–7.9 cm) were caught. The most effective gill net mesh size for pink happy in terms of number of fish per setting is 45 mm (**Table 5.35**). Fish caught with this mesh size have a mean length of 12.1 cm, which is shorter than the minimum length at maturity (**Table 5.24**). Gill nets with a mesh size of 150 mm have the highest catches in weight per setting, estimated to 0.086 kg. Fish caught with this mesh size have a mean length of 37.8 cm. The gill net mesh sizes used here efficiently catch pink happy from approximately 9 cm in length (**Figure 5.30**). The 93 mm and nets with larger mesh size catch mainly mature fish, i.e. larger than 17 cm, with maximum catchability at approximately 25 cm for the 93 mm net.

5.3.8 Summary of gill net selectivity

Table 5.36 summarises the most efficient gill net mesh sizes for the important species in local fisheries, in the survey gill nets, and in other gears used in the survey. The additional important angling species are also included. In general, the most efficient gill net mesh size in terms of weight of fish caught is larger than in terms of number of fish. For most of the important species (in local fisheries and in the survey fishing, see **Table 5.7**) the highest number of fish per setting is caught in small mesh sizes (22-45 mm, 15 species). In fact, ten of these species are most efficiently caught in the two smallest mesh sizes (22 and 28 mm). Only two species are most efficiently caught in larger mesh sizes (73 and 93 mm). The larger angling species are most efficiently caught in larger mesh sizes. In terms of weight of fish per setting, 11 species are most efficiently caught in the 22-45 mm mesh sizes, two species in 57 mm, and four species in 93-118 mm.

These results reflect that the fish community in the Okavango is dominated by relatively small species. Among the species that are important in local fisheries or in our survey catches, only six out of 21 species have a minimum mature length above 10 cm or are on average above 15 cm in the gill net catches. Only two out of 21 species have mean lengths above 20 cm in our survey catches. Moreover, only seven out of the additional 16 species that are considered attractive angling species, have mean lengths above 20 cm in the gill net catches.

Table 5.34. *Gill net selectivity for green happy* (S. codringtonii) *in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
22	1	8.2	0.03	0.0003
28	1	9.1	0.03	0.0003
35	36	10.1	0.39	0.006
45	18	13.3	0.21	0.008
57	6	15.7	0.07	0.005
73	8	19.1	0.12	0.018
93	6	22.6	0.07	0.016
118	2	26.9	0.02	0.007
Total			0.11	0.007

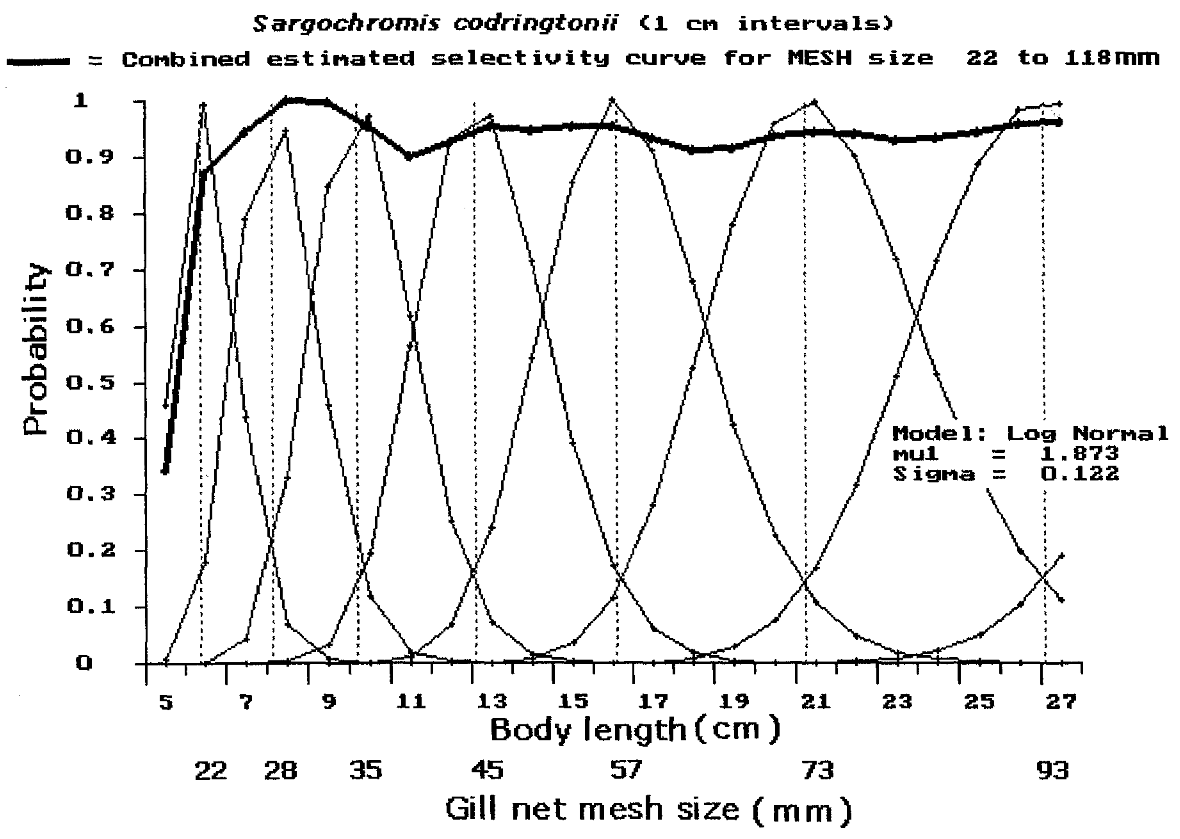

Figure 5.29. *Gill net selectivity curves for green happy* (S. codringtoni) *for each mesh size from 22 mm to 118 mm and combined estimated selectivity curve for all mesh sizes.*

***Table 5.35.** Gill net selectivity for pink happy (S. giardi) in catches from 1992 to 1999 with number of fish, mean length and mean CPUE for each mesh size. Total CPUE is calculated based on the full series of mesh sizes (22-150 mm). N = number of fish. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

Mesh size (mm)	Number of fish	Mean length (cm)	CPUE (N per setting)	CPUE (kg per setting)
35	5	10.4	0.04	0.0009
45	8	12.1	0.09	0.003
57	2	15.4	0.02	0.001
73	6	19.6	0.07	0.010
93	4	23.5	0.07	0.020
118	5	27.5	0.04	0.023
150	6	37.8	0.07	0.086
Total	36		0.05	0.017

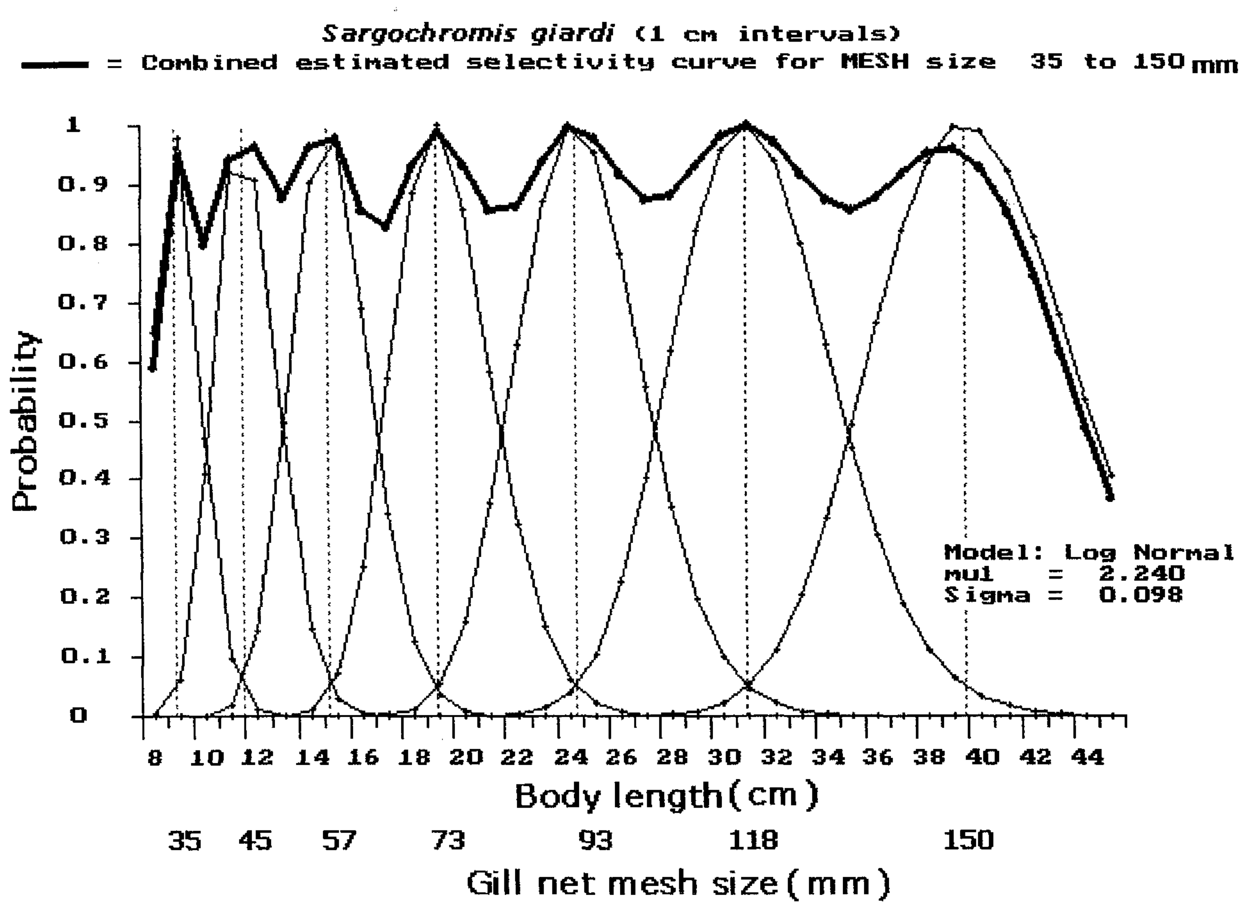

***Figure 5.30**. Gill net selectivity curves for pink happy (S. giardi) for each mesh size from 35 mm to 150 mm and combined estimated selectivity curve for all mesh sizes.*

Table 5.36. *The most efficient gill net mesh sizes, and size classification for the most important species in local fisheries, survey gill nets, and other gears used in the surveys (see* ***Table 5.7****), and the additional important angling species (see* ***Table 5.24****). Gill net efficiency is in terms of number of fish and in terms of weight per setting. The size classification is based on minimum length at maturity, if available or on mean length in gill net catches, or other gears (indicated by *) («small»: the smallest mature fish is maximum 7 cm in length, or mean length in catches is smaller than 10 cm).*

Species	Most efficient gill net mesh size (mm)		Size classification			
	number of fish	weight	Large	Small	Minimum length at maturity (cm)	Mean length in gill nets (cm)
Important species in local fisheries & survey fisheries						
Apolocheilichtys johnstoni	-	-		X	-	2.5*
Barbus paludinosis	22	22		X	5	7.3
Barbus poechii	22	28		X	7	8.5
Barbus thamalakanensis	-	-		X	-	3.0*
Brycinus lateralis	22	28		X	5	9.0
Clarias gariepinus	93	93	X		38	46.6
Hemigrammocharax machadoi	-	-		X	-	2.1*
Hepsetus odoe	35	57	X		27	19.9
Hippopotamyrus discorhynchus	28	35		X	7	10.8
Hydrocynus vittatus	28	93	X		18	18.3
Labeo cylindricus	28	35-45	X		8	12.4
Marcusenius macrolepidotus	35	45	X		10	12.4
Micralestes acutidens	22	22		X	-	7.5
Petrocephalus catostoma	22	28		X	6	7.6
Pharyngochromis acuticeps	28	28		X	6	8.6
Pseudocrenilabris philander	22	22		X	3	6.4
Schilbe intermedius	28	57	X		9	14.2
Serranochromis macrochephalus	45	93	X		14	18.8
Synodontis nigromaculatus	45	45	X		11	15.2
Tilapia rendalli	73	118	X		11	22.2
Tilapia sparrmanii	35	35		X	5	8.8
Angling species						
Barbus codringtonii	-	-	X		-	11.2
Clariallabes platyprosopos	-	-	X		21	16.4*
Clarias ngamensis	73	93	X		34	39.9
Hemichromus elongatus	-	-		X	-	6.8*
Labeo lunatus	45	45	X		21	19.1
Mormyrus lacerda	73	73	X		16	27.3
Oreochromis andersonii	93	150	X		13	29.3
Oreochromis macrochir	-	-	X		-	14.0
Parauchenoglanis ngamensis	28	28	X		11	14.7
Sargochromis carlottae	35	73	X		10	15.1
Sargochromis codringtonii	35	73	X		10	13.6
Sargochromis giardi	45	150	X		22	21.0
Serranochromis altus	57	93	X		15	20.5
Serranochromis angusticeps	93	93	X		16	21.2
Serranochromis robustus	45	118	X		19	20.7

5.4 Differences among localities

5.4.1 Catch per unit effort at different stations and river zones

The sampling stations along the Okavango River differ in their habitat characteristics, such as water discharge (especially above and below the confluence with Quito River); the extent of adjacent flood plains, oxbow lakes, and backwaters; the type of bottom substrate, etc. (cf. **Figures 3.5-3.11**). However, at all stations with the exception of Mbambi, both the main stream and backwaters have been sampled with gill nets, providing comparable results of catch per unit effort (CPUE) from similar river habitats. An additional factor of great influence on the fish stocks is the fishing pressure. In general, fishing pressure is correlated to the number of people living close to the river. However, the density of people in the vicinity of the river varies greatly between the sampling stations (**Table 5.37**).

In Namibia the population density is highest along the central part of the Okavango River (cf. **Figure 3.1**). For the sampling stations used in this investigation, the highest population density was found in Rundu (nearly 2000 people per km^2), whereas the lowest was in Kwetze (**Table 5.37**), which is inside the Mahongo Game Park with no permanent human inhabitants. Bunya was the second most densely populated area (approx. 120 people per km^2), while Musese, Matava, Cuito and Mbambi had similar population densities (approx. 40–60 people per km^2). However, people are becoming more mobile and may be able to exploit fish resources at some distance from their homes. The correlation between population density and local fishing pressure may therefore vary.

High yield per gill net setting usually reflects high fish densities or biomass, and indicates that the fish stocks are relatively unexploited. Assuming that high population density means high fishing pressure, we would expect lower catches in the survey nets in areas with a dense human population. The correlation between population density and mean catch in kilograms per unit effort in gill nets at the seven sampling stations is highly significant (**Figure 5.31**; $R^2 = 0.92$, $P<0.01$). The corresponding value for the correlation between population density and catch per unit effort in numbers of fish is not significant (**Figure 5.32**; $P>0.05$), although the trend is similar. At Kwetze, with practically no human population and a very low fishing pressure, catches in number of fish were higher than at the other localities. The densely populated areas at Rundu and Bunya, on the other hand, yield the lowest catches, whereas Matava, Musese and Mbambi were intermediate.

The total gill net catches in kilograms (combining main stream and backwaters) at Kwetze (3.76 kg per setting) were nearly five times as high as at Rundu, Bunya and Musese (0.61, 0.66 and 0.68 kg per setting, respectively) (**Table 5.37** and **Figure 5.33**). Catches at Cuito, Matava and Mbambi were also considerable lower than at Kwetze (1.30, 1.12 and 1.02 kg per setting, respectively). The catches at Kwetze were significantly higher than at all other stations, and the catches at Cuito were significantly higher than at Rundu (*t*-tests with sequential Bonferroni correction, $P<0.05$). Catches in number of fish were also highest at Kwetze (43 fish per setting) (**Table 5.37**), although the differences were not as pronounced as for catches in kilograms. Catches in number of fish were lowest at Musese, Bunya and Rundu, (< 20 fish), while catches at Cuito, Matava and Mbambi were intermediate (27-35 fish). The differences were significant only for Kwetze vs. Musese, Bunya and Rundu, and for Quito vs. Bunya (*t*-tests with sequential Bonferroni correction, $P<0.05$).

Table 5.37. *Population density (people per km^2) in 1991, mean standard CPUE in number of fish (No) and weight (Kg) per setting, number of settings (Sets) and recorded gill net catch in number and weight (N and W) in total gill net-catches (mesh size 22–150 mm) at the main sampling localities during the period 1992-99. SD = Standard Deviation. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2). Population density at Kwetze is close to zero, although exact figures are not available.*

Station	Zone	Population density	Cpue				Recorded catch		
			No.	SD	Kg	SD	Sets	N	W
Matava	1	48.3	35.34	94.92	1.12	1.87	120	2 161	83.40
Musese	1	37.9	19.92	42.98	0.68	1.14	188	1 585	61.03
Bunya	2	116.2	12.22	29.33	0.66	1.33	161	976	49.21
Rundu	2	1 936.6	19.60	46.71	0.61	1.00	111	1 042	34.69
Cuito	2	60.7	35.05	80.44	1.30	2.67	161	2 547	132.66
Mbambi	3	44.6	26.74	58.58	1.02	1.63	129	1 193	49.42
Kwetze	4	0	42.99	61.24	3.76	4.03	206	4 055	372,.28
Total			27.95	62.21	1.44	2.60	1 076	13 559	782.69

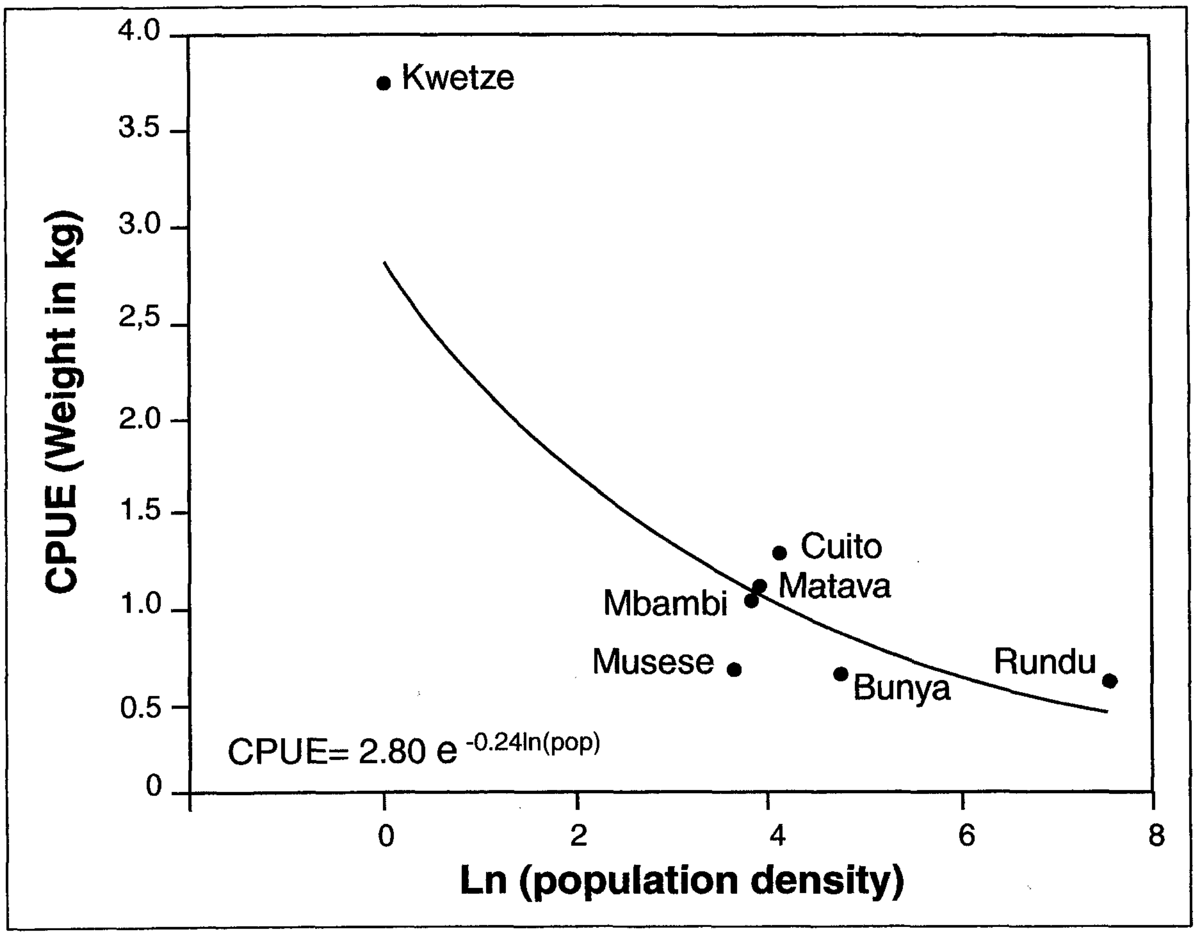

Figure 5.31. *Population density as ln (people per km²) in 1991 and mean standard CPUE in weight (Kg) per setting in total gill net samples (mesh size 22-150) at the main sampling localities during the period 1992-1999. Setting = 12 hours of fishing with one standard gill net (area = 50 m²). The correlation coefficient is significant (R^2 = 0.92, P<0.01).*

Species or size groups within a species may have different habitat preferences and segregate in their utilisation of habitats in the river. The main stream is most often characterised by more swift flowing and open water than the backwaters. Shoaling fish, and predatory or larger species often prefer open water habitats. For catches both in weight and numbers, differences between stations were more pronounced in the backwaters than in the main stream habitats (**Tables 5.38** and **5.39**). This might, however, be due to large differences in the sampling effort in the two habitats, especially at Kwetze, where gill net fishing was difficult in the main stream. In the main stream there were no significant differences in catches, neither in weight nor in numbers of fish (*t*-tests with sequential Bonferroni correction, P>0.05). In the backwater habitat, catches by weight were significantly higher at Kwetze than at all other stations, at Quito compared with Bunya and Musese, and at Matava compared with Bunya (*t*-tests with sequential Bonferroni correction, P<0.05). Catches in numbers of fish were significant larger at Kwetze than at Bunya and Musese, and at Cuito compared with Bunya (*t*-tests with sequential Bonferroni correction, P<0.05).

The relatively smaller differences in CPUE in numbers than in weight indicate that the differences between stations in fish densities were relatively smaller than in fish biomass. This is an important observation when evaluating the fish populations as a resource for subsistence fisheries. The most important factor for a subsistence fishery is the total biomass (weight) of fish caught, whereas the size of the individual fish is of minor importance. In commercial or recreational fisheries, on the other hand, the size of the individual fish may be very important.

The Namibian part of the Okavango River may be divided into four zones with some differences in substrate, water flow, adjacent floodplains and general morphology (**Figure 3.1**). There were significant differences in gill net catches by weight between the river zones both

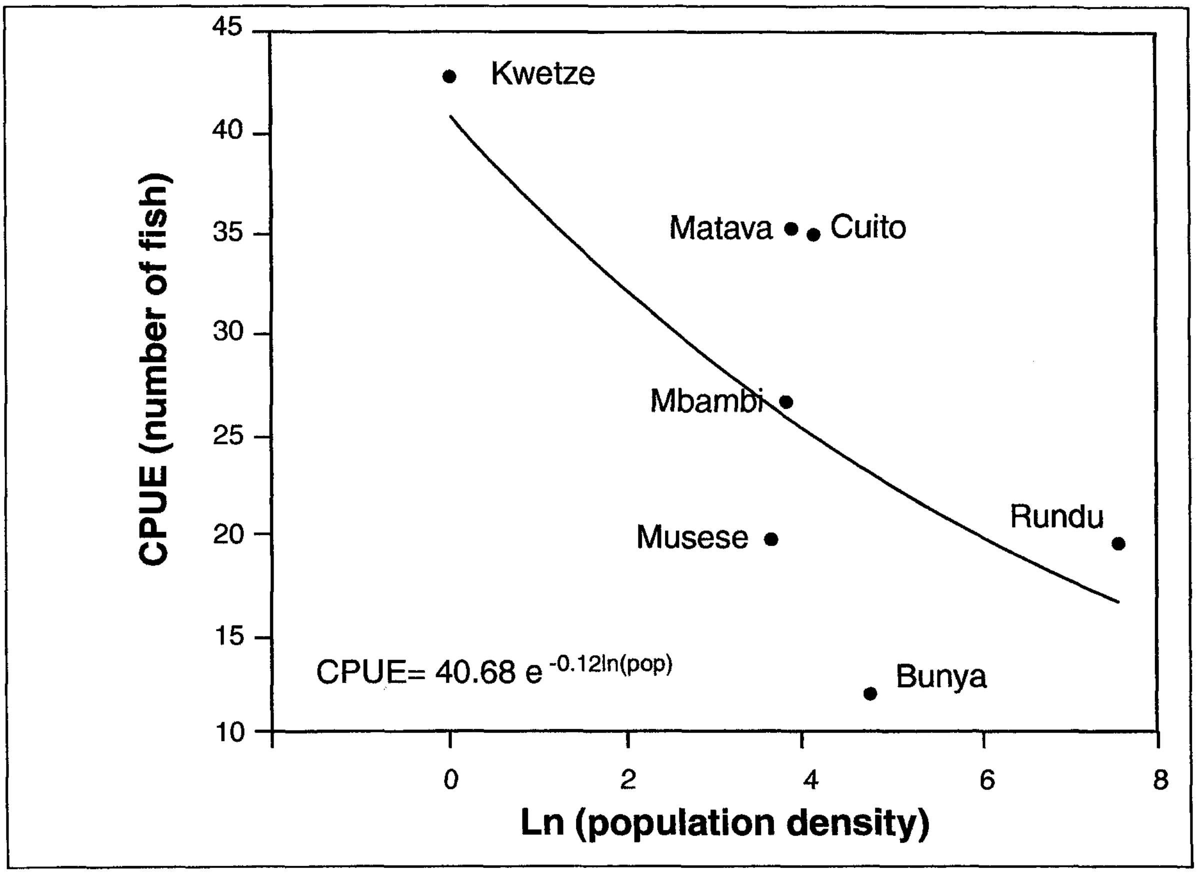

Figure 5.32. *Population density as ln (people per km²) in 1991 and mean standard CPUE in numbers per setting in total gill net samples (mesh size 22–150 mm) at the main sampling localities during the period 1992-99. Setting = 12 hours of fishing with one standard gill net (area = 50 m²). The correlation coefficient is not significant ($R^2 = 0.49$, $P > 0.05$).*

if one consider pooled gill net data (Figure 5.34), and if one separate data into main stream and backwaters (Figure 5.35). In pooled data there were no differences between Zone 1 (Matava and Musese; 0.9 kg per setting), Zone 2 (Bunya, Rundu and Cuito; 0.9 kg per setting) and Zone 3 (Mbambi; 1.0 kg per setting) (*t*-tests with sequential Bonferroni correction, P >0.05). In Zone 4, Kwetze, however, the catch was significantly higher (3.8 kg per setting) than in the other zones (*t*-tests with sequential Bonferroni correction, P<0.05).

When separating CPUEs in the two main habitats, main stream and backwaters, possible effects of different fishing effort in the habitats at the stations are reduced. However, dividing the data into main stream and backwaters only confirms the results from pooled habitats; mean $CPUEs_{(weight)}$ in Zone 4 (Kwetze) was more than the twice as large as in the other zones (**Figure 5.35**). Due to small sample number effort at Kwetze the differences were not significant for the stations in the main stream, while it was highly significant for backwaters where the sampling effort was much higher (*t*-tests with sequential Bonferroni correction).

5.4.2 Catch per unit effort in different gill net mesh sizes

Gill nets are size selective and differences in catch per unit effort in different mesh sizes may therefore reflect relative differences in the size distribution in the fish populations sampled. In our survey we have used 9 different mesh sizes varying from 22 to 150 mm stretched mesh

Differences in catch per unit effort in both weight and numbers were smaller when comparing catches in the smallest gill net mesh sizes than in the larger ones **(Tables 5.40** and **5.41**, **Figure 5.36**). Catches of small fish in 22 and 28 mm mesh size, were highest at Cuito, both in weight and number of fish per setting (1.47 kg and 127.4 fish), and smallest at Bunya (0.33 kg and

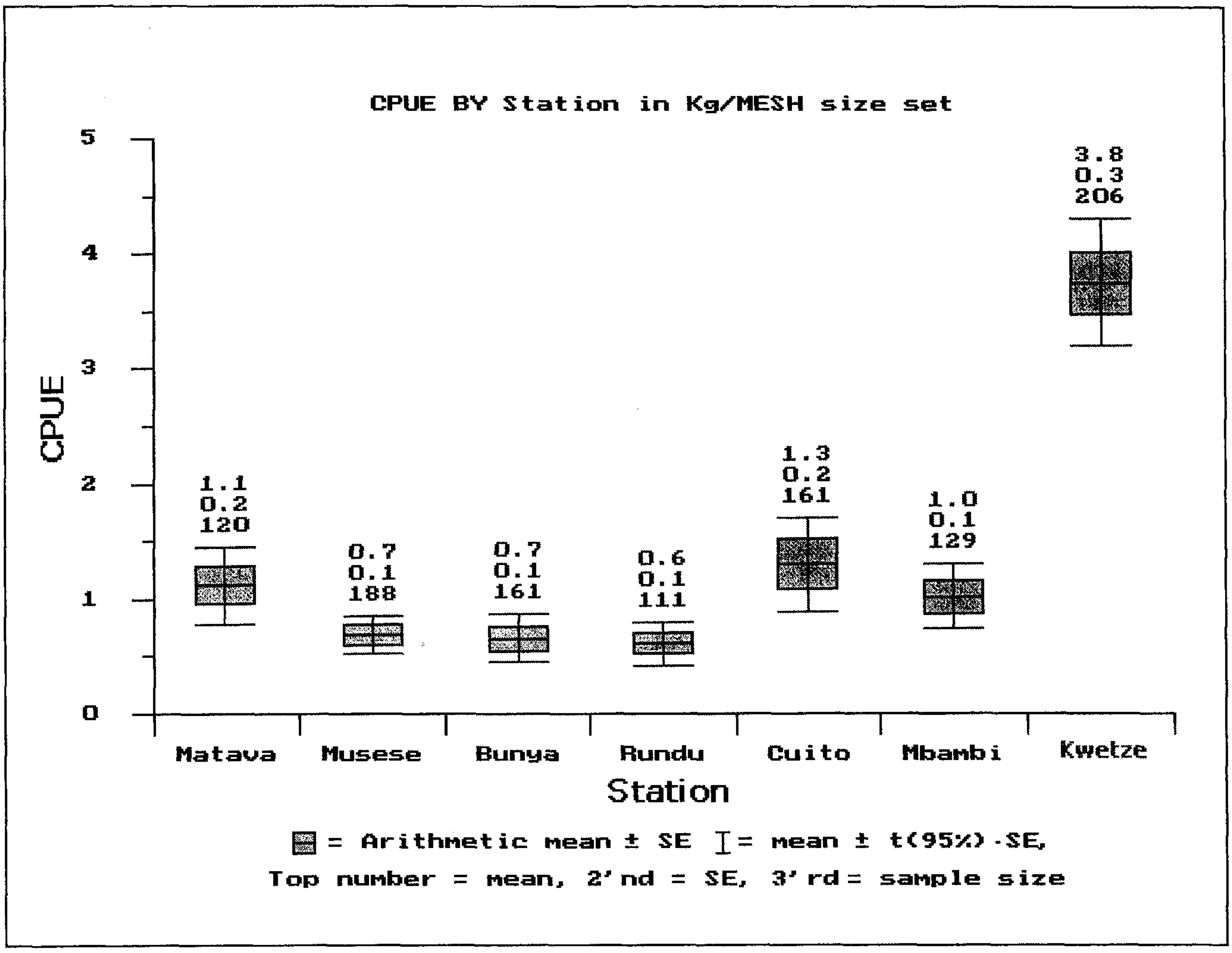

***Figure 5.33**. Mean CPUE in weight per setting with 95 % confidence limits in total gill net samples (mesh size 22–150 mm) from all habitats at the different sampling localities during the period 1992-99. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

***Table 5.38.** Mean CPUE in weight (Kg) per setting and number of settings (Sets) in total gill net catches (mesh size 22–150) mm at the seven main gill net stations during the period 1992-99. SD = Standard deviation. Zone = river zone (see **Figure 3.1**). Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

		Main stream			Backwaters		
Station	Zone	Cpue	SD	Sets	Cpue	SD	Sets
Matava	1	0.75	1.22	36	1.77	2.46	52
Musese	1	0.60	0.94	154	0.79	0.96	25
Bunya	2	0.76	1.56	104	0.49	0.73	57
Rundu	2	0.51	0.91	93	1.13	1.31	18
Cuito	2	0.64	1.22	95	2.25	3.71	66
Mbambi	3	1.02	1.63	129			0
Kwetze	4	2.45	3.03	10	3.82	4.07	196
Total		0.74	1.35	621	2.55	3.56	414

Table 5.39. *Mean CPUE in number of fish per setting and number of settings (Sets) in total gill net catches (mesh size 22–150) mm at the seven main gill net stations during the period 1992-99. SD = Standard deviation. Zone = river zone (see **Figure 3.1**). Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

		Main stream			Backwaters		
Station	Zone	Cpue	SD	Sets	Cpue	SD	Sets
Matava	1	23.61	35.41	36	58.59	137.52	52
Musese	1	21.23	45.70	154	15.20	30.99	25
Bunya	2	11.22	30.71	104	14.04	26.80	57
Rundu	2	14.58	39.75	93	45.56	68.68	18
Cuito	2	25.85	76.15	95	48.30	85.08	66
Mbambi	3	26.74	58.58	129			0
Kwetze	4	21.00	33.96	10	44.12	62.16	196
Total		20.54	51.13	621	40.78	76.42	414

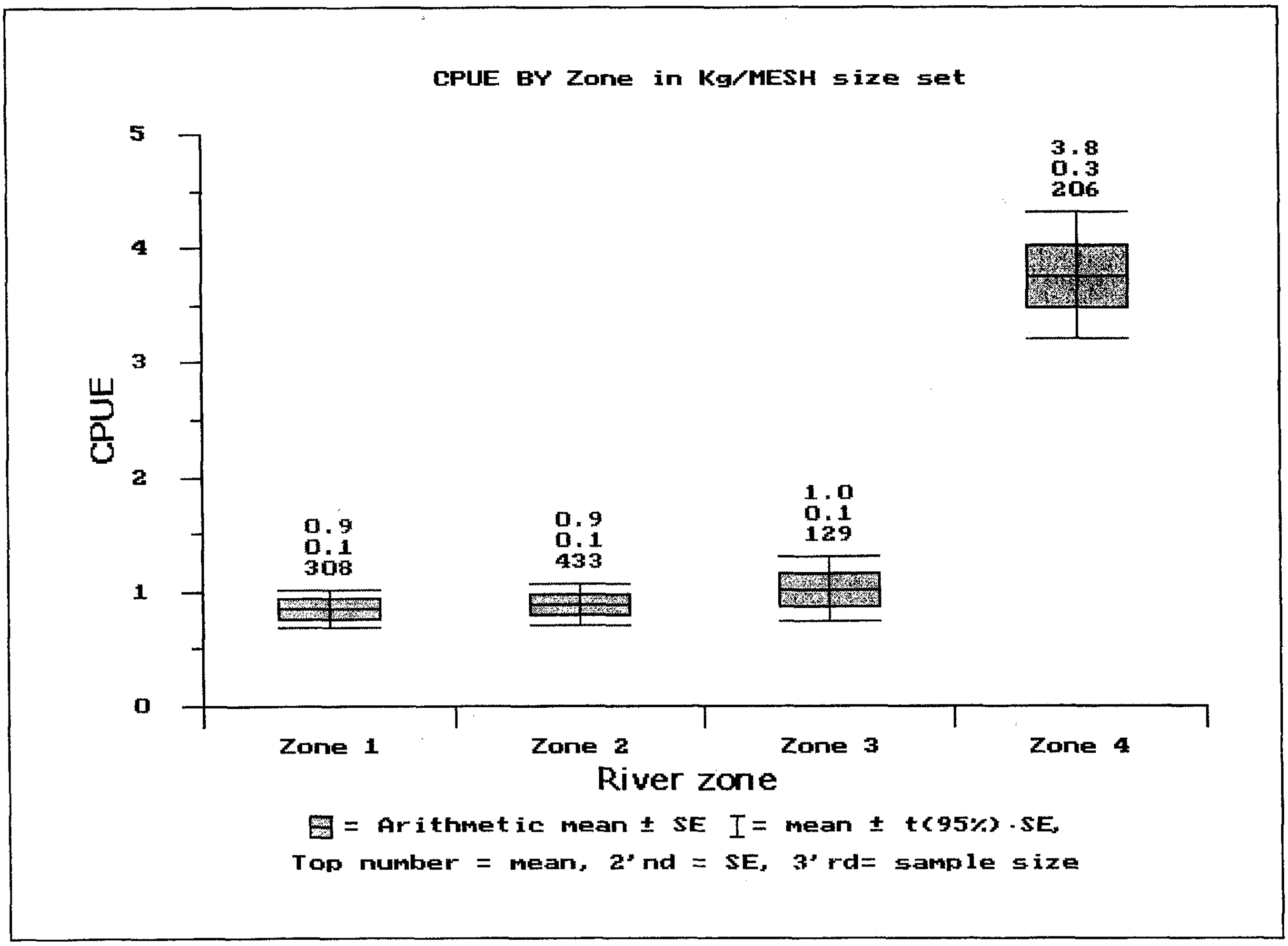

Figure 5.34. *Mean CPUE in weight per setting with 95 % confidence limits in the four different river zones of the Okavango River from all habitats. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

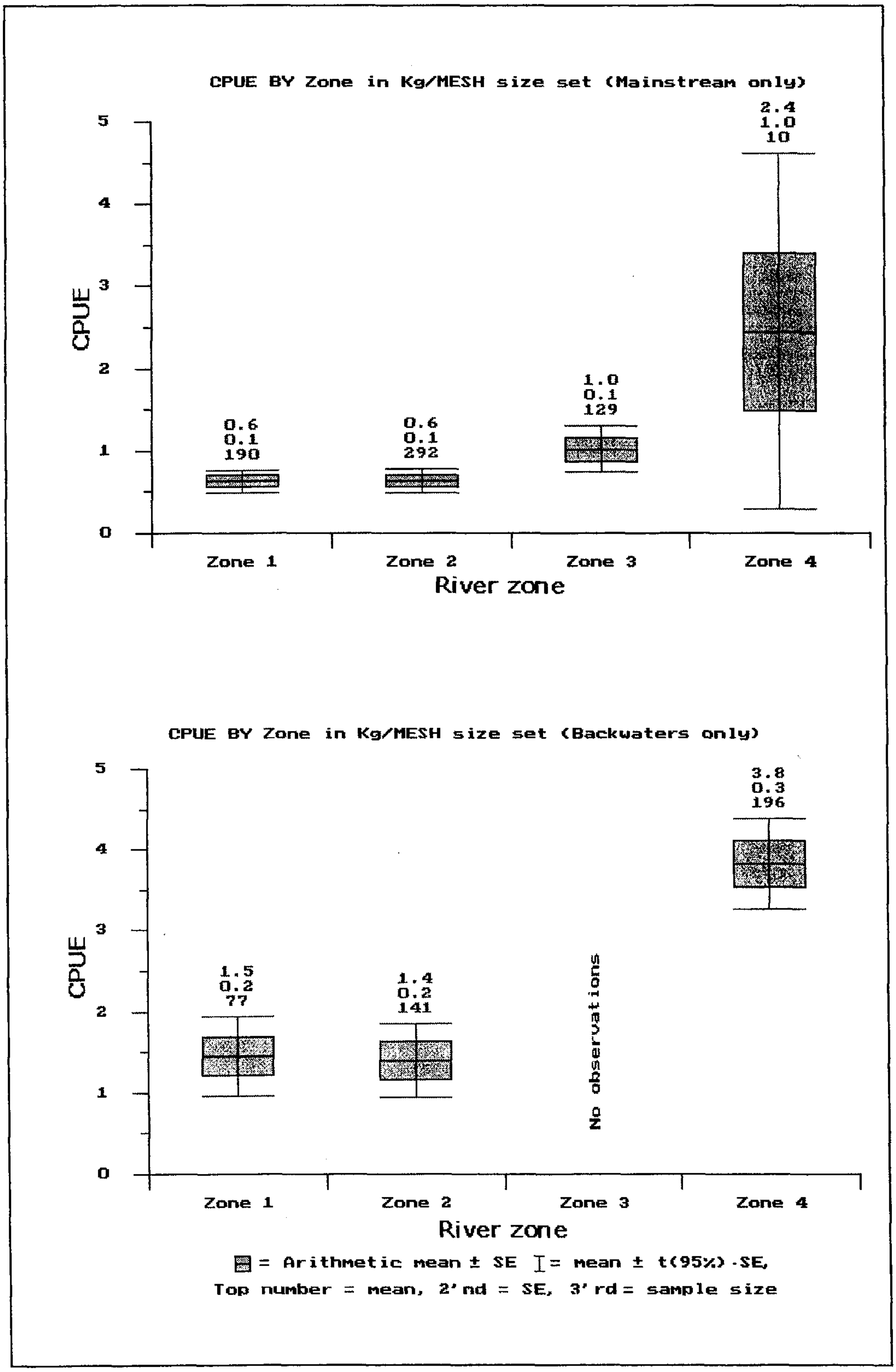

***Figure 5.35**. Mean CPUE in weight per setting with 95 % confidence limits in the four different river zones of the Okavango River from main stream and backwater habitats. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Table 5.40. *Mean CPUE in number (No) and weight (Kg) per setting and number of settings (Sets) in gill nets with mesh size 22 and 28 mm at different sampling localities during the period 1992-99. SD = Standard Deviation. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Station	Zone			Cpue		
		No	SD	Kg	SD	Sets
Matava	1	99.95	167.62	0.97	1.12	22
Musese	1	70.62	71.42	0.88	1.02	34
Bunya	2	25.91	34.97	0.33	0.44	28
Rundu	2	72.78	81.30	0.80	0.90	20
Cuito	2	127.38	138.88	1.47	1.78	28
Mbambi	3	89.26	108.36	1.17	1.65	24
Kwetze	4	56.78	71.74	1.12	1.36	38
Total		75.50	103.67	0.97	1.29	194

Table 5.41. *Mean CPUE in number (No) and weight (Kg) per setting and number of settings (Sets) in gill nets with mesh size 35 to 150 mm at different sampling localities during the period 1992-99. SD = Standard Deviation. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

Station	Zone			Cpue		
		No.	SD	Kg	SD	Sets
Matava	1	20.84	61.72	1.15	2.00	98
Musese	1	8.73	21.47	0.64	1.16	154
Bunya	2	9.33	27.28	0.73	1.45	133
Rundu	2	7.91	22.47	0.57	1.02	91
Cuito	2	15.61	41.33	1.26	2.82	133
Mbambi	3	12.46	22.79	0.99	1.63	105
Kwetze	4	39.87	58.40	4.35	4.19	168
Total		17.50	41.95	1.54	2.80	882

25.9 fish per setting). Catches in small mesh sizes at Kwetze (1.12 kg and 56.8 fish per setting) were not very different from the other stations (weight: Rundu 0.80 kg, Musese 0.88 kg, Matava 0.97 kg and Mbambi 1.17 kg; number: Musese 70.6 fish and Rundu 72.8 fish). However, the mean weight of the fish caught in 22 and 28 mm mesh size at Kwetze were on average larger, 20 g compared with 10–13 g at the other stations. Catch in weight was significantly larger at Cuito than Bunya, and at Kwetze than Bunya, while catch by number of fish was significantly larger at Cuito than at Bunya (*t*-tests with sequential Bonferroni correction, $P<0.05$).

In the larger meshed gill nets (35-150 mm), Kwetze had the highest catch both in weight and number of fish (4.35 kg and 39.9 fish per setting), whereas Rundu had the lowest catch (0.57 kg and 7.9 fish per setting). At Musese, Mbambi and Bunya catches in large mesh sizes were also low, both in weight and number of fish. These differences in catch by weight were significant for Kwetze compared with all the other stations. For catch in number of fish the differences were significant for Kwetze compared with all other stations except Matava (*t*-tests with sequential Bonferroni correction, $P<0.05$).

The relative differences in CPUE in small and large mesh sizes from different parts of the river were confirmed when pooling data in the four river zones. In the smallest mesh sizes (22–28 mm), catches by weight were similar in all zones, 0.9 kg-1.2 kg (**Figure 5.36**) (*t*-tests with sequential Bonferroni correction, $P>0.05$). In the larger mesh sizes (35–150 mm), the average catch were similar and equal to the smallest mesh sizes (22–28 mm) in Zone 1 to 3 (0.8 kg–1.0 kg), while Zone 4 had a significant larger catch (4.4 kg) (**Figure 5.36**) (*t*-tests with sequential Bonferroni correction, $P<0.05$).

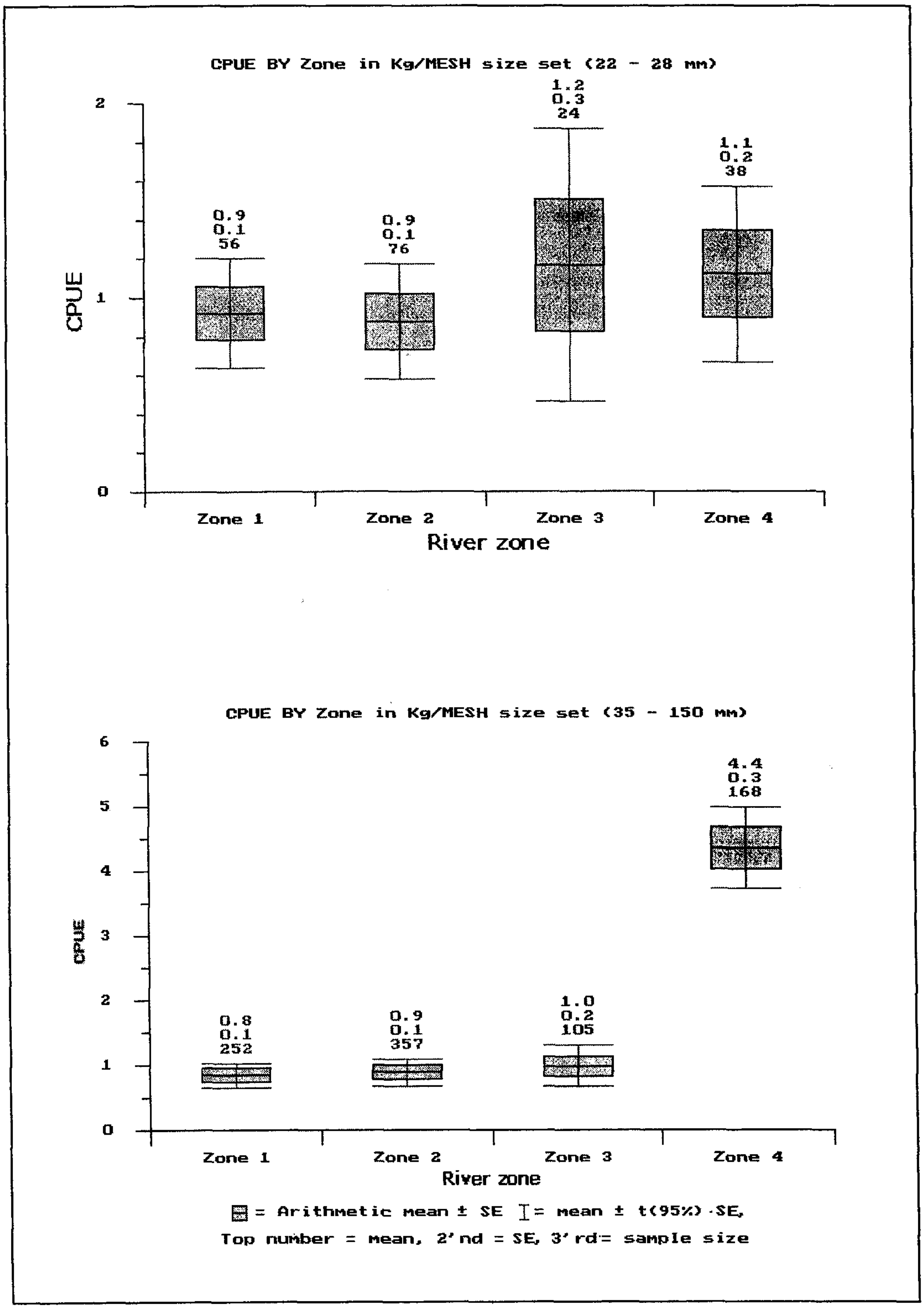

***Figure 5.36**. Mean CPUE in weight per setting with 95 % confidence limits in the four different river zones of the Okavango River for gill nets with mesh sizes 22-28 mm (top) and 35-150 mm (bottom). Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

The larger catch by weight observed in 35–150 mm mesh sizes at Kwetze (Zone 4) was mainly due to larger catches in the backwater habitats (**Table 5.42** and **5.43, Figure 5.36).** The sampling effort in the main stream at Kwetze was too small to provide reliable estimates. In the smallest mesh sizes (22–28 mm) the only significant differences in catch by weight were that catches at Musese were larger than at Bunya (*t*-tests with sequential Bonferroni correction, $P<0.05$). In the larger mesh sizes (35–150 mm) there were no significant differences in the main stream habitats (*t*-tests with sequential Bonferroni correction, $P>0.05$). In the backwater

Table 5.42. Mean CPUE in weight (Kg) per setting and number of settings (Sets) in gill nets with mesh size 22 and 28 mm at different stations, river zones and habitats during the period 1992-99. SD = Standard deviation. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).

Station	Zone	Main stream			Backwaters		
		Cpue	SD	Sets	Cpue	SD	Sets
Matava	1	0.66	0.73	8	1.50	1.37	10
Musese	1	0.95	1.05	28	0.86	0.98	4
Bunya	2	0.25	0.37	20	0.54	0.54	8
Rundu	2	0.59	0.67	16	1.65	1.27	4
Cuito	2	1.31	1.80	18	1.77	1.82	10
Mbambi	3	1.17	1.65	24			
Kwetze	4	0.26	0.21	3	1.23	1.40	34
Total		0.84	1.24	117	1.27	1.37	70

Table 5.43. Mean CPUE in weight (Kg) per setting and number of settings (Sets) in gill nets with mesh size 35 to 150 mm at different stations, river zones and habitats during the period 1992-99. SD = Standard deviation. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).

Station	Zone	Main stream			Backwaters		
		Cpue	SD	Sets	Cpue	SD	Sets
Matava	1	0.78	1.33	28	1.84	2.66	42
Musese	1	0.52	0.90	126	0.77	0.98	21
Bunya	2	0.88	1.71	84	0.48	0.76	49
Rundu	2	0.49	0.95	77	0.98	1.32	14
Cuito	2	0.48	0.99	77	2.33	3.96	56
Mbambi	3	0.99	1.63	105			
Kwetze	4	3.39	3.21	7	4.39	4.23	161
Total		0.72	1.37	504	2.82	3.80	343

habitat, however, the catch by weight at Kwetze was significant larger than at all the other stations sampled. In addition, catches at both Cuito and Matava were larger than catches at Bunya (*t*-tests with sequential Bonferroni correction, $P<0.05$).

In the backwater habitat (**Figure 5.37**) catches at Kwetze were larger than at all the other stations (Mbambi not sampled) in all mesh sizes from 35 mm upwards. The largest catches at Kwetze were taken in mesh sizes 35-73 mm. The less consistent results for catches in the main stream at Kwetze might be due to low fishing effort and consequently a low number of fish caught in this habitat. However one can notice that catches in 57 and 73 mm were low at all stations, Kwetze included. This may relate to the fact that relatively few fish species were most efficiently caught in these mesh sizes (cf. **Table 5.36**).

Based on population densities, Rundu and Kwetze may represent the extremes in fishing intensity in the Okavango River, with close to no fishing at Kwetze and possibly high exploitation rates at Rundu. These two sampling localities may therefore be used to exemplify possible differences in catches due to fishing intensity (**Figure 5.38**). At Rundu there was no significant differences between catches in the different mesh sizes, while at Kwetze catches in 25–45, 57-73, and 93 mm mesh size were significant larger than in 22–28 mm. In addition catches in 25–45 mm were significant larger than in 150 mm at Kwetze (*t*-tests with sequential Bonferroni correction, $P < 0.05$). In the smallest mesh sizes (22–28 mm) there were no differences in catches by weight between Rundu and Kwetze (0.8 and 1.1 kg, respectively). However, in larger mesh sizes (35–150 mm) catches were several times higher at Kwetze than at Rundu. In the largest mesh size (150 mm) there was no

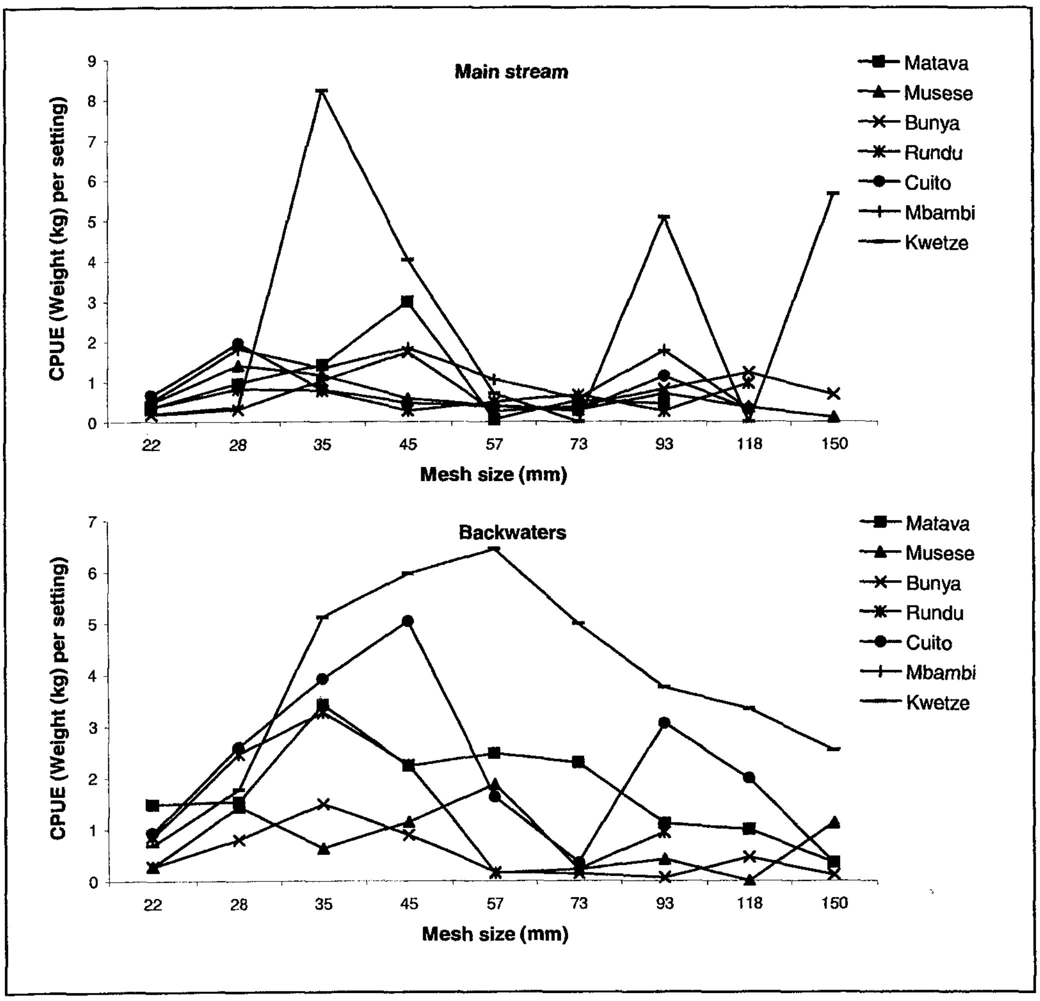

***Figure 5.37**. Mean CPUE in weight per setting in main stream (top) and backwater (bottom) habitats in different mesh sizes and at each station in the Okavango River. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).*

catch at all at Rundu, whereas the catch at Kwetze was 2.6 kg.

5.4.3 Variation in catch within species

Intensive fishing and exploitation of fish populations may reduce the overall number of individuals within a species. However, the result of selective fishing aiming at relatively large fish is often that the average size of species are reduced due to an increasing proportion of smaller fish.

We have selected six "large" and four "small" species that occur in representative numbers in the catches at all sampling stations (**Table 5.44**). The size classification is in accordance with **Table 5.36**. For most of the large species (species number 1-6 in **Table 5.44**), catches in weight were largest at Kwetze compared with the other stations. No such tendency was observed for the small species. This is in accordance with the lack of difference in overall gill net catches in small meshed gill nets (**Table 5.42**). In terms of number of fish per setting, there was no systematic difference between Kwetze and the other stations (**Table 5.45**).

5.4.4 Fish size at different stations

The gill net mesh sizes used in this investigation were chosen to obtain a representative catch and size distribution of the fish populations present at the locations sampled. On average a larger proportion of large fish were caught in gill nets at Kwetze than at other sampling localities. This was shown both in the total catches (**Figure 5.39**), and for many of the individual species sampled. Three examples are the common species silver catfish, bulldog and tigerfish (**Figure 5.40**). The largest fish were caught at Kwetze, where mean fish length in total gill net catches was 16.3 cm. The smallest fish were caught at Rundu, with a mean length of 10.7 cm (**Table 5.46**). The proportion of fish larger than 13 cm was 16 % at Rundu and 68 % at Kwetze, with the other localities at intermediate levels (22–38 %). The

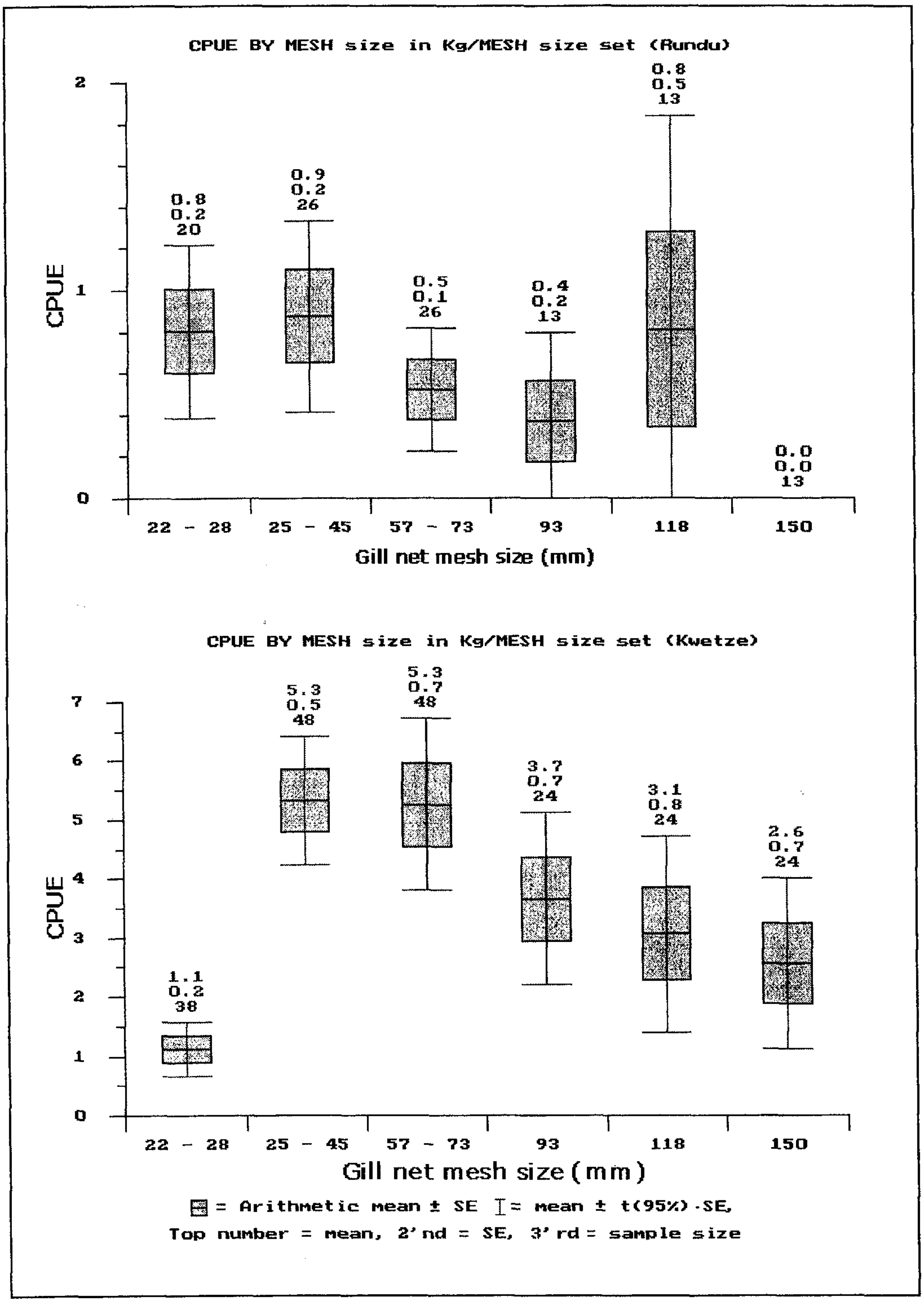

***Figure 5.38**. Mean CPUE in weight per setting with 95 % confidence limits on the different mesh sizes at Rundu and Kwetze. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2). Please note the different scale on the Y-axis.*

two numerically dominant species in the gill net catches, silver catfish and bulldog, showed a similar pattern in length distribution among localities (**Figure 5.40, Table 5.46**). Both species are largest at Kwetze and smallest at Rundu. At Kwetze, the proportion of silver catfish and bulldog larger than 13 cm were 80 and 59 %, respectively. The smallest proportions of large silver catfish were fond at Mbambi, Rundu and Matava (24, 25 and 25 %, respectively), while the smallest proportions of bulldog were found at Rundu and Bunya (14 and 15 %, respectively).

Table 5.44. *Mean CPUE in weight (kg) of fish per setting for different species in all mesh sizes. Species number 1-6 are relatively large while species number 7-10 are relatively small (based on length at maturity or mean length in catches, see* ***Table 5.36****). The selected species were caught in reasonable numbers at all or most of the sampling stations. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

	Species	Matava	Musese	Bunya	Rundu	Cuito	Mbambi	Kwetze
1	*S. intermedius*	0.16	0.09	0.04	0.09	0.33	0.16	0.93
2	*M. macrolepidotus*	0.27	0.11	0.04	0.05	0.11	0.09	0.26
3	*H. vittatus*	0.05	0.08	0.11	0.08	0.11	0.04	0.34
4	*S. nigromaculatus*	0.01	0.00	0.01	0.00	0.04	0.02	0.40
5	*C. gariepinus*	0.06	0.02	0.04	0.14	0.30	0.16	0.56
6	*H. odoe*	0.03	0.04			0.12	0.20	0.17
7	*B. lateralis*	0.04	0.09	0.02	0.08	0.05	0.02	0.01
8	*T. sparrmanii*	0.04	0.01	0.02	0.01	0.02	0.02	0.01
9	*B. poechii*	0.01		0.01		0.01	0.01	0.02
10	*P. catostoma*		0.01		0.01			0.02
	Sum	0.55	0.43	0.25	0.29	1.01	0.50	2.12

Table 5.45. *Mean CPUE in number of fish per setting for different species on all mesh sizes. Species number 1-6 are relatively large while species number 7-10 are relatively small (based on length at maturity or mean length in catches, see* ***Table 5.36****). The selected species were caught in reasonable numbers at all or most of the sampling stations. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).*

	Species	Matava	Musese	Bunya	Rundu	Cuito	Mbambi	Kwetze
1	*S. intermedius*	7.96	3.76	1.67	4.23	13.89	9.33	10.87
2	*M. macrolepidotus*	10.53	3.91	1.90	2.63	4.74	3.37	6.68
3	*H. vittatus*	0.87	0.57	1.44	0.86	1.66	0.44	1.57
4	*S. nigromaculatus*	0.11	0.03	0.21	0.10	0.95	0.34	7.15
5	*C. gariepinus*	0.15	0.01	0.06	0.15	0.37	0.22	0.48
6	*H. odoe*	0.44	0.15			*1.46*	2.51	0.67
7	*B. lateralis*	4.69	6.60	1.40	5.23	4.70	1.63	0.86
8	*T. sparrmanii*	2.15	0.66	0.96	0.58	1.64	1.14	0.16
9	*B. poechii*	0.89	0.38	0.62	0.46	0.93	0.56	2.13
10	*P. catostoma*	0.38	0.83	0.10	2.04	0.32	0.18	2.62
	Sum	28.17	16.90	8.36	16.28	30.66	19.72	33.19

5.4.5 Fish species composition

Two species, silver catfish and bulldog, are among the three most important species at all localities when ranging the ten most important species at each locality in terms of IRI (an index of relative importance) in gill net catches (**Table 5.47**). Tigerfish and striped robber were also important species, but IRI-values for this species were varying more between stations. Several species, which were important or common at the unexploited locality of Kwetze, were of little importance at the heavily fished locality of Rundu. These are in particular African pike (*Hepsetus odoe*), spotted sqeaker (*Synodontis nigromaculatus*) and dashtail barb (*Barbus poechii*). One large cichlid species, threespot tilapia (*Oreocromis andersonii*) (max. length 45 cm; Skelton 1993) was only found in any significant number at Kwetze. Most of the species caught were also larger at Kwetze than at the other localities (**Table 5.45**, **Figure 5.39** and **5.40**).

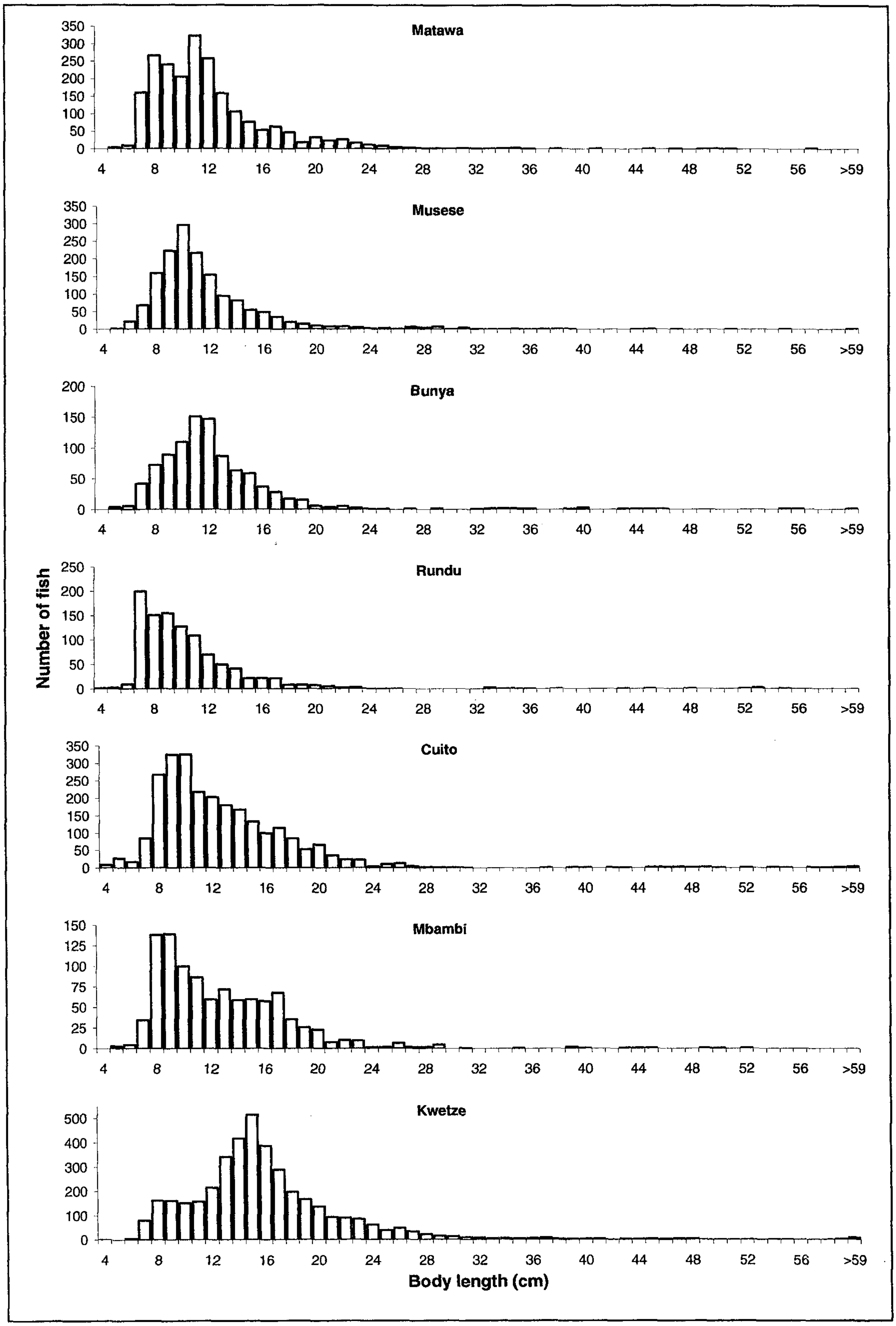

Figure 5.39. *Length distribution of total gill net catches at seven main sampling localities in the Okavango River during the period 1992-99. Notice different scales on y-axis.*

***Table 5.46.** Average length and the proportion of fish longer than 13 cm in total gill net catches of silver catfish (S. intermedius) and bulldog (M. macrolepidotus) caught at the main stations in the Okavango River from 1992-99.*

Locality	Matava	Musese	Bunya	Rundu	Cuito	Mbambi	Kwetze
				All species			
Length (cm)	12.1	11.8	12.6	10.7	12.9	12.9	16.3
>13 cm (%)	25	22	27	16	35	38	68
			Silver catfish *(S. intermedius)*				
Length (cm)	11.9	13.0	12.6	12.1	13.0	11.6	18.2
>13 cm (%)	25	36	37	25	37	24	80
			Bulldog *(M. macrolepidotus)*				
Length (cm)	12.1	12.5	11.9	10.5	11.6	12.3	13.9
>13 cm (%)	21	31	15	14	26	39	59

***Table 5.47.** The ten most important species in gill net catches, measured as IRI, at different sampling localities in the Okavango River during the period 1992-99. Average = average importance of the different species at all sampling localities where it was caught.*

				Locality				
Species	Matava	Musese	Bunya	Rundu	Cuito	Mbambi	Kwetze	Average
Schilbe intermedius	2	1	2	1	1	1	1	1.29
Marcusenius macrolepidotus	1	2	1	3	2	3	3	2.14
Hydrocynus vittatus	5	4	3	4	4	6	4	4.29
Brycinus lateralis	4	3	4	2	6	8		4.50
Clarias gariepinus	6		6	5	3	7	5	5.33
Tilapia sparrmanii	3	7	5	7	8	4		5.67
Hepsetus odoe		5			5	2	6	4.50
Synodontis nigromaculatus					7	10	2	6.33
Barbus poechii	8	10	9		9		10	9.20
Petrocephalus catostoma		8		6			8	7.33
Hippotamyrus discorhynchus	7	6		8				7.00
Labeo lunatus			7					7.00
Serranochromis macrocephalus	10				10	5	9	8.50
Clarias ngamensis	9		10					9.50
Oreocromis andersonii							7	7.00
Serranochromis robustus			8			9		8.50
Labeo cylindricus				9				9.00
Serranochromis angusticeps		9						9.00
Parauchenoglanis ngamensis				10				10.00

The backwaters are assumed to be a habitat type that is similar over all sampling stations. To compare the proportion of small fish (which includes both small species and juveniles of larger species), we have analysed the catches of fish in 22 and 28 mm gill nets in backwaters. There is substantial variation in catches among stations, both in weight (0.54-1.77 kg per setting), and in number of fish (44-167 fish per setting) (**Table 5.48**), but catches at Kwetze were intermediate (1.23 kg and 62 fish per setting). Thus, there is not the same tendency of higher catches at Kwetze when we consider small fish. There is, however, a somewhat higher number of species in the catches at Kwetze (17 spp.) than the other stations (10-15 spp), and a higher ratio of large species vs. small species (according to our classification in **Table 5.36**).

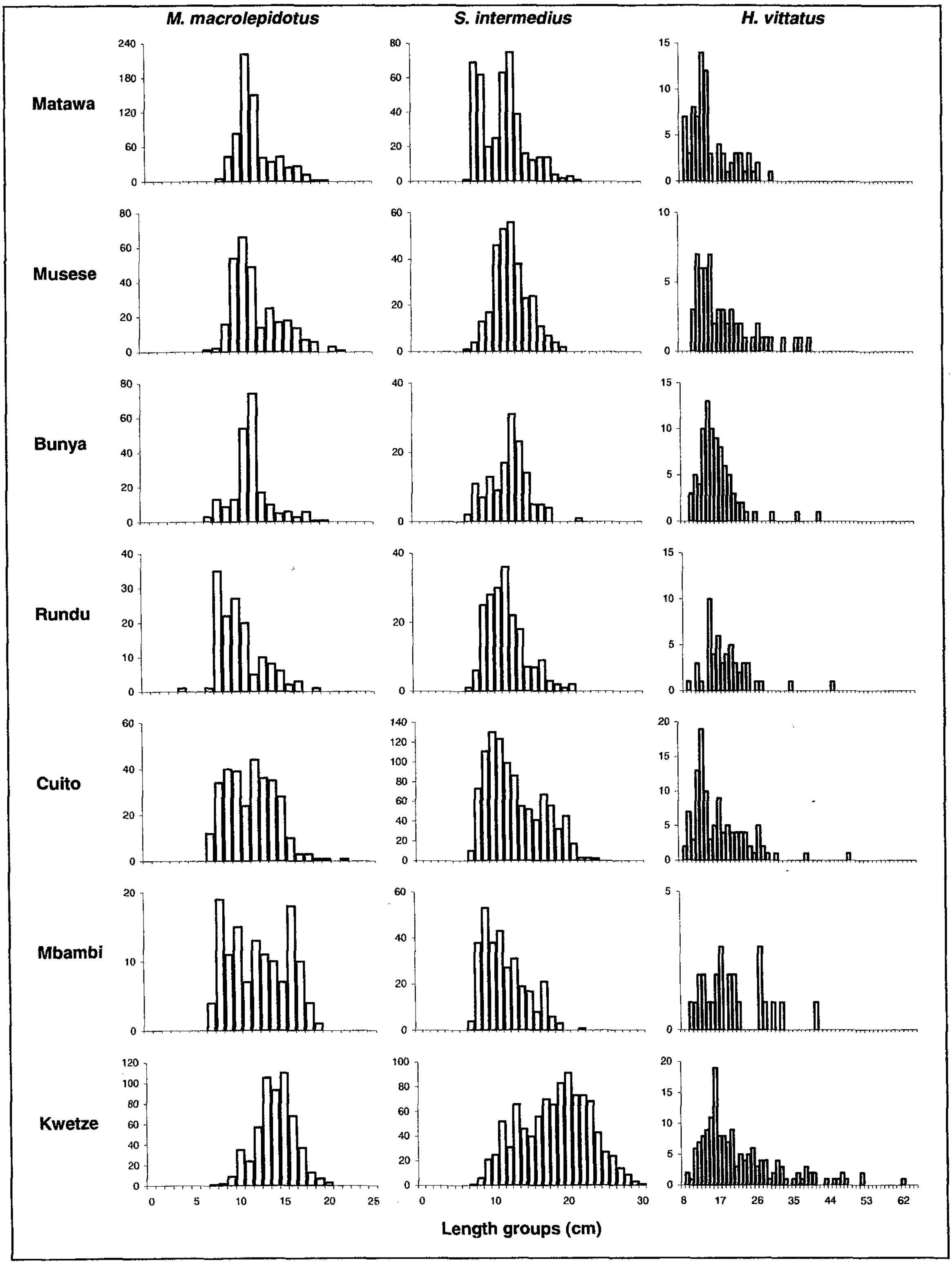

Figure 5.40. *Size frequency of M. macrolepidotus, S. intermedius and H. vittatus caught in gill nets at seven main sampling localities in Okavango River during the period 1992-99. Notice different scales on x- and y-axis.*

Table 5.48. *Catches in 22 and 28 mm gill nets in backwaters in the seven sampling stations in the Okavango River. The diversity index is the Shannon-Weaver index (H'= -$\sum p_i \ln p_i$ where p_i is the proportion of the total catch in numbers made up by species i). At Mbambi, no gill net fishing was possible in the backwaters. Classification of large and small species are according to* ***Table 5.36***.

	Matava	Musese	Bunya	Rundu	Cuito	Mbambi	Kwetze
Number of fish	661	158	106	166	549	-	736
CPUE, # fish	167.22	59.44	44.17	138.33	150.78	-	62.48
CPUE, weight (kg)	1.50	0.86	0.54	1.65	1.77	-	1.23
Number of species	15	10	13	14	15	-	17
Diversity index	2.02	1.49	2.03	1.57	1.84	-	2.04
# large species	5	3	5	6	6	-	9
# small species	7	6	7	5	7	-	6
Ratio #large/#small spp.	0.71	0.50	0.71	1.20	0.86	-	1.50

6 Recommended management actions

6.1 Background

The White Paper "Responsible Management of the Inland Fisheries of Namibia" was finalised in December 1995, and forms the basis for a new law and regulations concerning fish resources management in the different freshwater systems in Namibia. The Okavango River is one of the most important of the perennial rivers, and freshwater fish are a very important food source for local inhabitants. Hence, the protection of this resource is of utmost importance to secure the future food availability of the riparian population in this region of Namibia. In this report management actions are recommended on the basis of eight years of biological studies in the river. Later reports will give recommendations for regulations of fisheries in the other perennial rivers in Namibia.

Our main objective has been to develop applicable guidelines for regulations of the inland fisheries in the Okavango River. This report will further enable the Ministry of Fisheries and Marine Resources to implement the proposed law and regulations necessary for sustainable management of the fish resources in the river.

In addition, a second goal of this report has been to identify critical aspects and needs for more knowledge that should be addressed in future studies, and give recommendations on how to obtain the necessary information needed for future management of the Okavango River.

6.2 Management regulations

The rationale for management regulations is to maintain and protect a sustainable subsistence fishery for the local population along the different river systems in Namibia, where fish have been and still is an important source of animal protein. Due to the diverse nature of the different water systems, separate management regimes are envisaged for each river system in Namibia.

The Okavango River enters Namibia from Angola and follows the border between Angola and Namibia before flowing south through Namibia and into Botswana. The present collaboration with neighbouring countries on management issues is limited, and the available biological data from the sections of the river in Angola and Botswana is very restricted. The fish populations in the river may be strongly influenced by fishing and other activities in the different countries. Therefore, if at all possible, the future aim should be to establish a management regime in close collaboration with neighbouring countries.

Commercialisation of the fish resources in the Okavango is not an economically and ecologically viable option. This conclusion is based on the present state of the fish resources in the river and the high human population densities along most of the river. The supply to local fish markets in the Okavango region consists mainly of marine fish (horse mackerel) and lately of a limited amount of fresh water fish imported from the Caprivi. Although people in the region may prefer freshwater fish, marine fish is accepted and more affordable. Locally, the riverine fish resource has always been considered a source of subsistence, and approximately 90 percent of the people utilising fish as a supplement to their daily diet. Presently the fish populations in large part of the river are impacted by human exploitation. Few large fish are present and the catch per unit effort is smaller than in areas where fishing activities are restricted. The fish resource should therefore be regarded strictly as a source for a sustainable subsistence fishery utilised by the population along the Okavango River.

The fish community consists of more than 70 species each with their specific ecology, forming an integral part of a complex and dynamic ecosystem. Selective utilisation of the fish resources, for example catching mainly the large predatory species, may have a profound negative effect on the fish community structure. Therefore, any exploitation of such a multi-species fish resource should preferably be performed non-selectively, i.e., fish from all trophic levels should be caught in proportion to their occurrence in the aquatic ecosystem. This principle of proportional exploitation forms the basis of our management recommendations. As a consequence, regulations for the recreational fishery should be based on quotas and restriction of fishing effort rather than specific minimum sizes.

The fisheries in the Okavango River exploit a large number of species. Although some species may be preferred as food, the local fisheries spend more effort to increase the quantity of fish (and thereby food supply) rather than to catch specific species. Regulation of the artisanal fishery by means of a quota system thus becomes logistically impractical. A more practical system based on effort restrictions by means of gear regulations is therefore recommended. Recreational and trophy fishing, however, may be regulated through both quotas and gear restrictions.

6.3 Biological studies

The study presented in this report is based on a data series covering the period 1992 to 1999. This series constitutes good baseline data for future monitoring-programmes. Earlier fish data from the Okavango River were mainly limited to species lists and systematic studies with very little ecological information collected. Some ecological studies were done in the 1980's, but these were short-term projects and no data series were collected. Data for the present study were collected at seven main stations along the Namibian part of the Okavango River. Fishing was done with experimental gill nets in the deeper parts of the water bodies, and several other gears including rotenone, seines and traditional gears in shallow waters. In addition, the areas between these stations were occasionally sampled. The data series form the basis for our management recommendations as well as for the discussions on future research programmes.

The results obtained in this study do indicate that the structure of the fish community has changed because of fishing activities. This is seen when comparing the fish community within the protected area (Mahango Game Park, with no fishing) with the other stations where fishing is continuously going on. In the fished areas, there are less large fish within species and overall in the catches. Fewer fish are caught in the large meshed gill nets, and the large, long-lived species are replaced by small, short-lived species. There is also a tendency that catch per unit effort (by weight) in gillnets is lower in the heavily fished areas. The effect of these changes is observed by the Okavango fisherwoman saying "I still catch enough fish for my family, but I need to catch more, as they are smaller".

The biological study also clearly indicates that the fish resource will not be able to sustain a commercial fishery economically, sociologically nor ecologically. The present catches by the local fisherfolk consist mainly of small species with a relatively low commercial value. These catches are utilised mainly for subsistence, but a limited surplus may be sold or exchanged for goods. A commercial fishery, for example with beach seine, as occasionally seen today, may deplete the fish resources drastically in some areas and thereby reduce the food supply for other fisherfolk. Women and children are particularly vulnerable as they are exploiting the same fish resources but with less effective traditional gears.

The Okavango River is easily accessible for fishing activities, especially during the low water period between September and December when fishing becomes intense. This is the period just before the start of the ploughing season. Other types of food are not readily available, and the low water level concentrates fish, making fisheries more effective. However, this is also the onset of the breeding season of most fish species. Therefore the brood stock more vulnerable to disturbances and exploitation.

Our results clearly show the value of sanctuaries where fishing is prohibited. Catches at the study site within Mahango Game Park contained a higher number of large species, and within the same species, fish was larger than conspecifics caught in other areas. In gillnets, the catch per unit effort (by weight) was approximately 3-6 times higher within Mahango than at the other stations. The protected area protects the fish resource and its habitats as well as other aquatic organisms, maintaining a healthy aquatic ecosystem. Depending on their size and position, sanctuaries may protect breeding and/or feeding habitats for different species. The protected areas may also serve as source areas, where fish production provides a surplus that migrates out of the protected area and reinforce the exploited fish populations. Different fish species may have very different migration patterns, but very little is known about the migration patterns of the fish species found in the Okavango. However, it is reasonable to assume that sanctuaries may be an important management action to sustain the fishery in heavily exploited rivers such as the Okavango River. In addition, given the appropriate regulations, sanctuaries may provide excellent trophy fishing attracting exclusive fishing safaris creating economic activities to benefit local communities.

6.4 Management actions

The introduction of a proper management regime based on the new legislation should be done in two phases. The first phase would be the immediate implementation of actions based on present knowledge as soon as the bill is adopted by Parliament. These actions were identified through this study. The second phase should include issues that will need further research, considerations and deliberations with the local inhabitants. These actions may be included in future regulations as deemed necessary.

6.4.1 Management actions for immediate implementation

- All traditional gears may be allowed. These gears are an important part of the traditional life of local inhabitants. The manufacturing of these gears are often time consuming, but they are mainly produced from local materials. Many of them are not very efficient, although they may catch enough fish for household supplies.
- Gill nets, and angling equipment (rods and reels) should be the only modern gear allowed.
  - In accordance with the proportional exploitation principle all mesh sizes of gill nets should be allowed to prevent selective fishing.
  - Gill nets should be registered to prevent transboundary conflicts and to facilitate control of fishing effort.
  - Only people resident in the Okavango region should be allowed to register gill nets for use in

the Okavango River. This is necessary to prevent an influx of people from other regions, which will put more strain on the already exploited fish resource.
  - A maximum of two gill nets per fisherman with a maximum total length of 50 m may be allowed. Up to two nets per person may be advisable to secure the individual some catch even if a gill net is destroyed. Maximum depth of the gill nets should be 2 m.
  - The regional council may restrict the number of gill nets per region. Presently it is not possible on the basis on available data to advice on the total number of nets that should be allowed in the Okavango River, or in any section of the river.
  - No gill net should be set in such a way as to close off more than 50% of a water body, channel, or main stream.
- The dragging of any fishing device should be prohibited. The dragging of nets, mosquito nets, shade cloths, etc., are non-selective fishing methods, but often also the most destructive way to catch fish. The fish are especially vulnerable to this method during the low water period when migrating into shallow habitats for breeding. The fishing method may also destroy the habitat for fish and other aquatic organisms. In addition the use of dragging devices may spoil the water quality and its use for other purposes, for example watering household animals.
- No activities or gears should be allowed which may potentially pollute the environment.
- No explosives, noxious substances, poison or electrical devices should be allowed.
- No artificial light during any fishing activities should be allowed.
- The recreational fishery should be licensed.
  - Simultaneous use of maximum two rods/lines per person should be allowed.
  - Not more than two hooks or baits per line should be permitted.
  - A baglimit of not more than 10 fish per person per day should be set. A daily bag limit of two fish of selected trophy fishes (for example tiger fish and tilapia species) is also recommended.
  - All catches by recreational anglers should be recorded on a form to be provided with the licence. For each fish caught this form may include informa-tion on: Date of catch, place of catch, fish species caught, body length of fish kept by angler, and type of fishing tool. In addition information on total fishing effort as for example how many days of total fishing and average hours of fishing per day should be recorded. Failing to return this form may result in the refusal of obtaining a licence the next year.
- All motor powered boats used for fishing should be registered and licensed.
- Organisers of angling competitions must seek permission from the Ministry, who will eventually approve and control the event.

6.4.2 Management actions for future consideration

To implement the new legislation in practice, more precise information is needed on several aspects such as the type of gill nets used by fishermen, where they fish, the species composition of the catches, the abundance and size distribution of fish species and fish size at sexual maturity.

Several actions should be considered for the future, but for which more scientific research and collaboration with the communities and neighbouring countries are needed.

- The establishment of fish sanctuaries in addition to the Mahango Game Park should be considered. Sanctuaries are most often established to protect important breeding and/or feeding habitats or areas. For stationary species the sanctuary may include all areas or habitats used by the species. For migratory species the sanctuary may protect the species in certain phases of the life cycle. The purpose of the sanctuary may be to protect rare or endangered species, and it may also function as a source from which the surrounding waters can be restocked. Our knowledge about the habitat use and migration patterns of most of the species in the river is limited and should be further studied to establish the area, the management and the size of these sanctuaries. Sanctuaries may lead to an increase in the number of large individuals, which will be attractive to recreational anglers. The community may generate revenue by allowing fishing safaris with strict bag limits to these areas. Fish sanctuaries could be included in the already present community conservancies.
- Closed fishing seasons could be implemented to protect the fish population during vulnerable periods, for example when fish are congregated during spawning at low water discharge or during seasonal migrations.
- Defined areas for specific activities, such as areas for fishing safaris and fishing competitions should be considered.
- The initiation of a community data collection programme should be considered to increase the fish database.
- Continuos international collaboration with neighbouring countries should be given high priority.

6.5 Future research programmes

Future projects should be designed to ensure the availability of data needed for management purposes.

- The value of a continuous data series cannot be underestimated. Due to natural variasjons within fish stocks and ecosystems it is important to study long time trends in the populations. It is imperative that the monitoring of the river continues so that changes in the population structure may be identified and management actions taken to reverse possible future adverse effects. The emphasis of the monitoring, however, should be on fewer stations, but with an increased effort at each station. Stations should be sampled once a year, preferably in the spring before flooding. Smaller mesh size gill nets should be included in the surveys to sample the smaller individuals in the deeper, open water habitats.
- The collection of data by the community for research purposes have been done successfully elsewhere in Africa and should be considered in the Okavango to increase the database for future stock assessment studies. Data from the subsistence fishery should therefore be collected on a regular basis to more accurately assess the status of the fish resource. A community based data collection programme should be initiated which will increase the database as well as the frequency of data collection. The local involvement in community based data collection may also facilitate participation in any future management activities and raise local awareness about management and conservation issues.
- The knowledge of fish behaviour and migration, especially of potential angling species, is limited and resources should be allocated to conduct such studies. This is important for the establishment of fish sanctuaries and to dissolve conflicts between the recreational and subsistence fishermen.
- The socio-economic role of fish in the region should be subject to ongoing studies to complement the fishery and experimental data.
- Namibia has very little control over the management of the Okavango watershed as the catchment area falls within neighbouring countries. The Okavango River must be managed as an entity and regular collaboration with neighbouring countries is essential if the fish resource is to be managed properly.
- Where possible, comparable data sets from neighbouring countries should be included in future analysis.

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Appendix

List of species caught in gillnets and with other gears in the Okavango River 1992-99. Stations 1 to 7 are Matawa, Musese, Bunya, Rundu, Cuito, Mbambi and Kwetze, respectively. Gears 1 to 15 are the different other gears (see **Table 5.3**) and 20 is gillnets from 22 to 150 mm stretch mesh. Lengths are average, minimum and maximum of total catches of each species. Total number are the catches of each species in number and percentage from all stations in the Okavango River during the study period 1992 - 1999.

Species	Stations							Gears																Length (mm)			Total number	
																								Average	Min	Max	N	%
Barbus sp.				4		6		1	2	3														43	28	72	9	0,0
Barbus afrovernayi	1	2	3	4	5	6	7		2				6						12			15		27	15	45	159	0,3
Barbus barnardi	1	2	3	4	5	6	7	1	2	3		5	6						12			15		30	15	55	440	0,9
Barbus barotseensis				4	5	6		1	2			5												36	21	59	38	0,1
Barbus bifrenatus	1	2	3	4	5	6	7	1	2			5	6						12			15	20	32	16	78	288	0,6
Barbus codringtonii									2															112	93	125	4	0,0
Barbus eutaenia			3		5	6		1	2				6	7					12			15		51	25	98	470	1,0
Barbus cf. eutaenia			3	4	5	6	7	1	2			5	6	7					12					37	15	56	249	0,5
Barbus fasciolatus	1		3	4	5	6	7	1	2			5	6			9			12			15		31	15	48	272	0,6
Barbus haasianus	1	2		4	5	6	7	1	2			5	6						12					19	13	30	177	0,4
Barbus kerstenii	1		3	4	5	6	7	1	2			5							12				20	36	27	70	17	0,0
Barbus multilineatus			3		5	6	7		2				6	7					12					28	14	78	217	0,5
Barbus paludinosis	1	2	3	4	5	6	7	1	2	3	4	5	6						12			15	20	54	13	90	1692	3,6
Barbus poechii	1	2	3	4	5	6	7	1	2	3	4	5	6	7					12			15	20	58	20	160	2392	5,0
Barbus radiatus	1	2	3	4	5	6	7	1	2	3		5	6	7		9						15	20	42	14	88	430	0,9
Barbus thamalakanensis	1	2	3	4	5	6	7	1	2	3		5	6	7		9			12			15		29	14	50	641	1,4
Barbus unitaeniatus	1		3	4	5	6	7	1	2	3		5							12			15	20	50	28	94	178	0,4
Coptostomabarbus wittei					5	6	7	1	2				6											19	14	30	119	0,3
Labeo cylindricus	1	2	3	4	5	6	7		2	3		5	6	7		9			12				20	80	10	200	1558	3,3
Labeo lunatus		2	3	4	5	6	7	1	2	3													20	186	38	475	111	0,2
Mesobola brevianalis	1	2			5			1								9						15		30	20	34	6	0,0
Opsaridium zambezense	1	2	3	4	5		7	1	2	3			6			9			12			15		49	13	100	642	1,4
Hemigrammocharax machadoi	1	2	3	4	5	6	7	1	2	3		5	6			9						15		26	15	123	446	0,9
Hemigrammoch. multifasciatus	1	2	3	4	5	6	7	1	2	3		5	6			9			12			15		32	18	50	411	0,9
Nannocharax macropterus							7						6						12			15		29	23	39	50	0,1
Brycinus lateralis	1	2	3	4	5	6	7	1	2	3	4	5	6									15	20	78	14	140	2652	5,6
Hydrocynus vittatus	1	2	3	4	5	6	7	1	2	3		5	6				10					15	20	160	20	620	834	1,8
Micralestes acutidens	1	2	3	4	5	6	7	1	2	3		5	6			9			12			15	20	37	12	80	465	1,0
Rhabdalestes maunensis							7		2				6											31	25	39	4	0,0
Hippopotamyrus ansorgii	1	2	3	4	5	6			2										12				20	78	37	140	33	0,1
Marcusenius macrolepidotus	1	2	3	4	5	6	7	1	2	3		5	6			9		11	12			15	20	125	42	225	2505	5,3
Mormyrus lacerda	1	2	3	4	5	6	7		2	3							10						20	195	45	360	170	0,4
Petrocephalus catostoma	1	2	3	4	5	6	7	1	2	3		5	6	7		9			12				20	69	20	119	1148	2,4
Pollimyrus castelnaui	1	2	3	4	5	6	7	1	2	3		5	6			9			12				20	47	15	70	330	0,7
Hippotamyrus discorhynchus	1	2	3	4	5	6	7		2	3		5				9			12				20	100	26	190	376	0,8
Hepsetus odoe	1	2			5	6	7	1	2	3													20	197	20	430	445	0,9
Parauchenoglanis ngamensis	1	2	3	4	5	6	7		2					7			10						20	120	50	185	94	0,2
Amphilius uranoscopus									2										12					70	30	115	59	0,1
Leptoglanis cf dorae							7						6									15		27	22	30	12	0,0
Schilbe intermedius	1	2	3	4	5	6	7	1	2	3	4	5	6			9			12	13		15	20	135	17	300	4496	9,5
Clariallabes platyprosopos			3			6			2					7										164	40	300	33	0,1
Clarias sp.	1			4	5	6			2	3														77	18	146	49	0,1
Clarias gariepinus	1	2	3	4	5	6	7	1	2	3				7				11	12	13			20	335	50	790	207	0,4
Clarias liocephalus	1		3		5	6			2					7					12					89	32	200	17	0,0
Clarias ngamensis	1	2	3	4	5	6	7	1	2	3									12	13		15	20	220	76	730	165	0,3
Clarias stappersii	1	2	3		5	6	7	1	2								10						20	196	45	340	23	0,0
Clarias theodorae	1	2	3	4	5	6	7		2	3	4	5							12				20	98	24	264	101	0,2
Chiloglanis fasciatus	1						7		2				6			9								31	10	46	26	0,1
Synodontis sp.	1	2	3	4	5	6	7	1	2	3		5	6	7		9		11	12				20	88	10	250	6287	13,3
Synodontis nigromaculatus	1	2	3	4	5	6	7		2	3				7									20	146	25	240	1361	2,9
Aplocheilichthys hutereaui					5	6							6								14			18	16	20	6	0,0
Aplocheilichthys johnstoni	1	2	3	4	5	6	7	1	2	3		5	6						12		14	15		29	6	50	1655	3,5
Aplocheilichthys katangae					5	6	7		2			5	6						12		14			25	11	41	145	0,3
Cichlidae	1	2	3	4	5	6		1	2	3	4		6			9							20	34	10	105	238	0,5
Hemichromis elongatus					5		7		2				6											68	37	97	8	0,0
Oreochromis andersonii	1	2		4	5	6	7	1	2	3					8								20	113	28	500	355	0,7
Oreochromis macrochir	1	2		4	5	6	7	1	2	3	4								12			15	20	86	10	325	399	0,8
Pharyngochromis acuticeps	1	2	3	4	5	6	7	1	2	3		5	6	7		9			12	13		15	20	57	20	120	1445	3,0
Pseudocrenilabrus philander	1	2	3	4	5	6	7	1	2	3	4	5	6	7		9			12		14	15	20	42	10	105	3599	7,6
Serranochromis sp.	1					6		1	2	3						9								47	29	64	13	0,0
Serranochromis altus	1		3	4	5	6	7		2	3			6										20	194	72	441	31	0,1
Serranochromis angusticeps	1	2	3	4	5	6	7	1	2	3		5	6	7		9						15	20	148	30	462	106	0,2
Serranochromis macrocephalus	1	2	3	4	5	6	7	1	2	3	4	5	6	7		9			12			15	20	107	10	335	506	1,1
Serranochromis robustus	1	2	3	4	5	6	7	1	2	3	4	5				9						15	20	112	30	480	237	0,5
Serranochromis thumbergi		2		4	5				2	3						9			12				20	84	58	130	7	0,0
Sargochromis carlottae	1	2	3	4	5	6	7		2	3													20	143	80	300	79	0,2
Sargochromis codringtonii	1	2	3	4	5	6	7	1	2	3	4	5											20	109	30	270	245	0,5
Sargochromis giardi	1	2	3	4	5		7		2	3										13			20	185	60	450	50	0,1
Tilapia rendalli	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	9			12	13		15	20	64	11	375	1596	3,4
Tilapia ruweti					5	6	7	1	2	3									12				20	52	26	127	120	0,3
Tilapia sparrmanii	1	2	3	4	5	6	7	1	2	3	4	5	6	7		9			12	13		15	20	60	18	190	3099	6,5
Microctenopoma intermedium					5	6	7		2										12					34	22	76	138	0,3
Ctenopoma multispine			3	4	5	6	7		2										12				20	67	32	140	207	0,4
Aethiomastacembelus frenatus	1			4	5	6			2	3									12					124	60	271	11	0,0
Aethiomastacemb. vanderwaali		2	3	4	5	6			2			5												104	18	175	235	0,5
Total																								84	6	790	47438	100