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Directorate Resources Management
Ministry of Fisheries and Marine Resources
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Namibia

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Preface

Næsje, T.F., Hay, C.J., Nickanor, N., Koekemoer, J.H., Strand, R., and Thorstad, E.B. 2004. Fish populations, gill net catches and gill net selectivity in the Kwando River, Namibia. - NINA Project Report 27. 64pp.

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. Since all perennial rivers in Namibia forms the border to neighbouring countries, management of the fish resources also depends on a regional co-operation. The effects on the fish resources caused by subsistence, commercial and recreational fisheries in the neighbouring states must also be taken into consideration. When implementing fisheries regulations for such complex systems, information on the fish resources and their exploitation are needed.

Based on a series of studies of the fish resources in the perennial rivers, recommendations will be given for management and regulations of fisheries in the Caprivi Region. The management regulations are aiming to involve local, national and international authorities and stakeholders. It is a priority to secure a sustainable utilisation of the fish resources for the benefit of local communities and future generations, and important aspects of fisheries management have been studied to form the basis for new management strategies. Studies involve descriptions of the fish resources (Hay *et al.* 2002, this report), the exploitation of fish resources and stakeholders, including the socioeconomic infrastructure of local societies (Næsje *et al.* 2002, Purvis 2001a, b, Hay *et al.* in prep), fishing competitions (Næsje *et al.* 2001), and migrations and habitat utilisation of important fish species (Økland *et al.* 2000, 2002, Thorstad *et al.* 2001, 2002, 2003a, b).

The studies of fish migrations conclude that certain fish species may migrate between countries, both along and across the river system, which emphasise the importance of a joint local and regional co-management of the fish resources both on national and international scale. Other species, however, are more stationary and are more vulnerable to local exploitation. The biological and sociological aspects of the subsistence, semi-commercial and recreational fisheries in Caprivi have documented that in the absence of a strong formal system of fisheries management, the informal (or traditional) component in Namibia has remained. However, the studies document the calls from all levels for an improved and effective system for fisheries management in the region. Reasons cited for the need include: increasing number and magnitude of conflicts over fisheries – both within countries and with neighbouring countries; a perceived decline on the condition of fish stocks in the rivers; an increasing number of fishermen exploiting the resource; price increases of fish; and the potential for increased stress on the fishery as other components of the farming system are in decline because of the current drought.

In the present report, the fish populations in the Kwando River are described on the basis of five surveys performed in the period 1997-1999. The fish populations in the Zambezi and Chobe Rivers were studied in the same period (1997-2000) (Hay *et al.* 2002).

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

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C.J. Hay T.F. Næsje

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Summary

Objective
The objective of this report is to provide baseline information about the fish resources in the Namibian part of the Kwando River to form the biological foundation for recommendations for a sustainable management of the fish resources. Based on fish survey data from the period 1997-1999, the fish resources are described through studies of species diversity, relative importance of the different species, life history parameters, catch per unit effort and gill net selectivity.

Methods
Fish were collected at ten stations with survey gill nets (multi-filament, 22–150 mm stretched mesh size) and six other sampling methods, such as seine nets, cast nets, electrofishing apparatus and rotenone, which are collectively called "other gears" in this report. The gill nets were used to survey open, deep-water habitats (> 1 m) in the main stream near the shore and deep backwater areas with some aquatic vegetation. The other gears targeted mainly small species and juveniles of long-lived species in shallow, vegetated and rocky habitats.

Surveys were carried out in the spring in 1997 and 1998 and in the autumn in 1997, 1998 and 1999. A total of 2756 fish were caught; 1172 with gill nets and 1584 with other gears. The most important species in the catches were identified by using an index of relative importance (IRI), which is a measure of the relative abundance or commonness of the species based on number and weight of individuals in the catches, as well as their frequency of occurrence. Eighteen of the most important species collected were selected for a more detailed analysis of life history and gill net selectivity.

Results
A total of 48 fish species were recorded during the surveys, in addition to unidentified *Synodontis* species. Due to difficulties with the taxonomic classification in the *Synodontis* spp. group, these species have been pooled, except the easily recognised *Synodontis nigromaculatus*. Four *Synodontis* species have previously been listed for the Kwando River. The fish families represented with the highest number of species were the Cyprinidae and the Cichlidae, with 10 and 15 species, respectively.

Thirty species were caught in the gill nets (excluding *Synodontis* spp.). The ten most important species contributed to 97 % of the total IRI. The three most important species (*Marcusenius macrolepidotus*, *Hydrocynus vittatus* and *Petrocephalus catostoma*) contributed to 56 % of the total IRI. The Mormyridae family was the most important family in the gill net catches (50 % of the total IRI). The Characidae family was also important in the gill net catches (31 %), whereas the Cichlidae family constituted only a small part (5 %).

Thirty-eight species were caught with other gears than gill nets (no *Synodontis* spp. was caught with the other gears). The ten most important species contributed to 98 % of the total IRI. The three most important species (*Pharyngochromis acuticeps*, *Pseudocrenilabrus philander* and *Micralestes acutidens*) contributed to 68 % of the total IRI. In contrast to the gill net catches, the Cichlidae was the most important family in the catches with other gears, according to IRI (66 %). The number of species caught was higher for the catches with other gears than with gill nets, which is attributed to the flexibility of the other gears, and that a much wider range of habitats was sampled.

The body length of the fish caught was up to 66 cm. The modal length of fish caught in gill nets was 8.0-8.9 cm, whereas for fish caught with the other gears 3.0-3.9 cm. Thus, larger fish were caught with gill nets than with the other gears, and this was true both for the species combined and for individual species. Twelve of the species caught had a maximum body length of 6 cm or smaller.

The 18 species selected for a more detailed data analysis, contributed to 92 % of the gill net catches and 90 % of the catches with the other gears, according to IRI. These species represented a large variation in biology, distribution and sizes. Of the selected species, seven species had a minimum length at maturity smaller than 10 cm, three species between 11 and 20 cm and four species larger than 20 cm. The minimum length at maturity was larger than or similar to the smallest fish caught with gill nets in all the selected species, except for both sexes of *Pseudocrenilabrus philander*.

Comparison among rivers
The results from the surveys in the Kwando River were compared with previous studies in the Zambezi/

Chobe and Okavango Rivers (Hay et al. 2000, 2002). A higher number of species were recorded in the Okavango River (70 species + Synodontis spp.) and the Zambezi/Chobe Rivers (69 species + Synodontis spp.) than in the Kwando River (49 species + Synodontis spp.). Generally, the fish fauna in the Zambezi/Chobe and Okavango Rivers showed great similarities, and there is a considerable overlap in the distribution of species between the rivers. All the species recorded during the surveys in the Kwando River were recorded during the surveys in both the Okavango and Zambezi/ Chobe Rivers, except *Sargochromis giardi* recorded in the Kwando River but not in the Zambezi/Chobe Rivers. However, this species has previously been recorded in the Zambezi River.

Larger specimens were sampled with gill nets in the Zambezi/Chobe Rivers (body lengths up to 92 cm) than in the Okavango River (body lengths up to 79 cm) and the Kwando River (body lengths up to 66 cm). Especially most of the cichlid species seem not to reach the same maximum body lengths in the Kwando River as in the two other rivers. Differences in physical and biological characteristics of the rivers are probably the reasons for some of the differences in size distributions and lower number of species in the Kwando River than in the Okavango and Zambezi/ Chobe Rivers.

Conclusions

Little is generally known about the fish populations in the perennial rivers in the Caprivi Region in Namibia, and even less is known about the fish populations in the Kwando River than in the Okavango and Zambezi/ Chobe Rivers. The Kwando River is the most pristine of these rivers, whereas the Okavango River runs through the most densely populated areas and is exposed to the highest fishing intensity. The fish populations in the Kwando River seem stable and in a good condition. However, being a smaller system than the Okavango and Zambezi/Chobe Rivers, it is more vulnerable to external impacts, such as exploitation of the fish resources and other human activities.

The complex and diverse nature of the fish fauna in the Namibian part of the Kwando River has been revealed through the present surveys. However, detailed knowledge on the biology and behaviour of most of the species are still lacking. Basic information on life history, reproduction, movements, habitat preferences and habitat utilisation of target species is needed to give recommendations on the management of fisheries in neighbouring countries, and to evaluate the possible benefits of nature reserves and sanctuaries. Any changes to the flood regime caused by factors such as water abstraction, impoundment, canalisation and construction of roads on the floodplains can have serious negative effects on the functioning of the floodplain system. The Kwando River is presently still relatively undisturbed by human impacts. For that reason alone, this system should be better studied to provide baseline knowledge for the future.

1 Introduction

Namibia is an arid country and strongly depends on the availability of open waterbodies for human food consumption, industries, irrigation and farming activities. The interior of the country has several man-made reservoirs, mainly for human water consumption. The largest is Hardap Dam in the seasonal southern Fish River. People in the north have to turn to fountains, boreholes, oshanas (shallow interconnected channels and pans) and perennial rivers to obtain potable water for their households. In the Caprivi Region, the Kwando River, together with the Zambezi and Chobe Rivers, play a significant role in the daily activities of the local communities through fisheries, agriculture, transport and harvesting of vegetation.

Floodplain rivers, such as the Kwando River, are among the most endangered ecosystems, and their fauna is especially under threat of species extinction and population disturbance (Halls *et al.* 1999). Multi-species floodplains with multi-gear fisheries have complex interactions between the environment, the fish communities and the fishermen. Approximately 100 years ago, only 6000 people inhabited the Caprivi area (Mendelsohn and Roberts 1997). At that time, the resources available could sustain the communities, and the anthropological impacts on the environment were insignificant. Today, the human population has increased 13 fold, and natural resources related to the river have to various extent been impacted by human activities such as farming, deforestation, building of roads, harvesting of vegetation for building materials and fisheries.

Historically, fishing was an important part of the ritual and political power base in the traditional management in the Caprivi region, and also today fish occupy a central place in people's daily life (Tvedten *et al.* 1994). A common saying goes: "If you don't fish, you are not a Caprivian". Households eat fish daily for most of the year, and fish is the most important protein source ranked over beef, game and poultry (Turpie *et al.* 1999). Seventy-five percent of the households are engaged in subsistence fishing, with a mean reported catch of 370 kg per year per household (Turpie *et al.* 1999). A perceived decrease in the fish catches, however, has been reported by the fishermen in the last decades.

The importance of the rivers for local communities in the Caprivi cannot be over-emphasised. The fishery is important for several reasons as the fishery provides a crucial source of protein, employment and income for households in the region (Purvis 2001a, b). The trade in the fish products is especially important to the poorest households, which have no other means of generating an income. A further important aspect is the barter of fish products for other essential commodities (Purvis 2001a, b).

The fish resources in the Kwando River are limited. As the local population grows and fishing activities increase, conflicts arise between subsistence, commercial and recreational fisheries. In addition, all the perennial rivers in Namibia border on neighbouring countries. Management regulations and control measures are different in the countries sharing the same fish resources. This has, among other problems, resulted in conflicts between foreign and native fishermen.

The objective of this report is to produce baseline information about the fish resources in the Kwando River to form the biological fundament for recommendations for a sustainable management of the fisheries. Fish were collected at 10 stations with survey gill nets and six other sampling methods during 1997-1999. Based on these monitoring data, the fish resources are described through studies of species diversity in different parts of the river, the relative importance of the different species, the life history of important species and the catch per unit effort and selectivity of gill nets.

The stated policy in the White Paper "Responsible Management of the Inland Fisheries of Namibia" (Ministry of Fisheries and Marine Resources 1995) and the Inland Fisheries Resources Act (2003), is to ensure a sustainable and optimal utilisation of the freshwater resources, and to favour utilisation by subsistence households over commercialisation. The Kwando River is shared with the neighbouring countries Angola and Botswana. The fish resources play an important role in all these countries and should be co-managed to ensure the effective control of the fish resources to the benefit of all countries and communities. This report should not only benefit future management of the fish resources in Namibia, but also trans-boundary management actions of the freshwater fish resources the region.

2 Study area

2.1 The Caprivi Region

The Caprivi Region in Namibia is situated about halfway between the equator and the southern tip of Africa, and midway between the Atlantic and the Indian Ocean (**figure 2.1**). The region borders on Botswana in the south (the Kwando and Chobe Rivers and the Kwando/Linyanti System), Angola and Zambia (the Zambezi River) in the north and east, and Zimbabwe in the east.

Within Africa, Namibia's climate is second in aridity, after Sahara (Barnard 1998). Rainfall is lower and more variable than in the eastern subcontinent, and becomes lower and more variable towards the west. The country's average annual rainfall is less than 250 mm, and the mean annual evaporation may be as high as 3700 mm in some areas. The rainfall may be characterised as tropical semi-humid in the northeast, like in the Caprivi, to hyper-arid in the west. The Caprivi Region has the highest rainfall in Namibia, although a low rainfall in a global perspective. The average annual rainfall at Katima Mulilo at the Zambian border is approximately 680 mm, but has varied between approximately 260 mm and 1470 mm during the past 50 years. However, it is important to note that the rainfall in the catchment area of the Kwando River in Angola and Zambia is much higher, and that the

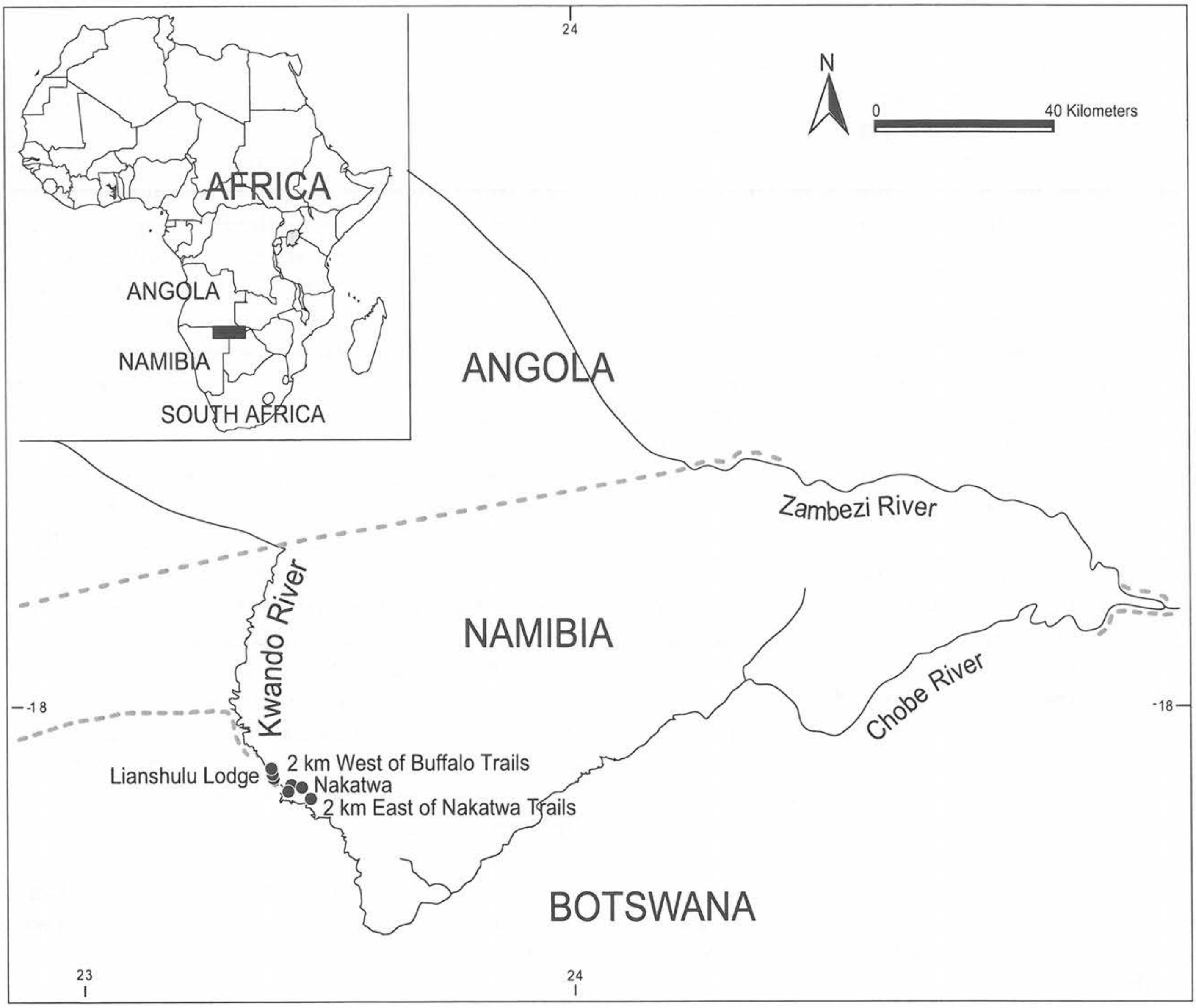

Figure 2.1
Location of the Kwando River and survey stations in north-eastern Namibia.

rainfall in the Caprivi region has minor effect on the water discharge in the river.

Six different land types are identified in the Caprivi (Mendelsohn and Roberts 1997). The largest portion of the region consists of the Kalahari Woodlands (55 %). The Caprivi Region has a flat topography, varying from 1100 m above sea level in the west, dropping gradually to 930 m in the east, and with elevations rarely exceeding 30 m (Mendelsohn and Roberts 1997). Due to the flat topography and the presence of perennial river systems, especially the eastern parts experience large annual flooding during summer and early winter. Floodplains cover 19 % of the Caprivi. In times of exceptional flooding, the Kwando - Linyanti and Zambezi - Chobe River systems are inter-linked, and large parts of the eastern Caprivi become one large floodplain (Curtis *et al.* 1998). In such cases, more than 30 % of the area east of the Kwando River becomes floodplains. The Caprivi wetlands have the highest overall species richness of the Namibian wetland systems, and 82 fish species occur in the Namibian part of this water system (Curtis *et al.* 1998). The floodplain ecosystems are complex and variable. Most Namibian fish species (78 %) are floodplain dependent for larval or juvenile stages and perform migrations between the floodplains and the main river (Barnard 1998).

The flat topography of the area creates a complicated and variable interaction between the Zambezi River and the Kwando-Linyanti-Chobe River systems. Lake Liambezi (**figure 2.1**) was dry in the 1940s, filled up around 1952, and dried up again in 1986. However, the lake was partly filled in 2001. The presence and the size of the lake are largely dependent on periods with floods and drought (Windhoek Consulting Engineers 2000). Flows in the Kwando River, which is the main source of inflow to Lake Liambezi, followed the patterns in the Zambezi River. Until 1999/2000, no significant floods have been recorded in the lower Kwando River since 1982.

The Okavango River may also connect with the Kwando River when river levels are exceptionally high (Mendelsohn and Roberts 1997). This is through the Selinda Spillway, an outlet from the north-eastern corner of the Okavango Swamps which joins the Kwando River and its southern limits and merges into the Linyanti. Water can potentially flow in either direction - from the Kwando River into the Okavango swamp, or from the swamps into the Kwando River.

Fishery and overgrazing of floodplains in the Eastern Caprivi are possibly the activities with the highest impact on the environment and fish community (Allcorn 1999). Pollution in the area is negligible. Large-scale development and urbanisation is not yet noticeable. Dams and weirs do not occur along any of the parts of the river.

2.2 The Kwando River

The Kwando River has its origin in the eastern parts of Angola, with a catchment area of 57 000 km^2. Floodwaters only reach the Namibian part in Eastern Caprivi in June-July due to a winding mainstream and reed marshes. High floods can be up to 2 m higher than the low flood level, but it is usually in the area of 1 m.

The Kwando River is a diverse system consisting of a main stream, small side streams, floodplains, pools and lakes or backwaters, which sometimes are isolated. The water velocity in the Kwando River is slow, and the river is dominantly deep with numerous bends. Deep isolated backwaters occur during low water, and these backwaters are well vegetated. Shallow, faster flowing, clear water habitats occur in the area of Nakatwa Island, but are otherwise scarce in the areas surveyed. During high flood, the river expands into large floodplains formed by shallow inundated fields and grasslands.

The bottom substrate of the mainstream is dominantly sand. Sedimentation of organic plant material is common in areas with slow stream. Marginal areas of the river are muddy in some areas due to animals foraging for roots and drinking from water holes. The backwaters have a muddy substrate with a layer of organic material. The floodplains are sandy with some muddy areas, and organic material over the bottom substrate is common. The large amount of organic material in the water is due to the large concentration of wildlife and their water associated activities. No rocky or gravel habitats occur in the areas surveyed.

The aquatic vegetation is mostly marginal reeds, lilies and water grass. Vegetation also occurs in the main stream (inner aquatic vegetation), such as lilies and submerged vegetation. The slow flow enables easy anchorage for aquatic plants. Locals report that poaching occurs in the area, and that the numbers of hippopotamus, which often keep river channels open, may be dwindling (Koekemoer 2003). Dead submerged trees are found occasionally, and small infrequent areas of erosion do occur. The floodplains support a diverse grassland flora characterised by grass, shrub and herb species. The seasonal inundated floodplains form productive wetlands, which account for much of the species richness found in open waters.

The gradient of the riverbank varies from low to steep, but banks are well vegetated with a dominantly low gradient and little erosion. Eroded banks occur due to wildlife drinking from the river, or on bends where the banks are usually steep.

Water levels have been recorded in the Kwando River since March 1968. The measuring station was washed away in July 1977, and water levels were not recorded during 1977-79 and parts of 1979/80. Based on the flow volume in the Zambezi River, the approximate flow volume in the Kwando River has been modelled back to 1912/1913. (**figure 2.2**).

Flows in the upper reaches of the Kwando River are caused by heavy rainfall, mainly falling between October and April in Angola and to some extent Zambia. About 200 km upstream of the Angolan-Namibian border, the river enters the Silowana plains in Angola and Zambia, which widen out into a huge flat sandy area with grassland and swampy vegetation. Based on satellite images, the storage volume is assumed to be as large as 1280 Mm^3 of water storage, if an average water depth of one meter is assumed (Windhoek Consulting Engineers 2000). This is more than the mean annual runoff of the Kwando River at Kongola. Hence, the Silowana floodplain has a significant impact on the downstream water flows. The effect of the huge storage volumes may last for more than one season. After two to three dry years, the flood peaks may be delayed in one to two years at Kongola. Thus, the flood peak for the Kwando River at Kongola may occur much later than the flood peak of the Zambezi River at Katima Mulilo (Windhoek Consulting Engineers 2000). The flood peak typically reaches Kongola near the northern border of Caprivi during May-June and

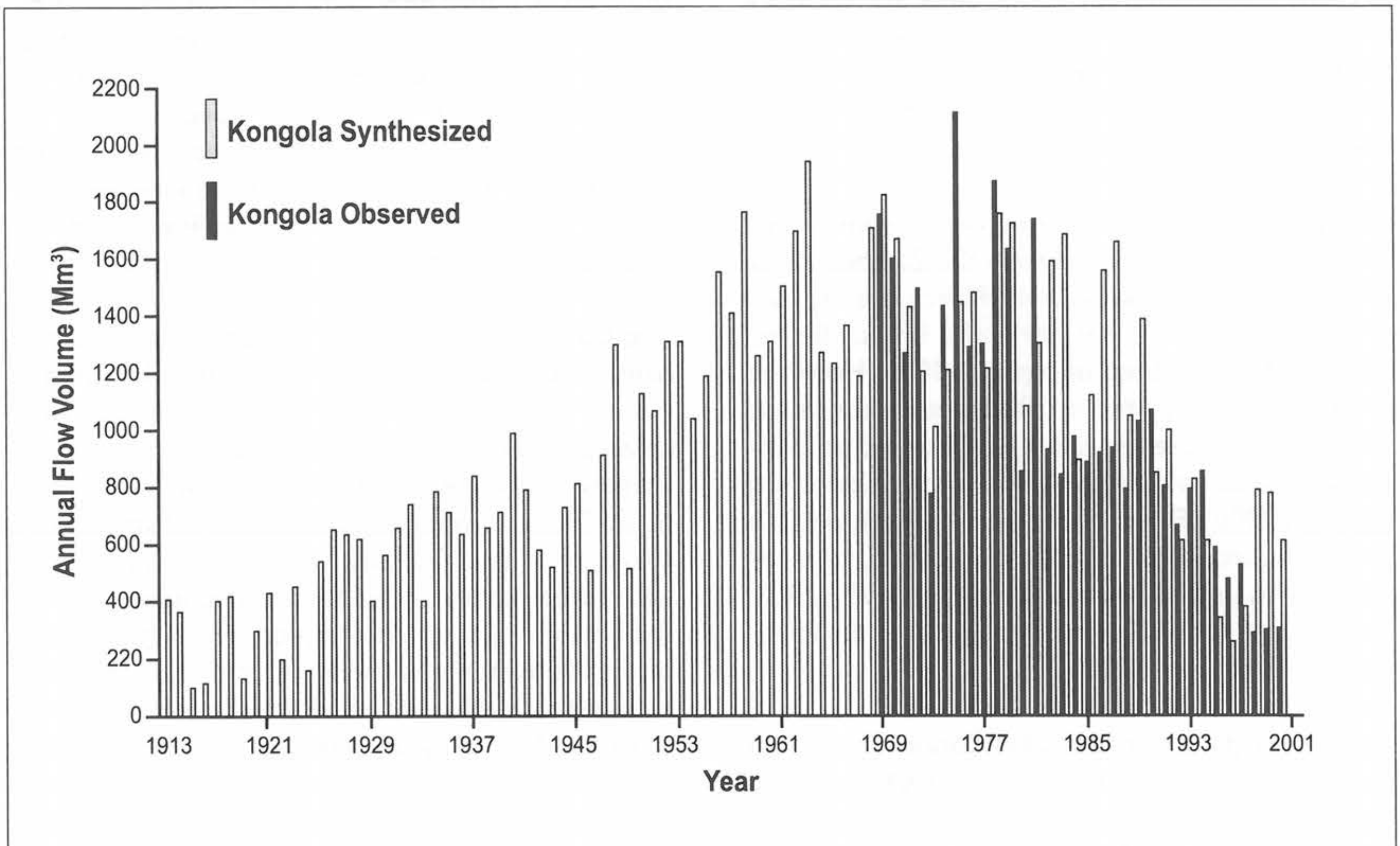

Figure 2.2
Annual water flow volume at Kongola in the Kwando River. Water levels have been recorded since 1968 (observed values). Based on the flow volume in the Zambezi River, the approximate flow volume in the Kwando River has been modelled back to 1912/1913 (synthesized values) (modified after Windhoek Consulting Engineers 2000).

Lake Liambezi at the end of the Linyanti swamp by August (Van der Waal and Skelton 1984).

The Linyanti, or the lower part of the Kwando River, depends on flows coming from Kongola through the wide swamp area around Nkasa Island. Water levels measured in the Linyanti have continued to drop since 1981. By 1982, the level had dropped to such a low level that the Linyanti stopped supplying water through to Lake Liambezi. By 1992, the downstream-most part of the Linyanti was dry (Windhoek Consulting Engineers 2000). However, the Linyanti was flowing again in 2001, as well as in 2002 and 2003.

Table 3.1. *Total catch during the fish surveys in the Kwando River during 1997-1999 (autumn 97 = 29 May - 1 June, spring 97 = 27-29 September, autumn 98 = 21-23 May, spring 98 = 23-25 October, autumn 99 = 28-31 May).*

Survey year	Total catch during spring surveys (number of fish)	Total catch during autumn surveys (number of fish)
1997	495	661
1998	557	496
1999	-	547

3 Materials and methods

3.1 Surveys and stations

The five surveys in the Kwando River in the period 1997 to 1999 were conducted in the autumn or the spring, at approximately the same water levels (**table 3.1**). The flood season is different from the Zambezi and Chobe Rivers, and the Kwando system takes longer to inundate than these rivers (flooding in June-July). Thus, the autumn surveys were conducted at the beginning of the high flood season, before the total effect of the rising floods had made an impact in this area. The spring surveys were conducted when the water level had decreased from its flow peak.

Stations were chosen with respect to commonness and similarity to the rest of the river system and habitat types. The ten localities sampled in the Kwando River were (**figure 2.1**):

1) Buffalo Trails (S18°09'23.6", E23°23'03.9")
2) One km west of Buffalo Trails (S18°08'43.2", E23°22'46.2")
3) Two km west of Buffalo Trails (S18°08'47.3", E23°22'56.7")
4) Two km east of Buffalo Trails (S18°09'50.4", E23°23'15.6")
5) Lianshulu Lodge (S18°08'05.7", E23°22'47.6")
6) New Lianshulu Bush Camp (S18°09'07.3", E23°22'54.5")
7) Nakatwa (S18°10'21.6", E23°25'13.3")
8) Two km east of Nakatwa (S18°10'33.6", E23°26'31.1")
9) Two km west of Nakatwa (no GPS recording)
10) Nakatwa Island (S18°11'06.5", E23°24'48.9")

Stations are named after the closest village or known area. The part of the Kwando River that was surveyed flows through the Mudumu and Mamili Nature reserves, such that the fish populations are to a small extent influenced by fishing and human populations. Nakatwa is the Nature Conservation camp for the staff patrolling the game park. Human activities are present such as pumping of water, fishing and washing of clothes.

3.2 Sampling design and methods

A wide range of gears and methods were used to limit the effect of gear selectivity and to survey all habitats under different physical conditions (**table 3.2**).

The gill nets were brown multifilament nets with stretch mesh sizes from 22 to 150 mm (**table 3.3**). The nets were set from approximately 18 hrs in the evening to 06 hrs the next morning. The gill nets were used to survey open, deep-water habitats in the main stream near the shore and deep backwater areas with some aquatic vegetation. Nets were set either in the middle of a water-body or near marginal vegetation.

The other gear types were used at or close to the gill net localities. These gears targeted mainly small species and juveniles of long-lived species in shallow and vegetated habitats. The top layer of sandy substrates was also surveyed for species inhabiting these habitats.

The following gears were used:

- 15 m seine net with a depth of 1.5 m made from 30 % black shade cloth. This was used to sample shallower habitats such as backwaters, bays and also in the main stream, usually with a sandy or muddy substrate. It was occasionally used within aquatic vegetation.
- Rotenone was used to collect fish from aquatic vegetated habitats.
- A 30 m seine net with a depth of 1.5 m made from green anchovy net with 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.
- Conical-shaped traps were made from wire with approximately 2 mm mesh size. They were placed near the shore in shallow, strong water currents and within aquatic vegetation.
- A 2 m cast (mono-filament nylon twine) net with a 20 mm stretched mesh was used to collect fish from deep-water habitats in backwaters and within the main stream. The water was either slow or fast flowing.
- A pulsed electrofishing apparatus (2 amperes and 600 volts) was used to sample vegetated habitats.

A total of 2756 fish were caught during the surveys in the Kwando River in 1997 to 1999 (**table 3.2** and **appendix 3**). Of these, 1172 fish were caught in survey gill nets and 1584 fish with other gears.

The body length data (**appendix 2**) were based on measurements of 2721 fish. All the fish caught with gill nets, and 98 % of the fish caught with other gears than gill nets were length measured (**table 3.4**).

The common names and family classification for all the species (**appendix 1**) are based on Skelton (2001). Seven *Synodontis* species are listed for the Zambezi River system (Hay *et al.* 1999), but only one species, *Synodontis nigromaculatus*, is easily identified morphologically. The other six species, *Synodontis leopardinus, Synodontis macrostoma, Synodontis thamalakanensis, Synodontis vanderwaali, Synodontis woosnami,* and *Synodontis macrostigma*, were grouped and recorded as one species group. When excluding the *Synodontis* spp. group, a total of 48 species were recorded in the total catches (**appendix 1**).

Table 3.2. *Catch at the different stations during fish surveys in the Kwando River during 1997-1999. Types of other gears used are 1 = 15 m seine net, 2 = rotenone, 3 = 30 m seine net, 4 = traps, 5 = 2 m cast net and 6 = electroshocker.*

Station	**Total catch (number of fish)**	**Catch in gill nets (number of fish)**	**Catch by other gears (number of fish)**	**Types of other gears used**
Buffalo Trails	29	24	5	3
1 km west of Buffalo Trails	14	-	14	1
2 km west of Buffalo Trails	229	184	45	1
2 km east of Buffalo Trails	349	-	349	1, 3, 6, 2
Lianshulu Lodge	144	59	85	1
New Lianshulu Bush Camp	923	252	671	1, 2, 3, 4, 6
Nakatwa	262	153	109	3, 6
2 km east of Nakatwa	727	481	246	1, 2, 4, 5, 6
2 km west of Nakatwa	60	-	60	1, 2
Nakatwa Island	19	19	-	-
Kwando total	**2756**	**1172**	**1584**	**1, 2, 3, 4, 5, 6**

3.3 Data collection and analysis

3.3.1 Biological data

Fish up to 100 mm in length were measured to the closest mm, whereas fish larger than 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. Fish caught in gill nets were weighed to the nearest gram. Fish caught with other gears smaller than 50 g were weighed to the nearest 0.1 g, while larger fish were weighed to the nearest 1 g. After measuring and weighing a large number of individuals (often 50 or more), the remaining fish were separated into species, counted, pooled and weighed.

Sexual maturity was classified on a scale from 1 to 5, where 1 is immature or not developed gonads, 2 is maturing gonads, 3 is mature gonads ready for spawning, 4 is spent gonads and 5 is resting mature fish.

Table 3.3. *Twine and mesh depth (number of vertical meshes) for gill nets of each stretched mesh size used during the surveys in the Kwando River in the period 1997 to 1999.*

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

3.3.2 Selected species

A large number of species (48, excluding *Synodontis* spp.) were caught in this study in the Kwando River (**appendix 1** and **2**). Of these, 18 species were selected for a more detailed data analysis (**table 3.5**). 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 or other gears, and b) their importance expressed by the numeric importance in survey catches in gill nets or other gears. The selected species represent a large variety

Table 3.5. *List of the ten most important species according to the index of relative importance (IRI) and numbers (No.) in gill nets and other gears during surveys in the Kwando River during 1997-1999 (see also* ***appendix 4*** *and* ***5****). The species are ranked in accordance with their importance, with 1 as the most important species.*

Species	Gill nets		Other gears	
	IRI	No.	IRI	No.
Marcusenius macrolepidotus	1	2		
Hydrocynus vittatus	2	5		
Petrocephalus catostoma	3	1		
Schilbe intermedius	4	6		
Cyphomyrus discorhynchus	5	4		
Clarias gariepinus	6	9		
Pharyngochromis acuticeps	7	7	1	3
Brycinus lateralis	8	3	5	4
Sargochromis giardi	9	10		
Hepsetus odoe	10	8		
Pseudocrenilabrus philander			2	2
Micralestes acutidens			3	1
Tilapia rendalli			4	8
Aplocheilichthys johnstoni			6	5
Tilapia sparrmanii			7	6
Oreochromis macrochir			8	7
Barbus unitaeniatus			9	9
Hemichromis elongatus			10	9

Table 3.4. *Length measurements of fish caught by different gears during surveys in the Kwando River during 1997-1999.*

Gear	Total catch (number of fish)	Length measured (number of fish)	Length measured (% of total catch)
Gill net	1172	1172	100
Other gears	1584	1549	97.8
Total	**2756**	**2721**	**98.7**

in habitat use, distribution, trophic status, body size and general ecology.

3.3.3 Species diversity

Species diversity is defined as both the variety and the relative abundance of species. To calculate the relative importance and diversity of the different species, an index of relative importance (IRI) was used, as well as a measure of the number of species weighted by their relative abundance, expressed as the Shannon diversity index (H`). An index of evenness (J`), which is the ratio between observed diversity and maximum diversity, was also calculated.

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

$$IRI = \frac{(\%\, N_i + W_i) \times F_i}{(\%\, N_j + \%\, W_j) \times F_j} \times 100 \qquad (1)$$

where j = 1–S, $\%N_j$ and $\%W_j$ is percentage number and weight 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.

Shannon index of diversity (H´)
The Shannon index of diversity (H´) (2) is a measure of the number of species weighted by their relative abundances (Begon *et al.* 1990), expressed as:

$$H' = -\sum p_i \ln p_i \qquad (2)$$

where p_i is the proportion of individuals found in the *i*th species. The Shannon index assumes that individuals are randomly sampled from an 'indefinitely large' population, and that all species are represented in the sample. The value of the Shannon diversity index is usually between 1.5 and 3.5. A high value indicates high species diversity.

Index of evenness (J´)
Shannon's index takes into account the evenness of the abundances of species, but we wanted a separate measure of evenness of species diversity. We used the ratio of observed diversity to maximum diversity to calculate the index of evenness (J´) (3) (Begon *et al.* 1990):

$$J' = H' / H_{max}, \text{ where } H_{max} = \ln H' \qquad (3)$$

J` is constrained between 0.0 and 1.0, with 1.0 representing a situation in which all species are equally abundant. As with H´, this evenness measure assumes that all species in the area are accounted for in the sample.

3.3.4 Gill net selectivity

Gill nets are selective fishing gears. A specific mesh size catches fish in a certain length category and is often most effective within a narrow length group. In addition, gill nets may discriminate among species according to fish morphology, for example body form and the presence of spines. Gill nets are also restricted to certain habitats, which will also influence the species selectivity of this gear.

The body length distribution 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. For management purposes it is also 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. An analysis of body length distribution in gears, body length of mature fish and gill net selectivity are given for the 18 selected species (selected species, see section 3.3.2).

The general statistical model for gill net selectivity 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 and habitat use compared with larger ones. This uncertainty cannot be quantified without independent information on population structure. Such information, however, is rarely available and difficult to obtain in natural fish

The fish habitats in the Kwando River varies in the different sampling areas and with the season. ***Top:*** *The main channel.* ***Bottom:*** *A small vegetated pool. Photos: Clinton J. Hay.*

A variety of sampling gears were used to make sure that the catches were representative for the fish populations in the area. Photos: Clinton J. Hay.

Samples of the fish were taken in the field as soon as possible after the fish were caught.

Top: *Survey team sampling fish.*
Bottom left: *Rainbow bream (*Sargochromis carlottae*).*
Bottom right: *Banded tilapia (*Tilapia sparrmanii*). Photos: Clinton J. Hay.*

The fishes' colouring are characteristically very dark in the Kwando River compared with the neighbouring Zambezi, Chobe and Okavango Rivers.
***Top**: Greenhead tilapia (*Oreochromis macrochir*). **Bottom**: Threespot tilapia (*Oreochromis andersonii*). Photos: Clinton J. Hay.*

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. Several statistical methods are developed to represent the selection curves. Two functions were used in this study. The standard normal function was applied for species that are mainly entangled by their gills, whereas a skewed normal function (Helser *et al.* 1991, 1994) was used for species that to some extent can be caught in other body structures such as fin rays, teeth and spines. The selection curves were standardised to unit height by dividing the number of fish in the modal length class.

3.3.5 Catch per unit effort (CPUE)

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

Measuring catches in number or weight of fish may give very different results. In this report, the results are generally presented in both units, but with an emphasis on weight, as this unit gives a better indication of the amount of fish protein and is, hence, more important to fishermen and fisheries managers.

3.3.6 Databases and software

All recorded data were compiled 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. PASGEAR (version May 2000) and SPSS for Windows (version 11.5) were used to perform the calculations and statistical analysis.

4 Background biology and distribution of selected species

As a background to the results and discussions in this study, an overview of the biology and distribution for the most important species found in the surveys is given in this chapter. The information is mainly collected from Skelton (2001). The reference under the separate species is given only when information is collected from other sources. The species are classified according to family.

Cichlidae

Pseudocrenilabrus philander (Southern mouthbrooder) is widespread in Southern Africa from the Orange River and northwards to Malawi and the southern tributaries of the Zaire River. Isolated populations have been recorded in Namibia, such as in the Lake Otjikoto and Otavi. It may reach a length of 13 cm and breeds from early spring to early autumn. It is a mouthbrooder with several broods raised in one season. This 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, and is also used in behavioural and evolutionary research.

Pharyngochromis acuticeps (Zambezi bream) occurs in the Okavango and Zambezi Rivers, but is absent from the Kunene River. It may grow to 22 cm, but is usually less than 10 cm. It is a female mouthbrooder and breeds in the summer. It occurs in a wide range of habitats, but needs cover such as vegetation or tree roots. Also commonly found in rocky habitats. It preys on insects, shrimps, small fish, and eggs and larvae of nesting fishes. It is a potential aquarium species.

Tilapia sparrmanii (Banded tilapia) is widespread in Southern Africa, with a similar distribution as *Pseudocrenilabrus philander,* and it has been extensively translocated south of the Orange River in the Cape. Individuals have also been translocated to several waterbodies in Namibia (Hay *et al.* 1999). 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 when angling.

Tilapia rendalli (Redbreast tilapia) is widespread in southern Africa where it occurs in the Kunene, Okavango and Zambezi River systems, in the eastern Zaire Basin and in coastal rivers south of the Zambezi. It is also translocated to many catchment areas in southern Africa. It has also been recorded from the Lower Orange River and several waterbodies in Namibia (Hay *et al.* 1999). This species 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.

Oreochromis macrochir (Greenhead tilapia) occurs in the Kunene, Okavango, Upper Zambezi and Kafue Rivers, as well as the Lake Kariba, the Busi River and in the southern tributaries of the Zaire River. This species may reach 40 cm in length, and the angling record in Zimbabwe is 2.6 kg. It breeds in summer. Preferred habitats are 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 is also a popular angling species.

Sargochromis giardi (Pink bream) occurs in the Kunene, Okavango, Upper Zambezi and Kafue River systems and Lake Kariba. The largest specimens have been found in the Upper Zambezi floodplains, and attained 48 cm in total length. It is a female mouthbrooder, and breeds in early summer. Nests consist of patches within dense vegetation in about three meter water depths. Prefers deep main river channels and floodplain lagoons with sandy bottoms. It is important in subsistence and commercial fisheries, and it is an angling target.

Hemichromis elongatus (Banded jewelfish) occurs in the Okavango and Upper Zambezi River systems. It is also widespread through the Zaire Basin to tropical West Africa. This species attains about 19 cm in total length. It occurs in littoral riverine habitats and permanent floodplain lagoons with clear water. It is a nesting substrate spawner, breeding in early summer. Preys on shrimps, insects and small fishes. It is occasionally used as aquarium fish, and is caught in small numbers in the subsistence fisheries.

Cyprinidae

Barbus unitaeniatus (Longbeard barb) is widely spread in Southern Africa from the Zambian-Zaire system and the Kunene, Okavango and Zambezi Rivers south to the Phongolo River. It is absent from the lower Zambezi River. This species grows to 14 cm, and breeds after rains during the summer months. It is found in a wide range of habitats including flowing and stagnant waters, and thrives in dams and lakes where it feeds on aquatic invertebrates and grass seeds.

Mormyridae

Marcusenius macrolepidotus (Bulldog) is widespread in Central and Southern Africa in the Kunene, Okavango and Zambezi Rivers and in east coastal rivers and lakes from Tanzania to Natal, and also in the upper Zaire River. It may grow to 30 cm and 0.5 kg, and breeds during the rainy season. It shoals in vegetated 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.

Petrocephalus catostoma (Northern churchill) is widespread from the Kunene, Okavango and Zambezi Rivers to the Zaire River and in the Lakes Malawi, Tanganyika and Victoria. It has a maximum size of 13 cm and breeds during the summer rainy season. The preferred habitats are 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.

Cyphomyrus discorhynchus (Zambezi parrotfish) is present in the Kunene, Okavango, Zambezi, Buzi and Pungwe Rivers, and is also found in the Upper Zambezi River and the Lakes Tanganyika and Malawi. It is absent from the Kafue River. This species may attain 31 cm and breeds during summer rainy season. It favours large river channels with soft bottom and fringing vegetation, and is a nocturnal, shoaling species feeding on bottom-living vertebrates. It is occasionally caught on rod and line.

Characidae

Micralestes acutidens (Silver robber) occurs in the Kunene, Okavango and Zambezi Rivers, in the east coastal rivers, and is also widespread in the Zaire River system. Maximum size is about 8 cm. It breeds throughout the summer months. It shoals in clear, flowing or standing, open water where it feeds on surface insects and zooplankton. It is a habitat specialist and is used as an indicator species (Hay et al. 1996). This species is an attractive aquarium species and is used as forage and bait for tigerfish and African pike.

Hydrocynus vittatus (Tigerfish) is widespread in Africa, but is absent from the Kunene and the Kafue Rivers. Females may grow to 70 cm, and males to 50 cm, and they may attain a body weight of more than 10 kg. It breeds during summer and spawns in shallow flooded areas. Fish larger than 10 cm prey on other fish, while smaller fish eat invertebrates. Adults prefer open waters in rivers or lakes. It is a popular fish in commercial and subsistence fisheries, and for angling and targeted in fishing competitions (Næsje *et al.* 2001).

Brycinus lateralis (Striped robber) is present in the Okavango, Zambezi and Kunene Rivers. It may reach a length of about 14 cm. This species shoals in slow flowing or quiet vegetated waters. It migrates upstream and possibly spawns in the rainy season. It is caught in subsistence fisheries and used as bait for tigerfish.

Schilbeidae

Schilbe intermedius (Silver catfish) is widely distributed in Sub-Saharan Africa. It reaches a length of about 30 cm and can weigh up to 1.3 kg. Generally it is found to mature sexually at approximately 16 cm. It breeds in the rainy season and has a life span of up to 6-7 years. The preferred habitats are stagnant or slow flowing water, where it is often shoaling. The varied diet may include fish, invertebrates, plant seeds and fruits. It is important in the subsistence fishery and is also subject to angling.

Cyprinodontidae

Aplocheilichthys johnstoni (Johnston's topminnow) occurs in the Kunene, Okavango and Zambezi Rivers. It can grow to about 5 cm, and 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.

Clariidae

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. It occurs in almost any habitat, but prefers floodplains, large sluggish rivers, lakes and dams where it feeds on virtually any available organic food source. This species is a potential species for aquaculture and has been farmed in several African countries. It is important in the subsistence fishery and is also regularly caught during fishing competitions in the Zambezi River (Næsje *et al.* 2001).

Hepsetidae

Hepsetus odoe (African pike) occurs in the Kunene, Okavango and Zambezi Rivers and is also widespread through central Zaire and West Africa. Maximum length is approximately 47 cm, and it can weigh up to 2.0 kg. Breeding takes place during the summer months. It prefers quiet, deep water in channels and lagoons of large floodplains where it feeds on fish. Habitat preferences may be influenced by the presence of *Hydrocynus vittatus*. 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.

5 Results

5.1 Species diversity

A total of 48 species (excluding *Synodontis* spp.), from 12 families were recorded during the surveys in the Kwando River. The Cichlidae and Cyprinidae families were the best represented families with respect to numbers of species, with 15 and 10 species, respectively (**appendix 1**).

5.1.1 Catches in all gears

The species caught during all the surveys from 1997 to 1999 were ranked based on the index of relative importance (IRI) (**figure 5.1**). The IRI for all the species caught in the Kwando River are listed in **appendix 3**. *Hydrocynus vittatus* was the most important species according to IRI (25 %), while *Marcusenius macrolepidotus* was second (19 %) and *Pharyngochromis acuticeps* third (12 %). The ten most important species comprised 88 % of the total IRI.

A total of 147 kg of fish was caught during the surveys (**appendix 3**). *Hydrocynus vittatus* and *Clarias gariepinus* had the highest biomass and comprised 27 and 16 % of the total biomass caught, respectively. Another catfish, *Clarias ngamensis*, also had a high biomass (11 %).

A total number of 2756 fish were caught during the surveys. Species with small body sizes, *Micralestes acutidens, Pharyngochromis acuticeps, Petrocephalus catostoma, Pseudocrenilabrus philander, Marcusenius macrolepidotus* and *Brycinus lateralis* were most numerous in the catches. Each of these species represented between 9 and 11 % of the total number caught (**appendix 3**). Only one individual was recorded of the species *Sargochromis codringtonii, Clarias stappersii, Barbus bifrenatus, Barbus thamalakanensis, Coptostomabarbus wittei, Hemmigrammacharax machadoi* and *Microtenopoma intermedium.*

The Shannon index (H´) was 2.90 for the total catch, and the evenness index (J´) was 0.74, indicating a high species diversity and that the abundance of species was

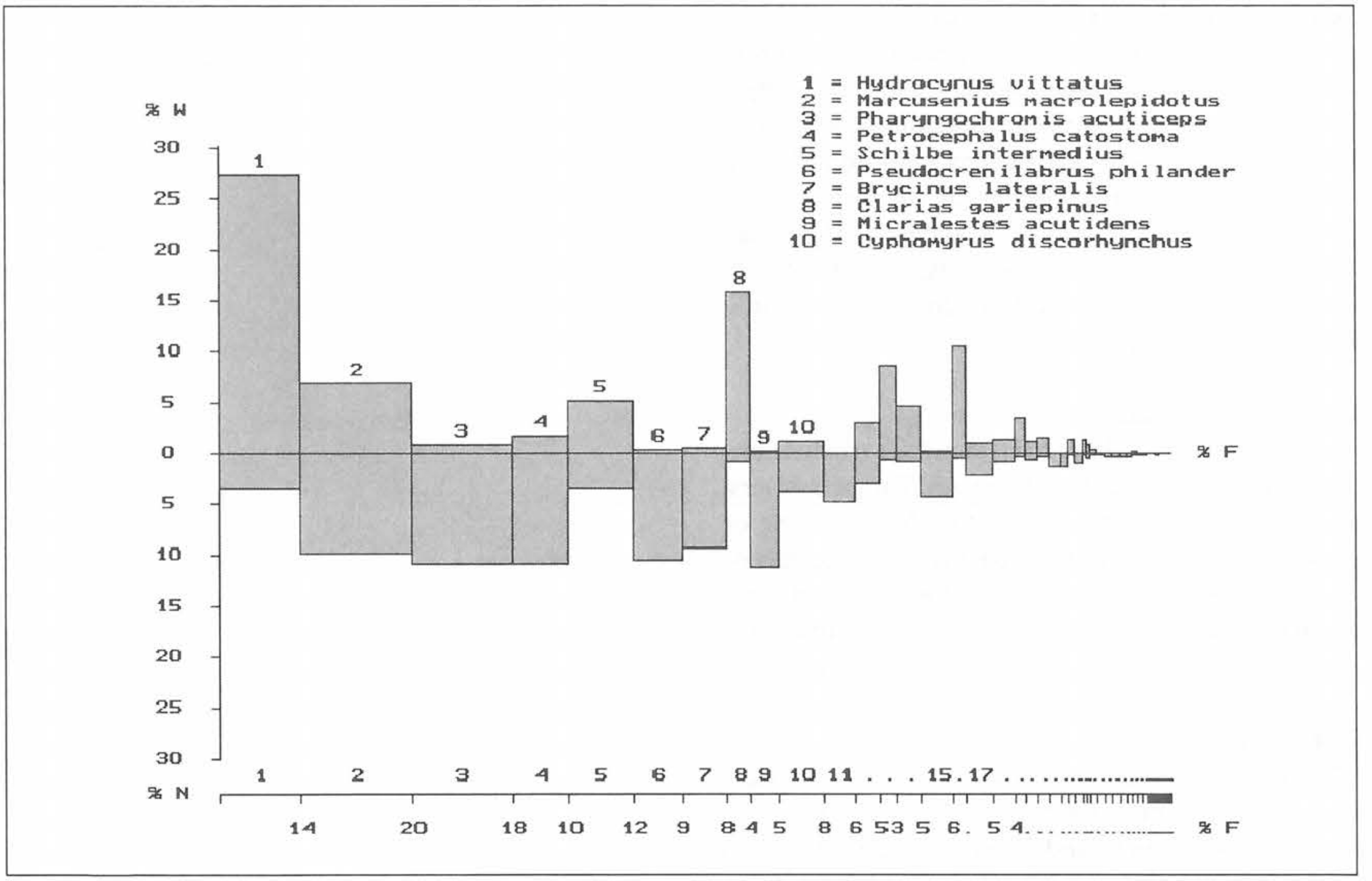

Figure 5.1
Index of relative importance (IRI) for the most important species caught during surveys in the Kwando River during 1997-1999.

relatively evenly distributed (see section 3.3.3). The species diversity was higher in the Kwando River (H´ = 2.90) than in the Zambezi River (H´ = 2.73, Hay *et al.* 2002) (t-test, $t = 8.43$, $df = 3268$, $p < 0.001$). The number of individuals within each species were more evenly distributed in the Kwando River surveys (J´ = 0.74) than in the Zambezi surveys (J´ = 0.64, Hay *et al.* 2002).

5.1.2 Catches in gill nets

Of the total catches in the Kwando River, 43 % were caught by survey gill nets of 22-150 mm mesh size. A total of 30 species (*Synodontis* spp. excluded) were recorded in the gill net catches. Nine families were represented. The Cichlidae family was by far the best represented with respect to number of species, with 14 species. The snoutfishes (Mormyridae) were the second best represented, with six species (**appendix 4**).

The index of relative importance of fish species in the gill net catches showed that the ten most important species constituted 97 % of the total IRI. *Marcusenius macrolepidotus* was the most important species with an IRI of 31 % (**appendix 4** and **figure 5.2**). In the total catches, including both gill nets and other gears, this species was the second most important (**appendix 3**). *Hydrocynus vittatus* and *P. catostoma* was the second and third most important species, with an IRI of 28 % and 14 %, respectively. The other species had all an importance less than 9 % (**appendix 4**).

The Mormyridae family (50 %) was the most important family in the gill net catches according to IRI. The Characidae family (31 %) was also important. The Cichlidae family were represented by 14 species, but accounted for only 5 % according to IRI. The most important cichlid was *Pharyngochromis acuticeps*, with an IRI value of only 2 %.

A total of 143 kg of fish were caught in gill nets (**appendix 4**). The *Hydrocynus vittatus* accounted for 28 % of the total biomass of the catches. Also *Clarias gariepinus* (16 %) and *Clarias ngamensis* (11 %) accounted for a large part of the biomass. The most important

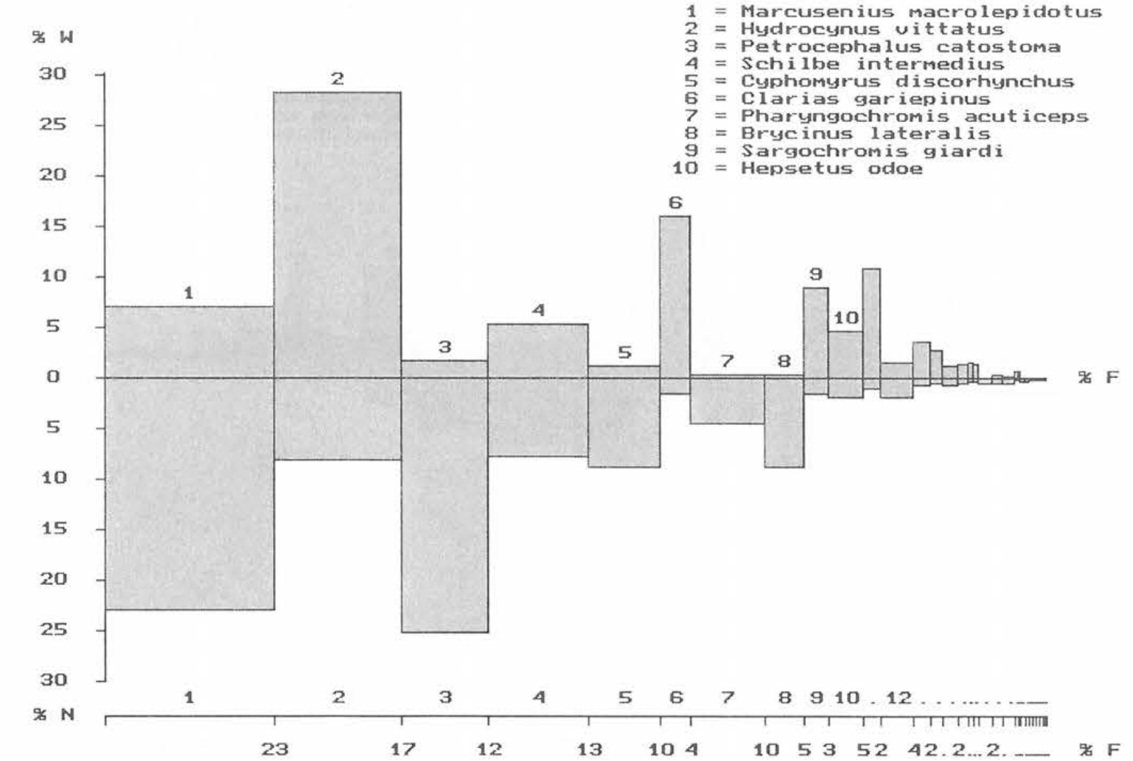

Figure 5.2
Index of relative importance (IRI) for the most important species caught by survey gill nets in the Kwando River during 1997-1999.

species according to IRI, *Marcusenius macrolepidotus*, accounted for only 7 % of the total biomass.

A total number of 1172 fish were caught in gill nets. The most numerous species was *Petrocephalus catostoma* (25 %), while *Marcusenius macrolepidotus* (23 %) was the second most numerous species. Each of the other species accounted for less than 10 % of the total number of fish caught in gill nets (appendix 4). Only one individual of each of the three species *Oreochromis andersonii, Sargochromis codringtonii* and *Barbus unitaeniatus* was caught in gill nets.

5.1.3 Catches in other gears than gill nets

A total of 38 species from 11 different families were caught during the surveys by other gears than gill nets. No *Synodontis* spp. was sampled using the other gears (**appendix 5**). Eight more species were caught by other gears than gill nets (when *Synodontis* spp. were excluded from gill net catches).

The most important species according to index of relative importance (IRI) in the catches with other gears were different from the catches with gill nets (**table 3.5**). The five most important species according to IRI belonged to the Cichlidae and Characidae families, where *Pharyngochromis acuticeps* (33 %) and *Pseudocrenilabrus philander* (23 %) were the most and second most important species, respectively. *Micralestes acutidens* was the third, and *Tilapia rendalli* and *Brycinus lateralis* were the fourth and fifth most important species according to IRI (**appendix 5** and **figure 5.3**). The ten most important species comprised an IRI of 98 %.

A total of only 4.2 kg fish were caught by other gears than gill nets (**appendix 5**). *Pharyngochromis acuticeps* (19 %) comprised the highest biomass, with *Tilapia rendalli* (15 %) as the second, *Pseudocrenilabrus philander* (10 %) as the third, *Clarias gariepinus* (9 %) as the fourth and *Oreochromis macrochir* (8 %) as the fifth. The Cichlidae family accounted for 65 % of the total biomass with ten species, while the Clariidae

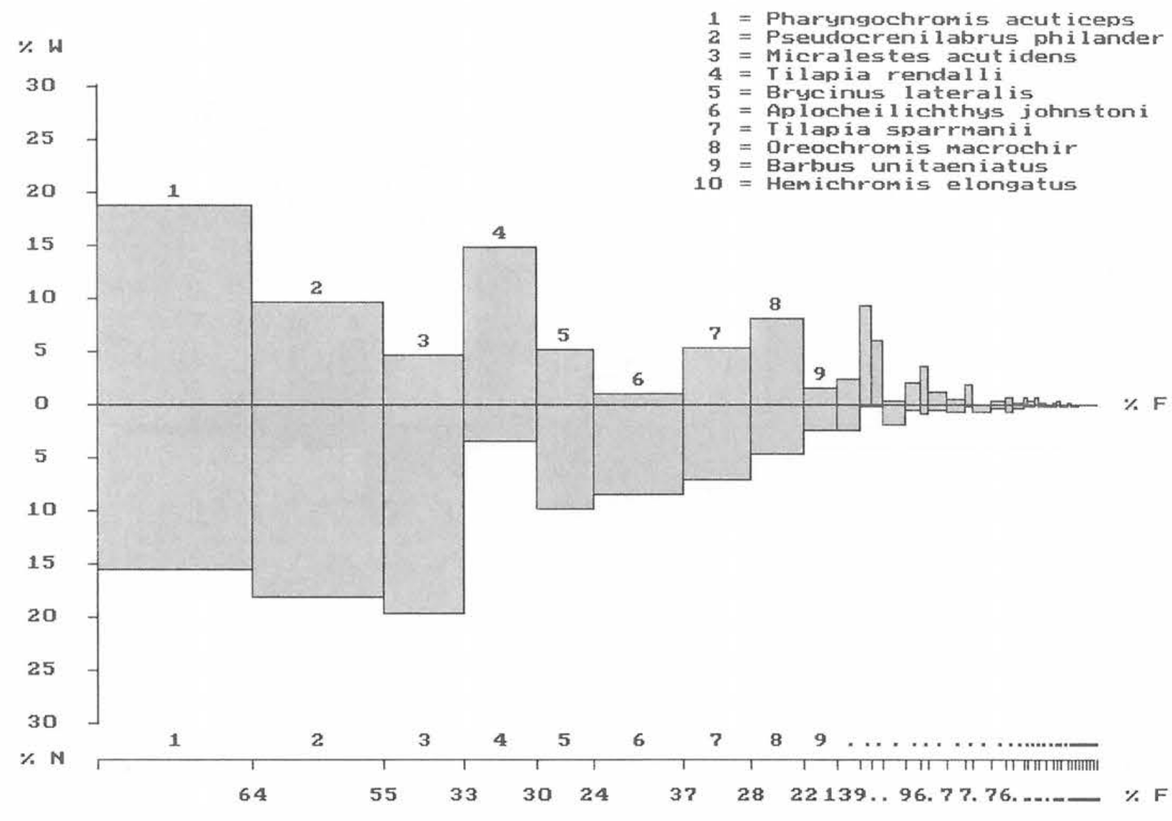

Figure 5.3
Index of relative importance (IRI) for the most important species caught by other gears than gill nets during surveys in the Kwando River during 1997-1999.

family accounted for 12 % with four species, and the Characidae family with 10 % with three species.

A total of 1584 fish were caught with the other gears. The ten most important species according to IRI were also the most numerous species (**appendix 5**). *Micralestes acutidens* comprised 20 %, *Pseudocrenilabrus philander* 18 % and *Pharyngochromis acuticeps* 16 % of the total number of fish caught by other gears. The Cichlidae and the Characidae families accounted for 53 % and 31 %, respectively.

The species diversity was higher for the catches with the other gears than for the gill net catches (Shannon diversity indices H′: 2.44 vs. 2.32; t-test, $t = 2.76$, $df = 2405$, $p < 0.01$). The number of individuals within each species were similar and evenly distributed both in the gill net caches and in the catches with other gears (Evenness indices: J′ = 0.68 and 0.67, respectively).

5.1.4 Catches in gill nets during autumn and spring

In the gill net surveys, a total of 26 species were caught during the autumn and 28 species during the spring (**appendix 6** and **7**). The *Synodontis* spp. group has been treated as one species. The number of fish caught were somewhat higher in autumn (N = 625) than in spring (N = 547). The fishing effort differed in the two seasons and, hence, the number of fish caught is not directly comparable. The species ranked as the ten most important species belonged to six families during autumn and seven families during spring (**appendix 6** and **7**). According to index of relative importance (IRI), *Marcusenius macrolepidotus* was the most important species during the autumn, while *Hydrocynus vittatus* was the most important during the spring. The *Petrocephalus catostoma* was the third most important species both in autumn and spring (**table 5.1**). Three species, *Marcusenius macrolepidotus*, *Hydrocynus vittatus* and *Cyphomyrus discorhynchus* experienced a marked increase in the IRI from autumn to spring. Also the percentage frequency, weight and number was higher for the catches during spring for these three species. *Clarias gariepinus* and *Sargochromis giardi* decreased in number, weight and frequency from autumn to spring. The catches of the other species showed a higher or approximately equal IRI in autumn than in spring (**table 5.1**).

In the catches with other gears than gill nets, a total of 35 species were caught during autumn and 26 species during spring (**appendix 8** and **9**).

Table 5.1. *The relative importance (IRI) of the most important species caught during gill net surveys during autumn (Aut) and spring (Spr) in the Kwando River in the period 1997-1999. The IRI takes into account the number of individuals, weight (kg) and frequency of occurrence of the species caught.*

Species	**Number (%)**		**Weight (%)**		**Frequency (%)**		**IRI (%)**	
	Aut	**Spr**	**Aut**	**Spr**	**Aut**	**Spr**	**Aut**	**Spr**
Marcusenius macrolepidotus	19.0	27.2	4.2	12.0	18.7	28.4	25.2	34.3
Hydrocynus vittatus	6.4	9.9	21.8	39.1	12.4	22.8	20.4	34.5
Petrocephalus catostoma	23.8	26.7	1.2	2.7	9.8	14.2	14.2	12.9
Schilbe intermedius	8.8	6.6	4.4	6.8	12.0	15.4	9.2	6.4
Clarias gariepinus	2.7	0.4	23.9	2.6	5.8	1.2	8.9	0.1
Brycinus lateralis	15.0	1.7	0.6	0.1	6.7	3.1	6.1	0.2
Sargochromis giardi	2.6	0.4	13.0	1.7	4.9	1.2	4.4	0.1
Hepsetus odoe	2.7	0.9	5.8	2.5	5.8	3.1	2.9	0.3
Pharyngochromis acuticeps	4.3	4.6	0.4	0.5	8.9	11.1	2.4	1.7
Cyphomyrus discorhynchus	5.4	12.4	0.5	2.3	6.2	14.2	2.2	6.5
Clarias ngamensis	1.0	1.1	9.4	13.2	2.2	2.5	1.3	1.1
Serranochromis altus	0.5	1.1	1.6	6.9	1.3	3.7	0.2	0.9
Synodontis spp.	1.8	2.2	1.1	2.3	3.6	5.6	0.6	0.8

5.2 Body length distributions and gill net selectivity

5.2.1 Body length distribution in gill nets and other gears

A wider range of body length classes were caught with gillnets than with the other gears (**figure 5.4**). Fish with body lengths from 6 to 66 cm were caught in gill nets, whereas fish with body lengths from 1 to 36 cm were caught with the other gears, with the majority of the catch between 2 and 7 cm. Modal length was 8.0-8.9 cm in the gill net catches (**figure 5.4**).

5.2.2 Body length at maturity

The minimum body length at maturity, and length at which 50 % of the fish caught were mature, varied considerably among the selected fish species (**table 5.2**).

5.2.3 Life history and gill net selectivity for selected species

Of the 18 selected species (see section 3.3.2), three species were not caught in gill nets. These were *Micralestes acutidens, Aplocheilichthys johnstoni* and *Hemichromis elongatus*. The following three species were not caught by other gears: *Hydrocynus vittatus, Cyphomyrus discorhynchus* and *Sargochromis giardi* (**table 3.5**). By numbers, the selected species contributed 92 % of the gill net catches and 90 % of the catches with other gears according to IRI (**appendix 4** and **5**). The selected species represent a large variation in biology, distribution and sizes. Life history and gill net selectivity were analysed in detail for each of these species.

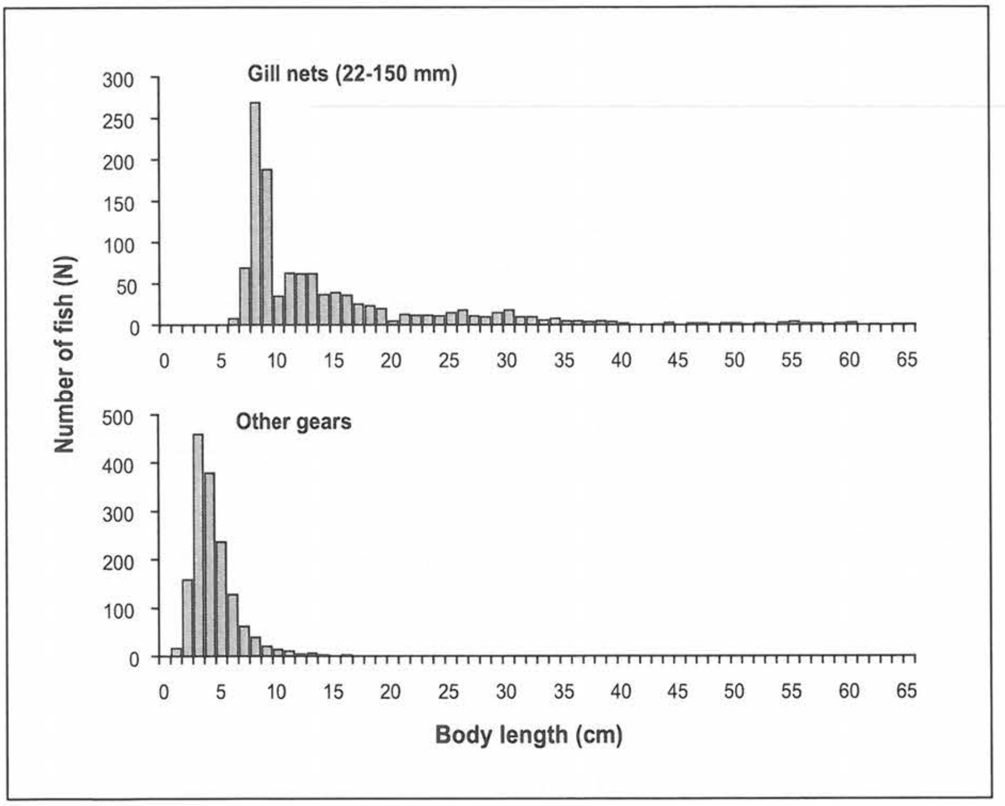

Figure 5.4
Length distribution of all fish caught with gillnets (22-150 mm stretch mesh) and other gears during surveys in the Kwando River during 1997-1999. Notice the different scale on the y-axis.

Table 5.2. *Minimum length of mature fish and length at which 50 % of the fish caught were mature during fish surveys (all gears) in the Kwando River during 1997-1999, for the selected species listed in* ***Table 3.5****. Minimum length at maturity for gill net catches only are given in parenthesis. n = number of fish.*

Species	Minimum length at maturity				Length at 50 % maturity	
	Males		Females		Males	Females
	cm	n	cm	n	cm	cm
Cichlidae						
Pharyngochromis acuticeps	10 (10)	18	7 (7)	8	10.5	-
Tilapia sparrmanii	11 (11)	3	9 (9)	2	-	-
Pseudocrenilabrus philander	3 (-)	1	5 (-)	4	-	-
Tilapia rendalli	- (-)	0	- (-)	0	-	-
Sargochromis giardi	24 (24)	8	18 (18)	9	-	-
Hemichromis elongatus	6 (-)	5	7 (-)	1	-	-
Oreochromis macrochir	22 (22)	5	- (-)	0	-	-
Cyprinidae						
Barbus unitaeniatus	- (-)	0	- (-)	0	-	-
Mormyridae						
Marcusenius macrolepidotus	10 (10)	106	11 (11)	150	-	13.9
Petrocephalus catostoma	8 (8)	61	6 (6)	223	-	6.9
Cyphomyrus discorhynchus	15 (-)	53	9 (-)	45	-	-
Characidae						
Hydrocynus vittatus	26 (26)	19	21 (21)	48	-	28.0
Micralestes acutidens	- (-)	0	- (-)	0	-	-
Brycinus lateralis	8 (8)	19	7 (7)	72	-	8.0
Schilbeidae						
Schilbe intermedius	14 (14)	12	14 (14)	63	-	-
Cyprinodontidae						
Aplocheilichthys johnstoni	- (-)	0	- (-)	0	-	-
Clariidae						
Clarias gariepinus	- (-)	0	46 (46)	11	-	-
Hepsetidae						
Hepsetus odoe	- (-)	0	26	(26)	17	- -

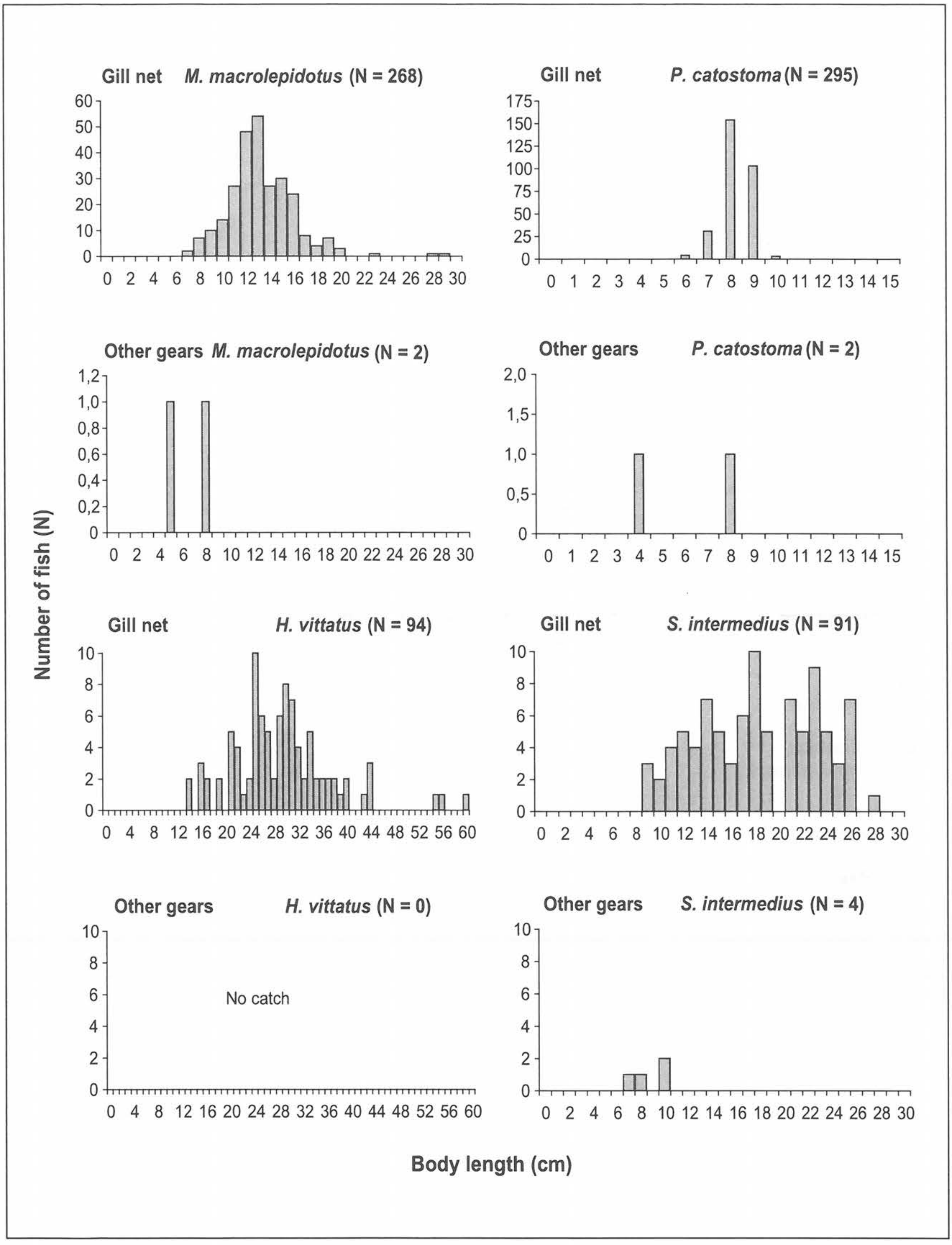

Figure 5.5
Length distribution of selected species caught with gillnets and with other gears during surveys in the Kwando River during 1997-1999 (selected species, see section 3.3.2).

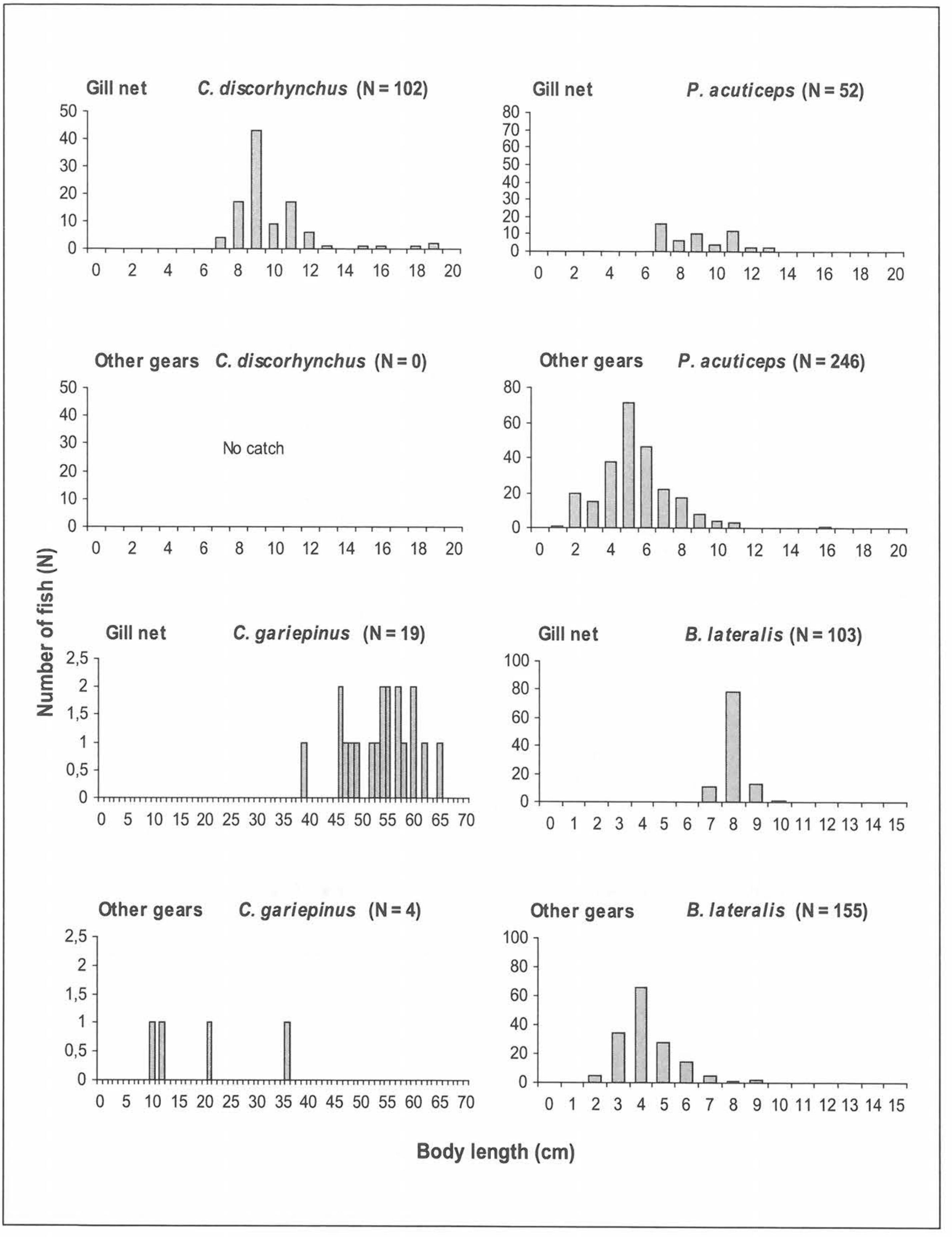

Figure 5.5
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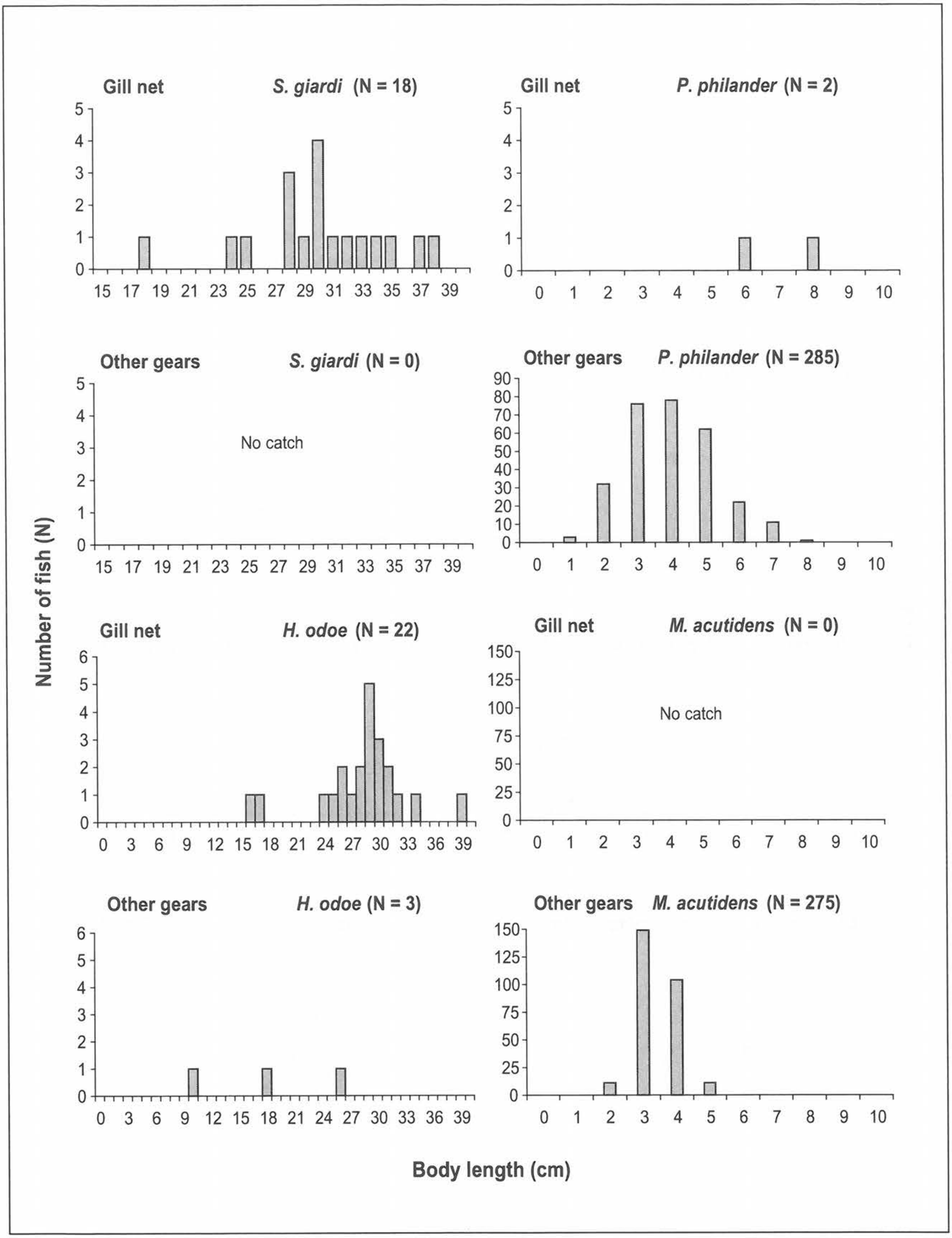

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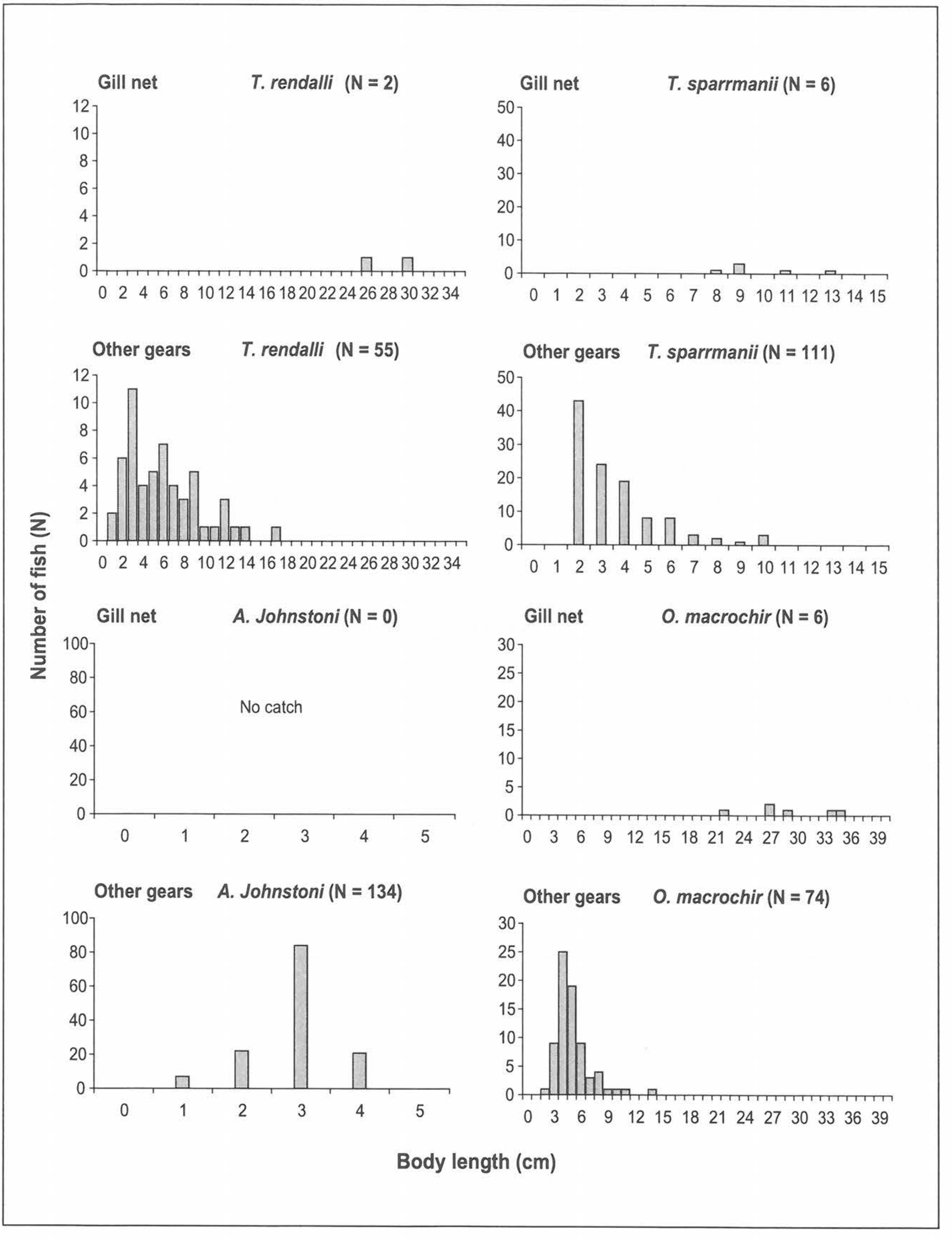

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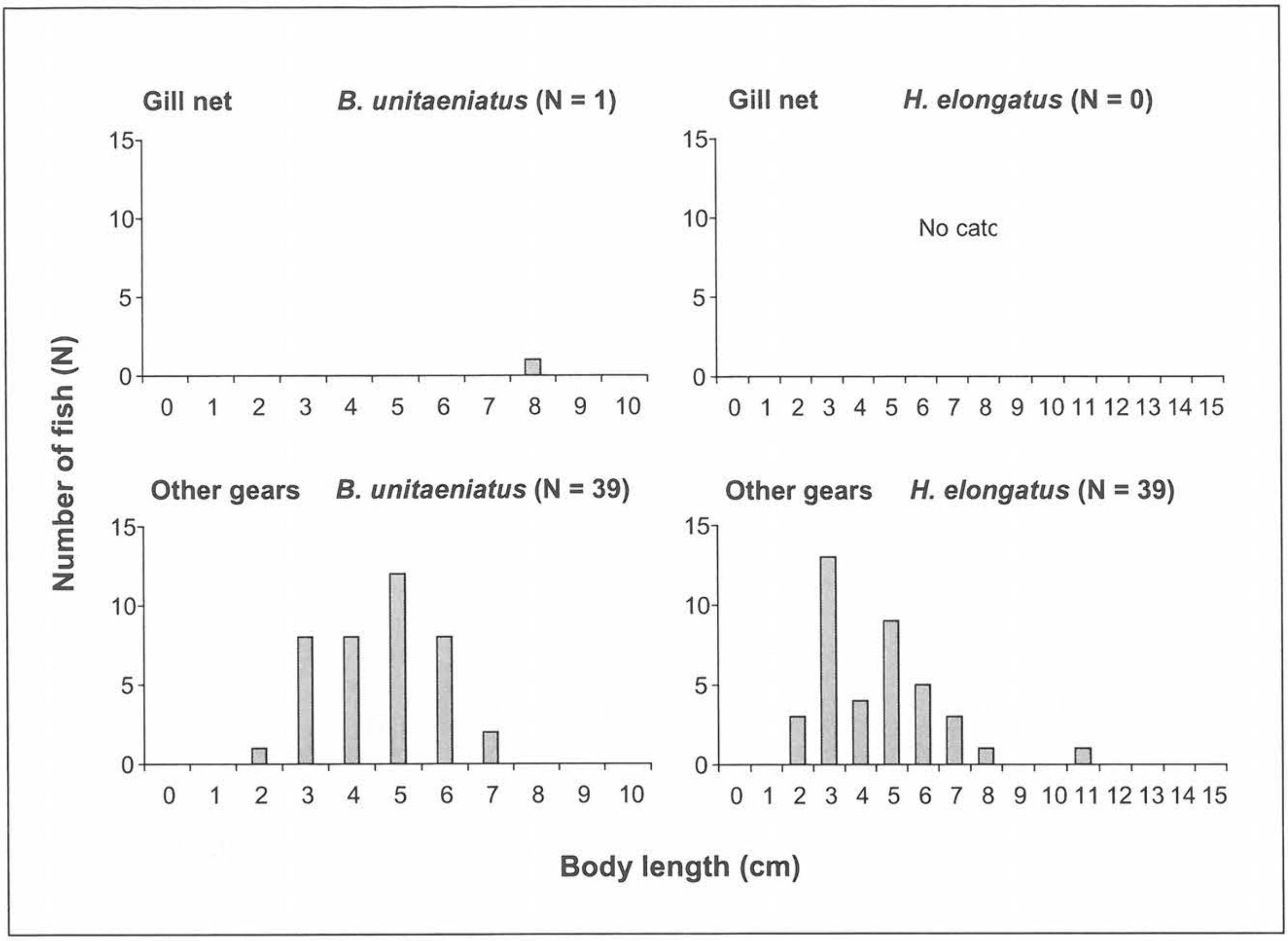

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Marcusenius macrolepidotus (Bulldog)

Marcusenius macrolepidotus was the most important species in the gill net catches, but only the twenty-fourth most important species caught by other gears (IRI, **appendix 4** and **5**). The minimum body length of mature fish was 10.0 cm for males and 11 cm for females (**table 5.2**). The length at 50 % maturity was 13.9 cm for females, but could not be determined for males.

A total of 268 individuals were caught in gill nets, with body lengths from 7.0 to 29 cm (mean 13.4 cm, modal length 13.0-13.9 cm) (**figure 5.5**). Several length classes between 21 and 27 cm were not sampled with the gill nets. Only two individuals were caught with other gears. Both the mean and modal lengths were longer than the minimum size at maturity (11 cm) (**table 5.2**). The lengths of fish caught with other gears ranged between 5.0 and 8.5 cm (mean length 6.8 cm).

The 35 mm mesh size caught the largest number of fish per setting (8.68 fish/setting) (**table 5.3**). Fish caught with this mesh size had an average length of 13.0 cm. The 45 mm nets had the highest catch in terms of weight per setting (0.285 kg/setting). Fish caught with this mesh size had an average length of 15.3 cm. Only a few fish were caught in mesh sizes larger than 57 mm.

Table 5.3. *Gill net selectivity for Marcusenius macrolepidotus during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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	18	9.3	1.40	0.015
28	46	11.2	3.57	0.062
35	112	13.0	8.68	0.271
45	75	15.3	5.81	0.285
57	12	17.5	0.93	0.078
73	4	19.3	0.31	0.035
118	1	29.0	0.08	0.039
Total	**268**	**13.4**	**2.31**	**0.087**

The catchability curve shows that the mesh sizes used in this study efficiently caught fish between 8.0 and 27 cm (**figure 5.6**). Mesh sizes from 22 to 57 were the most efficient.

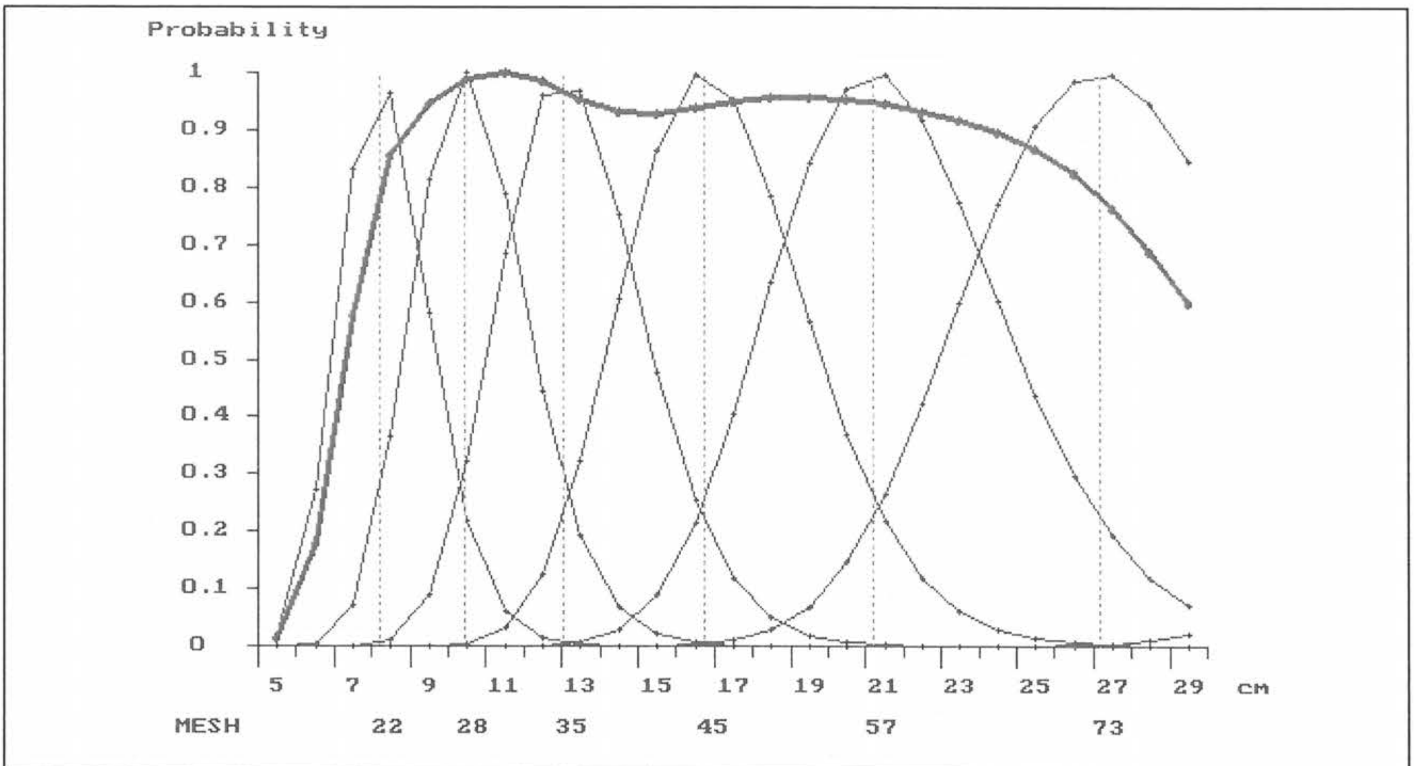

Figure 5.6
Gill net selectivity for Marcusenius macrolepidotus *for different mesh sizes from 22 mm to 73 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thicker line).*

Hydrocynus vittatus (Tigerfish)

Hydrocynus vittatus was the second most important species in the gill net catches, but was not caught with other types of gears during the surveys (IRI, **appendix 4** and **5**). The minimum body length of mature fish was 26 cm for males and 21 cm for females (**table 5.2**). The length at 50 % maturity was 28.0 cm for females, but could not be determined for males.

A total of 94 individuals were caught in gill nets, with body lengths from 14 to 60 cm (mean 29.4 cm, modal length 25.0-25.9 cm) (**figure 5.5**). No fish between 45 and 56 cm were caught. The mean length was larger than the minimum size at maturity, while the modal lengths were not different from the minimum size at maturity for males (26 cm), but larger than the minimum size at maturity for females (21 cm) (**table 5.2**).

The 73 mm mesh size caught both the largest number of fish per setting (2.56 fish/setting) and the highest weight per setting (1.044 kg/setting) (**table 5.4**). Fish caught with this mesh size had an average length of 31.0 cm. Very few individuals were caught with the mesh size smaller than 45 mm. One individual with a length of 55 cm was caught in the 150 mm mesh size.

Table 5.4. *Gill net selectivity for Hydrocynus vittatus during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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	2	39.5	0.16	0.247
28	4	26.8	0.31	0.093
35	5	20.8	0.39	0.056
45	22	25.8	1.71	0.534
57	19	27.1	1.47	0.380
73	33	31.0	2.56	1.044
93	6	37.8	0.47	0.373
118	2	44.0	0.16	0.180
150	1	55.0	0.08	0.217
Total	**94**	**29.4**	**0.810**	**0.350**

The catchability curve shows that the mesh sizes used in this study efficiently caught fish between 11 and 60 cm (**figure 5.7**). Mesh sizes from 35 to 73 were the most efficient.

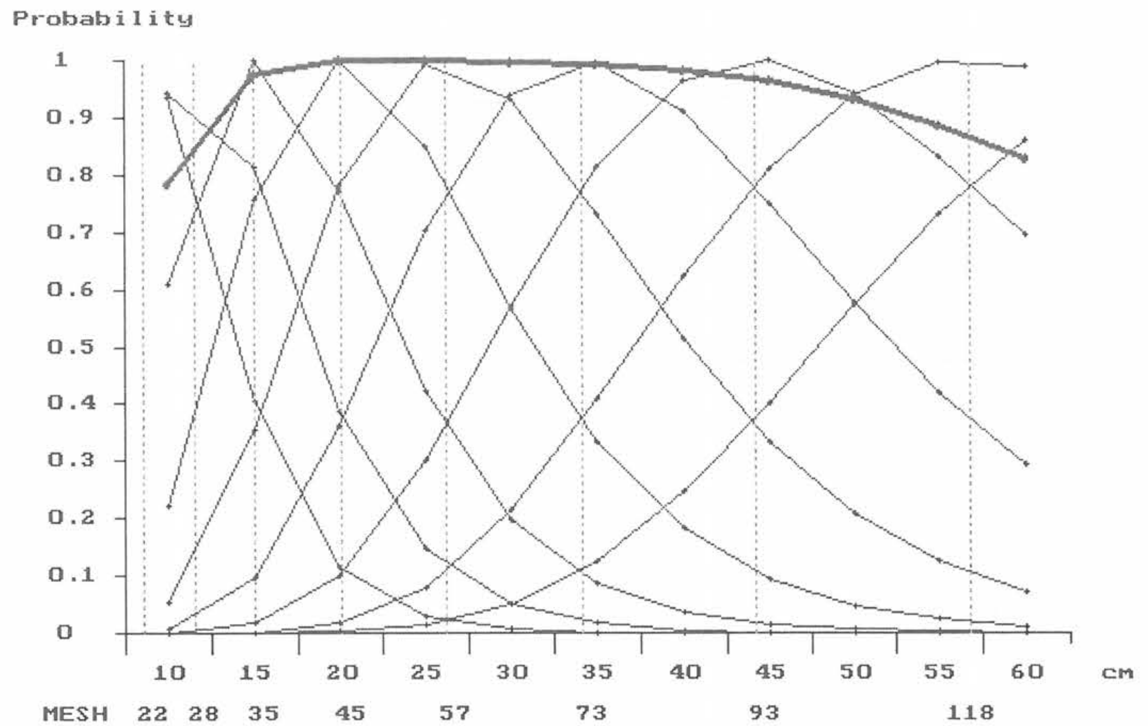

Figure 5.7
Gill net selectivity for Hydrocynus vittatus *for different mesh sizes from 22 mm to 118 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thicker line).*

Petrocephalus catostoma (Northern churchill)
Petrocephalus catostoma was the third most important species in the gill net catches, but only the twenty-eighth most important species caught by other gears (IRI, **appendix 4** and **5**). The minimum body length of mature fish was 8.0 cm for males and 6.0 cm for females (**table 5.2**). The length at 50 % maturity was 6.9 cm for females, but could not be determined for males.

A total of 295 individuals were caught in gill nets, with body lengths from 6.0 to 10.0 cm (mean 8.5 cm, modal length 8.0-8.9 cm) (**figure 5.5**). Both the mean and modal lengths were longer than the minimum size at maturity (8.0 and 6.0 cm) (**table 5.2**). Only two individuals were caught with the other gears, and the lengths of these were 4.1 and 8.0 cm.

The 28 mm mesh size caught both the largest number of fish per setting (17.9 fish/setting) and the highest weight per setting (0.159 kg/setting) (**table 5.5**). Fish caught with this mesh size had an average length of 8.7 cm. The nets with larger mesh sizes than 35 mm did not catch any fish of this species.

Table 5.5. *Gill net selectivity for Petrocephalus catostoma during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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	54	7.7	4.09	0.024
28	231	8.7	17.91	0.1591
35	10	9.1	0.78	0.0085
Total	**295**	**8.5**	**2.54**	**0.020**

The catchability curve shows that the mesh sizes used in this study efficiently caught fish between 6.7 and 10.4 cm (**figure 5.8**). The mesh size of 28 cm was most efficient.

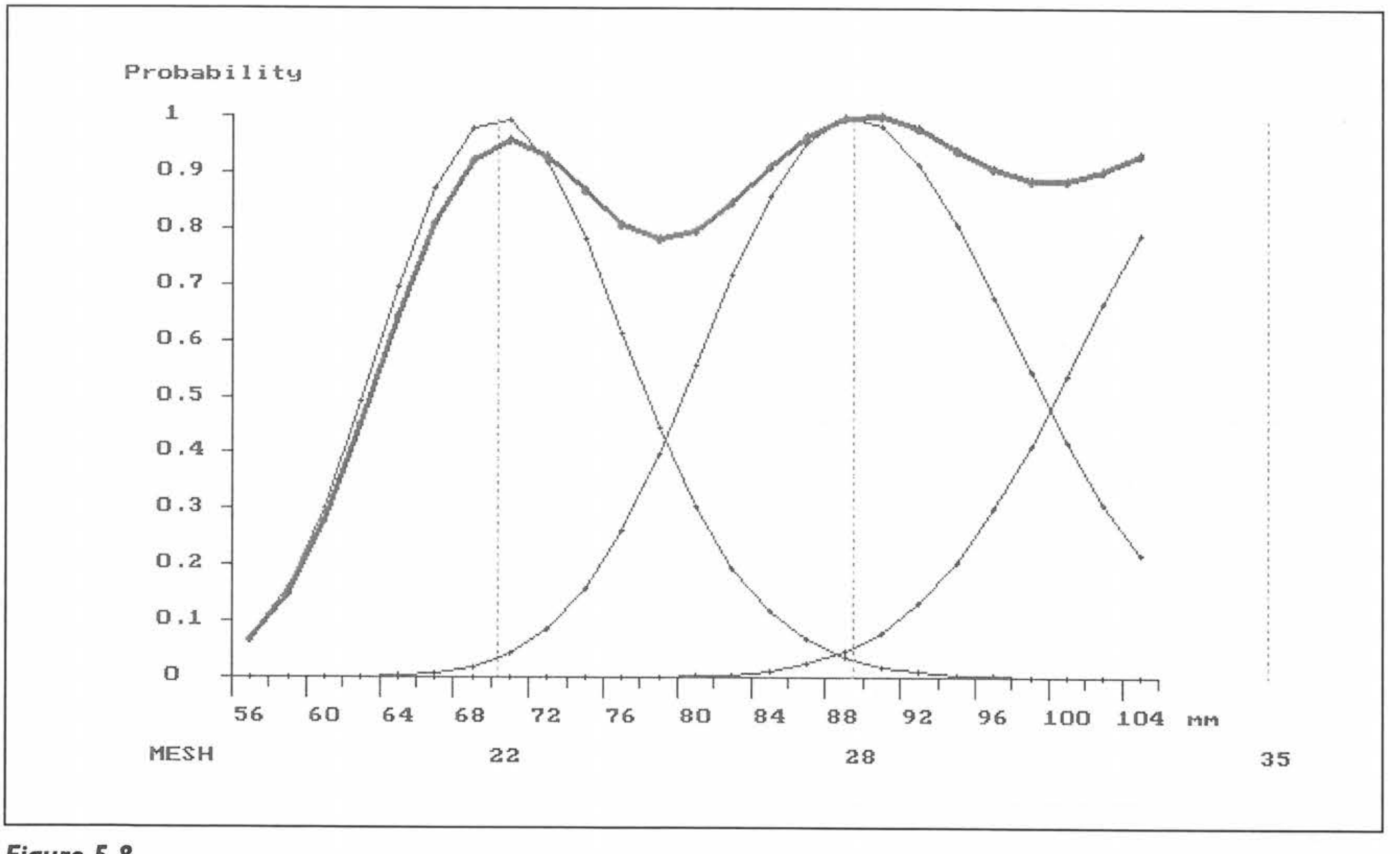

Figure 5.8
Gill net selectivity for Petrocephalus catostoma *for different mesh sizes from 22 mm to 35 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thicker line).*

Schilbe intermedius (Silver catfish)

Schilbe intermedius was the fourth most important species in the gill net catches and only the twenty-third most important species caught by other gears (IRI, **appendix 4** and **5**). The minimum body length of mature fish was 14 cm for males and females (**table 5.2**). The length at 50 % maturity could not be determined.

A total of 91 individuals were caught in gill nets, with body lengths from 9.0 to 28 cm (mean 18.4 cm, modal length 18.0-18.9 cm) (**figure 5.5**). Only four individuals were caught with the other gears. Both the mean and modal lengths were longer than the minimum size at maturity (14 cm) (**table 5.2**). The lengths of the fish caught with other gears were between 7.5 and 10.0 cm.

The 45 mm mesh size caught the largest number of fish per setting (2.09 fish/setting) (**table 5.6**). Fish caught with this mesh size had an average length of 18.0 cm. The 57 mm nets had the highest catch in terms of weight per setting (0.219 kg/setting). Fish caught with this mesh size had an average length of 23.1 cm. Only a few fish were caught in mesh sizes larger than 57 mm.

Table 5.6. *Gill net selectivity for Schilbe intermedius during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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	6	16.9	0.47	0.033
28	15	15.1	1.16	0.064
35	20	15.9	1.55	0.074
45	27	18.0	2.09	0.143
57	20	23.1	1.55	0.219
73	3	25.3	0.23	0.047
Total	**91**	**18.4**	**0.78**	**0.006**

The catchability curve shows that the mesh sizes used in this study efficiently caught fish between 12.0 and 27.0 cm (**figure 5.9**). Mesh sizes from 28 to 57 were the most efficient.

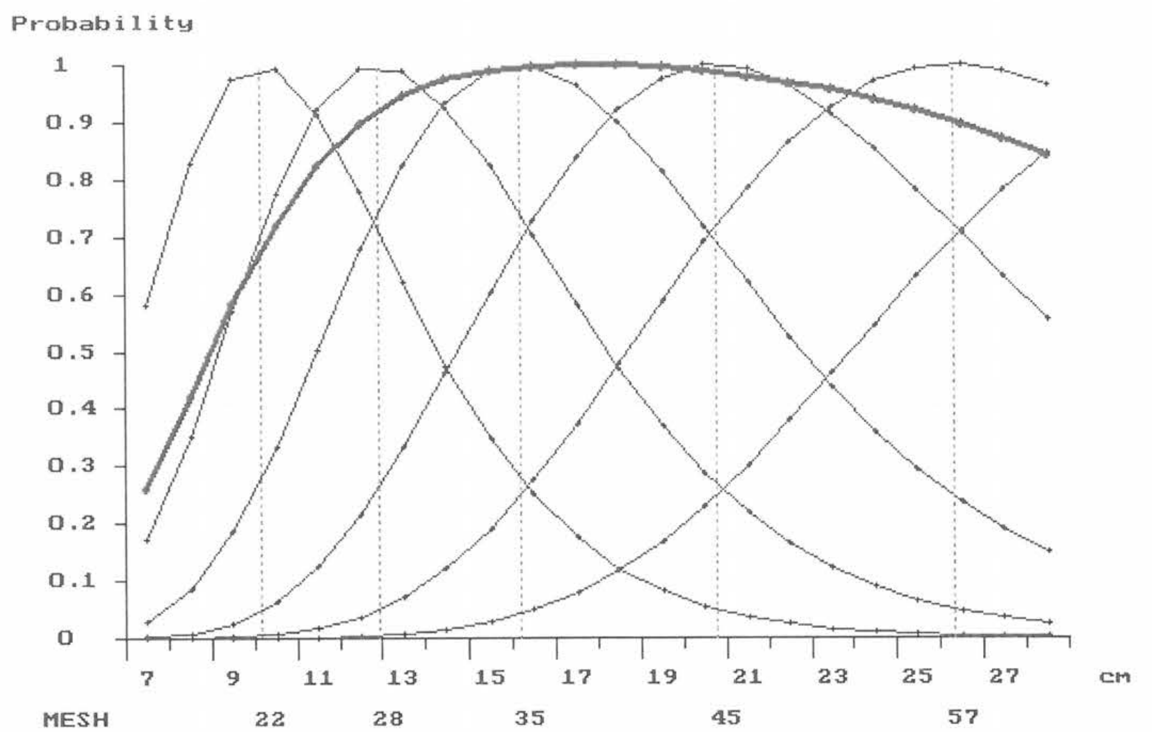

Figure 5.9
Gill net selectivity for Schilbe intermedius *for different mesh sizes from 22 mm to 57 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thicker line).*

Cyphomyrus discorhynchus (Zambezi parrotfish)
Cyphomyrus discorhynchus was the fifth most important species in the gill net catches and were not caught with other types of gears during the surveys (IRI, **appendix 4** and **5**). The minimum body length of mature fish was not recorded.

A total of 102 individuals were caught in gill nets, with body lengths from 7.0 to 19 cm (mean 10.1 cm, modal length 9.0-9.9 cm) (**figure 5.5**).

The 28 mm mesh size caught the largest number of fish per setting (4.11 fish/setting) (**table 5.7**). Fish caught with this mesh size had an average length of 9.3 cm. The 28 mm nets had also the highest catch in terms of weight per setting (0.045 kg/setting). Only a few fish were caught in mesh sizes larger than 35 mm.

The catchability curve shows that the mesh sizes used in this study efficiently caught fish between 7.0 and 19 cm (**figure 5.10**). Mesh sizes from 22 to 35 were the most efficient.

Table 5.7. *Gill net selectivity for Cyphomyrus discorhynchus during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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	18	8.5	1.40	0.012
28	53	9.3	4.11	0.045
35	25	11.2	1.94	0.040
45	4	15.8	0.31	0.020
57	1	18.0	0.08	0.006
73	1	19.0	0.08	0.007
Total	**102**	**10.1**	**0.88**	**0.010**

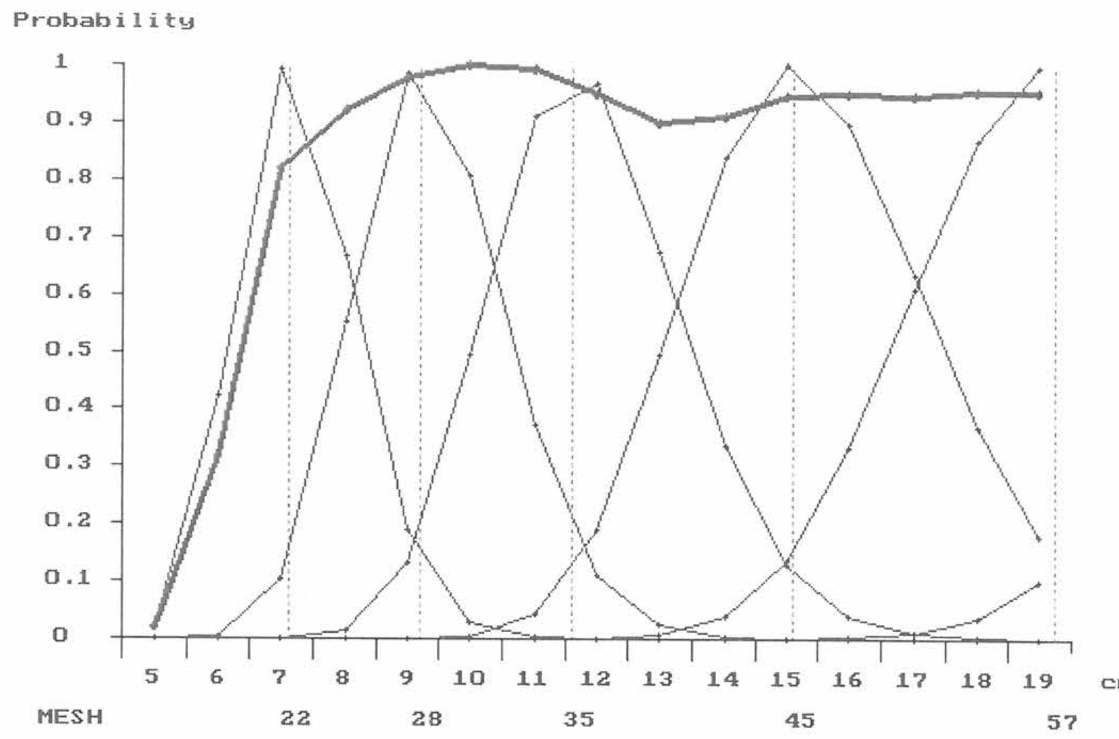

Figure 5.10
Gill net selectivity for Cyphomyrus discorhynchus *for different mesh sizes from 22 mm to 57 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thicker line).*

Clarias gariepinus (Sharptooth catfish)

Clarias gariepinus was the sixth most important species in the gill net catches and the eleventh most important species caught by other gears (IRI, **appendix 4** and **5**). The minimum body length of mature fish was 46 cm for females and could not be determined for males (**table 5.2**). The length at 50 % maturity could not be determined for either sexes.

A total of 19 individuals were caught in gill nets, with body lengths ranging from 39 to 65 cm (mean 53.5 cm, modal length could not be determined) (**figure 5.5**). Only four individuals were caught with the other gears, with body length between 10.0 and 36 cm (mean length 19.8 cm). The mean length was longer than the minimum size at maturity (46 cm) (**table 5.2**).

The 93 mm mesh size caught the largest number of fish per setting (0.70 fish/setting) (**table 5.8**). Fish caught with this mesh size had an average length of 51.0 cm. The 93 and 118 mm nets had the highest catch in terms of weight per setting (0.695 kg/setting for both meshes). Fish caught with this mesh size had an average length of 51.0 and 57.8 cm, respectively. Due to a low number of fish caught, studies of gill net selectivity could not be done.

Table 5.8. *Gill net selectivity for Clarias gariepinus during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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	1	65.0	0.08	0.150
73	3	48.7	0.23	0.234
93	9	51.0	0.70	0.695
118	6	57.8	0.47	0.695
Total	**19**	**53.5**	**0.16**	**0.200**

Pharyngochromis acuticeps (Zambezi bream)
Pharyngochromis acuticeps was the seventh most important species in the gill net catches and the most important species caught by other gears (IRI, **appendix 4** and **5**). The minimum body length of mature fish was 10.0 cm for males and 7.0 cm for females (**table 5.2**). The length at 50 % maturity was 10.5 cm for males, but could not be determined for females.

A total of 52 individuals were caught in gill nets, with body lengths from 7.0 to 14 cm (mean 9.3 cm, modal length 7.0-7.9 cm) (**figure 5.5**), while 246 individuals were caught with the other gears. The length of the fish caught with other gears were between 1.9 and 16 cm (mean 5.7 cm, modal length 5.0-5.9 cm). The mean and modal lengths were smaller or equal to the minimum size at maturity observed (**table 5.2**).

The 22 mm mesh size caught the largest number of fish per setting (1.47 fish/setting) (**table 5.9**). Fish caught with this mesh size had an average length of 7.4 cm. The 35 mm nets had the highest catch in terms of weight per setting (0.019 kg/setting). Fish caught with this mesh size had an average length of 11.0 cm. Only a few fish were caught in mesh sizes larger than 35 mm.

Table 5.9. *Gill net selectivity for Pharyngochromis acuticeps during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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	19	7.4	1.47	0.007
28	16	9.5	1.24	0.013
35	14	11.0	1.09	0.019
45	2	12.5	0.16	0.004
57	1	11.0	0.08	0.001
Total	**52**	**9.3**	**0.45**	**0.010**

The catchability curve shows that the mesh sizes used in this study efficiently caught fish between 8.0 and 13 cm (**figure 5.11**). Mesh sizes from 22 to 35 were most efficient.

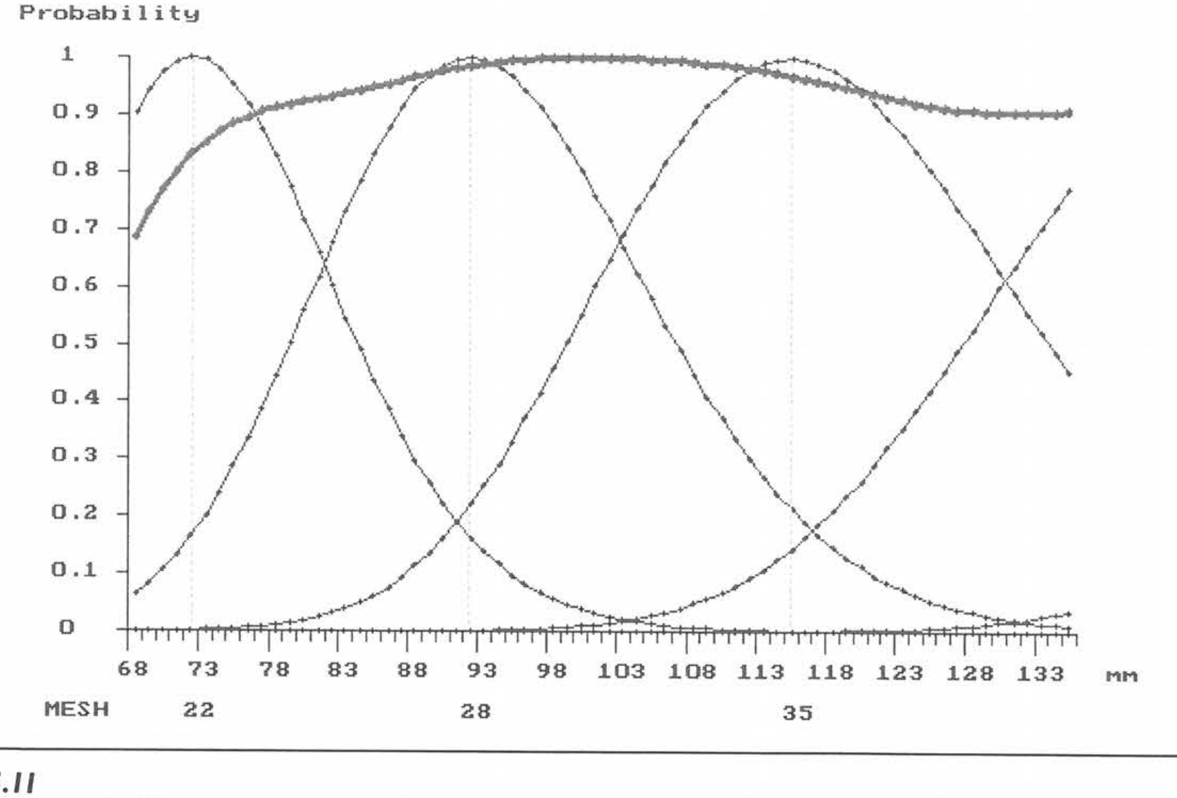

Figure 5.11
Gill net selectivity for Pharyngochromis acuticeps *for different mesh sizes from 22 mm to 45 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thicker line).*

Brycinus lateralis (Striped robber)
Brycinus lateralis was the eighth most important species in the gill net catches and the fifth most important species caught by other gears (IRI, **appendix 4** and **5**). The minimum body length of mature fish was 8.0 cm for males and 7.0 cm for females (**table 5.2**). The length at 50 % maturity was 8.0 cm for females, but could not be determined for males.

A total of 103 individuals were caught in gill nets, with body lengths from 7.0 to 11 cm (mean 8.3 cm, modal length 8.0-8.9 cm) (**figure 5.5**). In addition, 155 individuals were caught with the other gears, with body lengths from 2.5 to 9.5 cm (mean 4.7 cm, modal length 4.0-4.9 cm). The mean and modal lengths for the gill net catches were equal to the minimum size at maturity observed, while for the catches with other gears mean and modal length were smaller than the minimum size at maturity (**table 5.2**).

The 22 mm mesh size caught the largest number of fish per setting (7.83 fish/setting) (**table 5.10**). Fish caught with this mesh size had an average length of 8.3 cm. The 22 mm nets also had the highest catch in terms of weight per setting (0.045 kg/setting). Only two specimens were caught in mesh sizes other than 22 mm.

Table 5.10. *Gill net selectivity for Brycinus lateralis during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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	101	8.3	7.83	0.045
28	2	9.5	0.16	0.002
Total	**103**	**8.3**	**0.89**	**0.010**

The catchability curve shows that the mesh sizes used in this study efficiently caught fish between 8.0 and 10.0 cm (**figure 5.12**). The 22 mm mesh size was the most efficient.

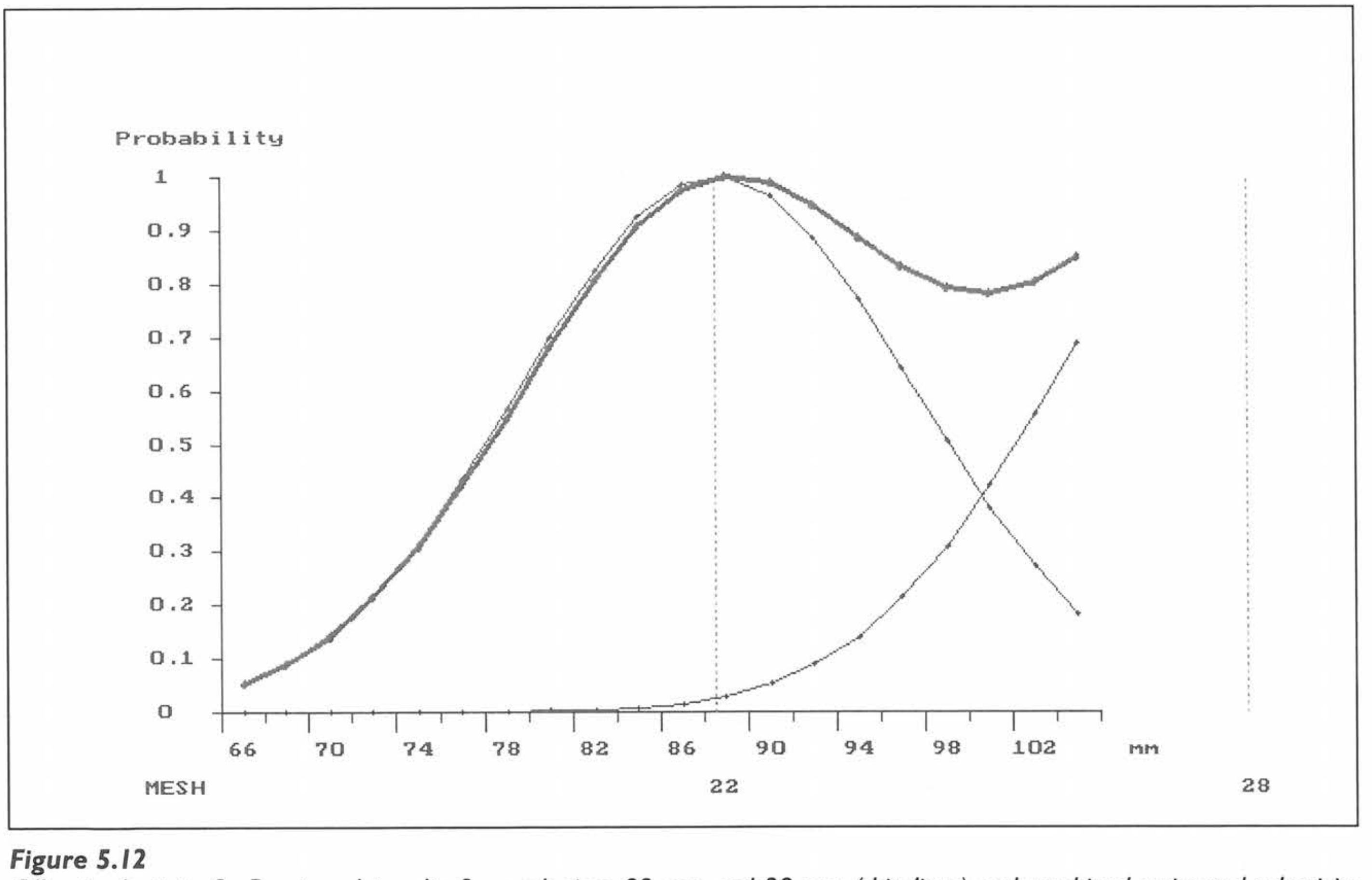

Figure 5.12
Gill net selectivity for Brycinus lateralis *for mesh sizes 22 mm and 28 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thicker line).*

Sargochromis giardi (Pink bream)

Sargochromis giardi was the ninth most important species in the gill net catches, but were not caught with other types of gears during the surveys (IRI, **appendix 4** and **5**). The minimum body length of mature fish could not be determined.

A total of 18 individuals were caught in gill nets, with body lengths from 18 to 38 cm (mean 30.0 cm, modal length 30.0-30.9 cm) (**figure 5.5**).

The 118 mm mesh size caught the largest number of fish per setting (0.62 fish/setting) (**table 5.11**). Fish caught with this mesh size had an average length of 29.6 cm. The 150 mm nets gave the highest catch in terms of weight per setting (0.453 kg/setting). The nets with the larger mesh sizes (93-150 mm) were the most efficient. Due to a low number of fish caught, studies of gill net selectivity could not be carried out for this species.

Table 5.11. *Gill net selectivity for Sargochromis giardi during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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)
73	1	18.0	0.08	0.010
93	4	27.0	0.31	0.142
118	8	29.6	0.62	0.376
150	5	35.4	0.39	0.453
Total	**18**	**30.0**	**0.16**	**0.110**

Hepsetus odoe (African pike)

Hepsetus odoe was the tenth most important species in the gill net catches and the twelfth most important species caught by other gears (IRI, **appendix 4** and **5**). The minimum body length of mature fish was 26 cm for females, and could not be determined for males (**table 5.2**). The length at 50 % maturity could not be determined.

A total of 22 individuals were caught in gill nets, with body lengths from 16 to 39 cm (mean 28.1 cm, modal length 29.0-29.9 cm) (**figure 5.5**), while only three individuals were caught with other gears. The lengths of fish caught with other gears ranged between 11.1 and 26 cm (mean 18.2 cm). The mean and modal lengths for the gill net catches were larger than the minimum size at maturity (**table 5.2**).

The 57 mm mesh size caught the largest number of fish per setting (0.78 fish/setting) (**table 5.12**). Fish caught with this mesh size had an average length of 27.3 cm. The 73 mm nets showed the highest catch in terms of weight per setting (0.246 kg/setting).

The catchability curve shows that the mesh sizes used in this study efficiently caught fish between 17 and 38 cm (**figure 5.13**). Mesh sizes of 57 and 73 mm were the most efficient.

Table 5.12. *Gill net selectivity for Hepsetus odoe during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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	29.0	0.08	0.021
35	3	23.0	0.23	0.038
57	10	27.3	0.78	0.204
73	8	31.0	0.62	0.246
Total	**22**	**28.1**	**0.19**	**0.060**

Pseudocrenilabrus philander (Southern mouth-brooder)
Pseudocrenilabrus philander was the twenty-seventh most important species in the gill net catches and the second most important species caught by other gears (IRI, **appendix 4** and **5**). The minimum body length of mature fish was 3.0 cm for males and 5.0 cm for females (**table 5.2**). The length at 50 % maturity could not be determined.

Only two individuals were caught in gill nets, with body lengths of 6.5 and 8.0 cm (**figure 5.5**). These fish were caught in gill nets 22 and 28 mm mesh size (**table 5.13**). A total of 285 individuals were caught with the other gears. The lengths of the fish caught with other gears ranged between 1.5 and 8.0 cm (mean 4.4 cm, modal length 4.0-4.9 cm). The mean and modal lengths for the catches with other gears were equal to the minimum size at maturity (**table 5.2**). Selectivity curve for gill nets could not be made due to the low number of fish caught.

Table 5.13. *Gill net selectivity for Pseudocrenilabrus philander during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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	6.5	0.08	0.0004
28	1	8.0	0.08	0.0004
Total	**2**	**7.3**	**0.02**	**0.0000**

Micralestes acutidens (Silver robber)
Micralestes acutidens was not caught in gill nets during the surveys, but was the third most important species caught with the other gears (IRI, **appendix 4** and **5**). A total of 275 individuals with body lengths from 2.6 cm to 5.7 cm (mean 3.8 cm, modal length 3.0-3.9 cm) were caught (**figure 5.5**). The body length at maturity could not be determined.

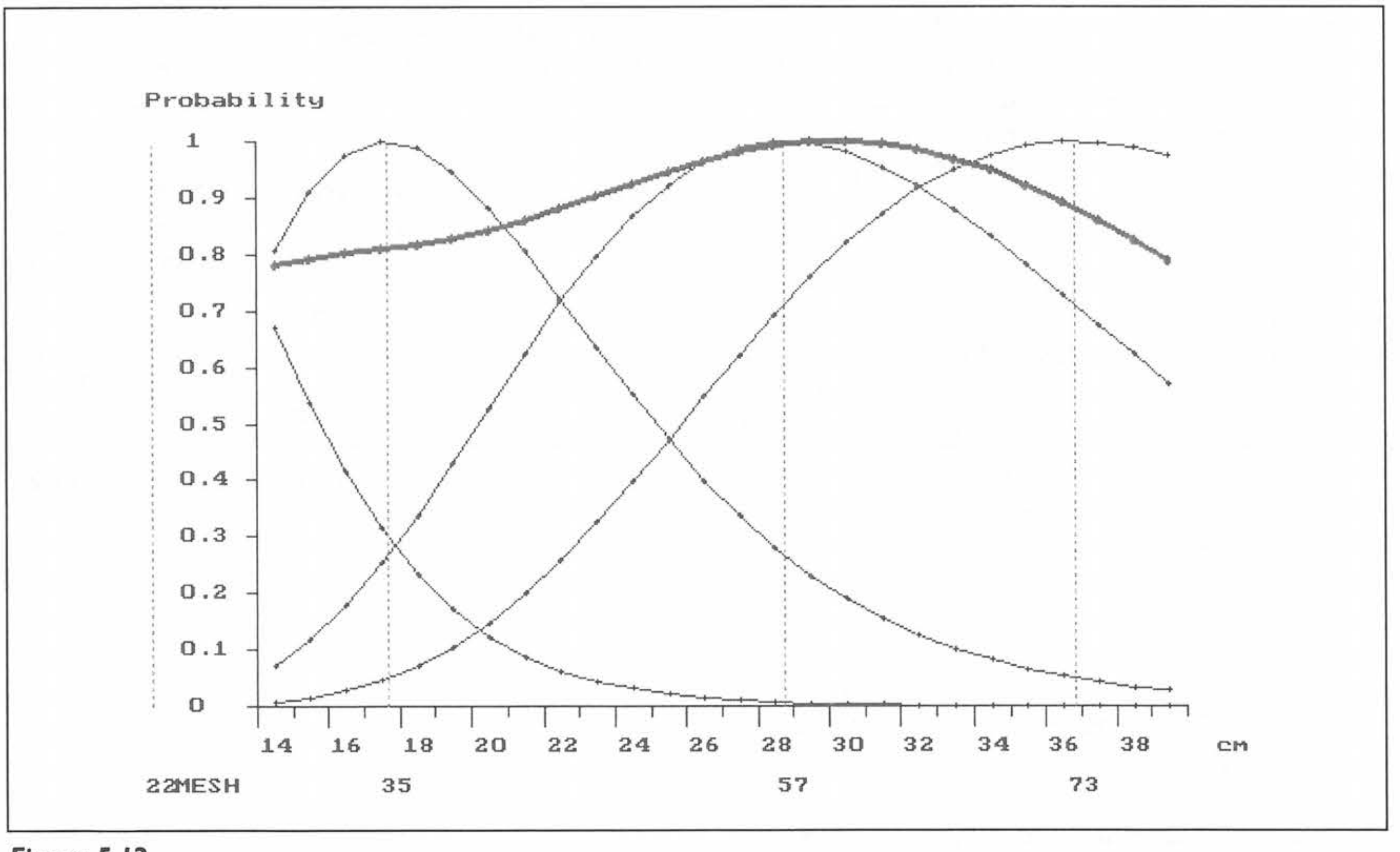

Figure 5.13
Gill net selectivity for Hepsetus odoe *for mesh sizes of 35 mm to 73 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thicker line).*

Tilapia rendalli (Redbreast tilapia)

Tilapia rendalli was the twenty-first most important species in the gill net catches, with only two individuals caught (IRI, **appendix 4**). These specimens were 26 cm and 30 cm in length, and were caught in 93 and 118 mm mesh sizes (**table 5.14**). *Tilapia rendalli* was the fourth most important species caught by other gears (**appendix 5**). A total of 55 individuals were caught, with body lengths between 1.9 and 17 cm (mean 6.4 cm, modal length 3.0-3.9 cm) (**figure 5.5**). The body length at maturity could not be determined.

Table 5.14. *Gill net selectivity for Tilapia rendalli during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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)
93	1	26.0	0.08	0.033
118	1	30.0	0.08	03042
Total	**2**	**28.0**	**0.02**	**0.010**

Aplocheilichthys johnstoni (Johnston's topminnow)

Aplocheilichthys johnstoni was not caught in gill nets during the surveys, but was the sixth most important species in the catches with the other gears (IRI, **appendix 4** and **5**). A total of 134 individuals with body lengths from 1.5 cm to 4.2 cm (mean 3.3 cm, modal length 3.0-3.9 cm) were caught (**figure 5.5**). The body length at maturity could not be determined.

Tilapia sparrmanii (Banded tilapia)

Tilapia sparrmanii was the twentieth most important species in the gill net catches, with only six individuals caught (IRI, **appendix 4**). These had body lengths between 8.5 and 14 cm (mean 10.2 cm). *Tilapia sparrmanii* was the seventh most important species caught by other gears, with 111 individuals caught (IRI, **appendix 5**). The lengths of the fish caught with other gears ranged between 2.0 and 11 cm (mean 4.1 cm, modal length 2.0-2.9 cm) (**figure 5.5**). The body length at maturity could not be determined.

The 35 mm mesh size caught the largest number of fish per setting (0.23 fish/setting) (**table 5.15**). Fish caught with this mesh size had an average length of 9.4 cm. The net of 57 mm mesh size gave the highest catch in terms of weight per setting (0.005 kg/setting).

Table 5.15. *Gill net selectivity for Tilapia sparrmanii during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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	8.5	0.08	0.001
35	3	9.4	0.23	0.004
45	1	11.0	0.08	0.002
57	1	13.5	0.08	0.005
Total	**6**	**10.2**	**0.05**	**0.001**

Oreochromis macrochir (Greenhead tilapia)

Oreochromis macrochir was the thirteenth most important species in the gill net catches, with only six individuals caught (IRI, **appendix 4**). These had body lengths between 22 and 35 cm. *Oreochromis macrochir* was the eighth most important species caught by other gears (IRI, **appendix 5**). A total of 74 individuals with body lengths between 2.5 and 14 cm (mean 5.4 cm, modal length 4.0-4.9 cm) were caught with other gears (**figure 5.5**). The minimum size at maturity

Table 5.16. *Gill net selectivity for Oreochromis macrochir during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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)
93	1	22.0	0.08	0.017
118	3	27.7	0.23	0.131
150	2	34.5	0.16	0.155
Total	**6**	**29.0**	**0.05**	**0.030**

for males was 22 cm, but could not be determined for females.

The 118 mm mesh size caught the largest number of fish per setting (0.23 fish/setting) (**table 5.16**). Fish caught with this mesh size had an average length of 27.7 cm. The 150 mm nets showed the highest catch in terms of weight per setting (0.155 kg/setting).

Barbus unitaeniatus (Longbeard barb)
Barbus unitaeniatus was the thirtieth most important species in the gill net catches, with only one individual caught (IRI, **table 5.17** and **appendix 4**). This species was the ninth most important species caught by other gears (measured as index of relative importance, IRI, **appendix 5**). A total of 39 individuals with body lengths between 2.8 and 7.0 cm (mean 5.0 cm, modal length 5.0-5.9 cm) were caught with other gears (**figure 5.5**). The body length at maturity could not be determined.

Hemichromis elongatus (Banded jewelfish)
Hemichromis elongatus was not caught in gill nets during the surveys, but was the tenth most important species in the catches with other gears (IRI, **appendix 4** and **5**). A total of 39 individuals with body lengths from 2.4 to 11 cm (mean 4.8 cm, modal length 3.0-3.9 cm) were caught (**figure 5.5**).

Table 5.17. *Gill net selectivity for Barbus unitaeniatus during surveys in the Kwando River during 1997-1999. Number of fish caught (n), mean length of the fish and mean standard catch per unit effort (CPUE) are given for each mesh size. 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	8.5	0.08	0.0004
Total	**1**	**8.5**	**0.01**	**0.0000**

5.2.4 Summary of life history and gill net selectivity for selected species

The most efficient gill net mesh size varied considerably among the most important species (selected species, see section 3.3.2), from 22 mm for *Brycinus lateralis* to 150 mm for *Sargochromis giardi* (**table 5.18**). Mean body length for fish caught in gill nets also varied considerably among the selected species, whereas mean length of fish caught with the other gears was relatively small (< 20 cm) (**table 5.19**). The length-weight relationship for the selected species are given in **table 5.20**.

Table 5.18. *Most efficient gill net mesh sizes in terms of number of fish and weight per setting for the ten most important species during gill net surveys in the Kwando River during 1997-1999. Fish species classified as "large" had a minimum length at maturity > 7 cm, whereas those classified as "small" had a minimum length at maturity ≤ 7 cm.*

Species	Most efficient gill net mesh size (mm)		Size classification	
	Number per set	Weight per set	Large	Small
Marcusenius macrolepidotus	35	45	x	
Hydrocynus vittatus	73	73	x	
Petrocephalus catostoma	28	28		x
Schilbe intermedius	45	57	x	
Hippopotamyrus discorhynchus	28	28	x	
Clarias gariepinus	93	93/118	x	
Pharyngochromis acuticeps	22	35		x
Brycinus lateralis	22	22		x
Sargochromis giardi	118	150	x	
Hepsetus odoe	57	73	x	

Table 5.19. *Mean body length of the selected species caught in gill nets and other gears during surveys in the Kwando River during 1997-1999 (n = number of fish). Test statistics (t-test) for differences in body length between gill net catches and catches with other gears are also shown.*

Species	Mean body length in gill net catches (cm)	n	Mean body length in catches with other gears (cm)	n	t-test t	df	p
Marcusenius macrolepidotus	13.4	268	6.8	2	3.330	268	< 0.005
Hydrocynus vittatus	29.4	94	-	0	-	-	-
Petrocephalus catostoma	8.5	295	6.1	2	5.074	295	< 0.001
Schilbe intermedius	18.4	91	8.9	4	3.763	93	< 0.001
Hippopotamyrus discorhynchus	10.1	102	-	0	-	-	-
Clarias gariepinus	53.5	19	19.8	4	8.199	21	< 0.001
Pharyngochromis acuticeps	9.3	52	5.7	246	11.800	296	< 0.001
Brycinus lateralis	8.3	103	4.7	155	29.657	256	< 0.001
Sargochromis giardi	30.0	18	-	0	-	-	-
Hepsetus odoe	28.1	22	18.2	3	3.103	23	< 0.01
Pseudocrenilabrus philander	7.3	2	4.4	285	3.238	285	< 0.005
Micralestes acutidens	-	0	3.8	275	-	-	-
Tilapia rendalli	28.0	2	6.4	55	8.627	55	< 0.001
Aplocheilichthys johnstoni	-	0	3.3	134	-	-	-
Tilapia sparrmanii	10.2	6	4.1	111	8.061	115	< 0.001
Oreochromis macrochir	29.0	6	5.4	74	24.780	78	< 0.001
Barbus unitaeniatus	8.5	1	5.0	39	-	-	-
Hemichromis elongatus	-	0	4.8	39	-	-	-

Table 5.20. *Length-weight relationship for selected species (see section 3.3.2) during gill net surveys in the Kwando River during 1997-1999. The formula W = a * L (exp b) was used, where a = intercept, b = exponent, W = weight of the fish and L = length of the fish. The relationship is not given for species caught in low numbers in the gill nets.*

Species fish	Intercept a	Exponent b	r^2	Number of
Marcusenius macrolepidotus	3.33	0.006	0.95	266
Hydrocynus vittatus	3.18	0.007	0.99	92
Petrocephalus catostoma	2.62	0.030	0.44	287
Schilbe intermedius	3.07	0.009	0.96	91
Hippopotamyrus discorhynchus	3.20	0.009	0.92	102
Clarias gariepinus	2.68	0.027	0.93	19
Pharyngochromis acuticeps	3.36	0.005	0.86	52
Brycinus lateralis	2.88	0.014	0.36	88
Sargochromis giardi	3.34	0.007	0.91	18
Hepsetus odoe	3.33	0.004	0.99	20
Pseudocrenilabrus philander	-	-	-	2
Micralestes acutidens	-	-	-	-
Tilapia rendalli	-	-	-	2
Aplocheilichthys johnstoni	-	-	-	0
Tilapia sparrmanii	3.21	0.012	0.91	6
Oreochromis macrochir	3.36	0.007	0.94	6
Barbus unitaeniatus	-	-	-	1
Hemichromis elongatus	-	-	-	0

5.3 Catch per unit effort (CPUE)

Catch per unit effort (CPUE) was estimated for the gill net surveys in order to obtain an indication of fish densities (**table 5.21**). The average CPUE in number of fish and weight was 10.1 fish and 1.23 kg per setting, respectively. The variation in catch among settings was considerable.

5.3.1 Catch per unit effort in different mesh sizes

Catch per unit effort was estimated for each mesh size (22 to 150 mm). CPUE in number of fish per setting was higher for smaller than for larger mesh sizes (**figure 5.14**), and a negative correlation between mesh size and CPUE in number of fish was found (Spearman rank, $r = -0.473$, $p = 0.01$). For the CPUE in weight of fish per setting, the opposite tendency was found. CPUE in weight increased with larger mesh sizes, but the correlation was not significant (Spearman rank, $r = 0.092$, $p = 0.071$) (**figure 5.15**).

5.3.2 Catch per unit effort in different habitats and seasons

Habitat characteristics such as water discharge, vegetation, depth, the extent of adjacent floodplains, backwaters and bottom substrate is known to affect fish abundance. We were able to estimate CPUE in

Table 5.21. *Number of settings (sets) and total gill net catches (22-150 mm mesh size) during surveys in the Kwando River during 1997-1999. Mean standard CPUE in number of fish (n) and weight per setting has been calculated (sd = standard deviation). Setting = 12 hours of fishing with one standard gill net (area = 50 m2).*

	Total catch		CPUE			
Number of sets	**Number of fish caught**	**Weight of fish caught** (kg)	**n**	**sd**	**Weight** (kg)	**sd**
387	1172	142.8	10.1	20.8	1.23	2.29

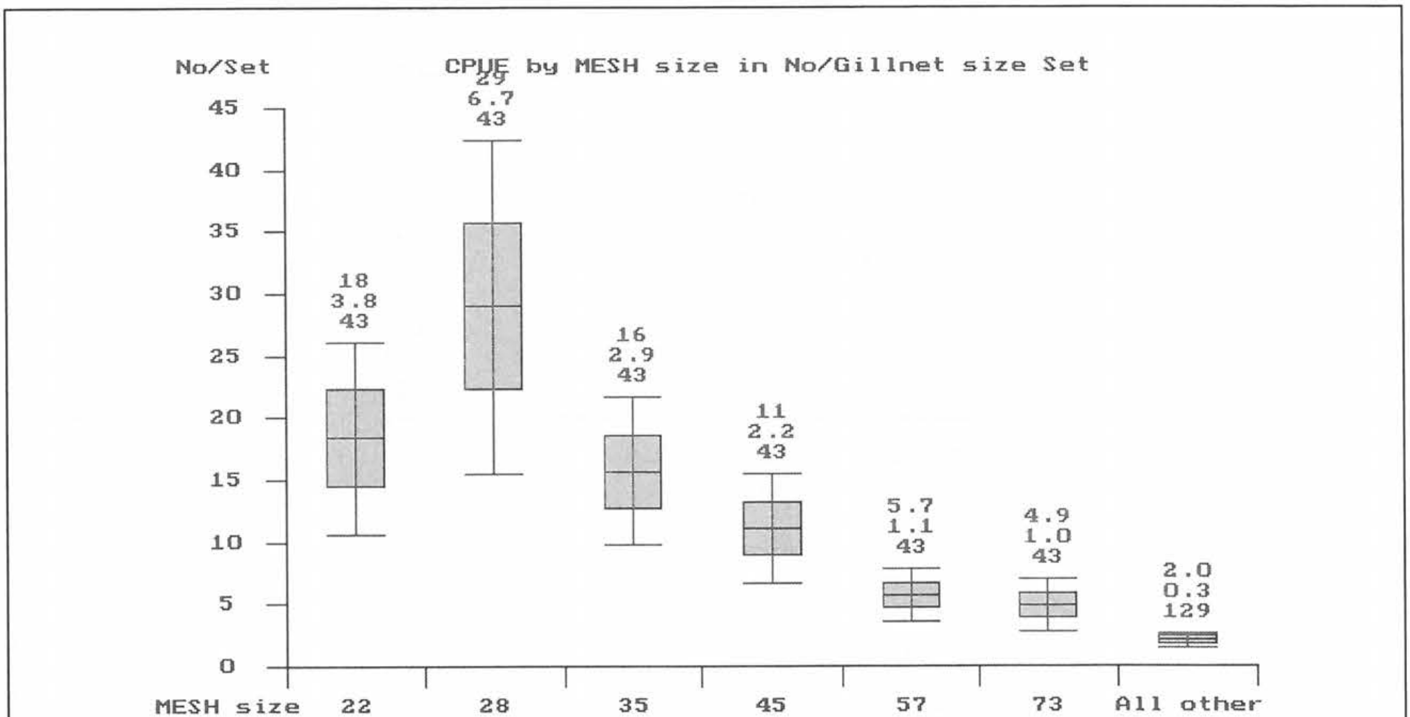

Figure 5.14
Mean standard catch per unit effort (CPUE) in number of fish per setting for total gill net samples (22-150 mm mesh size) during surveys in the Kwando River during 1997-1999. Top number = mean, second number = standard error and third number = sample size. Last mesh size > 73 mm. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).

Table 5.22. Catch per unit effort (CPUE) given as mean number of fish fish (n) and mean weight per gill net setting for mesh sizes 22-35 mm in different combinations of habitat (mainstream/backwater) and seasons (autumn/spring) during surveys in the Kwando River during 1997-1999 (sd = standard deviation). Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).

Habitat - season	Number of sets	CPUE (n/set)		CPUE (kg/set)	
		Mean	sd	Mean	sd
Mainstream - autumn	54	12.8	18.3	0.35	0.76
Mainstream - spring	42	22.6	25.6	0.84	1.91
Backwater - autumn	21	33.7	58.7	0.32	0.50
Backwater - spring	12	30.0	22.3	0.47	0.37

Table 5.23. Catch per unit effort (CPUE) given as mean number of fish fish (n) and mean weight per gill net setting for mesh sizes 45-73 mm in different combinations of habitat (mainstream/backwater) and season (autumn/spring) during surveys in the Kwando River during 1997-1999 (sd = standard deviation). Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).

Habitat - season	Number of sets	CPUE (n/set)		CPUE (kg/set)	
		Mean	sd	Mean	sd
Mainstream - autumn	54	5.9	8.0	1.2	2.0
Mainstream - spring	42	5.2	6.1	1.1	1.5
Backwater - autumn	21	8.9	12.3	1.9	1.8
Backwater - spring	12	17.8	18.3	2.2	1.9

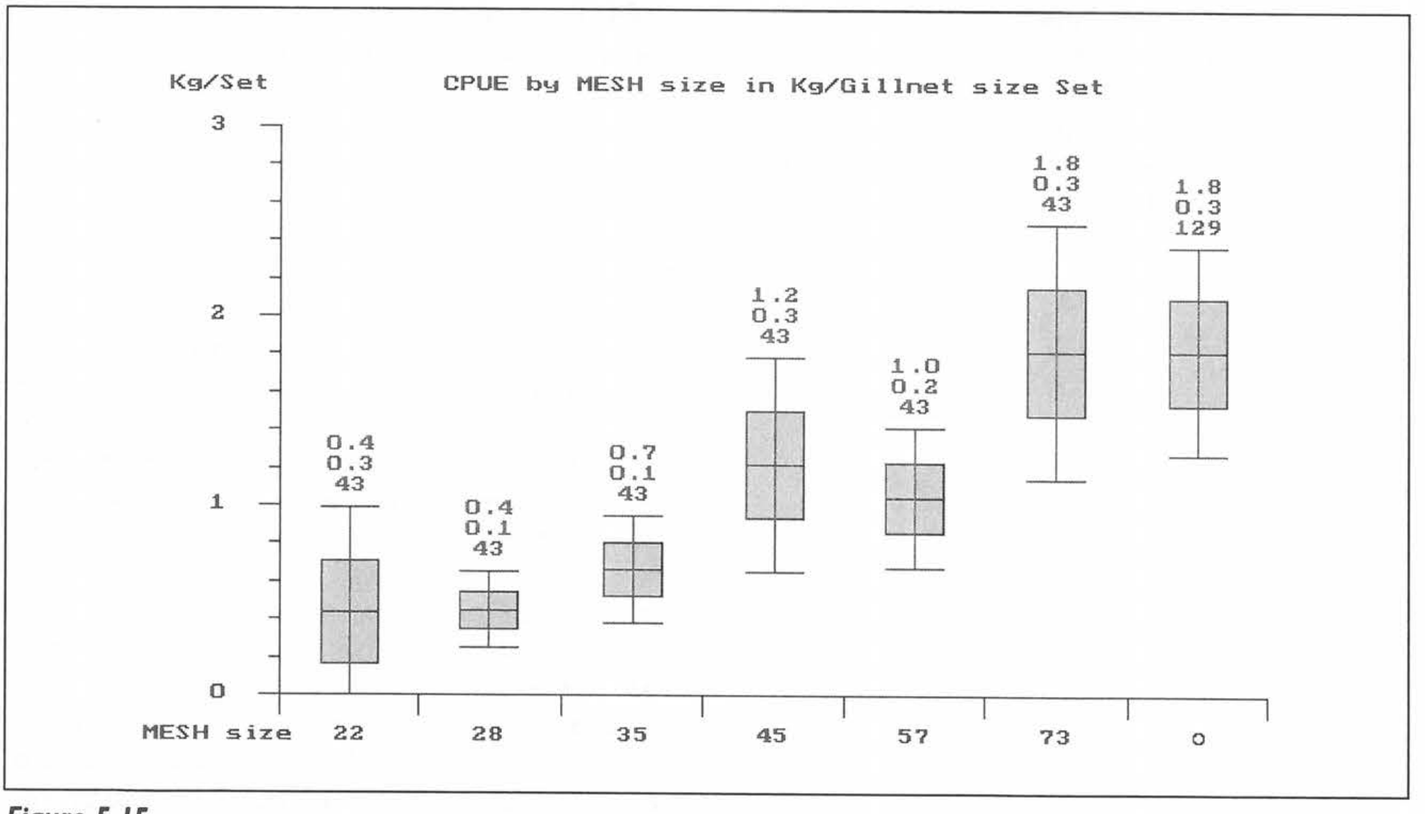

Figure 5.15
Mean standard catch per unit effort (CPUE) in weight of fish per setting for total gill net samples (22-150 mm mesh size) during surveys in the Kwando River during 1997-1999. Top number = mean, second number = standard error and third number = sample size. Last mesh size > 73 mm. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).

relation to main habitat (mainstream and backwater) and season (spring and autumn). To test how habitat type influences the CPUE, we had to exclude the mesh sizes larger than 73 mm, due to many empty gill net sets, resulting in a skewed catch distribution. The remaining data were divided into two groups, one with mesh sizes 22 to 35 and the other with mesh sizes 45 to 73 (**table 5.22** and **5.23**), to explore if habitat type affected CPUE differently for small and large mesh sizes.

In catches with gill nets ranging from 22 to 35 mm mesh size (**table 5.22**), the CPUE/number was significantly higher in backwater than in mainstream stretches (MANOVA, univariate analysis, $F = 6.775$, $df = 1$, $p = 0.010$). CPUE/weight did not differ between these two habitats ($F = 0.023$, $df = 1$, $p = 0.88$). CPUE for 22-35 mm mesh size in terms of weight was higher in the spring than in the autumn ($F = 6.318$, $df = 1$, $p = 0.013$). There was also a tendency that CPUE measured as number of fish was higher in the spring than in the autumn, but the result was not significant at an $\alpha = 0.05$ level ($F = 3.439$, $df = 1$, $p = 0.066$).

For mesh sizes 45-73 mm (**table 5.23**), CPUE was also affected by habitat. The CPUE both in number of fish and weight was higher in backwaters than in the mainstream (MANOVA, univariate analysis; CPUE/number: $F = 8.607$, $df = 1$, $p < 0.004$, CPUE/weight: $F = 8.759$, $df = 1$, $p = 0.004$). However, CPUE for 45-73 mm mesh sizes was not affected by season (CPUE/number: $F = 0.256$, $df = 1$, $p = 0.614$, CPUE/weight: $F = 0.061$, $df = 1$, $p = 0.81$).

6 Discussion

6.1 Species diversity

A total of 48 fish species were recorded during the field surveys in the Kwando River during 1997-1999, in addition to unidentified *Synodontis species*. Due to difficulties with the taxonomic classification in the *Synodontis* spp. group, these species have been pooled, except the easily recognised *Synodontis nigromaculatus*. Four *Synodontis* species have previously been listed for the Kwando River and seven species in the Zambezi River (Hay *et al.* 1999). The fish families represented with the highest number of species during the surveys were Cichlidae and Cyprinidae, with 15 and 10 species, respectively.

Hay *et al.* (1999) listed 59 fish species (including the different *Synodontis* species) for the Kwando River. The following five species were recorded during the present surveys but were not listed by Hay et *al.* (1999): *Hippopotamyrus ansorgii, Pollimyrus castelnaui, Mesobola brevianalis, Clarias stappersii* and *Serranochromis altus*. None of these species were caught in high numbers during the present survey. Fourteen species were listed by Hay *et al.* (1999), but were not recorded during the present study. Van der Waal and Skelton (1984) listed 56 fish species for the Kwando River. Five of the species recorded in our study were not recorded by Van der Waal and Skelton (1984), and these were *Cyphomyrus discorhychus, Serranochromis altus, Hippopotamyrus ansorgii, Pollimyrus castelnaui* and *Mesobola brevianalis*.

The most important species in the survey catches were identified by using an index of relative importance (IRI), which is a measure of the relative abundance or commonness of the species based on number and weight of individuals in catches, as well as their frequency of occurrence (see Kolding 1989, 1999). When discussing the most important species recorded during the surveys (see below), the unidentified *Synodontis* spp. are not included, although they were numerous in the gill net catches. *Synodontis* species may be found in a variety of habitats, typically feeding on detritus, algae and benthic invertebrates (Skelton 2001). They are generally well protected against predators due to their bony skull and large sharp dorsal and well-barbed pectoral fin spines (Skelton 2001), but seem to be frequently eaten by birds (own observations).

The most important species in the total catches according to IRI were *Hydrocynus vittatus, Marcusenius macrolepidotus* and *Pharyngochromis acutiseps*, which comprised 56 % of the total IRI. The ten most important species comprised 88 % of the IRI. Four of the ten most important species were small, with a mean body length less than 7 cm.

The most important species according to IRI based on gill net catches were the *Marcusenius macrolepidotus, Hydrocynus vittatus, Petrocephalus catostoma* and *Schilbe intermedius,* which comprised 82 % of total IRI. Gill nets are selective gears in the sense that different mesh sizes catch different fish species and size groups. They are also passive gears; thus, the outcome of the sampling is among others dependent on movements of the fish. Furthermore, gill nets are most often set in open water or along vegetation, and can not be used in strong currents. Gill net catches, therefore, does not reflect the entire fish population. On the other hand, gill nets give a more standardised data set than other gears used, and are more suitable for comparisons among years, stations, rivers and between seasons.

The sampling with other gears than gill nets were used to collect data on fish size and in habitats not accessible with gill nets. These samplings were not standardised. Comparisons of the most important species among stations, rivers and between high and low water periods based on sampling with other gears should, therefore, be interpreted with caution.

Different species were caught in gill nets and with other gears. Ten species (plus the *Synodontis* spp.) were only caught in gill nets, and 18 species were only caught by the other gears (no *Synodontis* spp. was caught with the other gears). A higher number of species was caught by other gears (38 species) than in gill nets (31 species), when excluding the *Synodontis* spp. This was mainly due to the small size of the fish and their residency in habitats unsuitable for gill net sampling. The higher number of species recorded with the other gears is attributed to the flexibility of these gears, and that a wider range of habitats were sampled. In addition, many of these other gears can be classified as active gears, in contrast to the gill nets. Reasons for the lower biomass recorded with the other gears are twofold; smaller species were sampled with the other gears, and the habitats targeted were seldom deep water areas where large fish often reside.

Eighteen of the species caught during the surveys were selected for a more detailed data analysis (see results section 5.2.3). The main criteria for selecting these species were their importance in the catches (see section 3.3.2). The selected species represent a large variety in habitat use, distribution, trophic status, body size and general ecology.

6.1.1 Comparison among rivers and studies

Although several fish collections have been made from the Upper Zambezi System and the Okavango Delta area, few reports of collections from the Caprivi area have previously been published (Van der Waal and Skelton 1984). However, during 1973-1976, several surveys were carried out in the Lake Liambezi (Van der Waal 1976, 1980, 1985, Van der Waal and Skelton 1984). Studies in the Lake Liambezi were also carried out by Grobler (1987). However, data from a shallow lake may not be directly comparable with data from large rivers. Van der Waal and Skelton (1984) and Van der Waal (1996) also collected fish from the Zambezi River, the Eastern Floodplain, the Chobe River, the Linyanti swamp and the Kwando River during 1973-1977.

Fish surveys comparable to the present study were recently carried out in the Namibian part of the Okavango and Zambezi/Chobe Rivers (Hay *et al.* 2000, 2002). A higher number of species were recorded in the Okavango River (70 species + Synodontis spp.) and the Zambezi/Chobe Rivers (69 species + Synodontis spp.) than in the Kwando River (49 species + Synodontis spp.). The surveys in the Okavango and Zambezi/Chobe Rivers were more extensive than the surveys in the Kwando River, which may partly explain the difference in the number of species collected during the surveys. However, the results in these surveys probably also reflect a difference in number of species among rivers, as the same difference appear in the species lists in Hay *et al.* (1999), with 87 species listed for the Okavango River, 90 species for the Zambezi River and 59 species for the Kwando River. Similarly, Van der Waal and Skelton (1984) recorded 56 fish species in the Kwando River and 73 species in the Zambezi River.

All the species recorded during the surveys in the Kwando River were also recorded during the surveys in both the Okavango and Zambezi/Chobe Rivers (Hay *et al.* 2000, 2002), except *Sargochromis giardi* recorded in the Kwando River but not in the Zambezi/Chobe Rivers. However, this species has previously been recorded in the Zambezi River (Hay *et al.* 1999). The families represented with the highest number of fish species were the Cyprinidae and the Cichlidae both in the Kwando, Okavango and Zambezi/Chobe Rivers (this study, Hay *et al.* 2000, 2002).

Generally, the fish fauna in the Kwando, Okavango, Zambezi/Chobe Rivers showed large similarities, and there is a large overlap in the distribution of species among the rivers (this study, Hay *et al.* 1999, 2000, 2002). Thus, the distribution of species provides evidence for past drainage connections between the Okavango and the Upper Zambezi basins, and that some of these connections have occurred relatively recently (Skelton 2001). The Kwando River is connected to the Zambezi/Chobe Rivers when water levels are high, and can also be connected to the Okavango River at exceptionally high water levels (see section 2.1). Thus, large similarities in the fish faunas among these rivers are expected.

Also a separate analysis of the gill net catches indicate a lower number of species in the Kwando River than in the Okavango and Zambezi/Chobe Rivers, with 30 species caught in the Kwando River, 40 species in the Zambezi/Chobe Rivers and 41 species in the Okavango River (excluding *Synodontis* spp.) (this study, Hay *et al.* 2000, 2002). Of the ten most important species in the Kwando River gill net catches (IRI), eight were found to be also among the ten most important in the Zambezi/Chobe Rivers gill net catches and six species among the ten most important in the Okavango River gill net catches (this study, Hay *et al.* 2000, 2002).

The ten most important species in the gill net catches constituted a larger proportion of the IRI in the Kwando River (97 %) and Zambezi/Chobe Rivers (96 %) than in the Okavango River (84 %) (this study, Hay *et al.* 2000, 2002). The two most important species constituted a larger proportion of the IRI in the Zambezi/Chobe Rivers (73 %, *Brycinus lateralis* and *Schilbe intermedius*, Hay *et al.* 2002) than in the the Kwando River (59 %, *Marcusenius macrolepidotus* and *Hydrocynus vittatus*) and Okavango River (58 %, *Schilbe intermedius* and *Marcusenius macrolepidotus*, Hay *et al.* 2000).

In contrast to the dominance of the Mormyridae family in the Kwando River gill net catches (50 %), this family comprised only 19 % of the catches in the Okavango River and 10 % in the Zambezi/Chobe Rivers (IRI, this study, Hay *et al.* 2000, 2002). The dominance of this family in the Kwando River was due to large catches of *Marcusenius macrolepidotus* and *Petrocephalus catostoma*. The second most dominant family in the gill net catches in the Kwando River was the Characidae family, which was the most dominant family in the Zambezi/Chobe Rivers (56 %, Hay *et al.* 2002), but much less dominant in the Okavango River (12 %, Hay *et al.* 2000). The Cichlidae family almost represented the same percentage in the Kwando River (5 %), Okavango River (3 %) and Zambezi/Chobe Rivers (2 %) (this study, Hay *et al.* 2000, 2002).

6.1.2 Rare species

Five species recorded in the present study can be considered to be habitat specialists. This means that their life history activities are confined to specific habitats, and that they require particular effort and equipment for collection. Habitat specialists are generally more vulnerable to habitat disruption than species that are able to thrive in various habitats. The habitat specialists recorded were *Coptostomabarbus wittei, Microctenopoma intermedium, Micralestes acutidens, Opsardium zambezense* and *Mesobola brevianalis. Coptostomabarbus wittei* are very small fish, which live in dense, swampy vegetation, usually on muddy substrate, in calm water. *Microctenopoma intermedium* have almost similar habitat requirements, but have a slightly wider habitat distribution, and are found in less muddy habitats. Both species can be found in large numbers within their habitat, but only one individual of each species was caught during this study. *Micralestes acutidens, Opsardium zambezense* and *Mesobola brevianalis* are reophilic species that need open clear flowing water habitats. Thus, these species are usually found in main channels of rivers. A relatively high number of *Micralestes acutidens* was caught during the surveys (n = 310), whereas low numbers of *Opsardium zambezense* and *Mesobola brevianalis* were caught (n = 6 and 2, respectively).

Only one individual of *Barbus bifrenatus, Barbus thamalalanensis, Hemigrammocharax macadoi, Clarias stappersii* and *Sargochromis codringtonii* were caught during the surveys. Less than five individuals were caught of the species *Barbus fasciolatus, Barbus poechii, Mesobola brevianalis, Mormyrus lacerda, Aplocheilichthys katangae, Tilapia ruweti* and *Ctenopoma multispine*. Some of these species (*Barbus bifrenatus, Barbus thamalalanensis* and

Barbus poechii) are usually found in larger numbers in the rivers in Caprivi, and the reasons for the low numbers caught during the surveys in the Kwando River are not known. *Mesobola brevianalis, Hippopotamyrus ansorgii, Clarias stappersii* and *Sargochromis codringtonii* are species that must be considered as not common in the Caprivi.

6.1.3 Catches during autumn and spring surveys

The water levels during the autumn and spring surveys were approximately similar. However, the autumn surveys were carried out during increasing flood, whereas the spring surveys were carried out during decreasing flood.

Among the ten most important fish species in the gill net catches according to the index of relative importance (IRI), seven species were on the list both during autumn and spring surveys. The three species *Marcusenius macrolepidotus, Hydrocynus vittatus* and *Petrocephalus catostoma* were the most important species in the gill net catches during both autumn and spring. The numbers of species caught during both seasons were similar (26 versus 28 species). Hence, season did not seem to have any profound effect on the species diversity in the gill net catches, although some species increased and some decreased in abundance from the autumn to the spring. Catch per unit effort was higher during spring for small gill net mesh sizes (22-35 mm), but not for the larger mesh sizes (45-73 mm).

There may be several reasons for changes in catches between autumn and spring. For example, variation in available habitats, fishing effort, gill net efficiency, fish behaviour, abundance, size and life history stages may all contribute to variations in the catches. Thus, differences seen in the data between autumn and spring may both be due to differences in the sampling efficiency, habitats and in the fish populations.

6.2 Body length distributions and gill net selectivity

6.2.1 Body length distribution in gill nets and other gears

Larger fish were caught with gill nets than with other gears, both in the Kwando, Okavango and Zambezi/Chobe Rivers (this study, Hay *et al.* 2000, 2002). This was true both for the species combined and for individual species.

Larger specimens were caught with gill nets in the Zambezi/Chobe Rivers (body lengths up to 92 cm) than in the Okavango River (body lengths up to 79 cm) and the Kwando River (body lengths up to 66 cm) (this study, Hay *et al.* 2000, 2002). Especially most of the cichlid species do not seem to reach the same maximum body lengths in the Kwando River as in the two other rivers (this study, Hay *et al.* 2000, 2002). The largest cichlids caught during the surveys in the Kwando River were of body length 38 cm, whereas cichlids of body lengths up to 50 cm are not unusual in the Okavango and Zambezi/Chobe Rivers. Modal length of fish caught in gill nets was larger in the Okavango River (9.0-9.9 cm) than in the Zambezi/Chobe and Kwando Rivers (8.0-8.9 cm in both rivers) (this study, Hay *et al.* 2000, 2002).

6.2.2 Body length at maturity

In the Kwando River, the minimum length at maturity was larger than or similar to the smallest fish caught with gill nets for all the selected species, except for both sexes of *Pseudocrenilabrus philander.* Species with comparable data among rivers were generally larger at maturity in the Kwando River than in the Okavango and Zambezi/Chobe Rivers. Comparable data for minimum length at maturity between the Kwando and the Okavango Rivers exist for males in 9 species and females in 11 species (this study, Hay *et al.* 2000). Minimum length at maturity in the Kwando River was larger than or equal to in the Okavango River, except for males of *Pseudocrenilabrus philander* and females of *Hydrocynus vittatus* and *Hepsetus odoe*, which had a larger minimum length at maturity in the Okavango River. Comparable data for minimum length at maturity between the Kwando and the Zambezi/Chobe Rivers exist for males in 9 species and females in 10 species (this study, Hay et al. 2002). For all species, minimum length at maturity in the Kwando River was larger than or equal to that in the Zambezi/Chobe Rivers, except for both sexes of *Pseudocrenilabrus philander,* which had a larger minimum length at maturity in the Zambezi/Chobe Rivers.

6.3 Catch per unit effort (CPUE)

Catch per unit effort was lower in the Kwando River (10 fish and 1.23 kg per setting) than in the Okavango (28 fish and 1.44 kg per setting) and Zambezi/Chobe Rivers (89 fish and 1.87 kg per setting) (this study, Hay *et al.* 2000, 2002).

In the Kwando River, 28 mm mesh size gave the highest catch per unit effort measured as number of fish per setting. For larger mesh sizes, catch per unit effort measured as number of fish decreased with increasing mesh size. In contrast, catch per unit effort in weight of fish increased with increasing mesh size. This was different from the results in the Zambezi/ Chobe Rivers, where a negative correlation was found between mesh size and catch per unit effort both in number and weight (Hay *et al.* 2002).

6.4 Conclusion

Little is generally known about the fish populations in the perennial rivers in the Caprivi Region in Namibia, and even less is known about the populations in the Kwando River than in the Okavango and Zambezi/ Chobe Rivers. The Kwando River is the most pristine of these rivers, whereas the Okavango River runs through the most densely populated areas and is exposed to the highest fishing intensity.

Most of the river stretches of the Kwando River included in this survey runs through nature conservation areas and is insignificantly influenced by fishing. The survey results from the Kwando River may, therefore, serve as baseline data for the other rivers in the area and future surveys. However, the Kwando River is a smaller river, especially compared with the Zambezi River, and it is more influenced by wildlife and has a denser vegetation. When using the fish data from the Kwando River as control, the differences in the physical and biological characteristics among the rivers must therefore be taken into consideration. Differences in physical and biological characteristics of the rivers are probably the reasons for the lower number of species in the Kwando River than in the Okavango and Zambezi/Chobe Rivers.

Large specimens of the larger species were sampled regularly in the Kwando River, and among these were *Hydrocynus vittatus, Clarias gariepinus, Clarias ngamensis, Sargochromis giardi, Schilbe intermedius, Oreochromis machrochir, Serranochromis altus, Tilapia rendalli, Mormyrus lacerda, Serranochromis robustus* and *Hepsetus odoe*. The fish populations in the Kwando River seem stable and in a good condition. However, being a smaller system than the Okavango and Zambezi/Chobe Rivers, it is more vulnerable to external impacts, such as for example intensive fisheries.

The complex and diverse nature of the fish fauna in the Namibian part of the Kwando River has been revealed through the present surveys. However, detailed knowledge on the biology and behaviour of most of the species are still lacking. Basic information on life history, reproduction, movements, habitat preferences and habitat utilisation of targeted species is needed to give recommendations on the management of fisheries, and to evaluate the possible benefits of nature reserves and sanctuaries. Any changes to the flood regime caused by factors such as water abstraction, impoundment, canalisation and construction of roads on the floodplains can have serious negative effects on the functioning of the floodplain system. The Kwando River is presently still undisturbed by human impacts. For that reason alone, this system should be better studied to provide a baseline database for future studies.

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Appendix

Appendix 1. *Scientific, common (English) and local names (Caprivi, after J. Purvis unpublished) of species caught during surveys in the Kwando River during 1997 to 1999, classified by family.*

Family number	Fish family	Scientific name	English name	Local name
1	**Cyprinidae** (barbs, yellowfish, labeos)	*Barbus bifrenatus*	Hyphen barb	Mbala
		Barbus fasciolatus	Red barb	Linyonga (rapid)
		Barbus paludinosus	Straightfin barb	Linyonga
		Barbus poechii	Dashtail barb	Ijungwe
		Barbus radiatus	Beira barb	Liminolale
		Barbus thamalakanensis	Thamalakane barb	
		Barbus unitaeniatus	Longbeard barb	Linyonga
		Coptostomabarbus wittei	Upjaw barb	
		Mesobola brevianalis	River sardine	Mbala
		Opsaridium zambezense	Northern barred minnow	Mbala (big)
2	**Distichodontidae** (citharines)	*Hemigrammocharax machadoi*	Dwarf citharine	
3	**Characidae** (characins)	*Brycinus lateralis*	Striped robber	Mbala (big)
		Hydrocynus vittatus	Tigerfish	Ngweshi
		Micralestes acutidens	Silver robber	Mbala
		Rhabdalestes maunensis	Slender robber	Mbala
4	**Mormyridae** (snoutfishes)	*Hippopotamyrus ansorgii*	Slender stonebasher	Ninga
		Marcusenius macrolepidotus	Bulldog	Nembele
		Mormyrus lacerda	Western bottlenose	Ndikusi
		Petrocephalus catostoma	Northern Churchill	Ninga/Kupandula
		Pollimyrus castelnaui	Dwarf stonebasher	Ninga
		Cyphomyrus discorhynchus	Zambezi parrotfish	Sakulo
5	**Hepsetidae** (African pike)	*Hepsetus odoe*	African pike	Mwelu
6	**Claroteidae**	*Parauchenoglanis ngamensis*	Zambezi grunter	Siabela
7	**Schilbeidae** (butter catfishes)	*Schilbe intermedius*	Silver catfish	Lubango
8	**Clariidae** (air-breathing catfish)	*Clarias gariepinus*	Sharptooth catfish	Ndombe-Mbundamusheke/ Mangwana
		Clarias ngamensis	Blunttooth catfish	Ndombe-Stama Nkoma
		Clarias stappersii	Blotched catfish	Lihwetete/Ndombe-Mabbozwa
		Clarias theodorae	Snake catfish	Kaminga/Ndombe-Kakokwe
9	**Mochokidae** (squeakers, suckermouth catlets)	*Synodontis spp.*	Squeakers	Singongi
10	**Cyprinodontidae** (topminnows)	*Aplocheilichthys hutereaui*	Meshscaled topminnow	
		Aplocheilichthys johnstoni	Johnston's topminnow	
		Aplocheilichthys katangae	Striped topminnow	

Appendix I. Continued

Family number	Fish family	Scientific name	English name	Local name
11	**Cichlidae** (cichlids)	*Hemichromis elongatus*	Banded jewelfish	Liulyungu
		Oreochromis andersonii	Threespot tilapia	Njinji
		Oreochromis macrochir	Greenhead tilapia	Imu
		Pharyngochromis acuticeps	Zambezi bream	
		Pseudocrenilabrus philander	Southern mouthbrooder	Kambanda
		Serranochromis altus	Humpback largemouth	Mushuna (Naluca)
		Serranochromis angusticeps	Thinface largemouth	Mushuna
		Serranochromis macrocephalus	Purpleface largemouth	Ngenga
		Serranochromis robustus	Nembwe	Nembwe
		Sargochromis carlottae	Rainbow bream	Imbuma (Mbuma)
		Sargochromis codringtonii	Green bream	Imbuma
		Sargochromis giardi	Pink bream	Siyeo
		Tilapia rendalli	Redbreast tilapia	Mbufu
		Tilapia ruweti	Okavango tilapia	
		Tilapia sparrmanii	Banded tilapia	Situhu
12	**Anabantidae** (labyrinth fishes)	*Microctenopoma intermedium*	Blackspot climbing perch	Singulungwe
		Ctenopoma multispine	Manyspined climbing perch	

Appendix 2. *Mean, minimum and maximum body lengths (cm) for all species caught with gill nets and other gears during surveys in the Kwando River during 1997 to 1999. Percent = percent of total catch.*

Family	Species	Mean length	Min.	Max.	N	Percent
Cyprinidae	*Barbus bifrenatus*	4.0	40	40	1	0.0
	Barbus fasciolatus	5.1	46	55	2	0.1
	Barbus paludinosus	5.2	25	70	10	0.4
	Barbus poechii	8.8	80	95	2	0.1
	Barbus radiatus	6.4	30	90	5	0.2
	Barbus thamalakanensis	3.6	36	36	1	0.0
	Barbus unitaeniatus	5.1	28	85	40	1.5
	Coptostomabarbus wittei	2.2	22	22	1	0.0
	Mesobola brevianalis	3.2	30	34	2	0.1
	Opsaridium zambezense	6.1	50	70	6	0.2
Distichodontidae	*Hemigrammocharax machadoi*	2.8	28	28	1	0.0
Characidae	*Brycinus lateralis*	6.1	25	105	258	9.5
	Hydrocynus vittatus	29.4	140	600	94	3.5
	Micralestes acutidens	3.8	26	57	275	10.1
	Rhabdalestes maunensis	3.4	20	41	29	1.1
Mormyridae	*Hippopotamyrus ansorgii*	9.0	72	115	7	0.3
	Marcusenius macrolepidotus	13.4	50	290	270	9.9
	Mormyrus lacerda	35.8	320	390	4	0.1
	Petrocephalus catostoma	8.5	41	105	297	10.9
	Pollimyrus castelnaui	5.4	31	75	8	0.3
	Cyphomyrus discorhynchus	10.1	70	190	102	3.7
Hepsetidae	*Hepsetus odoe*	26.9	105	390	25	0.9
Claroteidae	*Parauchenoglanis ngamensis*	14.5	110	195	5	0.2
Schilbeidae	*Schilbe intermedius*	18.0	75	280	95	3.5
Clariidae	*Clarias gariepinus*	47.7	100	650	23	0.8
	Clarias ngamensis	50.9	160	640	13	0.5
	Clarias stappersii	13.5	135	135	1	0.0
	Clarias theodorae	11.8	45	160	8	0.4
Mochokidae	*Synodontis spp.*	17.4	120	210	23	0.8
Cyprinodontidae	*Aplocheilichthys hutereaui*	2.3	19	34	11	0.4
	Aplocheilichthys johnstoni	3.3	15	42	134	1.8
	Aplocheilichthys katangae	1.9	19	19	3	0.1
Cichlidae	*Hemichromis elongatus*	4.8	24	114	39	1.4
	Oreochromis andersonii	10.3	52	320	14	0.5
	Oreochromis macrochir	7.2	25	350	80	2.9
	Pharyngochromis acuticeps	6.4	19	160	298	11.0
	Pseudocrenilabrus philander	4.4	15	80	287	10.5
	Serranochromis altus	32.0	270	380	9	0.3
	Serranochromis angusticeps	26.6	160	380	5	0.2
	Serranochromis macrocephalus	13.6	30	270	18	0.7
	Serranochromis robustus	16.1	30	370	11	0.4
	Sargochromis carlottae	14.9	75	240	6	0.2
	Sargochromis codringtonii	16.5	165	165	1	0.0
	Sargochromis giardi	30.0	180	380	18	0.7
	Tilapia rendalli	7.1	19	300	57	2.1
	Tilapia ruweti	6.8	65	70	2	0.1
	Tilapia sparrmanii	4.4	20	135	117	4.3
Anabantidae	*Microctenopoma intermedium*	2.1	21	21	1	0.0
	Ctenopoma multispine	7.5	70	80	2	0.1
Total		**9.1**	**15**	**650**	**2721**	**100**

Appendix 3. *Index of relative importance (IRI) of all species caught by gill nets and other gears during surveys in the Kwando River during 1997 to 1999. The IRI takes into account the number of individuals (No), weight (kg) and frequency of occurrence (Freq) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. no. = number designation for family classification according to* ***Appendix 1.***

Fam. no.	Species	No	%	Weight	%	Freq	%	IRI	%
3	*Hydrocynus vittatus*	94	3.41	40.28	27.40	65	14.32	441	25.26
4	*Marcusenius macrolepidotus*	270	9.80	10.13	6.89	90	19.82	331	18.94
11	*Pharyngochromis acuticeps*	298	10.81	1.37	0.93	81	17.84	210	12.00
4	*Petrocephalus catostoma*	297	10.78	2.48	1.69	46	10.13	126	7.23
7	*Schilbe intermedius*	95	3.45	7.53	5.12	53	11.67	100	5.73
11	*Pseudocrenilabrus philander*	287	10.41	0.42	0.28	39	8.59	92	5.26
3	*Brycinus lateralis*	258	9.36	0.81	0.55	36	7.93	79	4.50
8	*Clarias gariepinus*	23	0.83	23.28	15.83	18	3.96	66	3.78
3	*Micralestes acutidens*	310	11.25	0.20	0.13	22	4.85	55	3.16
4	*Cyphomyrus discorhynchus*	102	3.70	1.68	1.14	37	8.15	39	2.26
10	*Aplocheilichthys johnstoni*	134	4.86	0.04	0.03	25	5.51	27	1.54
11	*Oreochromis macrochir*	80	2.90	4.26	2.90	21	4.63	27	1.54
11	*Sargochromis giardi*	18	0.65	12.65	8.60	13	2.86	27	1.52
5	*Hepsetus odoe*	25	0.91	6.82	4.64	21	4.63	26	1.47
11	*Tilapia sparrmanii*	117	4.25	0.37	0.25	25	5.51	25	1.42
10	*Clarias ngamensis*	13	0.47	15.46	10.52	10	2.20	24	1.39
11	*Tilapia rendalli*	57	2.07	1.59	1.08	22	4.85	15	0.87
9	*Synodontis spp*	23	0.83	2.15	1.46	17	3.74	9	0.49
11	*Serranochromis altus*	9	0.33	5.07	3.45	9	1.98	7	0.43
11	*Serranochromis macrocephalus*	18	0.65	1.71	1.16	10	2.20	4	0.23
11	*Serranochromis robustus*	11	0.40	2.36	1.60	8	1.76	4	0.20
1	*Barbus unitaeniatus*	40	1.45	0.07	0.05	10	2.20	3	0.19
11	*Hemichromis elongatus*	39	1.42	0.10	0.07	6	1.32	2	0.11
11	*Serranochromis angusticeps*	5	0.18	1.89	1.29	5	1.10	2	0.09
3	*Rhabdalestes maunensis*	29	1.05	0.01	0.01	6	1.32	1	0.08
4	*Mormyrus lacerda*	4	0.15	2.04	1.39	3	0.66	1	0.06
11	*Oreochromis andersonii*	14	0.51	1.21	0.82	3	0.66	1	0.05
11	*Sargochromis carlottae*	6	0.22	0.49	0.33	6	1.32	1	0.04
4	*Hippopotamyrus ansorgii*	7	0.25	0.06	0.04	7	1.54	0	0.03
10	*Aplocheilichthys hutereaui*	11	0.40	0.00	0.00	5	1.10	0	0.03
1	*Barbus paludinosis*	10	0.36	0.02	0.01	5	1.10	0	0.02
4	*Pollimyrus castelnaui*	8	0.29	0.03	0.02	5	1.10	0	0.02
8	*Clarias theodorae*	8	0.29	0.09	0.06	4	0.88	0	0.02
6	*Parauchenoglanis ngamensis*	5	0.18	0.18	0.12	4	0.88	0	0.02
1	*Opsaridium zambezense*	6	0.22	0.01	0.01	4	0.88	0	0.01
1	*Barbus radiatus*	5	0.18	0.02	0.02	4	0.88	0	0.01
1	*Barbus poechii*	2	0.07	0.02	0.01	2	0.44	0	0.00
12	*Ctenopoma multispine*	2	0.07	0.01	0.01	2	0.44	0	0.00
11	*Tilapia ruweti*	2	0.07	0.01	0.01	2	0.44	0	0.00
1	*Barbus fasciolatus*	2	0.07	0.00	0.00	2	0.44	0	0.00
1	*Mesobola brevianalis*	2	0.07	0.00	0.00	2	0.44	0	0.00
10	*Aplocheilichthys katangae*	3	0.11	0.00	0.00	1	0.22	0	0.00
11	*Sargochromis codringtonii*	1	0.04	0.07	0.05	1	0.22	0	0.00
8	*Clarias stappersii*	1	0.04	0.01	0.01	1	0.22	0	0.00
1	*Barbus bifrenatus*	1	0.04	0.00	0.00	1	0.22	0	0.00
1	*Barbus thamalakanensis*	1	0.04	0.00	0.00	1	0.22	0	0.00
1	*Coptostomabarbus wittei*	1	0.04	0.00	0.00	1	0.22	0	0.00
2	*Hemigrammocharax machadoi*	1	0.04	0.00	0.00	1	0.22	0	0.00
12	*Microctenopoma intermedium*	1	0.04	0.00	0.00	1	0.22	0	0.00
	SUM	**2756**	**100**	**147**	**100**			**1747**	**100**

Appendix 4. *Index of relative importance (IRI) of all species caught by gill nets during surveys in the Kwando River during 1997 to 1999. The IRI takes into account the number of individuals (No), weight (kg) and frequency of occurrence (Freq) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. no. = number designation for family classification according to* ***Appendix 1****.*

Fam. no.	Species	No	%	Weight	%	Freq	%	IRI	%
4	*Marcusenius macrolepidotus*	268	22.87	10.12	7.09	88	22.74	681	31.36
3	*Hydrocynus vittatus*	94	8.02	40.28	28.21	65	16.80	609	28.02
4	*Petrocephalus catostoma*	295	25.17	2.47	1.73	45	11.63	313	14.40
7	*Schilbe intermedius*	91	7.76	7.50	5.25	52	13.44	175	8.05
4	*Cyphomyrus discorhynchus*	102	8.70	1.68	1.17	37	9.56	94	4.35
8	*Clarias gariepinus*	19	1.62	22.89	16.03	15	3.88	68	3.15
11	*Pharyngochromis acuticeps*	52	4.44	0.59	0.41	38	9.82	48	2.19
3	*Brycinus lateralis*	103	8.79	0.60	0.42	20	5.17	48	2.19
11	*Sargochromis giardi*	18	1.54	12.65	8.86	13	3.36	35	1.61
5	*Hepsetus odoe*	22	1.88	6.57	4.60	18	4.65	30	1.39
8	*Clarias ngamensis*	12	1.02	15.43	10.81	9	2.33	28	1.27
9	*Synodontis spp*	23	1.96	2.15	1.50	17	4.39	15	0.70
11	*Serranochromis altus*	9	0.77	5.07	3.55	9	2.33	10	0.46
11	*Oreochromis macrochir*	6	0.51	3.92	2.75	6	1.55	5	0.23
11	*Serranochromis macrocephalus*	8	0.68	1.68	1.17	8	2.07	4	0.18
11	*Serranochromis angusticeps*	5	0.43	1.89	1.33	5	1.29	2	0.10
11	*Serranochromis robustus*	4	0.34	2.31	1.62	3	0.78	2	0.07
4	*Mormyrus lacerda*	4	0.34	2.04	1.43	3	0.78	1	0.06
4	*Hippopotamyrus ansorgii*	7	0.60	0.06	0.04	7	1.81	1	0.05
11	*Sargochromis carlottae*	5	0.43	0.48	0.34	5	1.29	1	0.05
11	*Tilapia sparrmanii*	6	0.51	0.15	0.10	6	1.55	1	0.04
11	*Tilapia rendalli*	2	0.17	0.97	0.68	2	0.52	0	0.02
11	*Oreochromis andersonii*	1	0.09	1.05	0.74	1	0.26	0	0.01
1	*Barbus radiatus*	3	0.26	0.02	0.02	3	0.78	0	0.01
4	*Pollimyrus castelnaui*	3	0.26	0.02	0.01	2	0.52	0	0.01
6	*Parauchenoglanis ngamensis*	2	0.17	0.10	0.07	2	0.52	0	0.01
1	*Barbus poechii*	2	0.17	0.02	0.02	2	0.52	0	0.00
11	*Pseudocrenilabrus philander*	2	0.17	0.01	0.01	2	0.52	0	0.00
11	*Tilapia ruweti*	2	0.17	0.01	0.01	2	0.52	0	0.00
11	*Sargochromis codringtonii*	1	0.09	0.07	0.05	1	0.26	0	0.00
1	*Barbus unitaeniatus*	1	0.09	0.01	0.00	1	0.26	0	0.00
	SUM	**1172**	**100**	**143**	**100**			**2172**	**100**

Appendix 5**. Index of relative importance (IRI) of all species caught by other gears than gill nets during surveys in the Kwando River during 1997 to 1999. The IRI takes into account the number of individuals (No), weight (kg) and frequency of occurrence (Freq) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. no. = number designation for family classification according to **Appendix 1

Fam. no.	Species	No	%	Weight	%	Freq	%	IRI	%
11	*Pharyngochromis acuticeps*	246	15.53	0.79	18.75	43	64.18	2200	32.94
11	*Pseudocrenilabrus philander*	285	17.99	0.41	9.71	37	55.22	1530	22.90
3	*Micralestes acutidens*	310	19.57	0.20	4.66	22	32.84	796	11.91
11	*Tilapia rendalli*	55	3.47	0.62	14.84	20	29.85	547	8.18
3	*Brycinus lateralis*	155	9.79	0.22	5.12	16	23.88	356	5.33
10	*Aplocheilichthys johnstoni*	134	8.46	0.04	1.04	25	37.31	354	5.31
11	*Tilapia sparrmanii*	111	7.01	0.22	5.26	19	28.36	348	5.21
11	*Oreochromis macrochir*	74	4.67	0.34	8.01	15	22.39	284	4.25
1	*Barbus unitaeniatus*	39	2.46	0.07	1.54	9	13.43	54	0.81
11	*Hemichromis elongatus*	39	2.46	0.10	2.33	6	8.96	43	0.64
8	*Clarias gariepinus*	4	0.25	0.39	9.24	3	4.48	43	0.64
5	*Hepsetus odoe*	3	0.19	0.25	5.98	3	4.48	28	0.41
3	*Rhabdalestes maunensis*	29	1.83	0.01	0.30	6	8.96	19	0.29
8	*Clarias theodorae*	8	0.51	0.09	2.12	4	5.97	16	0.23
11	*Oreochromis andersonii*	13	0.82	0.15	3.62	2	2.99	13	0.20
11	*Serranochromis robustus*	7	0.44	0.05	1.16	5	7.46	12	0.18
1	*Barbus paludinosus*	10	0.63	0.02	0.46	5	7.46	8	0.12
6	*Parauchenoglanis ngamensis*	3	0.19	0.08	1.83	2	2.99	6	0.09
10	*Aplocheilichthys hutereaui*	11	0.69	0.00	0.03	5	7.46	5	0.08
1	*Opsaridium zambezense*	6	0.38	0.01	0.33	4	5.97	4	0.06
11	*Serranochromis macrocephalus*	10	0.63	0.03	0.75	2	2.99	4	0.06
4	*Pollimyrus castelnaui*	5	0.32	0.01	0.20	3	4.48	2	0.03
7	*Schilbe intermedius*	4	0.25	0.03	0.76	1	1.49	2	0.02
4	*Marcusenius macrolepidotus*	2	0.13	0.01	0.27	2	2.99	1	0.02
8	*Clarias ngamensis*	1	0.06	0.03	0.64	1	1.49	1	0.02
12	*Ctenopoma multispine*	2	0.13	0.01	0.22	2	2.99	1	0.02
1	*Barbus fasciolatus*	2	0.13	0.00	0.08	2	2.99	1	0.01
4	*Petrocephalus catostoma*	2	0.13	0.01	0.24	1	1.49	1	0.01
8	*Clarias stappersii*	1	0.06	0.01	0.26	1	1.49	0	0.01
1	*Mesobola brevianalis*	2	0.13	0.00	0.01	2	2.99	0	0.01
11	*Sargochromis carlottae*	1	0.06	0.01	0.15	1	1.49	0	0.00
10	*Aplocheilichthys katangae*	3	0.19	0.00	0.01	1	1.49	0	0.00
1	*Barbus radiatus*	2	0.13	0.00	0.05	1	1.49	0	0.00
1	*Barbus bifrenatus*	1	0.06	0.00	0.02	1	1.49	0	0.00
1	*Barbus thamalakanensis*	1	0.06	0.00	0.01	1	1.49	0	0.00
1	*Coptostomabarbus wittei*	1	0.06	0.00	0.00	1	1.49	0	0.00
2	*Hemigrammocharax machadoi*	1	0.06	0.00	0.00	1	1.49	0	0.00
12	*Microctenopoma intermedium*	1	0.06	0.00	0.00	1	1.49	0	0.00
	SUM	**1584**	**100**	**4.20**	**100**			**6679**	**100**

Appendix 6. *Index of relative importance (IRI) of all species caught during autumn gill net surveys in the Kwando River during 1997 to 1999. The IRI takes into account the number of individuals (No), weight (kg) and frequency of occurrence (Freq) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. no. = number designation for family classification according to* ***Appendix 1****.*

Fam. no.	Species	No	%	Weight	%	Freq	%	IRI	%
4	*Marcusenius macrolepidotus*	119	19.04	3.80	4.22	42	18.67	434	25.24
3	*Hydrocynus vittatus*	40	6.40	19.66	21.84	28	12.44	351	20.43
4	*Petrocephalus catostoma*	149	23.84	1.06	1.18	22	9.78	245	14.22
7	*Schilbe intermedius*	55	8.80	3.92	4.36	27	12.00	158	9.18
8	*Clarias gariepinus*	17	2.72	21.52	23.91	13	5.78	154	8.94
3	*Brycinus lateralis*	94	15.04	0.53	0.59	15	6.67	104	6.06
11	*Sargochromis giardi*	16	2.56	11.74	13.04	11	4.89	76	4.43
5	*Hepsetus odoe*	17	2.72	5.24	5.82	13	5.78	49	2.87
11	*Pharyngochromis acuticeps*	27	4.32	0.34	0.38	20	8.89	42	2.43
4	*Cyphomyrus discorhynchus*	34	5.44	0.45	0.50	14	6.22	37	2.15
8	*Clarias ngamensis*	6	0.96	8.47	9.41	5	2.22	23	1.34
11	*Serranochromis macrocephalus*	8	1.28	1.68	1.86	8	3.56	11	0.65
11	*Oreochromis macrochir*	5	0.80	3.48	3.86	5	2.22	10	0.60
9	*Synodontis sp,*	11	1.76	0.95	1.06	8	3.56	10	0.58
11	*Serranochromis angusticeps*	5	0.80	1.89	2.10	5	2.22	6	0.38
11	*Serranochromis altus*	3	0.48	1.42	1.58	3	1.33	3	0.16
11	*Serranochromis robustus*	3	0.48	1.41	1.56	2	0.89	2	0.11
11	*Sargochromis carlottae*	3	0.48	0.45	0.50	3	1.33	1	0.08
11	*Tilapia sparrmanii*	3	0.48	0.10	0.11	3	1.33	1	0.05
4	*Hippopotamyrus ansorgii*	3	0.48	0.02	0.02	3	1.33	1	0.04
11	*Oreochromis andersonii*	1	0.16	1.05	1.17	1	0.44	1	0.03
1	*Barbus radiatus*	2	0.32	0.01	0.02	2	0.89	0	0.02
11	*Tilapia rendalli*	1	0.16	0.43	0.48	1	0.44	0	0.02
4	*Mormyrus lacerda*	1	0.16	0.34	0.38	1	0.44	0	0.01
6	*Parauchenoglanis ngamensis*	1	0.16	0.04	0.04	1	0.44	0	0.01
11	*Pseudocrenilabrus philander*	1	0.16	0.01	0.01	1	0.44	0	0.00
	SUM	**625**	**100**	**90**	**100.0**			**1721**	**100**

***Appendix 7**. Index of relative importance (IRI) of all species caught during spring gill net surveys in the Kwando River during 1997 to 1999. The IRI takes into account the number of individuals (No), weight (kg) and frequency of occurrence (Freq) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. no. = number designation for family classification according to **Appendix 1**.*

Fam. no.	Species	No	%	Weight	%	Freq	%	IRI	%
3	*Hydrocynus vittatus*	54	9.87	20.63	39.07	37	22.84	1118	34.45
4	*Marcusenius macrolepidotus*	149	27.24	6.32	11.97	46	28.40	1113	34.31
4	*Petrocephalus catostoma*	146	26.69	1.42	2.68	23	14.20	417	12.85
4	*Cyphomyrus discorhynchus*	68	12.43	1.23	2.33	23	14.20	210	6.46
7	*Schilbe intermedius*	36	6.58	3.58	6.77	25	15.43	206	6.35
11	*Pharyngochromis acuticeps*	25	4.57	0.25	0.47	18	11.11	56	1.72
8	*Clarias ngamensis*	6	1.10	6.96	13.18	4	2.47	35	1.09
11	*Serranochromis altus*	6	1.10	3.65	6.91	6	3.70	30	0.91
9	*Synodontis sp,*	12	2.19	1.19	2.26	9	5.56	25	0.76
5	*Hepsetus odoe*	5	0.91	1.33	2.52	5	3.09	11	0.33
3	*Brycinus lateralis*	9	1.65	0.07	0.13	5	3.09	5	0.17
4	*Mormyrus lacerda*	3	0.55	1.70	3.22	2	1.23	5	0.14
8	*Clarias gariepinus*	2	0.37	1.37	2.59	2	1.23	4	0.11
11	*Sargochromis giardi*	2	0.37	0.91	1.72	2	1.23	3	0.08
4	*Hippopotamyrus ansorgii*	4	0.73	0.04	0.08	4	2.47	2	0.06
11	*Tilapia sparrmanii*	3	0.55	0.04	0.08	3	1.85	1	0.04
11	*Serranochromis robustus*	1	0.18	0.90	1.70	1	0.62	1	0.04
11	*Tilapia rendalli*	1	0.18	0.54	1.02	1	0.62	1	0.02
4	*Pollimyrus castelnaui*	3	0.55	0.02	0.04	2	1.23	1	0.02
11	*Oreochromis macrochir*	1	0.18	0.44	0.84	1	0.62	1	0.02
11	*Sargochromis carlottae*	2	0.37	0.04	0.07	2	1.23	1	0.02
1	*Barbus poechii*	2	0.37	0.02	0.04	2	1.23	1	0.02
11	*Tilapia ruweti*	2	0.37	0.01	0.02	2	1.23	0	0.01
11	*Sargochromis codringtonii*	1	0.18	0.07	0.14	1	0.62	0	0.01
6	*Parauchenoglanis ngamensis*	1	0.18	0.06	0.12	1	0.62	0	0.01
1	*Barbus radiatus*	1	0.18	0.01	0.02	1	0.62	0	0.00
1	*Barbus unitaeniatus*	1	0.18	0.01	0.01	1	0.62	0	0.00
11	*Pseudocrenilabrus philander*	1	0.18	0.01	0.01	1	0.62	0	0.00
	SUM	**547**	**100**	**53**	**100**			**3245**	**100**

Appendix 8. *Index of relative importance (IRI) of all species caught with other gears during autumn surveys in the Kwando River during 1997 to 1999. The IRI takes into account the number of individuals (No), weight (kg) and frequency of occurrence (Freq) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. no. = number designation for family classification according to* ***Appendix 1****.*

Fam. no.	Species	No	%	Weight	%	Freq	%	IRI	%
11	*Pharyngochromis acuticeps*	157	14.55	0.474	21.90	31	64.58	2354	35.67
11	*Pseudocrenilabrus philander*	173	16.03	0.201	9.31	24	50.00	1267	19.20
3	*Micralestes acutidens*	209	19.37	0.132	6.12	15	31.25	796	12.07
11	*Tilapia rendalli*	36	3.34	0.281	13.01	14	29.17	477	7.22
3	*Brycinus lateralis*	120	11.12	0.165	7.63	10	20.83	391	5.92
11	*Tilapia sparrmanii*	92	8.53	0.095	4.40	14	29.17	377	5.71
10	*Aplocheilichthys johnstoni*	86	7.97	0.025	1.17	18	37.50	343	5.19
11	*Oreochromis macrochir*	60	5.56	0.164	7.58	12	25.00	329	4.98
11	*Hemichromis elongatus*	38	3.52	0.092	4.25	5	10.42	81	1.23
5	*Hepsetus odoe*	3	0.28	0.251	11.61	3	6.25	74	1.13
3	*Rhabdalestes maunensis*	28	2.59	0.013	0.58	5	10.42	33	0.50
1	*Barbus unitaeniatus*	22	2.04	0.029	1.36	4	8.33	28	0.43
1	*Opsaridium zambezense*	6	0.56	0.014	0.64	4	8.33	10	0.15
8	*Clarias gariepinus*	2	0.19	0.068	3.15	1	2.08	7	0.11
6	*Parauchenoglanis ngamensis*	2	0.19	0.049	2.27	1	2.08	5	0.08
10	*Aplocheilichthys hutereaui*	6	0.56	0.001	0.04	4	8.33	5	0.08
11	*Serranochromis robustus*	5	0.46	0.006	0.29	3	6.25	5	0.07
7	*Schilbe intermedius*	4	0.37	0.032	1.48	1	2.08	4	0.06
4	*Pollimyrus castelnaui*	4	0.37	0.006	0.30	2	4.17	3	0.04
11	*Serranochromis macrocephalus*	5	0.46	0.011	0.50	1	2.08	2	0.03
1	*Barbus paludinosus*	2	0.19	0.005	0.25	2	4.17	2	0.03
8	*Clarias theodorae*	1	0.09	0.016	0.76	1	2.08	2	0.03
4	*Petrocephalus catostoma*	2	0.19	0.010	0.46	1	2.08	1	0.02
1	*Mesobola brevianalis*	2	0.19	0.000	0.01	2	4.17	1	0.01
11	*Sargochromis carlottae*	1	0.09	0.007	0.30	1	2.08	1	0.01
10	*Aplocheilichthys katangae*	3	0.28	0.000	0.01	1	2.08	1	0.01
12	*Ctenopoma multispine*	1	0.09	0.004	0.20	1	2.08	1	0.01
1	*Barbus radiatus*	2	0.19	0.002	0.10	1	2.08	1	0.01
11	*Oreochromis andersonii*	1	0.09	0.003	0.12	1	2.08	0	0.01
4	*Marcusenius macrolepidotus*	1	0.09	0.002	0.10	1	2.08	0	0.01
1	*Barbus fasciolatus*	1	0.09	0.001	0.06	1	2.08	0	0.00
1	*Barbus thamalakanensis*	1	0.09	0.000	0.02	1	2.08	0	0.00
1	*Coptostomabarbus wittei*	1	0.09	0.000	0.00	1	2.08	0	0.00
2	*Hemigrammocharax machadoi*	1	0.09	0.000	0.00	1	2.08	0	0.00
12	*Microctenopoma intermedium*	1	0.09	0.000	0.00	1	2.08	0	0.00
	SUM	**1079**	**100**	**2.16**	**100**			**6601**	**100**

Appendix 9. *Index of relative importance (IRI) of all species caught with other gears during spring surveys in the Kwando River during 1997 to 1999. The IRI takes into account the number of individuals (No), weight (kg) and frequency of occurrence (Freq) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. no. = number designation for family classification according to* ***Appendix 1.***

Fam. no.	Species	No	%	Weight	%	Freq	%	IRI	%
11	*Pseudocrenilabrus philander*	112	22.18	0.206	10.12	13	68.42	2210	29.63
11	*Pharyngochromis acuticeps*	89	17.62	0.313	15.40	12	63.16	2085	27.96
3	*Micralestes acutidens*	101	20.00	0.063	3.11	7	36.84	851	11.41
11	*Tilapia rendalli*	19	3.76	0.342	16.79	6	31.58	649	8.70
10	*Aplocheilichthys johnstoni*	48	9.50	0.018	0.90	7	36.84	383	5.14
3	*Brycinus lateralis*	35	6.93	0.050	2.44	6	31.58	296	3.97
11	*Tilapia sparrmanii*	19	3.76	0.126	6.17	5	26.32	261	3.50
11	*Oreochromis macrochir*	14	2.77	0.172	8.46	3	15.79	177	2.38
8	*Clarias gariepinus*	2	0.40	0.320	15.72	2	10.53	170	2.27
1	*Barbus unitaeniatus*	17	3.37	0.035	1.73	5	26.32	134	1.80
8	*Clarias theodorae*	7	1.39	0.072	3.55	3	15.79	78	1.05
11	*Oreochromis andersonii*	12	2.38	0.149	7.33	1	5.26	51	0.69
1	*Barbus paludinosus*	8	1.58	0.014	0.69	3	15.79	36	0.48
11	*Serranochromis robustus*	2	0.40	0.043	2.09	2	10.53	26	0.35
11	*Serranochromis macrocephalus*	5	0.99	0.021	1.01	1	5.26	11	0.14
6	*Parauchenoglanis ngamensis*	1	0.20	0.028	1.36	1	5.26	8	0.11
8	*Clarias ngamensis*	1	0.20	0.027	1.33	1	5.26	8	0.11
10	*Aplocheilichthys hutereaui*	5	0.99	0.000	0.02	1	5.26	5	0.07
8	*Clarias stappersii*	1	0.20	0.011	0.54	1	5.26	4	0.05
4	*Marcusenius macrolepidotus*	1	0.20	0.009	0.44	1	5.26	3	0.05
11	*Hemichromis elongatus*	1	0.20	0.006	0.29	1	5.26	3	0.03
12	*Ctenopoma multispine*	1	0.20	0.005	0.25	1	5.26	2	0.03
1	*Barbus fasciolatus*	1	0.20	0.002	0.10	1	5.26	2	0.02
4	*Pollimyrus castelnaui*	1	0.20	0.002	0.10	1	5.26	2	0.02
1	*Barbus bifrenatus*	1	0.20	0.001	0.05	1	5.26	1	0.02
3	*Rhabdalestes maunensis*	1	0.20	0.000	0.00	1	5.26	1	0.01
	SUM	**505**	**100**	**2.04**	**100**			**7459**	**100**