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Preface

The White Paper "Responsible Management of the Inland Fisheries of Namibia" was finalised in December 1995, and forms the basis for the new Inland Fisheries Resources Act and Regulations concerning fish resources management in the different freshwater systems. All perennial rivers in Namibia are shared with neighbouring countries and also form large sections of the international borders between these countries. The effects on the resources of the subsistence, commercial and recreational fisheries in neighbouring countries must also be taken into consideration. Hence, successful management of the fish resources must be regionally orientated. When implementing fisheries regulations for such complex systems, information on the fish resources and their exploitation in the different water bodies is needed.

Based on a series of studies of the fish resources in the perennial rivers in Namibia, recommendations are given for management regulations of the fisheries in the different rivers. These management regulations are aimed at involving 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. 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.* 2000, 2002, Næsje *et al.* 2004, this report) and the exploitation of fish resources, including the socioeconomic infrastructure of local societies (Purvis 2001a, b, Næsje *et al.* 2002, Hay *et al.* in prep.), fishing competitions (Næsje *et al.* 2001), catch and release fisheries (Thorstad *et al.* 2004), and movement, migrations and habitat utilisation of important fish species (Økland *et al.* 2000, 2002, 2005, Thorstad *et al.* 2001, 2002, 2003a, b, 2005).

The studies of fish migrations conclude that certain fish species may migrate between countries, both laterally and longitudinally in these river systems, which emphasise the importance of joint local and regional co-management of the fish resources both on a national and international scale. Other species, however, are more stationary and, hence, more vulnerable to local exploitation. The biological and sociological aspects of the subsistence, semi-commercial and recreational fisheries have documented that in the absence of a strong formal system of fisheries management, the informal (or traditional) management component has remained in Namibia. However, there are strong calls from all levels for an improved and effective system for national and multinational fisheries management.

In the present report, the fish populations in the Orange River are described on the basis of five surveys performed in the period 1995 - 2001. The project is a collaboration between the Freshwater Fish Institute of the Ministry of Fisheries and Marine Resources (MFMR), Namibia, and the Norwegian Institute for Nature Research (NINA). The study 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.

We are thankful to Prof. P. Skelton and Mr. R. Bills from South African Institute for Aquatic Biodiversity (SAIAB, formerly J.L.B Smith Institute of Ichthyology) who verified the identification of some of the fish species. Staff members from the Freshwater Fish Institute (MFMR), the Ministry of Fisheries and Marine Resources and the Norwegian Institute for Nature Research are all gratefully acknowledged for their involvement in the field surveys or data punching. Kari Sivertsen is acknowledged for her graphic work with the report.

Windhoek/Trondheim, October 2006

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The Orange River
The lower part of the Orange River forms the border between Namibia and South Africa from the mouth of the river and 580 km upstream. The river origins in the Lesotho Highlands, and runs for approximately 2300 km from the source to the Orange River Mouth at Oranjemund (Namibia) and Alexander Bay (South Africa), where it discharges into the Atlantic Ocean. The total Orange River catchment is approximately 1000000 km^2. The fish diversity in the Lower Orange River is relatively low.

Objective
The objective of this report is to provide baseline information about the fish resources in the Lower Orange River to form the biological foundation for recommendations for a sustainable management of the fish resources. Based on fish survey data from the period 1995-2001, 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 (multifilament, 22–150 mm stretched mesh size) and eight other sampling methods, such as seine nets, cast nets, electrofishing apparatus and rotenone. These additional gears are collectively called "other gears" in this report. The gill nets were used at seven of the stations to survey open, deep-water habitats in the main stream near the shore and deep backwater areas with some aquatic vegetation. Other gears were used at all ten stations and targeted mainly small species and juveniles of long-lived species in shallow, vegetated and rocky habitats. Monofilament gill nets were in addition used during one of the surveys, but for standardisation and comparison with studies in other Namibian rivers, these results were only used for analyses of number of species recorded, body length at maturity and length-mass relationships.

Surveys were carried out in the spring in 1995 (low flood) and in the autumn in 1996, 1998, 1999 and 2001 (high flood). A total of 18082 fish were caught; 3644 with multifilament gill nets, 294 with monofilament gill nets and 14144 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 biomass of individuals in the catches, as well as their frequency of occurrence.

Results
A total of 19 fish species from eight different families were recorded during the surveys, of which 13 species were freshwater species. The fish families represented with the highest number of species were the Cyprinidae and the Cichlidae, with 8 and 3 species, respectively. Further additional species were recorded by the Ministry during surveys between 2002 and 2005. These include the freshwater species *Labeobarbus* cf. *kimberleyensis* (hybrid yellow fish), *Tilapia rendalli* (introduced) and *Labeo umbratus*. The additional marine species recorded were *Argyrosomus inodorus*, *Pomatomus saltatrix* and *Lithognathus lithognathus*. These marine species were all recorded in the estuary.

Thirteen species were caught in the multifilament gill nets, of which three were marine species (*Liza richardsoni*, *Mugil cephalus* and *Lichia amia*). The two most important species, *Labeobarbus aenus* and *Labeo capensis*, contributed 90% of the total IRI. The Cyprinidae family was the dominating family in the gill net catches (94% of the total IRI). *Labeo capensis* dominated the gill net catches in the upper parts of the Orange River, whereas *Labeobarbus aeneus* dominated the catches closer to the river mouth. *Labeo capensis, Labeobarbus aeneus*, *Labeobarbus kimberleyensis* and *Clarias gariepinus* were the only species found at all the gill net stations.

Eighteen species were caught with other gears than gill nets, of which five were marine species (*Liza richardsoni, Mugil cephalus, Atherina breviceps, Gobiidae* sp. and Marine sp.). The five most important species contributed 85% of the total IRI. *Labeo capensis* was the most important species in the catches with other gears (IRI of 41%), followed by *Mesobola brevianalis, Oreochromis mossambicus, Clarias gariepinus* and *Labeobarbus aeneus*. Similar to the gill net catches, the Cyprinidae was the most important family in the catches with other gears, contributing 73% of the total

IRI. 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 importance of the Lower Orange River estuary, a designated Ramsar site, necessitated that the mouth area was studied in detail. At the two estuarine sampling stations, the freshwater species *Labeobarbus aenus* was the most important species in the total catches, with an IRI of 39%, followed by the marine species *Liza richardsoni*, with an IRI of 28%. *Liza richardsoni* contributed more to abundance than to mass, indicating the presence of small specimens, most likely juveniles. This species is probably using the estuary as a nursery area, rendering this area as important in the recruitment of this species. All the marine species were restricted only to the estuary, with no specimens recorded from the riverine section. The two sampling stations in the estuary were the two stations with the highest catch per unit effort in multifilament gill net catches, given as both number of fish and mass per setting.

The body length of the fish caught with multifilament gill nets and other gears was up to 96 cm. The mean body length was larger for fish caught with gill nets (mean 21.4 cm, range 4-96 cm) than with other gears (mean 5.8 cm, range 1-83 cm). Four of the species caught had a maximum body length of 6 cm or smaller, whereas nine of the species caught had a maximum length of 25 cm or larger.

Alien species

The alien species *Cyprinus carpio* constituted an IRI of 0.3% in the total catches, with 18 specimens caught. It was recorded at six of the ten sampling stations. *Cyprinus carpio* does not seem to pose a threat to the native fish population in the Lower Orange River, as very few individuals were recorded during this study. The riverine conditions do not seem to benefit this species, as poor recruitment was observed.

The other alien species, *Oreochromis mossambicus*, constituted to an IRI of 7.5%, with 2019 specimens caught. It was recorded at all ten sampling stations. *Oreochromis mossambicus* seems to have drastically increased in abundance since the early 1980's. Recruitment had also been extremely successful, with large numbers of juvenile fish recorded. It is expected that this abundance will increase in future, which may be detrimental to the native fish population, especially for *Tilapia sparrmanii*.

IUCN Red List species

Labeobarbus kimberleyensis, listed as near threatened on the IUCN Red List, constituted to an IRI of 2.1% in the total catches, with 208 specimens caught. It was recorded at eight of the ten sampling stations. It was slightly more common at Grootpenseiland than at the other stations, and this may be an area that can be identified as a protected area for this species. *Labeobarbus kimberleyensis* seem to have increased in abundance since the early 1980's. The length frequencies indicate successful recruitment, with also large individuals collected during the survey, indicating a relatively stable population. The large size at maturity, however, places this species in the vulnerable category, and steps should be taken in future to protect this species.

Barbus hospes, listed as of least concern in the IUCN Red List, constituted to and IRI of 2.9%, with 1305 specimens caught. It was recorded at nine of the ten sampling stations. *Barbus hospes* was found to be common in the system, with successful recruitment taking place. The status on the Red List should remain due to the restricted distribution of the species.

Austroglanis sclateri, listed as of least concern in the IUCN Red List, constituted to and IRI of 0.02%, with only 68 specimens caught. It was recorded at three of the ten sampling stations.

Comparison among rivers

In the Lower Orange River the catch per unit effort in the multifilament gill nets was higher in mass (3.9 kg per setting) than for any of the other Namibian rivers surveyed with similar methods (1.44 kg per setting in the Okavango River, 1.87 kg per setting in the Zambezi/Chobe Rivers and 1.23 kg per setting in the Kwando River). In number of fish per setting, the catches were higher in the Lower Orange River (17 fish per setting) than in the Kwando River (10 fish per setting), but lower in the Lower Orange River than in the Okavango River (28 fish per setting) and Zambezi/Chobe Rivers (89 fish per setting).

1 Introduction

Namibia is a large country, covering an area of about 823680 km^2. The population of 1.83 million (in 2001, Population and Housing Census, Central statistics Office) is small in relation to the size of the country. Approximately 40% of the people live in urban areas, while the majority of the remaining rural population lives in northern Namibia. Population growth has been at 3% during recent decades, but is now slowing due to lower fertility and increasing mortality due to AIDS. Fertility rates and life expectancy both declined with about one-third during the 1990s (Mendelsohn *et al.* 2002).

Approximately 43% of Namibia is allocated as freehold land, while 39% is communal land and 18% governmental land. Nature reserves and national parks make up about 14% of the country, while declared conservancies add another 10% to the protected areas. On a national scale, most of Namibia's wealth comes from the use of natural resources for farming, mining, fishing and tourism (Mendelsohn *et al.* 2002).

Broadly speaking, Namibia can be divided into two geologically zones, which are western Namibia with rock formations, escarpments, mountains and large open plains, and eastern Namibia where most of the surface is covered with sand and the landscape is much more uniform (Mendelsohn *et al.* 2002). Most of Namibia is arid for much of the year due to the country's position between two climatic systems, which are the inter-tropical convergence zone and the subtropical high pressure zone, where the latter pushes the moist air back north most of the year. Most of the rain falls during sporadic rainstorms in the summer months from September to February. The flow of moist air from the climatic systems in the north makes northern Namibia considerably wetter than other parts of the country, especially in contrast to the deserts to the east, along the coast and to the south.

Water is undoubtedly Namibia's most valuable and limiting natural resource (Barnard *et al.* 1998). The limited amount of rain that falls in most areas seeps into the ground or is rapidly drained into ephemeral rivers.

The Namibian rivers vary greatly, from the large perennial rivers that form the country's borders, to a multitude of small rivers and channels that flow at varying frequencies depending on the rainfall. There are also numerous pans of varying sizes that infrequently are covered with a shallow layer of water. The large perennial river systems that form parts of Namibia's borders drain huge areas in the neighbouring countries, and local rainfalls in Namibia contribute little towards the annual run-off of these rivers. The interior of Namibia has several man-made reservoirs, mainly built for human consumption and irrigation. The largest is Hardap Dam in the seasonal southern Fish River, which drains southwards to the Orange River.

People strongly depend on the availability of open water bodies for fish to eat and water for domestic and agricultural use. The permanent or regular surface waters of Namibia support a large number of Namibia's inhabitants, as 34% of the population live within 5 km of the perennial rivers or the channels in the Cuvelai Drainage System in the north (Mendelsohn *et al.* 2002).

The perennial rivers in the north, the Okavango and Zambezi Rivers, have been altered least by human activities as few dams have been built, little artificial channelling occur, and few agricultural chemicals are used in their drainage area (Mendelsohn *et al.* 2002). The Orange River in the south is much more impacted by human activity as many small and large dams are built in the river and its tributaries, and the river also drains large agricultural areas where substantial amounts of pesticide and fertilizers are used.

The water flow in the perennial rivers not only varies through the year, but might also vary largely among years. The fluctuation in the water level of the Orange River is less than in the past due to the large number of dams built in the river system. The high variability between the low and high water periods has changed to a more evenly discharge throughout the year. In the Orange River, dams and irrigation off-takes have reduced the annual flow rate to approximately 25% of the natural level.

As the local population grows, fishing activities will increase and conflicts may arise among different stakeholders. In addition, the Orange River forms the border between Namibia and South Africa, which are countries with different management regulations and control measures. The fish resources in the Orange River are under severe pressure, and may increase in the future, which make a long-term monitoring program important.

The Namibian Inland Fisheries Resources Act (Act No. 1 of 2003) states that nets are not allowed for fishing in the Namibian part of the Lower Orange River. The only legal way to harvest fish in the river is with hook and line, and fishing license is needed to fish. There is also a bag limit stipulated for the freshwater fish. The management of the marine fish caught in the estuary of the Orange River is covered by the Marine Resources Act (Act No. 27 of 2000), although only a few species are mentioned in the Act.

The objective of this report is to produce baseline information about the fish resources in the Lower Orange River to form the biological basis needed to identify current status and trends in the fish population for future management actions. Fish were collected at 23 locations with survey gill nets and/or six other sampling methods from 1995 to 2001. 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 importance of the Lower Orange River estuary, a designated Ramsar site, necessitated that the mouth area was studied in detail.

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 Lower Orange River is shared with South Africa, and should be co-managed to ensure the effective control of the fish resources to the benefit of both countries and local communities. The authors hope that this report will benefit future management of the fish resources in the Lower Orange River, and enhance the trans-boundary management of the freshwater fish resources in the region.

2 Study area

The lower part of the Orange River borders South Africa from the mouth of the river and 580 km upstream to a point where the river meets the 20 °E longitude (**figure 2.1**) The Orange River origins in the Lesotho Highlands, about 3300 m above sea level, where the precipitation is 1800 mm/year and evaporation 1700 mm/year. It runs for approximately 2300 km from the source to the Orange River mouth at Oranjemund (Namibia) and Alexander Bay (South Africa), where it discharges into the Atlantic Ocean. The total Orange River catchment area is approximately 1000000 km^2. Almost 600000 km^2 is located inside the Republic of South Africa, which represents 47% of the country (Benade 1993). The Orange River catchment also includes the whole of Lesotho. In Namibia, the main inflow comes through the Fish River Basin (Benade 1993). Water discharge and water level in the Orange River during the study period are shown in **figure 2.2**.

According to Barnard *et al.* (1998), the Orange River has some conservation problems linked to large quantities of fertilizers entering the river system from the Hardap Irrigation Scheme on the Fish River, which increases the growth of reeds in the river. The Lesotho Highland Scheme extracts large quantities of water from the river to supply large cities in South Africa.

The rainfall in the area around the Lower Orange River is unpredictable, and infrequent rain falls during summer. The median annual rainfall along the Lower Orange River in Namibia is very low and less than 50 mm in the lower part and between 100 and 150 mm in the upper part (Barnard *et al.* 1998). In addition, the rate of evaporation is high, making the water deficit between 2400 and 2600 mm in the mouth area of the river, increasing to between 3000 and 3400 mm in the upper part of the Orange River in Namibia.

The fisheries resources and fish diversity in the Lower Orange River are limited. The Orange River, which is turbid and temperate, has low species diversity, and has less than 20% of the number of fish species found in the tropical northern rivers of Namibia (Hay *et al.* 1999). In total, 14 freshwater fish species were found in the Lower Orange River survey from 1995 to 2001, of which five are endemic to the Orange River, and one is endemic to the Lower Orange River (*Barbus hospes*) (Hay *et al.* 1999) (**table 2.1**). Three of the species are alien species (carp *Cyprinus carpio*, Mozambique tilapia *Oreochromis mossambicus*, and redbreast tilapia *Tilapia rendalli*, Hay *et al.* 1999). Three of the species are listed on the IUCN Red List, namely Vaal-Orange largemouth yellowfish *Labeobarbus kimberleyensis*, Namaqua barb *Barbus hospes* and rock catfish *Austroglanis sclateri*.

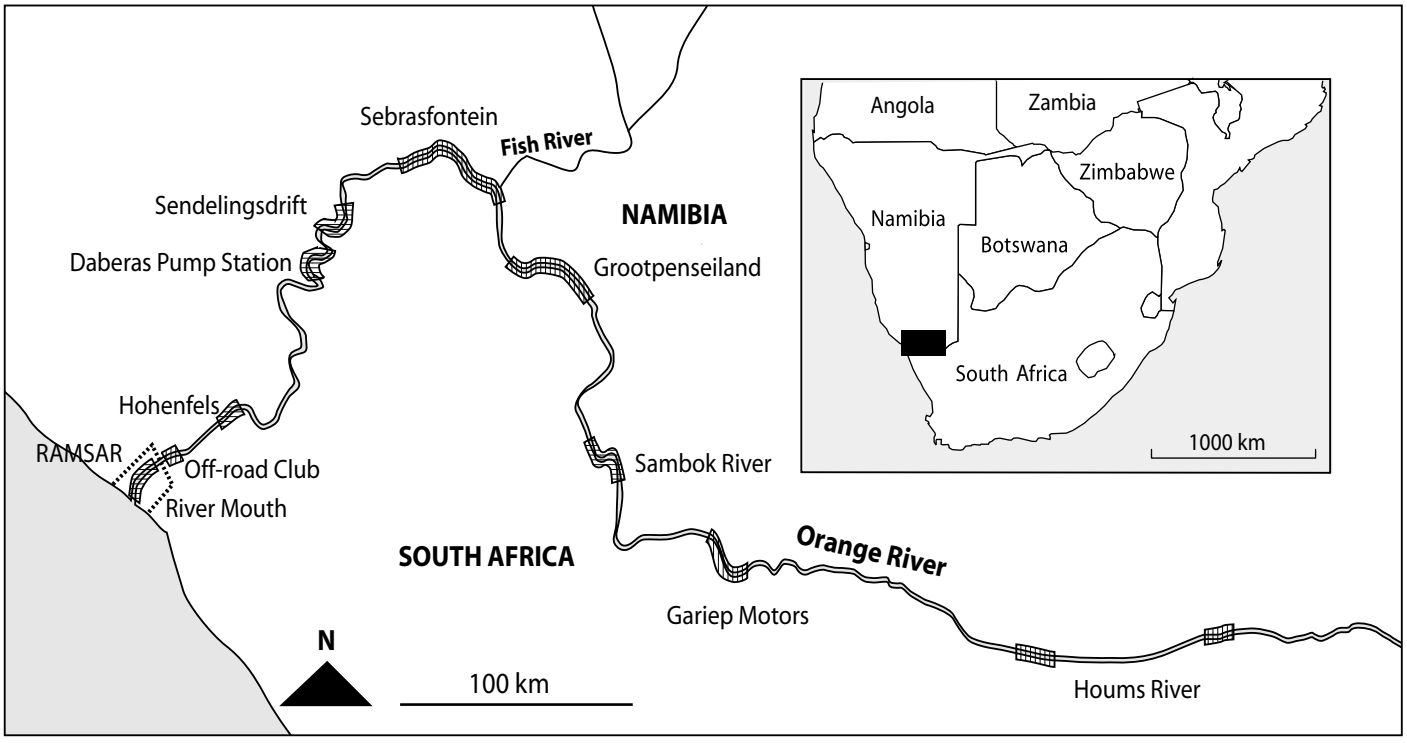


Figure 2.1
Location of the Orange River and survey stations (See table 3.2) in southern Namibia.

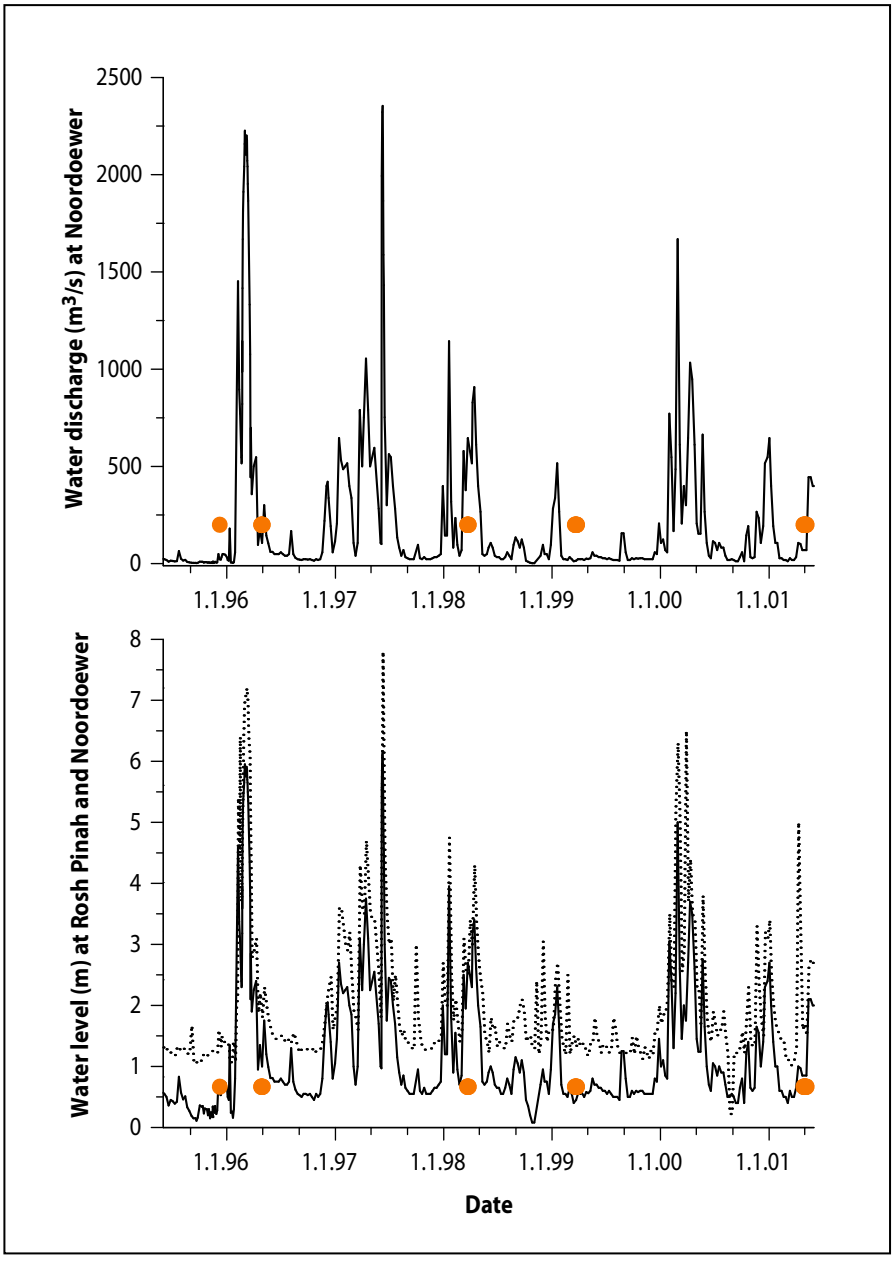


Figure 2.2
Water discharge at Noordoewer (upper figure) and water level at Rosh Pinah (dotted line, lower figure, gauge plate reading) and Noordoewer (solid line, lower figure) in the Lower Orange River during 1 June 1995 - 1 June 2001. Time of fish surveys are indicated with red dots. Data were provided by Water Affairs, Namibia.

The Ministry of Fisheries and Marine Resources recorded six additional species in surveys after 2001, which are not included in this report. These include the freshwater species *Labeobarbus* cf. *kimberleyensis* (hybrid yellow fish), *Tilapia rendalli* (introduced) and *Labeo umbratus*. The additional marine species recorded during this period were *Argyrosomus inodorus*, *Pomatomus saltatrix* and *Lithognathus lithognathus* all of which were recorded only in the estuary. Only six naturally occurring freshwater species in the Orange River are shared with the rivers in the north of Namibia. In addition, several estuary/marine species are found in the estuary or mouth region of the river. Very little data, however, are available on the fish populations and their biology within the Lower Orange River system.

Biomes describe areas that broadly share similar vegetation and climatic features. They also often have similar animal life, soils and geological features. The Lower Orange River can be divided into two main biomes, which are Succulent Steppe in the lower part and Karas Dwarf Shrubland in the upper part. The Succulent Steppe is characterized by soils consisting of sand, gravel and calcrete with succulent shrubs. The Karas Dwarf Shrubland soils are eutric leptosols and petric calcisols with grasslands and low shrubs.

The perennial rivers in the north and north-eastern parts of Namibia are flowing through landscapes with very little gradient and are characterized by large floodplains inundated during high water periods. In contrast, the Lower Orange River, similar to the Kunene River, is not a floodplain river, but has a channel-like profile.

Mining has long been the backbone of the Namibian economy, and remains an important contributor to the country's national economy and export revenues. Environmental conservation has in later years been recognised by the mining industry as an important by-product of its land tenure. The prohibited status of the "Sperrgebiets" (with restricted access to common people) have kept large land areas from being developed inappropriately and strongly restricted the access for people. The Orange River valley in the lower part of the Orange River is such an important area. In addition, the Orange River Mouth is a wetland of international significance. In 1995, Namibia acceded to the Ramsar Convention on Wetlands. Namibia initially designated four wetlands as Ramsar sites, of which the Orange River Mouth, which is shared with South Africa, was one (500 ha in Namibia and 2000 ha in South Africa). The Orange River Coastal Wetland consists of an area of about 18 km^2 between the sea and the Ernest Oppenheimer Bridge, approximately 10 km upstream (Barnard *et al.* 1998). This area is strongly influenced by salt water pushing in from the sea. However, the mouth area may be blocked by sand bars when the freshwater inflow to the estuary is low. The mean tidal range of the mouth of the Orange River is approximately 1.5 m and can be as much as 2.2 m during spring tides. With a restricted open mouth, these tidal variations in the water level result in strong currents, which are an important factor in the mouth dynamics.

Although there are no formalized subsistence fishery such as in the Zambezi and Okavango Rivers, some fishing activities have been noted during the surveys. Fishers are using gill nets, seine nets and hook and line. The fishing activities appear to be more intensified at Noordoewer with the higher density of people in the area along the irrigation farms. The use of the gill nets and seine nets are illegal as no nets are allowed in the Lower Orange according to the Inland Fisheries Resources Act (Act No. 1 of 2003). The overall impact of the subsistence fishery on the resource is considered less than in the Zambezi and Okavango Rivers, although no data are available to confirm this. Some net fishing has also been observed in the estuary at Oranjemund.

Table 2.1. *Freshwater fishes found in the Lower Orange River and their status.*

Family	Scientific name	English name	Status	Found after 2001
Cyprinidae	*Labeobarbus aeneus*	Vaal-Orange smallmouth yellowfish		
	Labeobarbus kimberleyensis	Vaal-Orange largemouth yellowfish	IUCN Red List, near threatened, endemic Orange system	
	Labeobarbus cf. kimberleyensis	Yellowfish hybrid		X
	Barbus trimaculatus	Threespot barb		
	Barbus hospes	Namaqua barb	Endemic Lower Orange River	
	Barbus paludinosus	Straightfin barb		
	Labeo capensis	Orange River mudfish	Endemic Orange system	
	Labeo umbratus	Moggel		X
	Mesobola brevianalis	River sardine		
	Cyprinus carpio	Common carp	Alien	
Clariidae	*Clarias gariepinus*	Sharptooth catfish		
Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	Alien	
	Pseudocrenilabrus philander	Southern mouthbrooder		
	Tilapia sparrmanii	Banded tilapia		
	Tilapia rendalli	Redbreast tilapia	Alien	X
Austroglanididae	*Austroglanis sclateri*	Rock catfish	Endemic Orange system	

3 Materials and methods

3.1 Surveys, locations and stations

Five surveys were conducted in the Lower Orange River during the period 1995 to 2001. Only one period was surveyed during spring (low flood) while the remaining surveys were conducted during autumn (high flood) (**figure 2.2, table 3.1**). In total, 23 locations were sampled during the surveys, and were named after the closest village or known area (**table 3.2**). The locations were representative for the different habitats of the river system. The locations located closest in distance and with similar habitat types were merged into 10 stations in order to simplify the data analyses. The 10 merged stations were named after the most important station with respect to catch efficiency and were: 1) River Mouth, 2) Off-Road Club, 3) Hohenfels, 4) Daberas Pump Station, 5) Sendelingsdrif, 6) Sebrasfontain, 7) Grootpenseiland, 8) Sambok River, 9) Gariep Motors, and 10) Houms River (**figure 2.1, table 3.2**).

Table 3.1. *Survey year, sampling dates and total catch in numbers of fish for the fish surveys in the Lower Orange River during 1995 - 2001.*

Survey year	Survey period	Season	Total catch (n)
1995	08.12 - 09.12	Spring	653
1996	25.04 - 02.05	Autumn	3044
1998	20.03 - 27.03	Autumn	3929
1999	18.03 - 27.03	Autumn	6707
2001	26.04 - 08.05	Autumn	3749
Total 1995-2001			**18082**

Table 3.2. *Name and position of the locations sampled during the fish surveys in the Lower Orange during 1995 - 2001, and the merged station number and name.*

Location	Location namea	Position	Station no.	Station name
1	River Mouth	S28°36'04.4", E16°27'16.2"	1	River Mouth
2	Lagoon	S28°37'36.6", E16°26'44.3"	1	River Mouth
3	Island River Mouth	S28°36'20.4", E16°27'19.2"	1	River Mouth
4	Jetty Oranjemund	S28°36'02.8", E16°27'19.1"	1	River Mouth
5	Off-road Club	S28°35'24.3", E16°27'38.0"	2	Off-road Club
6	Hohenfels	S28°30'40.9", E16°37'05.0"	3	Hohenfels
7	East of Daberas Pump	S28°15'15.1", E16°47'01.5"	4	Hohenfels
8	Daberas Pump Station	S28°15'34.6", E16°46'23.6"	4	Daberas Pump Station
9	Sendelingsdrif	S28°15'36.6", E16°46'25.8"	5	Sendelingsdrif
10	Sebrasfontein	S28°04'09.5", E16°59'40.1"	6	Sebrasfontein
11	Boom River	S28°02'14.9", E17°05'14.7"	6	Sebrasfontein
12	Fish River Mouth	S28°05'37.2", E17°10'20.7"	6	Sebrasfontein
13	Jansen Camp	S28°08'35.3", E17°11'37.9"	6	Sebrasfontein
14	Storm Berg	S28°14'34.6", E17°16'03,6"	7	Grootpenseiland
15	Ghaapkloof	S28°13'45.1", E17°18'10.0"	7	Grootpenseiland
16	Grootpenseiland	S28°15'48.7", E17°21'28.5"	7	Grootpenseiland
17	Gamkab River Mouth	S28°14'19.1", E17°20'38.9"	7	Grootpenseiland
18	Sambok River	S28°34'17.1", E17°25'35.4"	8	Sambok River
19	Johan Silver	S28°41'24.5", E17°35'35.5"	9	Gariep Motors
20	Gariep Motors	S28°44'21.1", E17°36'33.5"	9	Gariep Motors
21	Border Post Noordoewer	S28°45'56.4", E17°36'59.9"	9	Gariep Motors
22	Langkweek	S28°53'41.2", E18°09'22.7"	10	Houms River
23	Houms River	S28°50'17.3", E18°37'28.8"	10	Houms River

3.2 Sampling design and methods

Seven of the ten stations were sampled with brown multifilament gill nets with nine mesh sizes varying from 22 to 150 mm (**table 3.3** and **3.4**). The three stations not sampled with multifilament gill nets were Hohenfels, Sendelingsdrif and Sambok River. The multifilament gill nets were used during the entire sampling period and were used to survey open, deep-water habitats in the mainstream and deep backwater areas with some aquatic vegetation. Nets were set either in the middle of a water-body or near marginal vegetation. The multifilament gill nets consisted of separate 9 m panels tied together, approximately 3 m high (mesh depths are given in **table 3.3**). The sequence of gill nets was determined randomly (**table 3.3**). The nets

Table 3.3. *Twine and mesh depth (number of vertical meshes) of each stretched mesh size in the multifilament gill nets used during the surveys in the Lower Orange River during 1995 - 2001.*

Stretched 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

Table 3.4. *The different fishing gears and methods used, and number of fish caught in gill nets, other gears and in total at the different locations in the Lower Orange River during the surveys during 1995 - 2001. The names in bold indicate the merged stations. For the gears used, the number of settings (e.g. panels) is given in parentheses. In addition to gill nets, the other gears used were 1) mosquito net, 2) rotenone, 3) 30 m long seine net, 4) traps, 5) cast net 2 m long, 6) electro shocker, 7) angling, 8) 5 m long mosquito net, and 9) longline.*

Location	**Station no.**	**Multifilament gill net n fish** (n settings)	**Monofilament gill net n fish** (n settings)	**Other gears n fish** (n settings)	**Other gear types used**	**Total catch** n fish
River Mouth	1	*	*	215 (10)	1, 8	215
Lagoon	1	*	*	1207 (7)	1, 8	1207
Island River Mouth	1	77 (45)	*	362 (7)	1, 8	439
Jetty Oranjemund	1	471 (81)	59 (12)	661 (9)	1, 4	1191
Off-road Club	2	1475 (90)	*	106 (6)	1, 4, 5	1581
Hohenfels	3	*	*	292 (7)	1, 8	292
East of Daberas Pump	4	*	*	638 (4)	1,2 , 8	638
Daberas Pump Station	4	63 (117)	10 (12)	455 (12)	1,7 ,8 ,9	528
Sendelingsdrif	5	*	*	263 (2)	1	263
Sebrasfontein	6	*	*	688 (7)	1, 2 ,5 , 6	688
Boom River	6	16 (9)	*	1143 (8)	1, 2, 6, 8	1159
Fish River Mouth	6	*	*	327 (4)	1	327
Jansen Camp	6	55 (36)	*	106 (2)	2	161
Storm Berg	7	*	*	14 (1)	8	14
Ghaapkloof	7	*	*	678 (3)	2	678
Grootpenseiland	7	170 (54)	*	1383 (11)	1, 2, 6, 7 ,8	1553
Gamkab River Mouth	7	383 (126)	126 (12)	402 (10)	1, 4, 6	911
Sambok River	8	*	*	1652 (8)	1, 2, 6	1652
Johan Silver	9	*	*	195 (2)	2, 8	195
Gariep Motors	9	517 (180)	46 (12)	887 (10)	1, 3, 4, 7, 8, 9	1450
Border Post Noordoewer	9	79 (27)	*	982 (5)	1,8	1061
Langkweek	10	19 (18)	*	456 (4)	1, 2, 4, 8	475
Houms River	10	319 (99)	53 (12)	1032 (15)	1, 2, 4, 7, 8, 9	1404
Total		**3644 (882)**	**294 (60)**	**14144 (154)**	**1, 2, 3, 4, 5, 6, 7, 8, 9**	**18082**

***** indicates no settings

were set from approximately 18:00 hrs in the evening to 06:00 hrs the following morning.

Monofilament gill nets with 12 mesh sizes varying from 10 to 110 mm were included in the sampling protocol only in 2001 and used at five of the 10 stations (**table 3.4** and **3.5**). These gill nets were 30 m in total length and 1.5 m in height, consisting of 12 mesh sizes, with each mesh panel being 2.5 m in length (**table 3.5**). The monofilament gill nets were used to sample deep-water, densely vegetated habitats.

In addition to gill nets, different other gears were used at all stations to limit the effect of gear selectivity, and to be able to survey all habitat types. Depending on the water level, sampling gears were used in the same area at the sampling locations for standardisation purposes. The other gear types were used at or close to the gill net localities to supplement the gill net catches, and are collectively termed 'other gears' in this report. These other gears targeted mainly small species and juveniles of long-lived species in shallow, vegetated and rocky habitats.

The following other gears were used in addition to gill nets:

- A five meter mosquito net with a depth of 1.5 m made of 30% shade netting was used in shallow sandy substrates in the mainstream and backwater habitats.
- Rotenone was mainly used to survey rocky or 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, was used in large, open waterbodies 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 net (monofilament nylon twine) 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 electro shocker (2 amperes and 600 volts) was used to sample rocky and vegetated habitats.
- Angling with rod and reel was used to catch larger fish.
- Longlines were used in deep water habitats, usually in the mainstream.

Table 3.5. *Twine and mesh depth (number of vertical meshes) of each stretched mesh size in the monofilament gill nets used during surveys in the Lower Orange River during 1995 - 2001.*

Stretched mesh size (mm)	**Twine** (mm)
10	0.10
12	0.10
16	0.10
20	0.12
25	0.12
32	0.15
39	0.15
48	0.17
58	0.17
70	0.20
86	0.20
110	0.20

A total of 18082 fish were caught during the surveys between 1995 and 2001 (**table 3.4**). Of these, 3644 fish were caught in the multifilament gill nets, 294 fish in the monofilament gill nets, and 14144 fish by using other gear types (**table 3.4**).

The fish length data (**appendix 2**) were based on measurements of 11710 fish, constituting 65% of the total number of fish caught. The length measured fish were sampled from all ten stations (**table 3.6**), and sampled with all sampling gears (**table 3.7**).

The common name and family classification for the species (**table 2.1** and **appendix 1**) are based on Skelton (2001) and van der Elst (1998).

Table 3.6. *Number and proportion of fish that were length measured of the total catch at different stations during surveys in the Lower Orange River during 1995 - 2001.*

Station	**Length measured** (n)	**Total catch** (n)	**Proportion of total catch length measured** (%)
River Mouth	1745	3052	57
Off-Road Club	1581	1581	100
Hohenfels	292	292	100
Daberas Pump Station	829	1166	71
Sendelingsdrif	62	263	24
Sebrasfontein	1022	2335	44
Grootpenseiland	2473	3156	78
Sambok River	1009	1652	61
Gariep Motors	1701	2706	63
Houms River	996	1879	53
Total	**11710**	**18082**	**65**

Table 3.7. *Number and proportion of fish that were length measured of the total catch in different fishing gears used during surveys in the Lower Orange River during 1995 - 2001.*

Gear	**Length measured** (n)	**Total catch** (n)	**Proportion of total catch length measured (%)**
Multifilament gill nets	3643	3644	100
Monofilament gill nets	240	294	82
Other gears	7827	14144	55
Total	**11710**	**18082**	**65**

3.3 Data collection and analyses

The catches in monofilament nets were only used for analyses of total number of species recorded (**appendix 1**), body length recordings (**appendix 2**), body length at maturity (**table 5.5**) and length-mass relationships (**table 5.21**). In all other analyses, tables, figures and appendixes, only data from multifilament gill nets, other gears, or both, are included. This is done for standardisation and comparison with studies in other Namibian rivers. No species were caught in monofilament gill nets that where not caught in multifilament gill nets and/or other gears during the surveys. This was also true for each of the stations surveyed with monofilament gill nets.

3.3.1 Biological data

Fish up to 100 mm in length were measured to the nearest millimetre, whereas fish larger than 100 mm were measured to the nearest centimetre. Fork length was measured on fish with a forked caudal fin, while total length was measured on fish with a rounded caudal fin. Fish mass was measured in the field as wet mass. Fish caught in gill nets were weighed to the nearest gram. Fish smaller than 200 g caught with other gears were weighed to the nearest 0.1 g, while larger fish were weighed to the nearest 1 g. After measuring and weighing a representative and large number of individuals (often 50 or more), the remaining fish were sorted into species, counted, pooled and weighed.

Sexual maturity was classified on a scale from 1 to 5, where 1 is immature, 2 is maturing gonads, 3 is mature gonads ready for spawning, 4 is spent gonads and 5 is resting mature fish.

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

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

where j = 1–S, $\%N_i$ and $\%W_i$ is percentage number and biomass of each species in the total catch, $\%F_i$ 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') is a measure of the number of species weighted by their relative abundance (Begon *et al.* 1990), expressed as:

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

where pi is the proportion of individuals found in the ith species. Assumptions for the Shannon index are 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')
The Shannon's index takes into account the evenness of the abundances of species, but a separate measure of evenness of species diversity was also calculated. The ratio of observed diversity to maximum diversity to calculate the index of evenness (J') (Begon *et al.* 1990) was used:

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

J' is constrained between 0 and 1.0, with 1.0 representing a situation in which all species are equally abundant. 'S' represents the total number of individuals for all species in each sample. As with Shannon index of diversity, the assumption for this evenness measure is that all species in the area are accounted for in the sample.

3.3.3 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, such as body form and the presence of spines, and fish with different activity levels. Gill nets are also restricted to certain habitats, which will also influence the species selectivity of this gear. However, when taking into account the possible problems with the method, the use of standard series of gill nets with various mesh sizes catching overlapping length intervals of the fish species, is often the best method to study fish populations.

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 all species caught during the surveys.

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 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.

3.3.4 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 multifilament gill nets, catch per unit effort was defined as the number or biomass of fish caught during 12 hours of fishing with a panel size of 50 m^2 gill net.

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

3.3.5 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 analyses.

Bootstrap estimates (Efron and Tibshirani 1986, 1993) were used to calculate confidence intervals on Shannon's diversity index (H') and evenness index (J').

Top:
River mouth.

Middle:
The estuary at Oranjemund.

Bottom:
White steenbras caught in the estuary.

Photos:
Clinton J. Hay

Top:
Lagoon habitat in the estuary.

Middle:
Daberas Pump Station where species from the family Mugilidae were caught.

Bottom:
Labeobarbus kimberleyensis.

Photos:
Clinton J. Hay

Top:
Gamkab River Mouth Station.

Middle:
Houms River.

Bottom:
Narrowing of the river at Houms River Station.

Photos:
Clinton J. Hay

4 General biology and distribution of the species

An overview of the general biology and distribution for the species found in the Lower Orange River are here given as a background for the results and discussion. The biology, distribution, life history, family classification and common names for the freshwater species are mainly based on Skelton (2001), and the estuarine/marine species are based on van der Elst (1998). According to the new edition of 'A Complete guide to freshwater fishes of South Africa' (Skelton 2001), there are three species in the Lower Orange River that have changed name since the previous edition (Skelton 1993). These are *Barbus aeneus* that has changed to *Labeobarbus aeneus*, *Labeo capensis* that has changed to *Labeobarbus capensis*, and *Barbus kimberleyensis* that has changed to *Labeobarbus kimberleyensis*.

Cyprinidae

Vaal-Orange smallmouth yellowfish, *Labeobarbus aeneus* (freshwater species, endemic to the Orange-Vaal System), has its natural distribution in the Orange-Vaal system, and has been spread to larger Cape coastal rivers including the Gourits, Great Fish and the Kei, as well as the Limpopo and the Mutirikwe Dam in Zimbabwe (Skelton 2001). The males mature at about 20 cm and females from 24 cm standard length. They may grow to about 50 cm. They prefer clear-flowing waters of large rivers with sandy or rocky substrates, but are also found in large dams. Vaal-Orange smallmouth yellowfish breed in spring through midsummer after the first major rains of the season. Eggs are laid in gravel and hatch after 3-8 days. After further 4-6 days, larvae begin to feed on microscopic organisms. Larger fish are broadly omnivorous and feed on benthic invertebrates, vegetation, algae and detritus.

Orange River mudfish, *Labeobarbus capensis* (freshwater species, endemic to the Orange-Vaal System). They prefer running waters of large rivers, and also do well in large impoundments (Skelton 2001). They feed on firm surfaces of rocks and plants. Orange River mudfish breed in summer, after gathering in large numbers in shallow, rocky rapids where the eggs are laid. The growth is rapid, and the young may reach 8-9 cm standard length after one year. Males mature from about 22 cm and females from about 24 cm. Maximum length is approximately 50 cm, and they may attain ages of 8 to 9 years.

River sardine, *Mesobola brevianalis* (freshwater species), occurs in Kunene, Okavango, Upper Zambezi River systems and in east coastal rivers from the Limpopo to the Umfolozi in northern KwaZulu-Natal (Skelton 2001). An isolated population is also found in the Orange River below the Augrabies Falls. River sardine occur in shoals and prefer well-aerated, open water of flowing rivers. They feed on planctonic crustaceans and insects, breed in early summer, and can attain a size of 7.5 cm standard length.

Vaal-Orange largemouth yellowfish, *Labeobarbus kimberleyensis* (freshwater species, IUCN listed as near threatened, endemic to the Orange-Vaal System), is distributed within the Orange-Vaal river system, and is most often found in larger tributaries and dams (Skelton 2001). It is absent from higher reaches in Lesotho and the southern tributaries of the Cape. This is the largest scale-bearing indigenous fish species in South Africa, with a maximum recorded size of 22.2 kg and 82.5 cm. Females generally attain a higher age and larger size than males. Adults prefer flowing water in deep channels, but do also well in dams. Vaal-Orange largemouth yellowfish are primarily predators, initially taking insects and small crustaceans, but become piscivorous above 30 cm fork length. They breed in mid to late summer over gravel beds in running water. Growth is relatively slow for this species, reaching about 10 cm after two years and 30 cm after five years. Males mature usually at 6 years and females at 8 years. Vaal-Orange largemouth yellowfish used to be defined as vulnerable on the IUCN Red List, but is at present (2006) defined as near threatened.

Threespot barb, *Barbus trimaculatus* (freshwater species), occurs in rivers from Ruvuma in Tanzania, to Umvoti in KwaZulu Natal, and also in Orange, Kunene and Zambian Congo River systems (Skelton 2001). Threespot barb are found in a wide variety of habitats, and especially where vegetation occurs. They eat insects and other small organisms. They may attain 15 cm standard length, and breed in summer. This species is used as bait for catching predatory fish such as tigerfish.

Namaqua barb, *Barbus hospes* (freshwater species, IUCN listed as of least concern, endemic to the Lower Orange), is present in the Orange River below the Augrabies Falls (Skelton 2001). They may attain about 7.5 cm standard length, and favour open water in the mainstream and backwaters, where they feed on

zooplankton and aquatic insects. Namaqua barb used to be defined as near threatened on the IUCN Red List, but is at present (2006) defined as of least concern. The species was found to be common at Ai-Ais in the lower Fish River with a restricted distribution (Hay et. al 1997a). A waterfall prevents any upstream movement to the upper reaches of the Fish River. This was also found to be true for Barbus trimaculatus and Mesobola brevianalis. All three species are small, having difficulty to pass the waterfall (Hay 1991).

Common carp, *Cyprinus carpio* (freshwater species, alien), is widespread throughout Southern Africa, but absent from mountainous areas (Skelton 2001). The natural distribution of common carp is in Central Asia to the Black Sea and the Danube in Europe. According to early writings, the common carp was introduced into South Africa in the 1700's, and several introductions are reported from the 1800's (Skelton 2001). Common carp is now established in many countries around the world. It was found to be uncommon in the Fish River in Namibia, which is the northern tributary of the Lower Orange River (Hay 1991). Some individuals grow large, and the angling record of South Africa is 22 kg. They are hardy and tolerant of a wide variety of conditions, but favour large water bodies with slow-flowing or standing water with soft bottom sediments. Common carp are omnivorous and eat a wide range of plant and animal matter by grubbing in sediments. They breed in spring and summer and grow fast. Common carp is a valued aquaculture and angling species.

Straightfin barb, *Barbus paludinosus* (freshwater species), is widespread from East Africa to the Vungu in KwaZulu-Natal, and from the Congo tributaries to the Orange River. In Namibia it is found in all the northern perennial rivers as well as through the interior in small water-bodies. It is usually one of the last species to die in a receding water-pool. It is common in the pools of the Fish River (Hay 1991). Straightfin barb feed on a wide variety of small organisms including insects, snails, algae, diatoms, and detritus. They inhabit well-vegetated waters in lakes, swamps and marshes (Skelton 2001). It is an important species in the subsistence fishery. The females are multiple spawners, breeding in the summer months.

Cichlidae

Mozambique tilapia, *Oreochromis mossambicus* (freshwater species, alien), occurs in the east coastal rivers from the lower Zambezi system south to the Bushman's system in Eastern Cape, and is present south of the Phongolo system (Skelton 2001). Mozambique tilapia is widely spread beyond this range to inland regions and to the south-west and west coast rivers including the Lower Orange. It is also introduced to tropical and warm temperate localities around the world. Mozambique tilapia attain a body length of 400 mm standard length, and the angling record of South Africa is 3.3 kg. They thrive in standing waters and are tolerant of fresh, brackish or marine waters (van Zyl *et al.* 1997). Mozambique tilapia prefer temperatures above 22 °C, but survive at lower temperatures (about 15 °C) in brackish or marine waters. They feed on algae, but large individuals may take insects and other invertebrates. Mozambique tilapia breed in summer and females raise multiple broods every 3-4 weeks during a season. Males build a nest on sandy bottom and females mouthbrood the eggs, larvae and small fry. Growth is fast, and they may breed within a year. The Mozambique tilapia is widely used in aquaculture and is important for commercial and subsistence fisheries. It is also a valued angling species and is extensively used in biological, physiological and behavioural studies.

Southern mouthbrooder, *Pseudocrenilabrus philander* (freshwater species), is widespread in southern Africa from the Orange River northwards to Malawi and the southern tributaries of the Congo River (Skelton 2001). They may reach lengths of 13 cm and breed from early spring to late summer. The females protect the eggs, larvae and juveniles. Several broods may be raised in one season. They live in a wide variety of habitats, but prefer vegetated areas, feeding on insects, shrimps and even small fish. It is an aquarium species and is also used in behavioural and evolutionary studies.

Banded Tilapia, *Tilapia sparrmanii* (freshwater species), is widespread in Namibia present in the Kunene, Okavango, the Caprivi Systems and in several waterbodies throughout the country (Skelton 2001). It is further widespread in Southern Africa from the Orange River and KwaZulu-Natal northwards to the upper reaches of the Congo tributaries, Lake Malawi and the Zambezi. They prefer quiet vegetated water-bodies and feed on a wide variety such as algae, soft plants, invertebrates and small fish. Banded tilapia are sub-

strate brooders, breeding throughout the spring and summer months. It is an important species as a food source in the subsistence fishery in the Okavango and in the Caprivi.

Clariidae

Sharptooth catfish, *Clarias gariepinus* (freshwater species), is probably the most widespread fish species in Africa (Skelton 2001). They may reach 1.4 m in length and 60 kg in biomass and occur in almost any habitat, but prefer floodplains, large slow flowing rivers, lakes and dams where they feed on virtually any available organic food source. The sharptooth catfish is an important species for angling and has potential in the aquaculture industry.

Atherinidae

Cape silverside, *Atherina breviceps* (estuary/salt water species), is common in estuaries along the coastal rivers of South Africa. This species is used regularly as bait by recreational fishermen and is an important prey of piscivores and birds (Skelton 2001). Cape silverside can withstand reduced salinities and are able to complete their life cycle within the estuary (van der Elst 1985). They feed on large planctonic animals and the fry of other species. They attain a maximum length of 11 cm (Smith and Heemstra 1986).

Mugilidae

Southern mullet, *Liza richardsoni* (estuary/salt water species), is distributed off the rocky points and sandy beaches of the southern and western Cape coast (van der Elst 1998). Many also frequent estuaries where tolerance to low salinities enables the young to use these regions as nursery areas. Instead of a stomach, the southern mullet has a long muscular crop, rather like the gizzard of a bird. The diet consists of easily digestible microscopic plant organisms. Southern mullet may reach a length of 40 cm, and sexual maturity is attained at a length of about 20 cm. Spawning takes place during the spring in shallow areas.

Flathead mullet, *Mugil cephalus* (estuary/salt water species), is distributed along coastal rivers throughout southern Africa as well as worldwide in coastal, estuarine areas and in freshwaters of tropical or warm-temperate zones (van der Elst 1998). Flathead mullet tolerate a wide range of salinities from fresh water to above sea water concentrations, and breed at sea near the mouths of estuaries during the winter. Juveniles enter estuaries, and to a lesser extent rivers, mainly during the winter months. They remain in the estuary for one or two years and mature before moving out to sea to breed. They feed on algae and other tiny organisms from the bottom, and may attain body lengths of 60 cm fork length. Flathead mullet is a valuable food fish.

Carangidae

Garrick, *Lichia amia* (estuary/salt water species), is distributed along the African coast from Maputo at the east coast, around the Cape, along the west coast to the Mediterranean as well as along the coast of Portugal (van der Elst 1998). The Garrick may attain a length of about 150 cm fork length, and is one of the most aggressive fish predators, with a great preference for elf (*Pomatomus saltatrix*), pinkies (*Pomadasys olivaceum*) and karanteen (*Salpa salpa*). Seasonal migrations occur with garrick moving to Natal in winter and to the Cape during the summer months. Winter migrations usually coincide with the onset of the annual Natal sardine run, and take place during a period of increased reproductive activity. Sexual maturity is attained at about 60 cm, and spawning occurs off the Natal coast during spring. The Agulhas Current probably distributes the young among the estuaries of the Eastern Cape. The garrick is of no major commercial significance, but is a popular recreational fishery species.

Austroglanididae

Rock catfish, *Austroglanis sclateri* (freshwater species, IUCN listed as of least concern, endemic to the Orange-Vaal System) is distributed in the Orange-Vaal system, but translocated to the Olifants-Limpopo System. They are found mainly in rocky habitats in flowing water, feeding on invertebrates. Larger individuals may turn into piscivores. This species is defined as of least concern on the IUCN Red List (2006), and recent studies indicate that it is more common than previously thought (Skelton 2001).

5 Results

5.1 Species diversity

During the surveys in the Lower Orange River from 1995 to 2001 a total of 19 fish species were identified, of which 13 were freshwater species and six estuarine/marine species. One of the marine species was not identified. Of the eight fish families found, the Cyprinidae family was most numerous with eight species, while the Cichlidae family were represented with three species, the Mugelidae with two, and the Clariidae, Austroglanididae, Atherinidae, Carangidae and Gobiidae with one species each (**appendix 1**).

5.1.1 Catches in all gears

The species caught during the surveys were ranked based on the index of relative importance (IRI), which takes into account both the number, biomass and frequency of species caught (**figure 5.1**, **appendix 3**). To be able to compare with catches from the Okavango River (Hay *et al.* 2000), Zambezi River (Hay *et al.* 2002), Chobe River (Hay *et al.* 2002) and Kwando River (Næsje *et al.* 2004), catches from the monofilament gill nets were excluded from the ranking (n = 294 fish). According to the IRI, *Labeo capensis* (35%) and *Labeobarbus aeneus* (28%) were by far the most important species, and constituted together 63% of the total IRI. They were followed by *Mesobola brevianalis* (9.3%), *Oreochromis mossambicus* (7.5%) and *Clarias gariepinus* (7.4%). Each of the remaining species had an IRI of less than 3% (**appendix 3**). The vulnerable species, *Labeobarbus kimberleyensis*, was relatively common (2.1%), as was the red listed species, *Barbus hospes* (2.9%). *Oreochromis mossambicus* (7.5%) had the highest IRI of the two alien species in the system, while *Cyprinus carpio* had 0.3%.

A total of 914 kg of fish were caught during the surveys (**appendix 3**). *Labeo capensis* (285 kg, 31%) and *Labeobarbus aeneus* (273 kg, 30%) had the highest biomass, and together comprised 61% of the total biomass. *Clarias gariepinus* (19%), *Labeobarbus kimberleyensis* (7%) and *Oreochromis mossambicus* (5%) are relatively large species with high biomasses compared with the number of fish caught (**appendix 3**).

A total number of 17788 fish were caught during the surveys with multifilament gill nets and other types of gears (**appendix 3**). *Labeo capensis* was also the most numerous species and comprised 25% of all fish caught. The second most numerous was *Mesobola brevianalis* with 16% of all individuals, followed by *Labeobarbus aeneus* (14%) and the alien species *Oreochromis mossambicus* (11%). High numbers (7%) of the red listed species *Barbus hospes* were sampled, while very few individuals of the alien species *Cyprinus carpio* (n = 18, 0.1%) were sampled in the system.

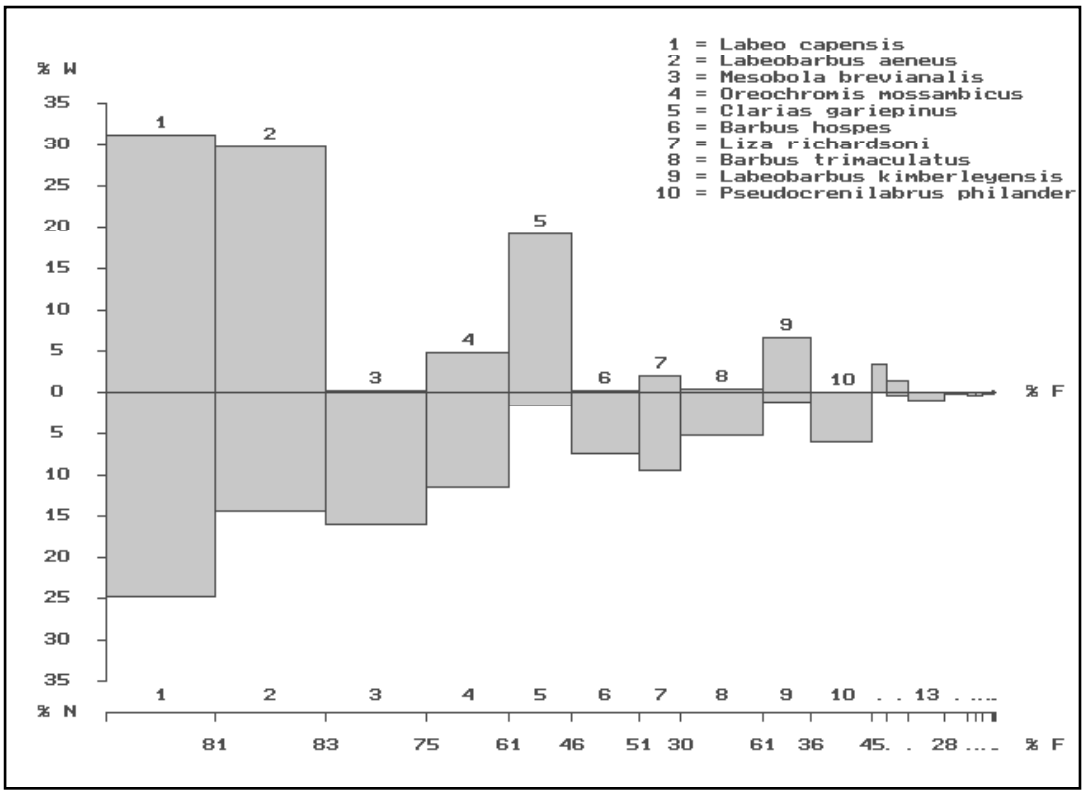


Figure 5.1
Index of relative importance (IRI) for the most important species caught in all gears combined, excluding monofilament gill nets, during surveys in the Lower Orange River during 1995 - 2001.

5.1.2 Catches in multifilament gill nets

Twenty percent (3644 fish) of the total catches were caught in multifilament gill nets (**table 3.4**). Among the 13 fish species caught, three were marine species, *Liza richardsoni, Mugil cephalus* and *Lichia amia*, and found in the estuary (**appendix 4**). The 13 species belonged to five families, with the Cyprinidae family represented by seven species, Cichildae and Mugelidae families with two species each and the remaining families with one species each (**appendix 4**).

As for all gears combined, the most important species in the multifilament gill nets, according to IRI, were *Labeobarbus aeneus* (53%) and *Labeo capensis* (37%) (**figure 5.2**, **appendix 4**). These two species comprised an IRI of 90%. These were followed by *Clarias gariepinus* (4%), *Labeobarbus kimberleyensis* (3%), *Oreochromis mossambicus* (2%) and *Barbus trimaculatus* (1%). The two alien species *Oreochromis mossambicus* (2.1%) and *Cyprinus carpio* (0.1%) only contributed to 2.2% of the total IRI of the gill net catches.

At family level, the Cyprinidae (IRI = 94%) was the most important family in the gill net catches (**appendix 4**). The second most important, the Clariidae, accounted for an IRI of only 4%, and the third most important family was the Cichlidae, accounting for 2%.

A total of 839 kg fish were caught in the multifilament gill nets, and 20% of the catch in numbers constituted 92% of the total biomass (**appendix 4**). The two most important species according to biomass, *Labeobarbus aeneus* and *Labeo capensis,* together made up more than half of the total biomass (63%) in the gill nets, being 268 kg and 262 kg, respectively. *Clarias gariepinus,* being the third most important species, constituted 18% of the total biomass, while the other species represented less than 7% of the biomass.

Labeobarbus aeneus was by far the most numerous species in the multifilament gill net catches and constituted 44% of the total catches, followed by *Labeo capensis* (25%) and *Barbus trimaculatus* (10%). *Oreochromis mossambicus* (8%) and *Labeobarbus kimberleyensis* (5%) were also important with respect to abundance (**appendix 4**). *Labeobarbus kimberleyensis*, a vulnerable species, was also important in the gill net catches, ranked as number four according to IRI.

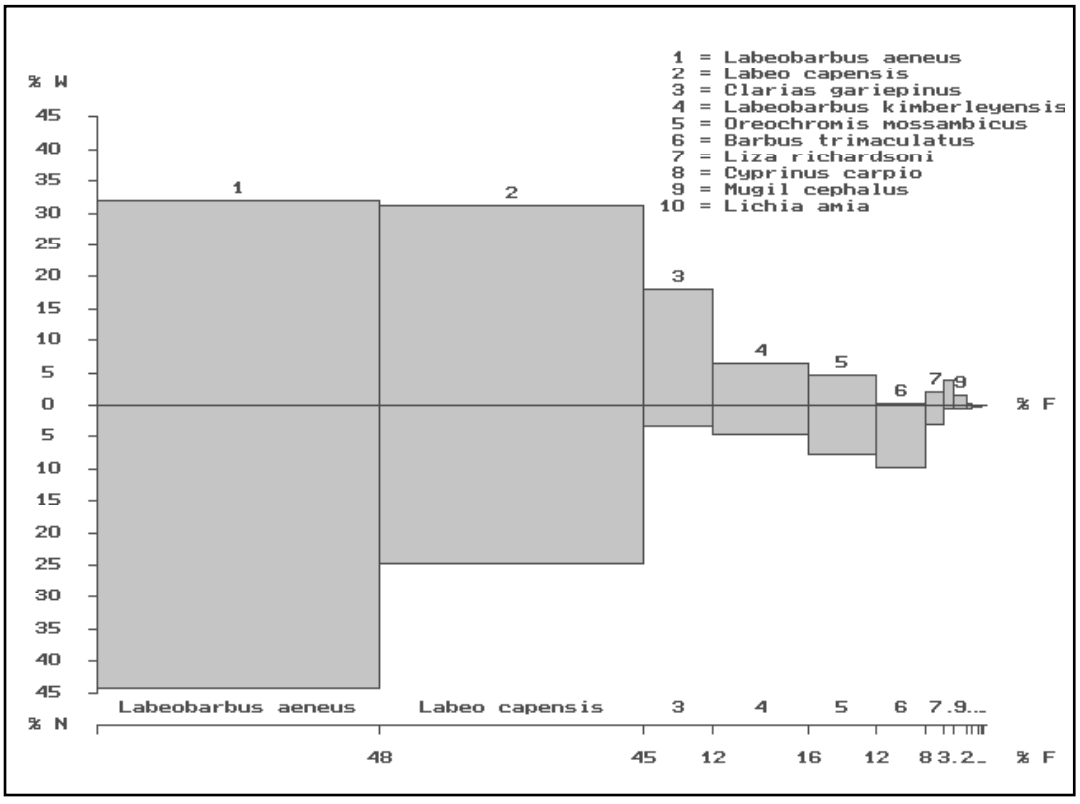


Figure 5.2
Index of relative importance (IRI) for the most important species caught by multifilament gill nets (22-150 mm) during surveys in the Lower Orange River during 1995 - 2001.

5.1.3 Catches in other gears than gill nets

The total catch, 14144 fish, in the other gears used in addition to gill nets, constituted 78% of the total number of fish caught during the fish surveys. Seventeen species from seven different families and one unidentified species (Marine sp.) were recorded in the catches with other gears (**appendix 5**). This is five more species than in the gill net catches. Three new families were represented in the catches with other gears that were not present in gill net catches. These were the Austroglandidae family (*Austroglanis sclateri*), the Atherinidae (*Atherina breviceps*) and the Gobiidae (unidentified species). The Carangidae family (*Lichia amia*) was only represented in the gill net catches.

According to the IRI, the most important species caught with other gears was *Labeo capensis* (41%), while *Mesobola brevianalis* (14%) was the second most important species. *Labeobarbus aeneus*, which was the most important species in the gill net catches, was only the fifth most important species in the catches with other gears (9%) (**appendix 5**, **figure 5.3**). *Labeobarbus kimberleyensis*, a vulnerable species, was not regularly sampled and had an IRI of only 1%. *Oreochromis mossambicus,* one of the alien species, was the third most important species according to IRI (10%). Only one individual of the alien species *Cyprinus carpio* was recorded using the other gears.

The family Cyprinidae was by far the most important family also in the catches with other gears, constituting an IRI of 73%. The Cichlidae was the second most important (14%), while the Clariidae was third most important (10%).

Only 75 kg of fish were caught by other gears during the surveys, which mean that 78% of the catches in numbers constituted 8% of the total biomass. This implies that a large number of small individuals dominated the catch by the other types of gears as opposed to the multifilament gill nets. Together, *Clarias gariepinus* (24 kg) and *Labeo capensis* (23 kg) constituted 64% of the total biomass. *Oreochromis mossambicus* was the third most important species with respect to biomass (9%) (**appendix 5**).

Labeo capensis was the most numerous species (3511 individuals) together with *Mesobola brevianalis* (2841 individuals), constituting 25 and 20% of the catches in

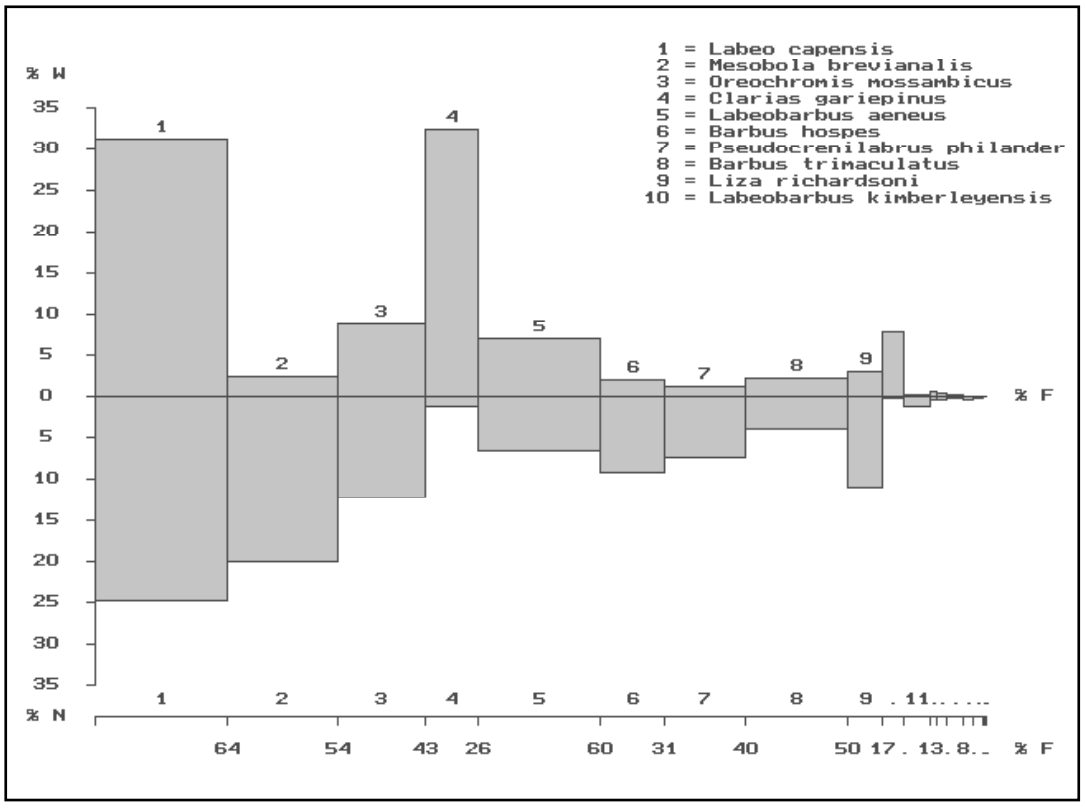


Figure 5.3
Index of relative importance (IRI) for the most important species caught by other gears than gill nets during surveys in the Lower Orange River during 1995 - 2001.

the other gears, respectively. *Oreochromis mossambicus, Liza richardsoni, Barbus hospes* and *Pseudocrenilabrus philander* were also important with respect to abundance, representing 12, 11, 9, and 7% of the total catches in numbers.

Species diversity and evenness

Several smaller species were only sampled in the other gears, resulting in a lower Shannon diversity index (*H'*) for the gill nets (1.6) compared to the other gears (2.1). The diversity index for all gears combined was also 2.1 (**table 5.1**). Also the evenness index differed between gear types. The species composition in the catches in other gears was more evenly distributed (0.73) than it was for catches in the multifilament gill nets (0.63) (**table 5.2**). The evenness index for all gears combined was similar to the index for other gears (**table 5.2**).

IUCN Red List species

Labeobarbus kimberleyensis is classified as near threatened and was considered the ninth most important species according to the IRI (2.1%) by all gear types at all stations (**appendix 3**). This species contributed more to the biomass (6.6%) than to abundance (1.2%). When considering only the multifilament gill nets, *Labeobarbus kimberleyensis*, was the fourth most important species (2.6%), but only the tenth most important species for the other gears used (**appendix 4** and **5**). In biomass, this species contributed more to the catches of the other gears (7.9%) than to the catches in multifilament gill nets (6.5%). This is reversed when considering the catches in numbers, being 4.5% in the gill nets and only 0.3% in the other gears.

Barbus hospes, which is classified as of least concern, is a small-sized species and contributed more in numbers (7.3%) than in biomass (0.2%) in the total catches in all gears (**appendix 3**). The species was recorded in the gill nets with only seven specimens, probably due to its small size (**appendix 4**). In the catches with the other gears, the contribution in number was 9.2% and biomass 2.0% (**appendix 5**).

Austroglanis sclateri, which is classified as of least concern, had a small contribution both in numbers (0.4%) and in biomass (0.1%) for catches in all gears at all the stations (**appendix 3**). The species was not recorded in the gill nets due to its small size (**appendix 4**). In the catches with the other gears, the contribution in number was 0.5% and biomass 0.7% (**appendix 5**).

Alien species

Oreochromis mossambicus was the fourth most important species (IRI of 7.5%) in all gear types, contributing to 11.4% of the abundance in number, but only 4.9% of

Table 5.1. *Bootstrap estimates of the Shannon's diversity index (H') for catches with multifilament gill nets and other gears during surveys in the Lower Orange River during 1995 - 2001.*

Catch composition	Mean	Min	Max	SE	95% confidence interval (mean ± 2*SE)
All gear	2.137	1.894	2.285	0.045	2.048 - 2.227
Other gear	2.086	1.870	2.235	0.051	1.984 - 2.189
Gill nets	1.608	1.428	1.732	0.037	1.534 - 1.683

Table 5.2. *Bootstrap estimates of the evenness index (J') for catches with multifilament gill nets and other gears during surveys in the Lower Orange River during 1995 - 2001.*

Catch composition	Mean	Min	Max	SE	95% confidence interval (mean ± 2*SE)
All gear	0.737	0.655	0.806	0.017	0.704 - 0.771
Other gear	0.733	0.647	0.790	0.020	0.692 - 0.774
Gill nets	0.630	0.575	0.687	0.015	0.599 - 0.661

the biomass (**appendix 3**). This species was the fifth most important in the gill net catches (2.1%) and the third most important in the catches in the other gear types (10.3%). In both gill net catches and in catches with other gears, this species was more important in number than in biomass (**appendix 4** and **5**).

Cyprinus carpio was not important in the catches with all gear types (0.3% total IRI), constituting only 0.1% in number and 3.5% in biomass (**appendix 3**). In the gill net catches, the species had an IRI of only 0.1%, with a higher contribution in biomass (3.8%) than in number (0.5%) (**appendix 4**). Only one individual was sampled using the other gear types (**appendix 5**).

5.2 Species diversity at the different stations

5.2.1 Catches in multifilament gill nets

Among the different stations surveyed with multifilament gill nets, the number of species caught varied between 4 and 11 species (**table 5.3**, **appendix 6** to **12**). Gill nets were used at 7 of the 10 stations (**figure 2.1**). Together, the two cyprinids *Labeobarbus aeneus* and *Labeo capensis* constituted between 70 and 94% of the total IRI at the respective stations. *Labeobarbus aeneus* was the most important species in the catches at the four lower stations, River Mouth, Off-Road Club, Daberas Pump Station and Sebrasfontein, with IRIs varying from 46 to 88%. *Labeo capensis* was the most important species in the upper parts of the survey area, at stations Grootpenseiland, Gariep Motors and Houms River, with IRIs varying from 44 to 71%. At the stations where *Labeobarbus aeneus* was the most important species, *Labeo capensis* was the second most important and vice versa, except at Daberas Pump Station where *Clarias gariepinus* was slightly more important than *Labeo capensis*.

The marine species *Mugil cephalus, Liza richardsoni* and *Lichia amia* were found at the two estuarine stations, i.e. at the River Mouth and at the Off-Road Club (**appendix 6** and **7**). At these two stations the three marine species comprised 0.6 to 7.3% of the catches in numbers, and 0.3 to 5.2% in biomass. Altogether, 8 freshwater species were caught in the estuary.

The species diversity, measured as the Shannon diversity index (H'), was significantly lower at the River Mouth Station in the estuary (H' = 0.82) than at the stations in the riverine environment, except for Daberas Pump Station (Bootstrap confidence intervals, **table 5.3**). At the River Mouth Station, eight species were caught, but *Labeobarbus aeneus* dominated in the catches (IRI of 88%).

The evenness index was similar for all the stations, except for the River Mouth station that had a significantly lower index (Bootstrap confidence intervals, **table 5.3**).

Table 5.3. *Bootstrap estimates of the Shannon index (H') and evenness index (J') (± standard error, SE), number of species and total number of fish caught in multifilament gill nets at the different stations during surveys in the Lower Orange River during 1995 - 2001.*

Station	H'	95% confidence interval (mean ± 2*SE)	J'	95% confidence interval (mean ± 2*SE)	Number of species	Number of fish
River Mouth	0.82	0.631 - 0.991	0.39	0.308 - 0.483	8	548
Off-Road Club	1.58	1.442 - 1.691	0.66	0.602 - 0.706	11	1475
Daberas Pump Station	0.97	0.703 - 1.160	0.70	0.524 - 0.866	4	63
Sebrasfontein	1.38	1.146 - 1.507	0.77	0.686 - 0.925	6	71
Grootpenseiland	1.51	1.373 - 1.595	0.69	0.633 - 0.781	9	553
Gariep Motors	1.50	1.378 - 1.581	0.65	0.603 - 0.737	10	596
Houms River	1.63	1.490 - 1.724	0.74	0.707 - 0.853	9	338
Total						**3644**

The total biomass of fish caught in the gill nets at the different stations varied between 32 kg (Sebrasfontain) and 309 kg (Off-Road Club) (**appendix 6** to **12**). At the majority of stations, *Labeobarbus aeneus, Labeo capensis* and *Clarias gariepinus* were among the three most important species with respect to biomass. The three species constituted between 70 and 98% of the catches in biomass, and at five of the stations they constituted more than 84% of the biomass. However, at Grootpenseiland *Labeobarbus kimberleyensis* (15%) was the third most important species and *Clarias gariepinus* (4%) the sixth most important species. Further, at Gariep Motors *Clarias gariepinus* (4%) was the fourth most important species, while *Oreochromis mossambicus* (10%) was the third most important. The River Mouth and the Gariep Motor stations were dominated by only one species, which was *Labeobarbus aeneus* (61%) and *Labeo capensis* (62%), respectively. The alien species *Oreochromis mossambicus* contributed a high percentage of the total biomass at Gariep Motors (10%), the Off-road Club (7%), and Grootpenseiland (5%). *Cyprinus carpio*, the other alien species, contributed to the total biomass at Grootpenseiland (9%) and the Off-road Club (7%). The vulnerable species *Labeobarbus kimberleyensis* had a high biomass contribution at Grootpenseiland (15%), Houms River (9%), Sebrasfountain (8%), and the Off-road Club (6%).

The total number of fish caught in the gill nets at the different stations varied between 63 (Daberas Pump Station) and 1475 individuals (Off-Road Club) (**appendix 6** to **12**). *Labeobarbus aeneus* and *Labeo capensis* were the two most numerous species at all stations except at Gariep Motors, where *Barbus trimaculatus* was the most numerous species. *Clarias gariepinus* was the third most numerous species at the River Mouth and the Daberas Pump Station, while *Oreochromis mossambicus* was the third most numerous at the Off-Road Club, *Labeobarbus kimberleyensis* at Sebrasfontain and Grootpenseiland and *Barbus trimaculatus* at Houms River.

IUCN Red List species

Labeobarbus kimberleyensis was not very important in the catches at any of the stations (**appendix 6** to **12**). It was slightly more important at the stations Off-road Club, Sebrasfontain, Grootpenseiland and Houms River. *Barbus hospes* was only recorded at Grootpenseiland, Gariep Motors and Houms River stations and in very low numbers. *Austroglanis sclateri* was not recorded in the gill nets.

Alien species

The contribution by the alien species was mainly by *Oreochromis mossambicus* at the stations Off-road Club, Grootpenseiland and Gariep Motors. It was important both in numbers and biomass. Only a few individuals of *Cyprinus carpio* were sampled, with the majority recorded at the Off-road Club station (**appendix 6** to **12**).

5.2.2 Catches in other gears than gill nets

Due to different habitats, different catch methods were used at the different stations (**table 3.4**). Furthermore, the fishing effort with different gears varied among stations. The results from other gears than gill nets might, therefore, rather give indications of which species that was present at the stations, than giving correct information of the relative abundance of the different species. Among the different stations, the number of species caught in the other gears varied between 7 and 14 species. According to the index of relative importance (IRI), the most important species also varied among stations (**appendix 13** to **22**).

Furthest down in the estuary, at the River Mouth (n = 2445 fish), the marine species *Liza richardsoni* constituted 75% of the total IRI, made up 47% of the biomass and was the most numerous species (63%) (**appendix 13**). *Labeobarbus aeneus* was the second most important species with respect to IRI (10%). Eight species comprised less than 1% of the total IRI, including four marine species, which were *Mugil cephalus, Atherina breviceps,* one Gobiidae, and one small, unidentified marine species (**appendix 13**). The alien species (*Oreochromis mossambicus*) comprised 2% of the IRI, and the Red List species (*Barbus hospes*) comprised only 0.01%.

At the Off-Road Club (n = 106 fish), the large species *Labeobarbus kimberleyensis* was the most important species according to IRI (30%) and biomass (53%), but only three individuals were caught (3%) (**appendix 14**). *Oreochromis mossambicus* was the most numerous species at this station (26%).

At the Hohenfels (n = 292), *Barbus hospes,* a near threatened species, and *Labeobarbus aeneus* were the most important species according to IRI, constituting 32 and 31%, respectively (**appendix 15**). *Barbus hospes* was also the most numerous species (38%)

and had the second largest biomass (22%). The individuals of *Labeobarbus aeneus* were large, and it was the most important species with respect to biomass (33%). This species, however, only constituted 9% of the catch in numbers. *Oreochromis mossambicus* was not very important, with an IRI of only 2%.

At the Daberas Pump Station (n = 1093), *Labeo capensis* and *Clarias gariepinus* were the most important species according to IRI, constituting 33 and 32%, respectively (**appendix 16**). *Labeo capensis,* being a smaller species, constituted 41% of the catch in numbers, while the larger *Clarias gariepinus* constituted 72% of the biomass. At this station, also large numbers of *Mesobola brevianalis* were caught, constituting 25% of the total catch in numbers. When considering the alien species, *Oreochromis mossambicus* made up only 2% of the total IRI and *Cyprinus carpio* only 0.01%. The Red List species, *Barbus hospes,* however, was numerous with 13% of the abundance, whereas only four individuals of *Labeobarbus kimberleyensis* were recorded at this station.

At the Sendelingsdrif (n = 263), only relatively small individuals were caught in the other gears, and the total biomass of the fish was only 0.89 kg. *Mesobola brevianalis* had the highest index of relative importance (62%) due to large numbers caught, constituting 80% of the total catch (**appendix 17**). *Oreochromis mossambicus* was the most important species with regard to biomass (47%), but only four individuals were caught. Neither the alien nor the Red List species were recorded in any significant numbers.

At Sebrasfontain (n = 2264), Grootpenseiland (n = 2477) and Sambok River (n = 1652), *Labeo capensis* was the most important species at all the stations, both with respect to index of relative importance (IRI of 60, 55, and 70%, respectively), biomass (52, 44, and 79%), and number fish caught (37, 41, and 42%) (**appendix 18**, **19**, and **20**). In addition, with regard to numbers, *Mesobola brevianalis* (28%) and *Barbus hospes* (22%) were important at Sebrasfontain, *Barbus hospes* (14%) and *Labeobarbus aeneus* (11%) at Grootpenseiland, and *Pseudocrenilabrus philander* (19%), *Labeobarbus aeneus* (14%), and *Oreochromis mossambicus* (13%) at Sambok River. With regard to biomass, *Clarias gariepinus* (22%) was important at Sebrasfontain, and *Clarias gariepinus* (21%) and *Labeobarbus aeneus* (10%) at Grootpenseiland. The alien species *Oreochromis mossambicus* was considered the sixth most important species at Sebrasfontain station, fourth at Grootpenseiland and fifth at Sambok River station. The other alien species, *Cyprinus carpio*, was not found at any of these stations. The Red List species *Barbus hospes*, was the third most important species at Sebrasfontain, fifth at Grootpenseiland, while only 17 individuals were caught at Sambok River. *Labeobarbus kimberleyensis* was recorded at all these three stations, but in low numbers.

At Gariep Motors (n = 2064) and Houms River (n = 1488), the alien species *Oreochromis mossambicus* was the most important species both with respect to index of relative importance (35 and 37%, respectively), number of fish caught (33% and 30%) and biomass (30% and 30%), except for the biomass of *Clarias gariepinus* (35%) being largest at Houms River (**appendix 21** and **22**). In addition, with regard to numbers at both stations, *Mesobola brevianalis* (29% and 28%, respectively), *Pseudocrenilabrus philander* (12% and 22%) and *Labeo capensis* (11% and 7%) were the second, third and forth most important species. With regard to biomass, *Barbus trimaculatus* (22%) and *Labeo capensis* (18%) were also important at Gariep Motors, and *Clarias gariepinus* (35%) at Houms River. The Red List species *Barbus hospes* contributed to 2% of the IRI at Gariep Motors and 0.7% at Houms River. *Labeobarbus kimberleyensis* was only recorded at Houms River, with a total number of 17 individuals caught.

IUCN Red List species

Barbus hospes was collected at eight of the ten stations, being important according to IRI at four of them (**appendix 13** to **22**). These were Hohenfels (32%), Sebrasfontain (10%), Daberas pump (5%), and Grootpenseiland stations (5%). This species was mainly important in numbers, and biomass was only important at Hohenfels. *Labeobarbus kimberleyensis* was recorded at six of the ten stations (**appendix 13** to **22**). It was only important at the Off-Road Club, with an IRI of 29%. This importance was due to biomass contribution. *Austroglanis sclateri* was recorded in low numbers, and only at Grootpenseiland, Sambok River and Houms River stations.

Alien species

Oreochromis mossambicus was considered important at the stations Sendelingsdrif, Grootpenseiland, Gariep Motors and Houms River. It was the most important species at the two latter stations, both in number and biomass, except at Houms River, where it was the second most important in biomass. *Cyprinus carpio* was

not important in the catches with the other gears, as only one individual was recorded at Daberas Pump Station (**appendix 13** to **22**).

5.3 Species diversity in the estuary versus the river

5.3.1 Catches in all gears

When combining the catches from multifilament gill nets and other gears, all together 18 species, when including the one Gobiidae and one unidentified small marine species, were caught at the two lower stations (n = 4574 fish). The most important species caught at the two lower stations, according to the index of relative importance, was the riverine species *Labeobarbus aeneus* (IRI = 39%), constituting 27% of the catches in numbers and 41% of the biomass (**appendix 23**). The estuarine/marine species caught were *Liza richardzoni*, *Mugil cephalus, Atherina breviceps*, *Lichia amia*, one Gobiidae and one unidentified species. In the total catch, *Liza richardzoni* was caught in largest numbers (36%) and was the second most important species in the estuary (IRI = 28%). The other mullet, *Mugil cephalus*, constituted approximately 2% of the total IRI, while the remaining of the estuarine/marine species constituted less than 0.2%. The alien species *Oreochromis mossambicus* was the fourth most important species in the estuary, with a similar contribution for both numbers (6%) and biomass (5%). *Cyprinus carpio* constituted 0.5% of the total IRI with 11 individuals recorded. The Red List species were low on the IRI list with *Labeobarbus kimberleyensis* having a percentage of 1% and *Barbus hospes* of 0.01% in the estuary. *Labeobarbus kimberleyensis* contributed slightly more in biomass (5%) than in numbers (1%).

In the riverine environment, i.e. the stations above the estuary and Ramsar area, from Hohensfels to Houms River, altogether 13 species were caught in all gears combined (n = 13214 fish). The most important species caught, according to the index of relative importance, was *Labeo capensis* (IRI = 42%), constituting 30% of the catches in numbers and 42% of the biomass (**appendix 24**). *Labeobarbus aeneus* was the second most important species (16%), representing 10% of the catches in numbers and 18% of the biomass. In addition, *Mesobola brevianalis* and *Oreochromis mossambicus* were caught in relatively large numbers, being 19 and 13% of the total catch, respectively. In addition, *Clarias gariepinus* was the second most important species with regard to biomass (22%). The alien species *Oreochromis mossambicus* was the fifth most important species caught in the riverine environment, with abundance in numbers being the important contributing factor (**appendix 24**). Only seven individuals of *Cyprinus carpio* were recorded. Both Red List species were recorded. *Barbus hospes* constituted 10% of the total number recorded, but only 0.3% of the biomass. *Labeobarbus kimberleyensis* constituted 1% in numbers and 8% in biomass.

Alien species

Oreochromis mossambicus was listed as the fourth most important species in the estuary and fifth most important in the river (IRI being 4% and 8%, respectively), but the IRI, number of individuals and biomass was higher in the river than in the estuary (**appendix 23** and **24**). *Cyprinus carpio* contributed to only 0.2% of the IRI in the river and 0.5% in the estuary.

IUCN Red List species

Labeobarbus kimberleyensis contributed less than 3% of the total IRI both in the estuary and in the river (**appendix 23** and **24**). The contribution was more important in biomass than in number. *Barbus hospes* was mainly caught in the river (n = 1302), while only a few were sampled in the estuary (n = 3). *Austroglanis sclateri* was only recorded in the river, and not in the estuary.

5.3.2 Species diversity and evenness

Eleven species were caught in the gill nets in the estuarine area and 10 in the river (**table 5.4**). The species diversity for the gill net catches was slightly lower in the estuary (H' = 1.43) than in the river (H' = 1.60), but no significant difference was observed (Bootstrap confidence intervals, $p > 0.05$). The species diversity for the other gears in the estuary (H' = 1.43) was not different from the diversity in the river (H' = 1.90) (Bootstrap confidence intervals, $p > 0.05$).

Table 5.4. *Bootstrap estimates of the Shannon index (H') and Evenness index (J') for fish caught in multifilament gill nets and other gears than gill nets at the estuarine river mouth area (River Mouth and Off-Road Club stations) and the river (Hohenfels, Daberas Pump, Sendelingsdrif, Sebrasfontain, Grootpenseiland, Sambok River, Gariep Motors and Houms River stations) during surveys in the Lower Orange River during 1995 - 2001.*

Gear type	Area of the river	H'	95% confidence interval (mean ± 2*SE)	J'	95% confidence interval (mean ± 2*SE)	Number of species	Number of fish
Multifilament gill net	Estuary	1.43	1.295 - 1.555	0.60	0.540 - 0.649	11	2023
	River	1.60	1.539 - 1.650	0.70	0.666 - 0.730	10	1621
Other gears	Estuary	1.43	0.984 - 1.869	0.53	0.365 - 0.700	16	2551
	River	1.90	1.790 - 2.003	0.75	0.701 - 0.796	13	11593
Total							17788

5.4 Body length distributions and gill net selectivity

5.4.1 Body length distribution in multifilament gill nets and other gears

The body length distribution was significantly different between fish caught with gill nets and with other gears, as a wider range of body length classes were caught in the gill nets (Kolmogorov- Smirnov two-sample test, $Z = 40.7$, $p < 0.001$). Fish with body lengths from 4 to 96 cm were caught in the gill nets, whereas fish with body lengths from 1 to 83 cm were caught with the other gears (**figure 5.4**). The mean body length was also larger for fish caught with gill nets (21.4 cm) than with the other gears (5.8 cm) (ANOVA, $F = 11406$, df = 1, $p < 0.001$). The length distribution for the catches in the gill nets was bimodal with a lower peak around 8-9 cm (**figure 5.4**). Modal length was 8.0-8.9 in the gill net catches. Modal length for the other gears was 4.0-4.9 cm (**figure 5.4**).

5.4.2 Body length at maturity

The minimum body length at maturity, and length at which 50% of the fish were mature, varied considerably among species (**table 5.5**). With the reservation that few or no mature individuals were caught for some of the species, the species with the smallest size at maturity were *Mesobola brevianalis* (minimum lengths

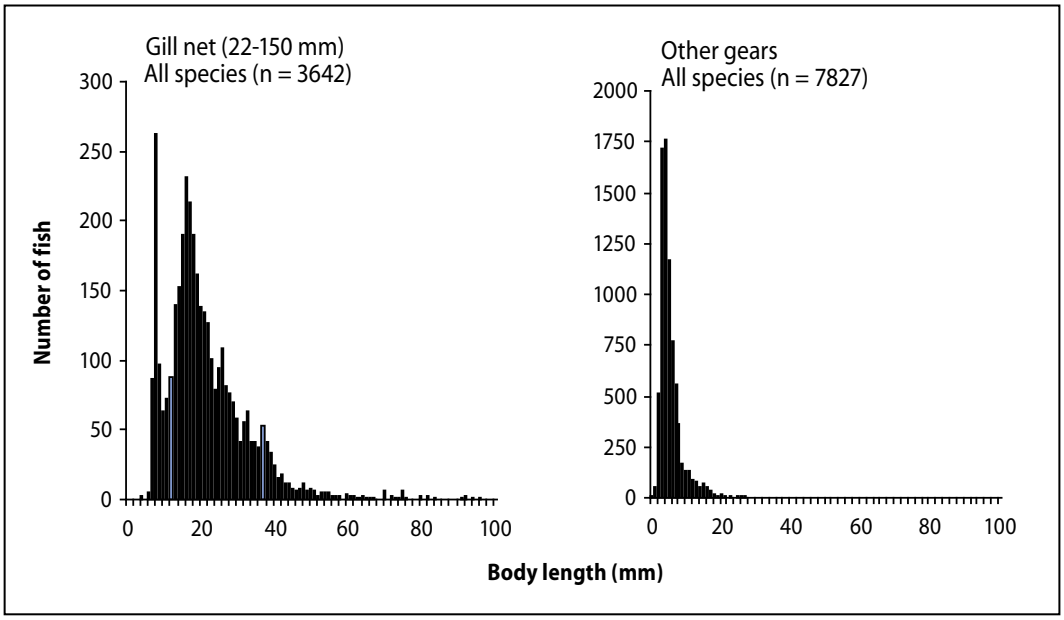


Figure 5.4
Length distribution of all fish caught with gillnets (22-150 mm mesh size) and other gears during surveys in the Lower Orange River during 1995 - 2001.

Table 5.5. *Minimum length of mature fish and length at which 50% of the fish caught were mature during surveys (multifilament gill nets, monofilament gill nets and other gears) in the Lower Orange River during 1995 - 2001. Minimum length at maturity for gill net catches is given in parenthesis. n = number of fish.*

Species	Minimum length at maturation						Length at 50% maturation	
	Males			Females			Males	Females
	cm		n	cm		n	cm	cm
Cyprinidae								
Labeobarbus aeneus	10	(10)	411	17	(17)	525	19.0	24.5
Labeo capensis	16	(16)	165	19	(19)	412	24.0	28.0
Mesobola brevianalis	3	(-)	11	3	(-)	41	-	-
Labeobarbus kimberleyensis	22	(25)	51	20	(40)	63	-	-
Barbus trimaculatus	5	(6)	165	5	(7)	363	5.8	5.9
Barbus hospes	3	(-)	65	4	(8)	104	4.5	5.2
Cyprinus carpio	38	(38)	9	25	(25)	8	-	-
Barbus paludinosus	-	(-)	1	5	(-)	5	-	-
Cichlidae								
Oreochromis mossambicus	13	(14)	136	12	(12)	113	12.4	15.4
Pseudocrenilabrus philander	4	(-)	35	4	(-)	30	-	-
Tilapia sparrmanii	6	(10)	9	6	(10)	4	-	-
Austroglanididae								
Austroglanis sclateri	8	(-)	19	6	(-)	15	8.6	-
Atherinidae								
Atherina breviceps	-	(-)	0	-	(-)	0	-	-
Clariidae								
Clarias gariepinus	37	(45)	66	37	(37)	86	-	-
Mugilidae								
Liza richardsoni	19	(19)	10	17	(17)	63	-	-
Mugil cephalus	31	(31)	5	32	(32)	11	-	-
Gobiidae								
Gobiidae sp.	-	(-)	0	-	(-)	0	-	-
Carangidae								
Lichia amia	-	(-)	0	25	(25)	2	-	-
Marine sp.	-	(-)	0	-	(-)	0	-	-

at maturity of 3 cm for both males and females) and *Barbus hospes* (minimum lengths at maturity of 3 cm for males and 4 cm for females). The species with the largest size at maturity were *Cyprinus carpio* (minimum lengths at maturity of 38 cm for males and of 25 cm for females) and *Clarias gariepinus* (minimum lengths at maturity of 37 cm for both males and females).

5.4.3 Life history and gill net selectivity

Of the 19 species caught in the fish surveys (all gear types), 13 species were caught in multifilament gill nets (**appendix 3** and **4**). The six species not caught in the multifilament gill nets were *Mesobola brevianalis, Pseudocrenilabrus philander*, *Austroglanis sclateri*, *Atherina breviceps,* an unidentified marine species, and one species of the family Gobidae. All these species were small, with mean sizes varying between 3.5 and 10.0 cm (**appendix 2**). *Lichia amia* was the only species only caught in gill nets and not in the other gears (**appendix 4** and **5**). The species in the Lower Orange River represent a large variation in biology, distribution and sizes. Aspects of their life history and gill net selectivity are analysed in detail for each of the species in the following section.

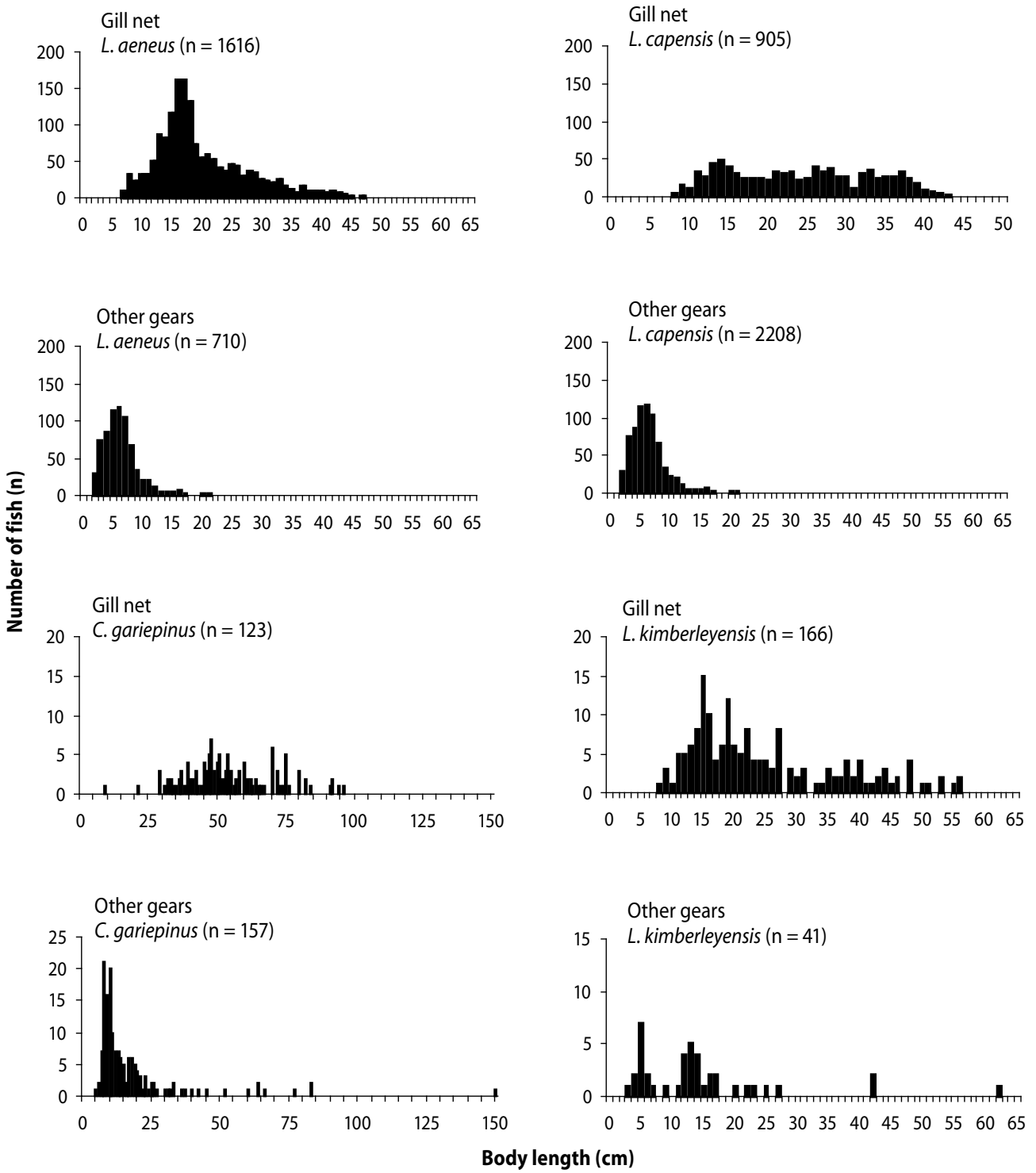


Figure 5.5. *Length distribution of* Labeobarbus aeneus, Labeo capensis, Barbus trimaculatus, Oreochromis mossambicus, Labeobarbus kimberleyensis, Clarias gariepinus, Liza richardsoni, Mugil cephalus, Lichia amia, Cyprinus carpio, Mesobola brevianalis, Barbus hospes *and* Pseudocrenilabrus philander *caught with multifilament gill nets (22-150 mm) and with other gears than gill nets in the Lower Orange River during 1995 - 2001. Note the different scales on the x- and y-axes. The figure continues on the next pages.*

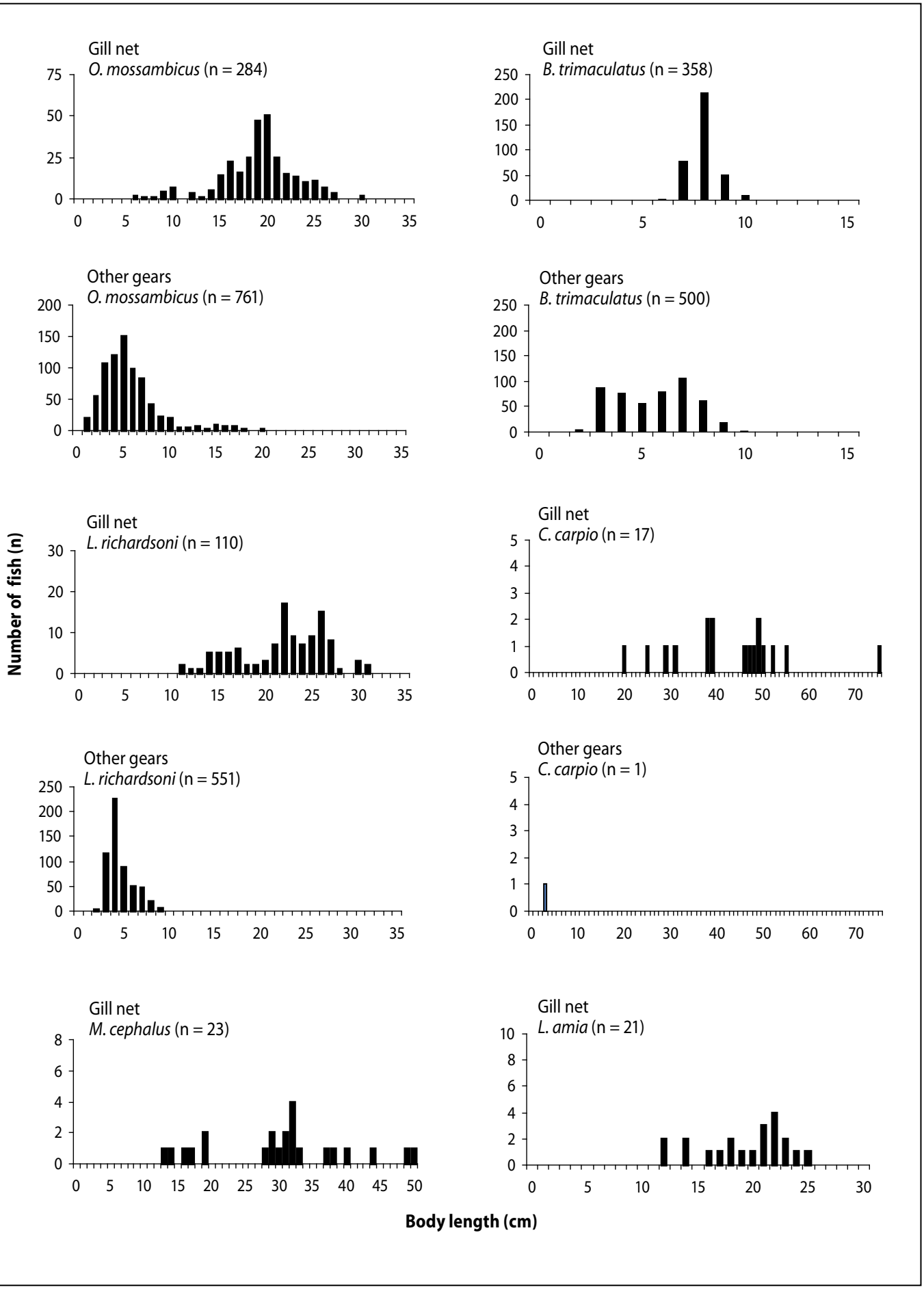


Figure 5.5. *Continued.*

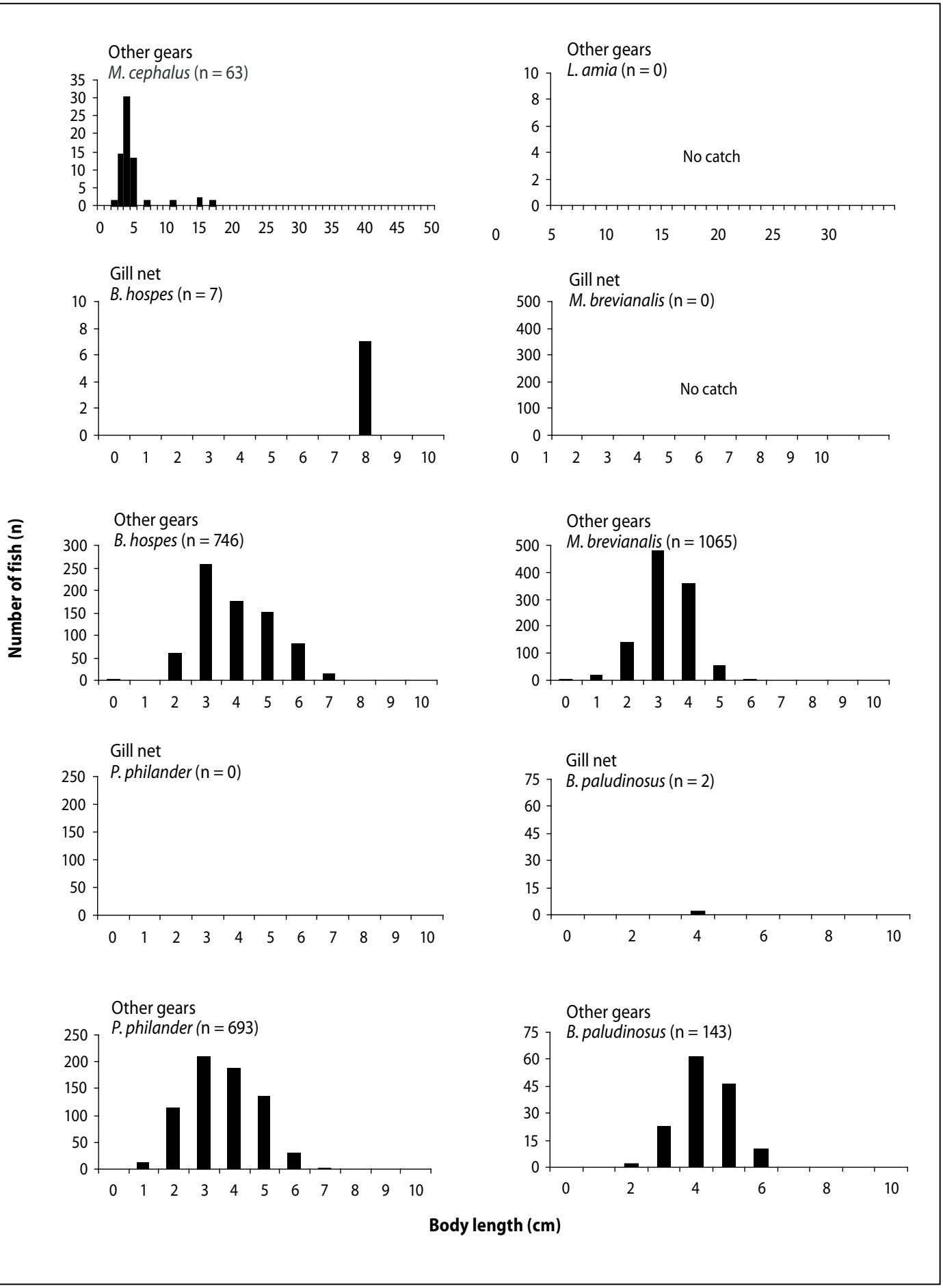


Figure 5.5. *Continued.*

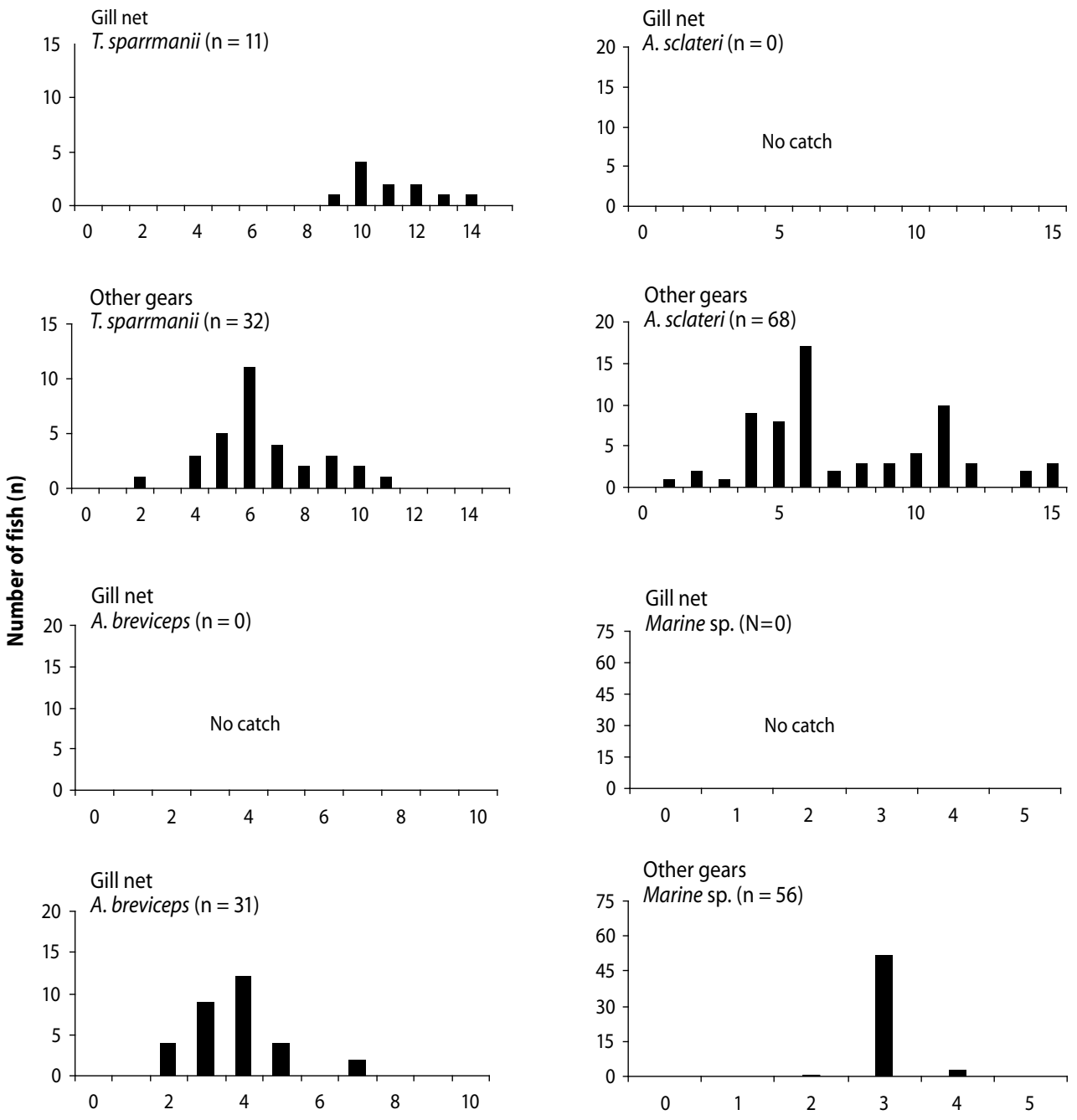


Figure 5.5. *Continued.*

Labeo capensis (Orange River mudfish): Overall IRI = 35%

Labeo capensis was the most important fish in the pooled total catches in multifilament gill nets and other gears with regard to numbers (n = 4416, 25% of total catch), the second most important species in the gill net catches (IRI = 37%), and the most important species in the catches with other gears (IRI = 41%) (**appendix 3**, **4** and **5**). The minimum body length of mature fish was 16 cm for males and 19 cm for females (**table 5.5**). The length at 50% maturity was 24 cm and 28 cm for males and females, respectively.

A total of 905 individuals were caught in gill nets, with body lengths from 5 to 46 cm (mean 24.3 cm, modal length 14.0 - 14.9 cm) (**figure 5.5**). A total of 3511 individuals were caught in the other gears, of which 2208 were length measured. Their body lengths varied from 1 to 32 cm (mean 6.8 cm, modal length 4.0 - 4.9 cm).

Labeo capensis was caught in all mesh sizes used (22 - 150 mm). The 73 mm mesh size had the highest catch in terms of number of fish per setting (7.04 fish/setting) (**table 5.6**). Fish caught with this mesh size had an average body length of 29.7 cm. The 93 mm mesh size had the highest catch in terms of biomass per setting (3.04 kg/setting). Fish caught with this mesh size had an average body length of 35.5 cm.

Table 5.6. *Gill net selectivity for* Labeo capensis *caught during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Number of fish caught (n), mean length of 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	23	9.3	0.78	0.01
28	88	12.5	2.99	0.09
35	145	15.3	4.93	0.26
45	116	19.6	3.95	0.42
57	154	24.6	5.24	1.15
73	207	29.7	7.04	2.70
93	134	35.5	4.56	3.04
118	35	38.7	1.19	1.09
150	3	41.7	0.10	0.14
All mesh sizes	**905**	**24.3**	**3.42**	**0.99**

In the survey with multifilament gill nets, the size group of *Labeo capensis* most efficiently caught was fish with body lengths between 10 and 46 cm. They were caught in gill net mesh sizes from 22 to 118 mm (**figure 5.6**).

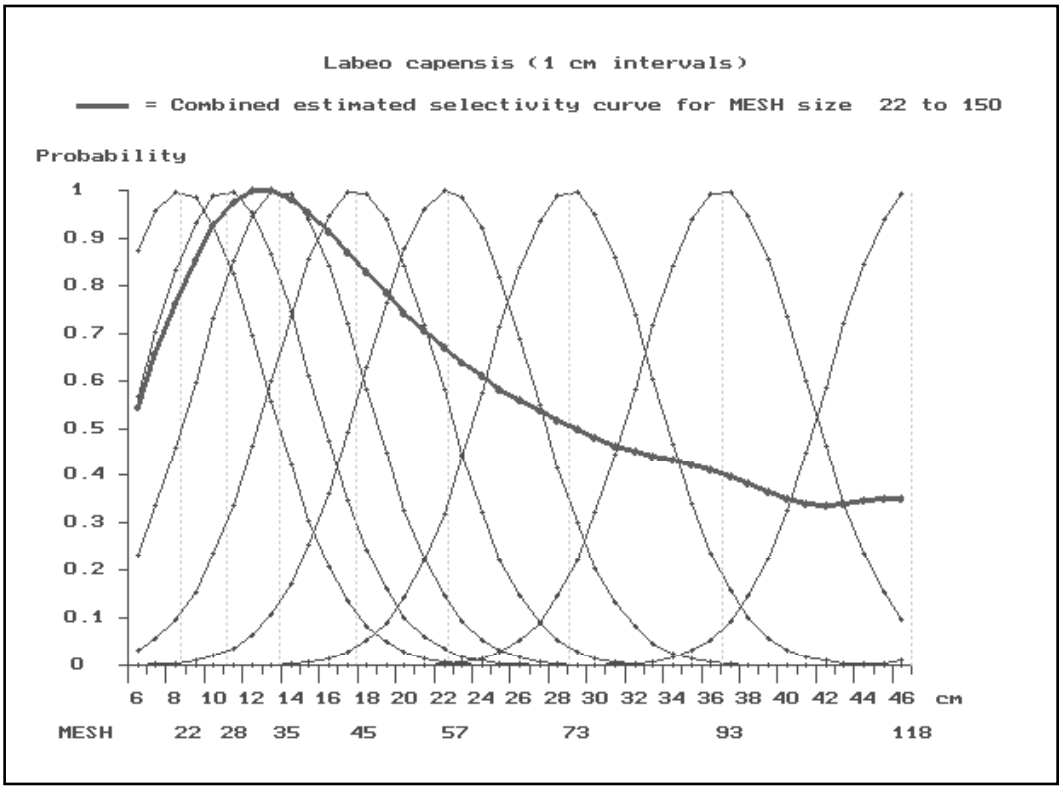


Figure 5.6
Gill net selectivity for Labeo capensis *for different mesh sizes from 22 mm to 150 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thick line).*

Labeobarbus aeneus (Vaal-Orange smallmouth yellowfish): Overall IRI = 28%

Labeobarbus aeneus was the third most important species in the pooled total catches in multifilament gill nets and the other gears with regard to numbers (n = 2564, 14% of total catch), the most important species in the multifilament gill net catches (IRI = 53%), and the fifth most important in the catches with other gears (IRI = 9%) (**appendix 3**, **4** and **5**). The minimum body length at maturity was 16 cm for males and 17 cm for females (**table 5.5**). The length at 50% maturity was 29.7 cm for males and 26.7 cm for females.

A total of 1616 individuals were caught in multifilament gill nets, with body lengths from 7 to 64 cm (mean 20.1 cm, modal length 16.0 - 16.9 cm) (**figure 5.5**). Few fish larger than 44 cm were caught in the gill nets. A total of 948 individuals were caught in the other gears than gill nets, of which 710 were length measured. The body lengths of these fish were between 2 and 30 cm, with a modal length of 6.0 cm (mean length 6.7 cm).

Labeobarbus aeneus was caught in all mesh sizes (22 - 150 mm), but the 45 mm mesh size had the highest catch in terms of number of fish per setting (15.30 fish/setting) (**table 5.7**). Fish caught with this mesh size (n = 450 fish) had an average body length of 17.9 cm. The 73 mm mesh size had the highest catch in terms of biomass per setting (n = 187 fish; 2.48 kg/setting). Fish caught with this mesh size had an average body length of 30.3 cm.

Table 5.7. *Gill net selectivity for* Labeobarbus aeneus *caught during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Number of fish caught (n), mean length of 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	74	10.0	2.52	0.06
28	132	12.4	4.49	0.16
35	395	15.4	13.44	0.68
45	450	17.9	15.31	1.20
57	284	23.8	9.66	1.87
73	187	30.3	6.36	2.48
93	72	36.6	2.45	1.80
118	20	40.6	0.68	0.71
150	2	51.5	0.07	0.15
All mesh sizes	**1616**	**20.1**	**6.1**	**1.01**

In the surveys with multifilament gill nets, the size group of *Labeobarbus aeneus* most efficiently caught was fish with body lengths between 10 and 57 cm. They were caught in gill net mesh sizes from 22 to 118/150 mm (**figure 5.7**).

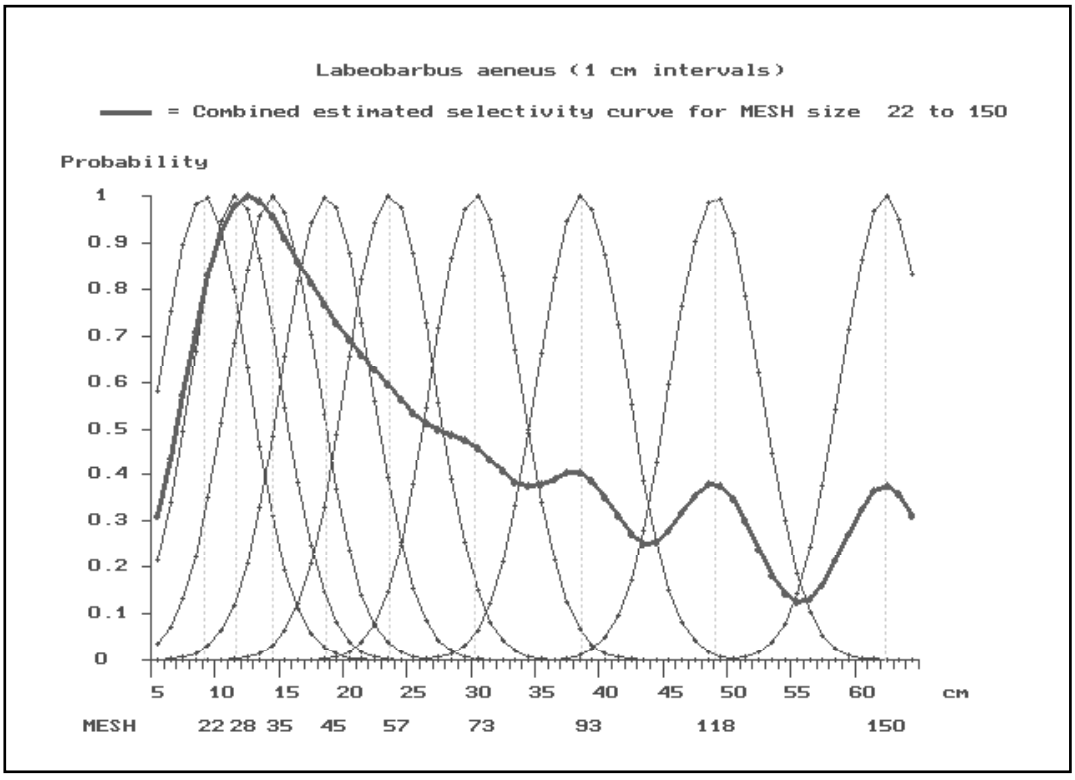


Figure 5.7
Gill net selectivity for Labeobarbus aeneus *for different mesh sizes from 22 mm to 150 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thick line).*

Mesobola brevianalis (River sardine):
Overall IRI = 9%

Mesobola brevianalis was the third most important species in the pooled total catches with an IRI of 9%. No individuals were caught using the multifilament gill nets, but it was the second most important species in the catches with other gears, with an IRI of 14%. The contribution was mainly due to the number of fish sampled (n = 2841, 20%), constituting only 2% of the biomass (**appendix 3**, **4 and 5**). The minimum length at maturity was 3.0 cm both for males and females (**table 5.5**). The 50% maturity length was 3.8 cm for females, but could not be calculated for the males.

Mesobola brevianalis was not recorded in the multifilament gill nets, and no selectivity analysis was done for this species.

Seine netting (other gears) at Gariep Motors in the Lower Orange River. Photo: Clinton J. Hay

Oreochromis mossambicus (Mozambique tilapia): Overall IRI = 8%

Oreochromis mossambicus was the forth most important species with regard to numbers in the pooled total catches in multifilament gill nets and the other gears (n = 2019, 11% of total catch), the fifth most important species in the gill net catches (IRI = 2%), and the third most important in the catches with other gears (IRI = 10%) (**appendix 3**, **4** and **5**). The minimum body length of mature fish was 13.0 cm for males and 12.0 cm for females (**table 5.5**). The length at 50% maturity was 15.9 cm for males and 18.9 cm for females.

A total of 284 individuals were caught in gill nets, with body lengths from 6 to 30 cm (mean 19.2 cm, modal length 20.0 - 20.9 cm) (**figure 5.5**). A total of 1735 individuals were caught in the other gears, of which 761 were length measured. Their body lengths varied from 1 to 21 cm (mean 5.9 cm, modal length 5.0 - 5.9 cm) (**figure 5.5**).

Oreochromis mossambicus was caught in mesh sizes from 22 to 93 mm. The 73 mm mesh size had the highest catch in terms of number of fish per setting (5.31 fish/setting) (**table 5.8**). Fish caught with this mesh size had an average body length of 20.2 cm. The 73 mm mesh size also had the highest catch in terms of biomass per setting (0.75 kg/setting).

Table 5.8. *Gill net selectivity for* Oreochromis mossambicus *caught during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Number of fish caught (n), mean length of 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	4	8.0	0.14	0.001
28	4	11.5	0.14	0.004
35	16	12.9	0.54	0.027
45	11	16.4	0.37	0.031
57	61	17.2	2.07	0.190
73	156	20.2	5.31	0.751
93	32	24.8	1.09	0.280
All mesh sizes	**284**	**19.2**	**1.07**	**0.140**

In the survey with multifilament gill nets, the size group of *Oreochromis mossambicus* most efficiently caught was fish with body lengths between 7 and 25 cm. They were caught in gill net mesh sizes from 22 to 73/93 mm (**figure 5.8**).

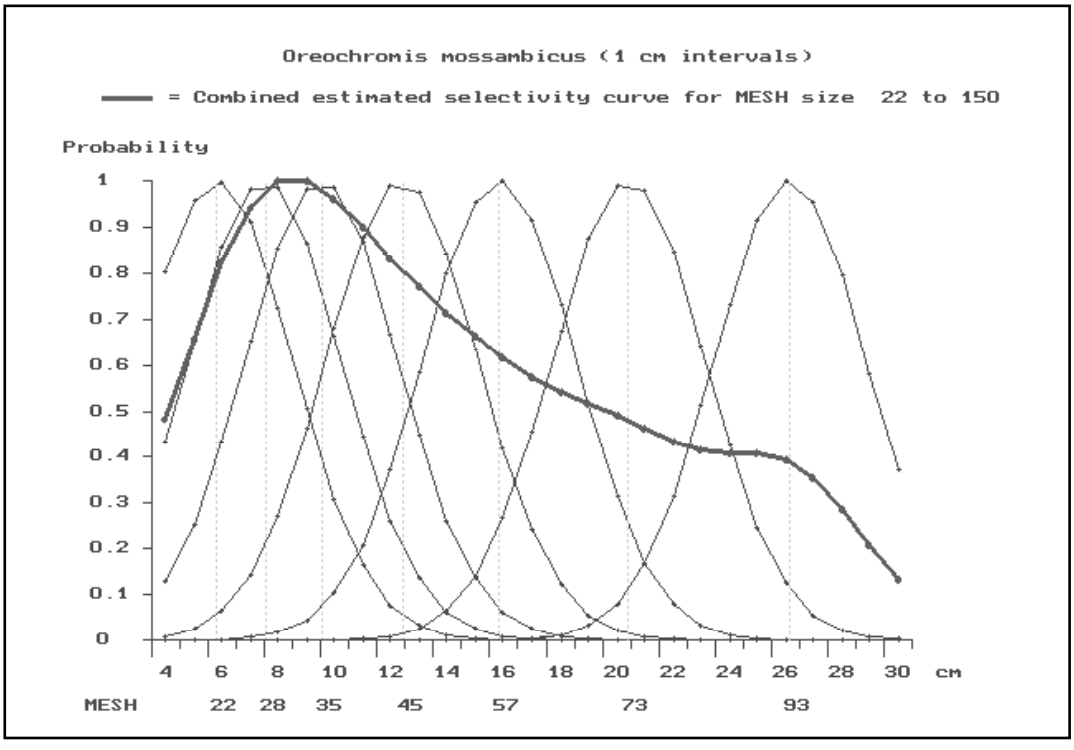


Figure 5.8
Gill net selectivity for Oreochromis mossambicus *for different mesh sizes from 22 mm to 150 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thick line).*

Clarias gariepinus (Sharptooth catfish):
Overall IRI = 7%

Clarias gariepinus was the ninth most important fish in the pooled total catches in multifilament gill nets and the other gears with regard to numbers (n = 286, 2% of total catch), the third most important species in the gill net catches (IRI = 4%), and the fourth most important in the catches with other gears (IRI = 10%) (**appendix 3**, **4** and **5**). The minimum body length of mature fish was 37.0 cm for both males and females (**table 5.5**). The length at 50% maturity was 48.0 cm for females, but could not be determined for males.

A total of 123 individuals were caught in gill nets, with body lengths from 9 to 96 cm (mean 54.5 cm, modal length 48.0 - 48.9 cm) (**figure 5.5**). Both the mean and modal lengths in the gill net catches were longer than the minimum size at maturity (37.0 cm) (**table 5.5**). A total of 163 individuals were caught in the other gears, of which 157 were length measured. Their body lengths varied from 5 to 150 cm (mean 18.0 cm, modal length 8.0 - 8.9 cm) (**figure 5.5**). However, no fish with body length between 83 and 150 cm were caught with the other gears, and only one fish with body length 150 cm was caught.

Clarias gariepinus was caught in mesh sizes between 35 and 150 mm (**table 5.9**). The 93 mm mesh size had the highest catch in terms of number of fish per setting (1.29 fish/setting). Fish caught with this mesh size had an average body length of 50.9 cm. The 150 mm mesh size had the highest catch in terms of biomass per setting (2.29 kg/setting). Fish caught with this mesh size had an average body length of 73.8 cm.

In the survey with multifilament gill nets, the size group of *Clarias gariepinus* most efficiently caught was fish with body lengths between 19 and 72 cm. They were caught in gill net mesh sizes from 45 to 150 mm (**figure 5.9**).

Table 5.9. *Gill net selectivity for* Clarias gariepinus *caught during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Number of fish caught (n), mean length of 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)
35	1	21.0	0.03	0.00
45	1	33.0	0.03	0.01
57	11	37.5	0.37	0.07
73	24	43.5	0.82	0.45
93	38	50.9	1.29	1.20
118	23	61.4	0.78	1.12
150	25	73.8	0.85	2.29
All mesh sizes	**123**	**54.5**	**0.46**	**0.57**

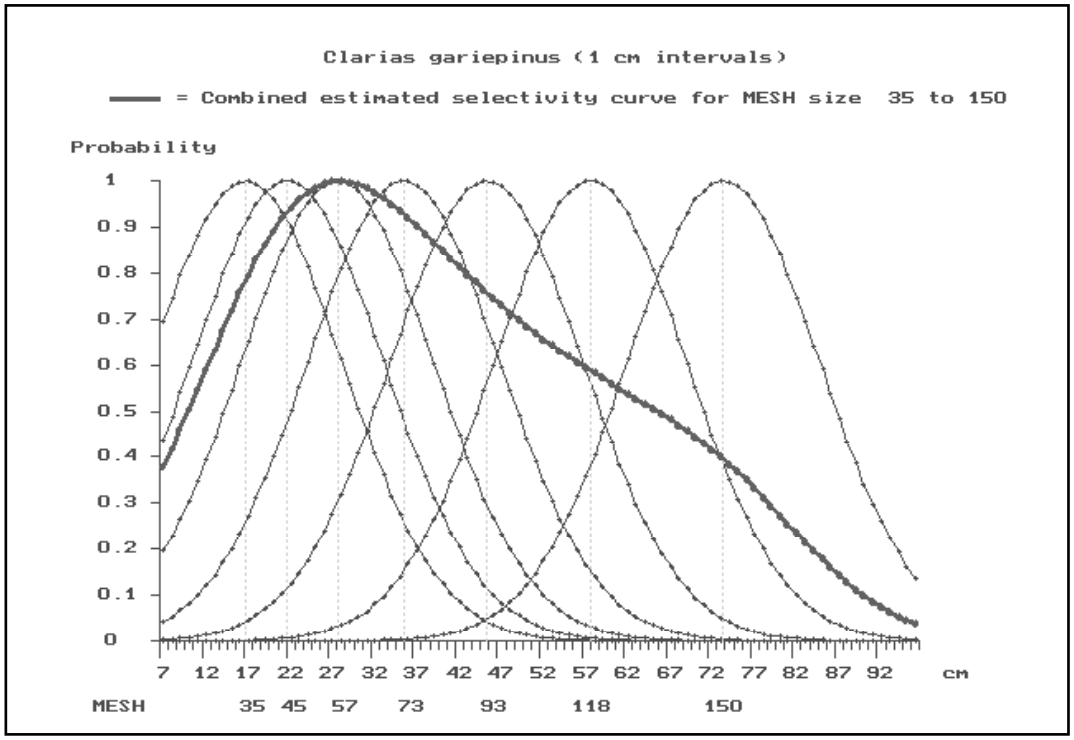


Figure 5.9
Gill net selectivity for Clarias gariepinus *for different mesh sizes from 22 mm to 150 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thick line).*

Barbus hospes (Namaqua barb):
Overall IRI = 3%

A total of 1305 individuals of *Barbus hospes* were caught in the pooled total catches in multifilament gill nets and the other gears (7% of total catch) (**appendix 3**). It was the twelfth most important species in the gill net catches (IRI < 0.01%), and the sixth most important in the catches with other gears (IRI = 4%) (**appendix 4** and **5**). The minimum body length of mature fish was 3.0 cm for males and 4.0 cm for females (**table 5.5**). The length at 50% maturity could not be determined.

Only seven individuals were caught in the gill nets, with body lengths from 8 to 9 cm (mean 8.1 cm) (**figure 5.5**). A total of 1298 individuals were caught in the other gears, of which 746 were length measured. Their body lengths varied from 2 to 7 cm (mean 4.4 cm, modal length 3.0 - 3.9 cm) (**figure 5.5**).

Table 5.10. *Gill net selectivity for* Barbus hospes *caught during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Number of fish caught (n), mean length of 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	7	8.1	0.24	0.002

All the gill netted fish were caught in the 22 mm mesh size (0.24 fish/setting) (**table 5.10**). The biomass per setting was 0.002 kg/setting.

Gill netting at Gariep Motors in the Lower Orange River. Photo: Clinton J. Hay

Liza richardsoni (Southern mullet):
Overall IRI = 3%

A total of 1664 individuals of *Liza richardsoni* were caught in pooled total catches in multifilament gill nets and the other gears (9% of total catch) (**appendix 3**). It was the seventh most important species in the gill net catches (IRI = 0.2%), and the ninth most important in the catches with other gears (IRI = 3%) (**appendix 4** and **5**). The minimum body length of mature fish was 19.0 cm for males and 17.0 cm for females (**table 5.5**). The length at 50% maturity could not be determined.

A total of 110 individuals were caught in gill nets, with body lengths from 11 to 31 cm (mean 22.0 cm, modal length 22.0 - 22.9 cm) (**figure 5.5**). A total of 1554 individuals were caught in the other gears, of which 551 were length measured. Their body lengths varied from 2 to 26 cm (mean 4.9 cm, modal length 4.0 - 4.9 cm) (**figure 5.5**). However, no *Liza richardsoni* with body lengths between 11 and 25 cm were sampled with the other gears.

The 45 mm gill net mesh size had the highest catch in terms of number of fish per setting (1.33 fish/setting) (**table 5.11**). Fish caught with this mesh size had an average body length of 23.0 cm. The 45 mm mesh size also had the highest catch in terms of biomass per setting (0.20 kg/setting).

Table 5.11. *Gill net selectivity for* Liza richardsoni *caught during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Number of fish caught (n), mean length of 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	17.0	0.03	0.002
28	8	17.0	0.27	0.021
35	37	19.5	1.26	0.143
45	39	23.0	1.33	0.198
57	20	25.0	0.68	0.134
73	5	29.4	0.17	0.059
All mesh sizes	**110**	**22.0**	**0.42**	**0.060**

In the survey with multifilament gill nets, the size group of *Liza richardsoni* most efficiently caught was fish with body lengths between 12 and 31 cm. They were caught in gill net mesh sizes from 22 to 57 mm (**figure 5.10**).

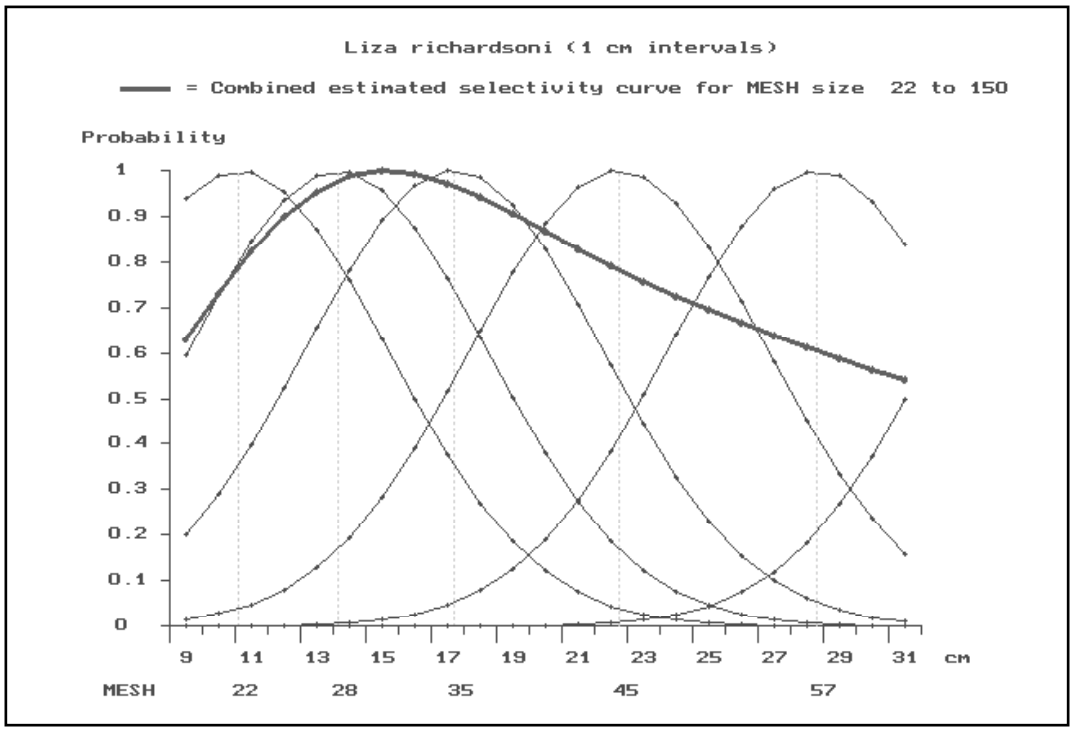


Figure 5.10
Gill net selectivity for Liza richardsoni *for different mesh sizes from 22 mm to 150 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thick line).*

Barbus trimaculatus (Threespot barb):
Overall IRI = 3%

A total of 924 individuals of *Barbus trimaculatus* were caught in the pooled total catches in multifilament gill nets and other gears (5% of total catch) (**appendix 3**). It was the sixth most important species in the gill net catches (IRI = 1%), and the eighth most important in the catches with other gears (IRI = 4%) (**appendix 4** and **5**). The minimum body length of mature fish was 5.0 cm for both males and females (**table 5.5**). The length at 50% maturity was 5.8 cm for males and 5.9 cm for females.

A total of 358 individuals were caught in gill nets, with body lengths from 6 to 10 cm (mean 8.4 cm, modal length 8.0 - 8.9 cm) (**figure 5.5**). A total of 566 individuals were caught in the other gears, of which 500 were length measured. Their body lengths varied from 2 to 10 cm (mean 6.1 cm, modal length 7.0 -7.9 cm) (**figure 5.5**).

The 22 mm mesh size had the highest catch in terms of number of fish per setting (11.6 fish/setting) (**table 5.12**). Fish caught with this mesh size had an average body length of 8.4 cm. The 22 mm mesh size also had the highest catch in terms of biomass per setting (0.08 kg/setting).

Only two mesh sizes caught this species (**figure 5.11)** and selectivity analyses were not performed.

Table 5.12. *Gill net selectivity for* Barbus trimaculatus *caught during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Number of fish caught (n), mean length of 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	342	8.4	11.6	0.084
28	16	9.4	0.5	0.006
All mesh sizes	**358**	**8.4**	**1.4**	**0.010**

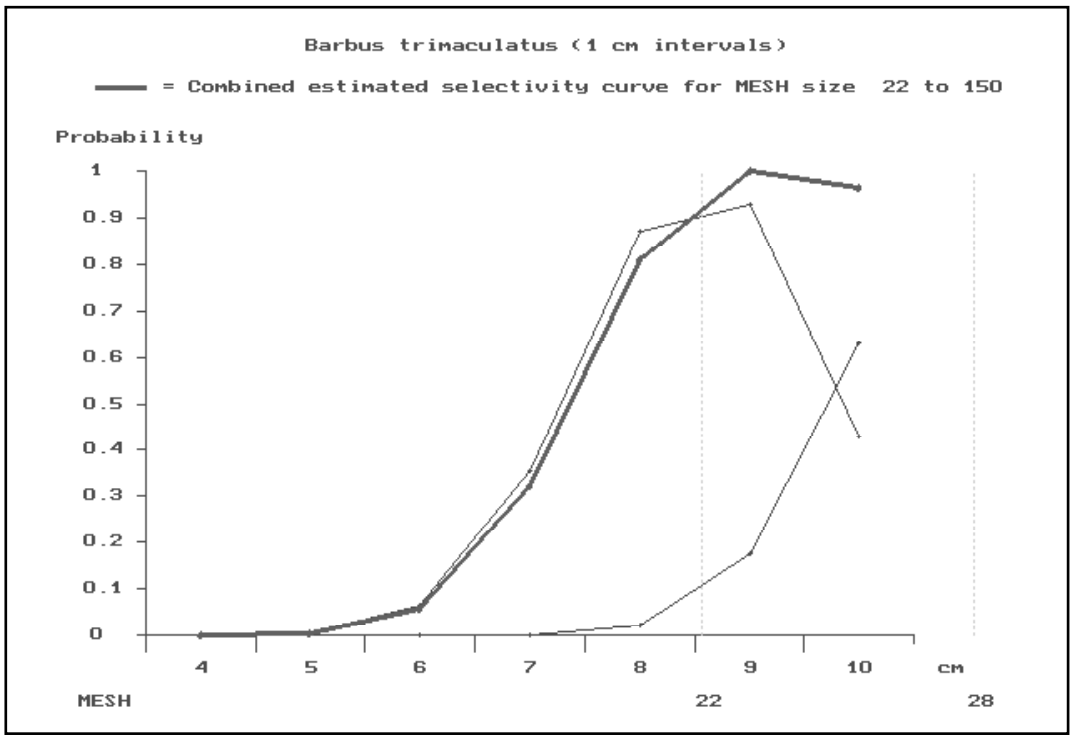


Figure 5.11
Gill net selectivity for Barbus trimaculatus *for different mesh sizes from 22 mm to 150 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thick line).*

Labeobarbus kimberleyensis (Vaal-Orange largemouth yellowfish): Overall IRI = 2%

A total of 208 individuals of *Labeobarbus kimberleyensis* were caught in the pooled total catches in multifilament gill nets and the other gears (1% of total catch) (**appendix 3**). It was the fourth most important species in the gill net catches (IRI = 3%), and the tenth most important in the catches with other gears (IRI = 1%) (**appendix 4** and **5**). The minimum body length of mature fish was 29.0 cm for males and 20.0 cm for females (**table 5.5**). The length at 50% maturity could not be determined.

A total of 167 individuals were caught in gill nets (166 were length measured), with body lengths from 8 to 56 cm (mean 24.7 cm, modal length 15.0 - 15.9 cm) (**figure 5.5**). A total of 41 individuals were caught in the other gears, with body lengths from 3 to 62 cm (mean 14.7 cm, modal length 5.0 - 5.9 cm) (**figure 5.5**). Few length classes larger than 27 cm were sampled with the other gears.

Labeobarbus kimberleyensis was caught in all mesh sizes (22 - 150 mm). The 45 mm mesh size had the highest catch in terms of number of fish per setting (1.09 fish/setting) (**table 5.13**). Fish caught with this mesh size had an average body length of 21.0 cm. The 93 and 118 mm mesh sizes had the highest catch in terms of biomass per setting (both 0.48 kg/setting). Fish caught with 93 mm and 118 mm mesh sizes had average body lengths of 41.6 and 51.3 cm, respectively.

In the survey with multifilament gill nets, the size group of *Labeobarbus kimberleyensis* most efficiently caught was fish with body lengths between 11 and 56 cm. They were caught in gill net mesh sizes from 22 to 118 mm (**figure 5.12**).

Table 5.13. *Gill net selectivity for* Labeobarbus kimberleyensis *caught during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Number of fish caught (n), mean length of 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	8	10.5	0.27	0.00
28	22	14.4	0.75	0.04
35	30	15.7	1.02	0.04
45	32	21.0	1.09	0.12
57	31	24.5	1.05	0.19
73	17	33.2	0.58	0.30
93	16	41.6	0.54	0.48
118	8	51.3	0.27	0.48
150	3	51.3	0.10	0.19
All mesh sizes 167		**24.5**	**0.63**	**0.20**

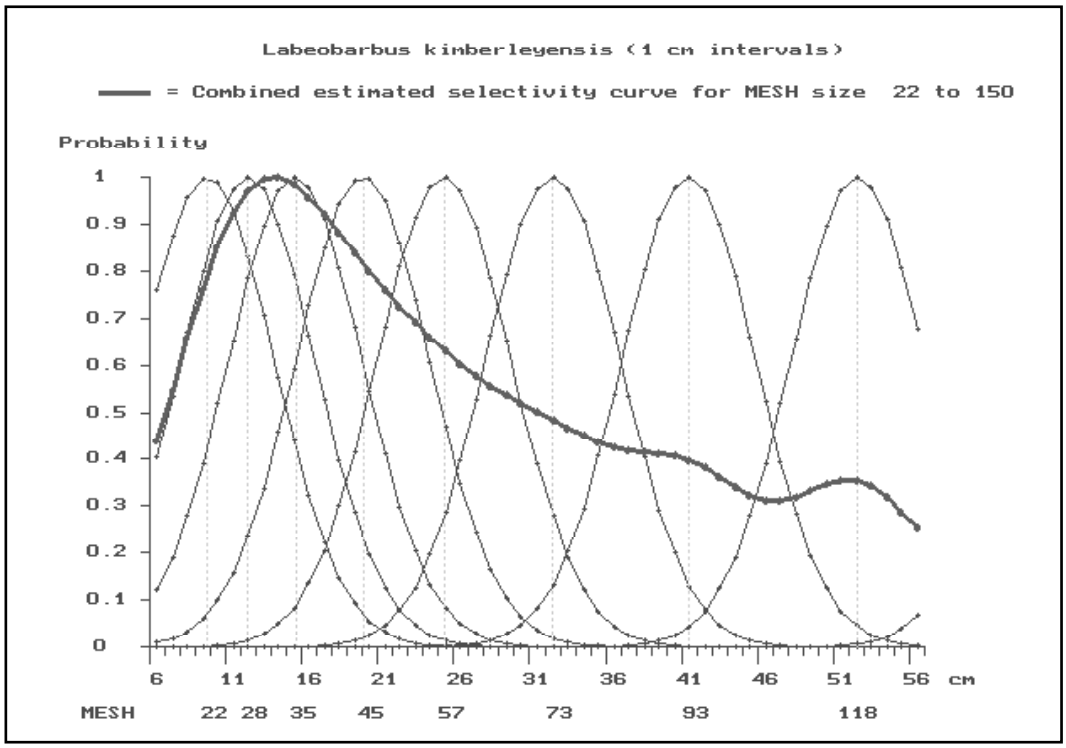


Figure 5.12
Gill net selectivity for Labeobarbus kimberleyensis *for different mesh sizes from 22 mm to 150 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thick line).*

Pseudocrenilabrus philander (Southern mouthbrooder): Overall IRI = 2%
A total of 1055 individuals were caught in the pooled total catches (6% of the total catch) (**appendix 3**). This species was not sampled with the gill nets, but was the seventh most important species in the other gears used during the surveys (4%) (**appendix 4** and **5**). The minimum length at maturity was 4.0 cm both for males and females (**table 5.5**). The length at 50% maturity could not be determined.

Pseudocrenilabrus philander was not recorded in the multifilament gill nets, and selectivity analyses were, therefore, not performed.

Cyprinus carpio (Common carp): Overall IRI < 1%
A total of 18 individuals of *Cyprinus carpio* were caught in the pooled total catches in multifilament gill nets and the other gears (0.1% of total catch) (**appendix 3**). It was the eighth most important species in the gill net catches (IRI = 0.1%), and the least important species in the catches with other gears, with only one fish caught (IRI < 0.01) (**appendix 4** and **5**). The minimum body length of mature fish was 38.0 cm for males and 25.0 cm for females (**table 5.5**). The length at 50% maturity could not be determined.

A total of 17 individuals were caught in gill nets, with body lengths from 20.0 to 75.0 cm (mean 43.1 cm) (**figure 5.5**). Only one common carp was caught in other gears, with a body length of 3.0 cm.

Table 5.14. *Gill net selectivity for* Cyprinus carpio *caught during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Number of fish caught (n), mean length of 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	2	25.0	0.07	0.020
93	1	25.0	0.03	0.009
118	4	36.5	0.14	0.143
150	10	51.1	0.34	0.916
All mesh sizes	**17**	**43.1**	**0.06**	**0.120**

The 150 mm mesh size had the highest catch in terms of number of fish per setting (0.34 fish/setting) (**table 5.14**). Fish caught with this mesh size had an average body length of 51.1 cm. The 150 mm mesh size also had the highest catch in terms of biomass per setting (0.92 kg/setting).

In the survey with multifilament gill nets, the size group of *Cyprinus carpio* most efficiently caught was fish with body lengths between 23 and 43 cm. They were caught in gill net mesh sizes from 73 to 150 mm (**figure 5.13**).

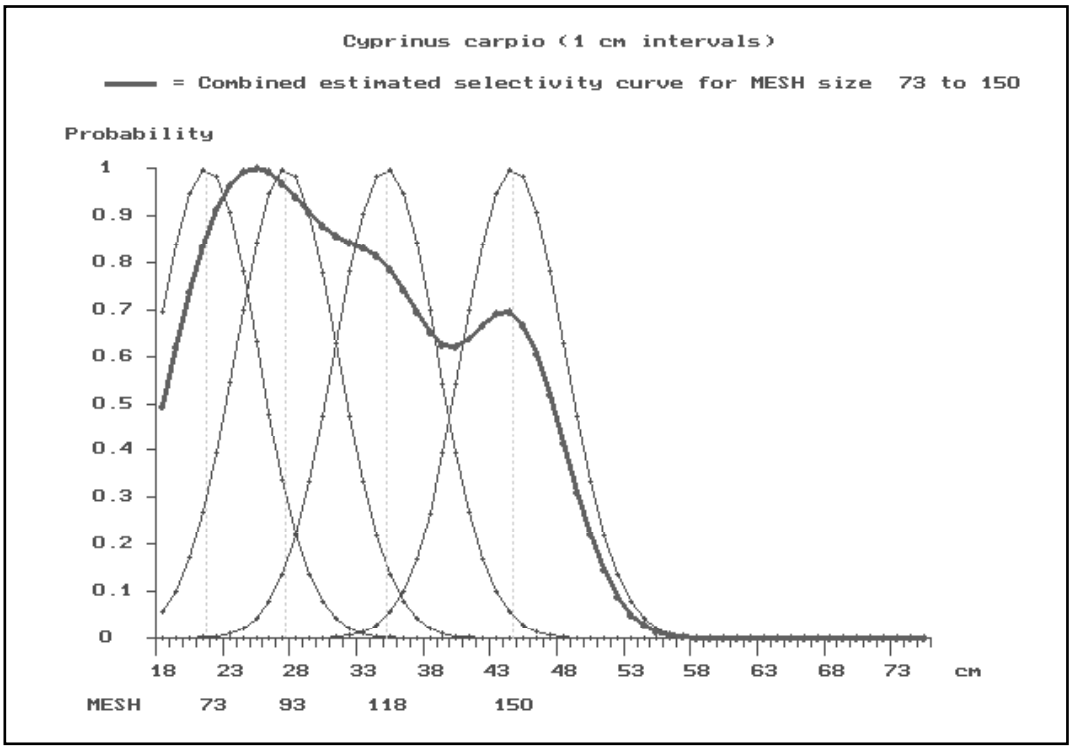


Figure 5.13
Gill net selectivity for Cyprinus carpio *for different mesh sizes from 22 mm to 150 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thick line).*

Mugil cephalus (Flathead mullet): Overall IRI < 1%
A total of 86 individuals of *Mugil cephalus* were caught in the pooled total catches in multifilament gill nets and other gears (0.5% of total catch) (**appendix 3**). It was the ninth most important species in the gill net catches (IRI = 0.1%), and the thirteenth most important in the catches with other gears (IRI = 0.04%) (**appendix 4** and **5**). The minimum body length of mature fish was 31.0 cm for males and 32.0 cm for females (**Table 5.5**). The length at 50% maturity could not be determined.

A total of 23 individuals were caught in gill nets, with body lengths from 13 to 50 cm (mean 30.4 cm, modal length 32.0 - 32.9 cm) (**figure 5.5**). A total of 63 individuals were caught in the other gears, with body lengths from 2 to 17 cm (mean 5.1 cm, modal length 4.0 - 4.9 cm) (**figure 5.5**).

The 73 mm mesh size had the highest catch in terms of number of fish per setting (0.37 fish/setting) (**table 5.15**). Fish caught with this mesh size had an average body length of 33.3 cm. The 73 mm mesh size also had the highest catch in terms of biomass per setting (0.23 kg/setting).

Table 5.15. *Gill net selectivity for* Mugil cephalus *caught during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Number of fish caught (n), mean length of 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)
35	3	14.7	0.10	0.004
45	3	19.0	0.10	0.008
57	2	30.0	0.07	0.025
73	11	33.3	0.37	0.228
93	3	43.0	0.10	0.127
118	1	44.0	0.03	0.043
All mesh sizes	**23**	**30.4**	**0.09**	**0.050**

In the survey with multifilament gill nets, the size group of *Mugil cephalus* most efficiently caught was fish with body lengths between 14 and 43 cm. They were caught in gill net mesh sizes from 35 to 118 mm (**figure 5.14**).

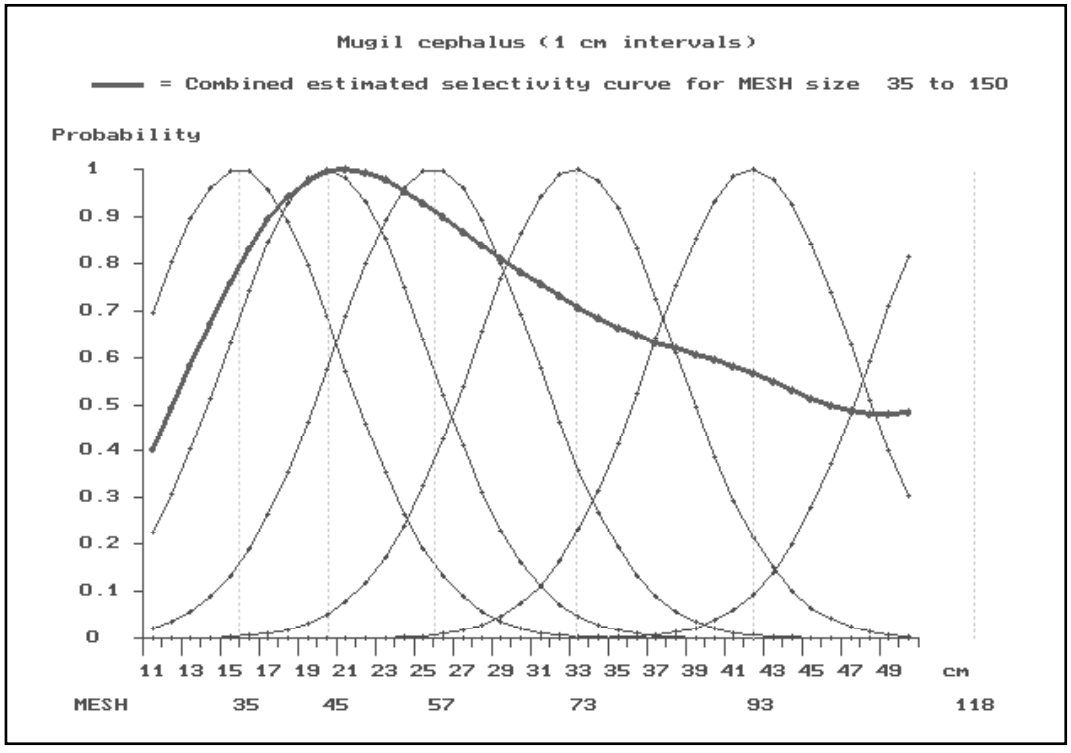


Figure 5.14
Gill net selectivity for Mugil cephalus *for different mesh sizes from 22 mm to 150 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thick line).*

Barbus paludinosus (Straightfin barb):
Overall IRI < 1%
A total of 170 individuals were sampled in the pooled total catches in multifilament gill nets and the other gears (1% of the total catch) (**appendix 3**). Only two individuals were recorded with the gill nets (IRI < 0.01%) (**appendix 4**). It was the eleventh most important species recorded with the other gears (IRI 0.2%) (**appendix 5**).

The two individuals caught with gill nets both had body lengths of 4.0 cm (**figure 5.5**). A total of 143 individuals were caught in the other gears, with body lengths from 2 to 6 cm (mean 4.6 cm, modal length 4.0 - 4.9 cm) (**figure 5.5**). The two individuals caught with gill nets were caught with the 22 mm mesh size (0.27 fish/setting) (**table 5.16**).

Due to the low number of fish sampled with the multifilament gill nets, selectivity analyses were not performed.

Table 5.16. *Gill net selectivity for* Barbus paludinosus *caught during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. 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	4.0	0.08	0.000
All mesh sizes	**2**	**4.0**	**0.01**	**0.000**

Tilapia sparrmanii (Banded tilapia):
Overall IRI < 1%
A total of 43 individuals were recorded in the pooled total catches in multifilament gill nets and other gears (0.2% of the total catch) (**appendix 3**). *Tilapia sparrmanii* was the eleventh most important species recorded with the gill nets (IRI = 0.01%) (**appendix 4**). It was the fourteenth most important species in the other gears (IRI = 0.04%) (**appendix 5**).

A total of 11 individuals were caught in gill nets, with body lengths from 9 to 14 cm (mean 1.8 cm, modal length 10.0 - 10.9 cm) (**figure 5.5**). A total of 32 individuals were caught in the other gears, with body lengths from 2 to 11 cm (mean 3.5 cm, modal length 4.0 - 4.9 cm) (**figure 5.5**).

The 35 mm mesh size had the highest catch in terms of number of fish per setting (0.27 fish/setting) (**table 5.17**). Fish caught with this mesh size had an average body length of 10.6 cm. The 73 mm mesh size also had the highest catch in terms of biomass per setting (0.005 kg/setting).

Due to the low number of fish sampled with the multifilament gill nets, selectivity analyses were not performed.

Table 5.17. *Gill net selectivity for* Tilapia sparrmanii *caught during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. 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)
5	7	10.6	0.27	0.005
45	3	12.7	0.12	0.005
57	1	15.0	0.04	0.003
All mesh sizes	**11**	**11.6**	**0.05**	**0.001**

Austroglanis sclateri (Rock catfish):
Overall IRI < 1%
A total of 68 individuals were recorded in the pooled total catches (IRI = 0.4% of total catch) (**appendix 3**). No individuals were caught in the gill nets, and it was the twelfth most important species caught with the other gears (IRI = 0.04%) (**appendix 4** and **5**). Body lengths varied from 1 to 15 cm (mean 8.0 cm, modal length 6.0 - 6.9 cm) (**figure 5.5**).

The minimum length at maturity was 8.0 cm for males and 6.0 cm for females (**table 5.5**). The length at 50% maturity could not be determined.

No fish were sampled with the multifilament gill nets, and selectivity analyses were, therefore, not performed.

Marine sp.: Overall IRI < 1%
A total of 68 individuals of an unidentified marine species were recorded in the pooled total catches (IRI = 0.01% of total catch) (**appendix 3**). No individuals were recorded in gill nets, and it was the fifteenth most important species in the other gears used (IRI = 0.03%) (**appendix 4** and **5**). Body lengths varied from 2 to 4 cm (mean 3.5 cm, modal length 3.0 - 3.9 cm) (**figure 5.5**). The lengths at maturity could not be determined.

No individuals was sampled with the multifilament gill nets, and selectivity analyses were, therefore, not performed.

Atherina breviceps (Cape silverside):
Overall IRI < 1%
A total of 31 individuals were recorded in the pooled total catches (IRI = 0.2% of the total catch) (**appendix 3**). No individuals were recorded in the gill nets, and it was the sixteenth most important species recorded with the other gears (IRI = 0.01%) (**appendix 4** and **5**). The minimum length at maturity or length at 50% maturity could not be determined. Body lengths varied from 2 to 7 cm (mean 4.2 cm, modal length 4.0 - 4.9 cm) (**figure 5.5**).

No fish were sampled with the multifilament gill nets, and selectivity analyses were, therefore, not performed.

Gill netting in backwater at Off-Road Club in the Lower Orange River. Photo: Clinton J. Hay

Lichia amia (Garrick): Overall IRI < 1%
A total of 21 individuals of *Lichia amia* were caught in the pooled total catches (0.1% of total catch) (**appendix 3**). It was the tenth most important species in the gill net catches (IRI = 0.2%) (**appendix 4**). *Lichia amia* was not caught in the other gears (**appendix 5**). The minimum body length of mature fish was 25.0 cm for females, but could not be determined for males (**table 5.5**). The length at 50% maturity could not be determined.

A total of 21 individuals were caught in the gill nets, with body lengths from 12 to 25 cm (mean 19.3 cm, modal length 21.0 - 21.9 cm) (**figure 5.5**).

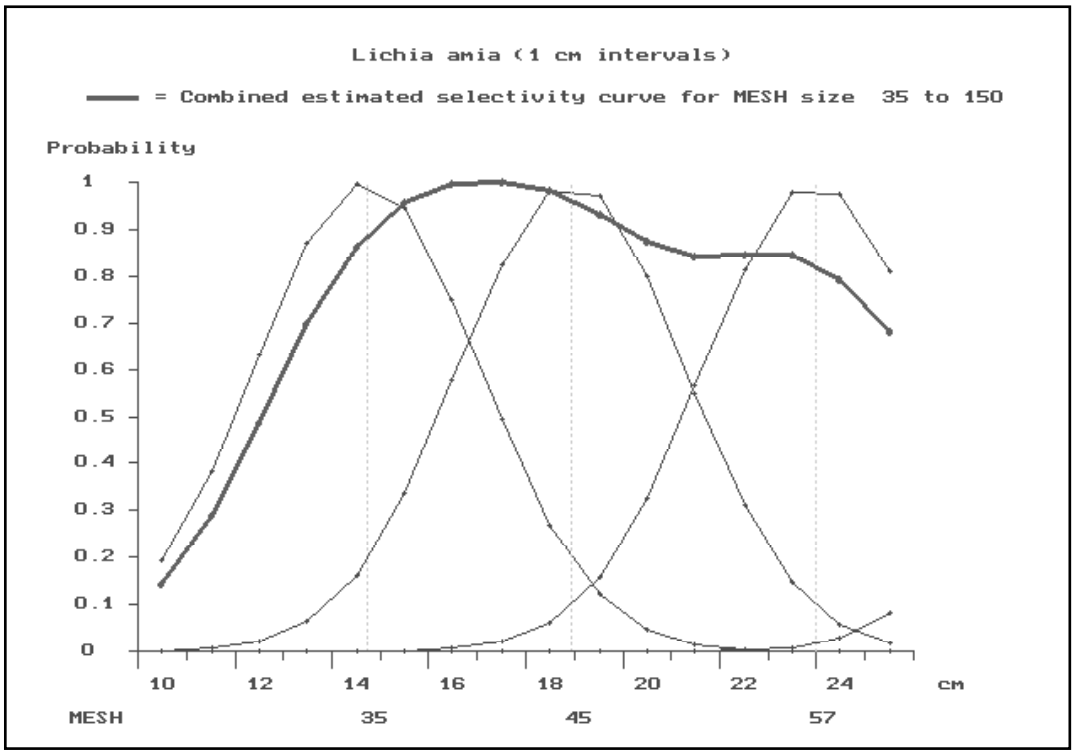
The 45 mm mesh size had the highest catch in terms of number of fish per setting (0.31 fish/setting) (**table 5.18**). Fish caught with this mesh size had an average body length of 19.9 cm. The 45 mm mesh size also had the highest catch in terms of biomass per setting (0.03 kg/setting).

Due to the low number of fish sampled with the multifilament gill nets (**figure 5.15**), selectivity analyses were not performed.

Table 5.18. *Gill net selectivity for* Lichia amia *caught during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Number of fish caught (n), mean length of 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)
35	5	13.6	0.170	0.006
45	9	19.9	0.306	0.031
57	6	22.3	0.204	0.030
73	1	25.0	0.034	0.008
All mesh sizes	**21**	**19.3**	**0.080**	**0.010**

Figure 5.15
Gill net selectivity for Lichia amia *for different mesh sizes from 22 mm to 150 mm (thin lines) and combined estimated selectivity curve for all mesh sizes (thick line).*



5.4.4 Summary of life history and gill net selectivity

The most efficient gill nets mesh sizes varied considerably among the species (**table 5.19**). For example, both with regards to numbers and biomass per setting the smallest mesh size, 22 mm, was most effective for targeting *Barbus trimaculatus, Barbus hospes, and Barbus paludinosus*, whereas the largest mesh size, 150 mm, was most effective for targeting *Cyprinus carpio*. The largest biomass of *Clarias gariepinus* was also caught in the 150 mm mesh size.

For all species caught in both multifilament gill nets and other gears, the mean size of individuals caught in gill nets were larger than those caught in the other gears (t-tests, all $p < 0.001$). The mean size of the different species caught in gill nets also varied considerably, varying between 8.1 cm (*Barbus hospes*) and 54.5 cm (*Clarias gariepinus*). The mean size of species caught in the other gears were smaller, varying between 3.0 cm (*Cyprinus carpio*) and 18.0 cm (*Clarias gariepinus*) (**table 5.20**).

The length-mass relationships for the various species are given in **table 5.21.**

Table 5.19. *The most efficient multifilament gill net mesh sizes in terms of number and biomass of fish caught per setting for the species caught in multifilament gill nets during surveys in the Lower Orange River during 1995 - 2001. Fish species classified as "large" had a minimum length at maturity larger than 7 cm, whereas those classified as "small" had a minimum length at maturity equal to or smaller than 7 cm.*

Species	Most efficient gill net mesh size (mm)		Size classification	
	Number of fish per setting	Biomass per setting	Large	Small
Labeobarbus aeneus	45	73	x	
Labeo capensis	73	93	x	
Clarias gariepinus	93	150	x	
Labeobarbus kimberleyensis	45	93/118	x	
Oreochromis mossambicus	73	73	x	
Barbus trimaculatus	22	22		x
Liza richardsoni	45	45	x	
Cyprinus carpio	150	150	x	
Mugil cephalus	73	73	x	
Lichia amia	45	45	x	
Tilapia sparrmanii	35	35	-	x*
Barbus hospes	22	22	-	x
Barbus paludinosus	22	22	-	x**

*From Hay *et al.* 2000. **From Skelton 2001.

Table 5.20. *Mean body length of species caught in multifilament gill nets and the other gears during surveys in the Lower Orange River during 1995 - 2001. Test statistics (t-test) for differences in fish body lengths between gill net catches and catches with other gears are also given. n = number of fish.*

Species	Mean body length in gill net catches		Mean body length in catches with other gears		t-test		
	(cm)	n	(cm)	n	t	df	p
Clarias gariepinus	54.5	123	18.0	157	17.66	278	<0.001
Cyprinus carpio	43.1	17	3.0	1	-	-	-
Mugil cephalus	30.4	23	5.1	63	18.21	84	<0.001
Labeobarbus kimberleyensis	24.7	166	14.7	41	4.88	205	<0.001
Labeo capensis	24.3	905	6.8	2208	74.88	3111	<0.001
Liza richardsoni	22.0	110	4.9	551	67.97	659	<0.001
Labeobarbus aeneus	20.1	1616	6.7	710	44.48	2324	<0.001
Lichia amia	19.3	21	-	0	-	-	-
Oreochromis mossambicus	19.2	284	5.9	761	57.30	1043	<0.001
Tilapia sparrmanii	11.6	11	6.8	32	6.70	41	<0.001
Barbus trimaculatus	8.4	358	6.1	500	22.94	856	<0.001
Barbus hospes	8.1	7	4.4	744	7.74	749	<0.001
Barbus paludinosus	4.0	2	4.0	168	-	-	-
Austroglanis sclateri	-	0	8.0	68	-	-	-
Atherina breviceps	-	0	4.2	31	-	-	-
Pseudocrenilabrus philander	-	0	4.1	693	-	-	-
Mesobola brevianalis	-	0	3.8	1062	-	-	-
Marine sp.	-	0	2.9	56	-	-	-
Gobiidae sp.	-	0	10.0	1	-	-	-

Table 5.21. *Length-mass relationship for the species caught during surveys in the Lower Orange River during 1995 - 2001 (multifilament gill nets, monofilament gill nets and other gears). The formula $W = a * L^b$ was used, where a = intercept, b = exponent, W = mass of the fish and L = length of the fish. The relationship is not given for species caught in low numbers.*

Species	Intercept a	Exponent b	r^2	Number of fish
Labeobarbus aeneus	0.009	3.12	0.99	2147
Labeo capensis	0.010	3.09	0.99	2339
Clarias gariepinus	0.005	3.06	1.00	243
Labeobarbus kimberleyensis	0.008	3.12	1.00	201
Oreochromis mossambicus	0.015	3.03	0.98	870
Barbus trimaculatus	0.007	3.28	0.96	720
Liza richardsoni	0.008	3.16	0.97	604
Cyprinus carpio	0.025	2.93	1.00	18
Mugil cephalus	0.016	2.95	0.99	89
Lichia amia	0.024	2.80	0.97	21
Tilapia sparrmanii	0.019	2.95	0.97	26
Barbus hospes	0.012	2.90	0.80	554
Mesobola brevianalis	0011	265	076	793
Pseudocrenilabrus philander	0013	2.99	089	519
Austroglanis sclateri	0.028	252	096	63
Atherina breviceps	0.004	3.46	0.78	26
Barbus paludinosus	-	-	-	2
Gobiidae sp.	-	-	-	1

5.5 Catch per unit effort (CPUE)

Catch per unit effort (CPUE) was estimated for the catches in the multifilament gill nets in order to obtain a relative estimate of the fish densities at the sampling stations in the Lower Orange River. The average CPUE in number of fish and biomass were 17.0 fish and 3.9 kg per setting, respectively (**table 5.22**). As indicated by the large standard deviation (sd), there was a large variation in catch among settings.

5.5.1 Catch per unit effort in different mesh sizes

Catch per unit effort (CPUE) was estimated for each multifilament mesh size (22 - 150 mm) (**figure 5.16**, **table 5.23**). Mean CPUE given as number of fish caught per setting was lower for the mesh sizes 118 and 150 mm (2.4 - 4.5 fish/setting) than for the mesh sizes 22 to 93 mm (12.0 - 26.6 fish/setting) (ANOVA, tuckey test, $p < 0.05$) (**figure 5.16**, **table 5.23**). There was a negative correlation between mesh size and mean CPUE given as number of fish (Spearman rank, $r = -0.258$, $p = 0.01$). For CPUE given as biomass per setting, the opposite relationship was found, as mean CPUE increased with increasing mesh sizes (Spearman rank, $r = 0.113$, $p = 0.01$) (**figure 5.16**, **table 5.23**). The mean CPUE given as biomass was lowest in the 22 and 28 mm mesh sizes (0.2 and 0.4 kg/setting, respectively) and largest in the 93 mm mesh size (8.3 kg/setting).

Table 5.22. *Mean catch per unit effort (CPUE) given as number of fish and biomass per setting in the total multifilament gill net catches (22 - 150 mm mesh size) during surveys in the Lower Orange River during 1995 - 2001. Setting = 12 hours of fishing with one standard gill net (area = 50 m²). sd = standard deviation.*

Total number of settings	Total number of fish caught	Total biomass of fish caught (kg)	CPUE (number of fish per setting ± sd)	CPUE (kg per setting ± sd)
715	3644	839.2	17.0 ± 31.4	3.9 ± 7.1

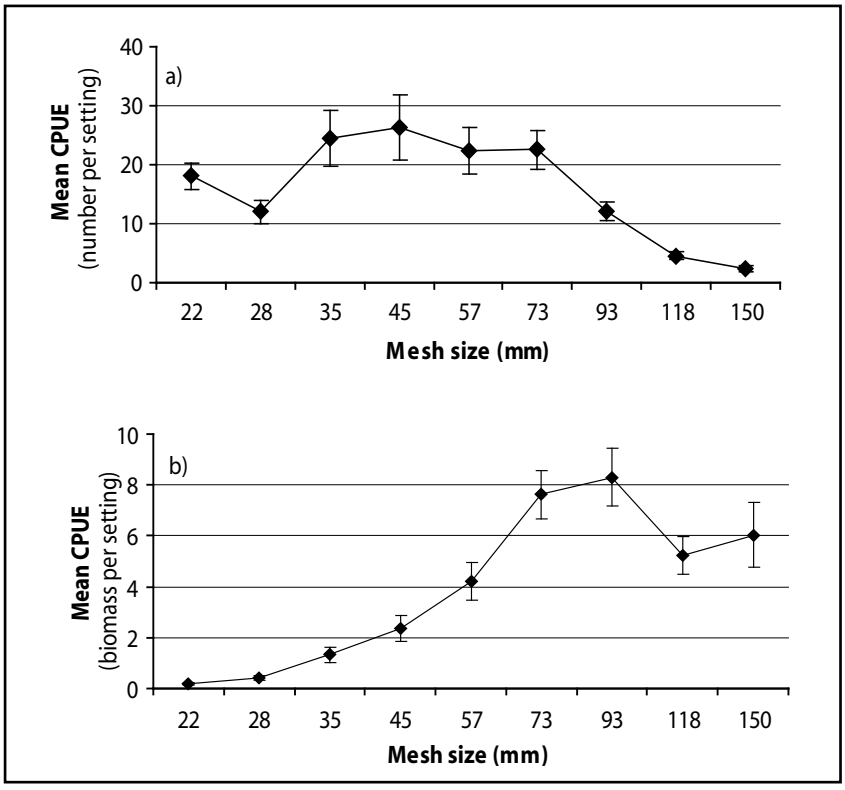


Figure 5.16
Mean catch per unit effort (CPUE) given as a) number of fish and b) biomass (kg) per setting for total multifilament gill net samples (22-150 mm mesh size) during surveys in the Lower Orange River during 1995-2001. Setting = 12 hours of fishing with one standard gill net (area = 50 m²).

***Table 5.23**. Mean catch per unit effort (CPUE) given as number of fish and biomass (kg) per setting for total multifilament gill net samples (22-150 mm mesh size) during surveys in the Lower Orange River during 1995-2001. Setting = 12 hours of fishing with one standard gill net (area = 50 m²). SE = Standard error, sd = standard deviation.*

Mesh size	CPUE, number of fish (n)			CPUE, biomass (kg)			Number of settings
	n per setting	SE	sd	biomass per setting	SE	sd	
22	18.1	2.3	20.8	0.2	0.0	0.4	85
28	12.0	1.9	16.3	0.4	0.1	0.8	75
35	24.5	4.8	45.0	1.3	0.3	2.7	87
45	26.3	5.5	50.4	2.4	0.5	4.6	84
57	22.4	4.0	36.4	4.2	0.7	6.6	85
73	22.6	3.3	31.2	7.6	0.9	8.9	90
93	12.0	1.6	14.6	8.3	1.1	10.3	82
118	4.5	0.7	5.4	5.2	0.7	6.1	67
150	2.4	0.5	3.6	6.0	1.3	9.9	60
Total	**17.0**	**1.2**	**31.4**	**3.9**	**0.3**	**7.1**	715

5.5.2 Catch per unit effort and average catches at different stations

The average catch per unit effort (CPUE) given as numbers of fish per setting varied between 2.8 and 55.9 fish/setting among the different sampling stations. The CPUE given as biomass per setting varied between 1.4 and 11.7 kg/setting (**table 5.24**). CPUEs given both as number (55.9 fish/setting) and biomass (11.7 kg/setting) were significantly higher at Off-Road Club than at all the other sampling stations (t-tests with Bonferroni corrections, all $p < 0.001$) (**figure 5.17**, **table 5.24**). The lowest CPUE given as number of fish was recorded at Daberas Pump Station (2.8 fish/setting) and Sebarasfontein (5.3 fish/setting) (**table 5.24**). The lowest CPUE given as biomass was recorded at Gariep Motors (1.4 kg/setting) and Daberas Pump Station (1.7 kg/setting) (**table 5.24**).

***Table 5.24.** Total number and biomass of fish caught, the percentage of the total catch and number of settings for all mesh sizes (22 - 150 mm mesh size) at the different sampling stations during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Mean catch per unit effort (CPUE) given as number of fish and biomass per setting is also given. Setting = 12 hours of fishing with one standard gill net (area = 50 m2). sd = standard deviation.*

Station	Total catch in number and biomass					CPUE number		CPUE biomass	
	n	%	kg	%	Settings	n/setting	sd	kg/setting	Sd
River Mouth	548	15.0	155.6	18.5	95	19.2	26.0	5.5	7.7
Off-Road Club	1475	40.5	308.8	36.8	88	55.9	67.6	11.7	12.7
Daberas Pump Station	63	1.7	37.9	4.5	75	2.8	3.3	1.7	3.5
Sebrasfontein	71	1.9	31.5	3.8	45	5.3	6.3	2.3	4.8
Grootpenseiland	553	15.2	114.7	13.7	149	12.4	12.8	2.6	3.8
Gariep Motors	596	16.4	70.6	8.4	173	11.5	15.1	1.4	2.0
Houms River	338	9.3	120.1	14.3	90	12.5	11.5	4.5	6.8
All stations combined	**3644**	**100**	**839.2**	**100**	**715**	**17.0**	**31.4**	**3.9**	**7.1**

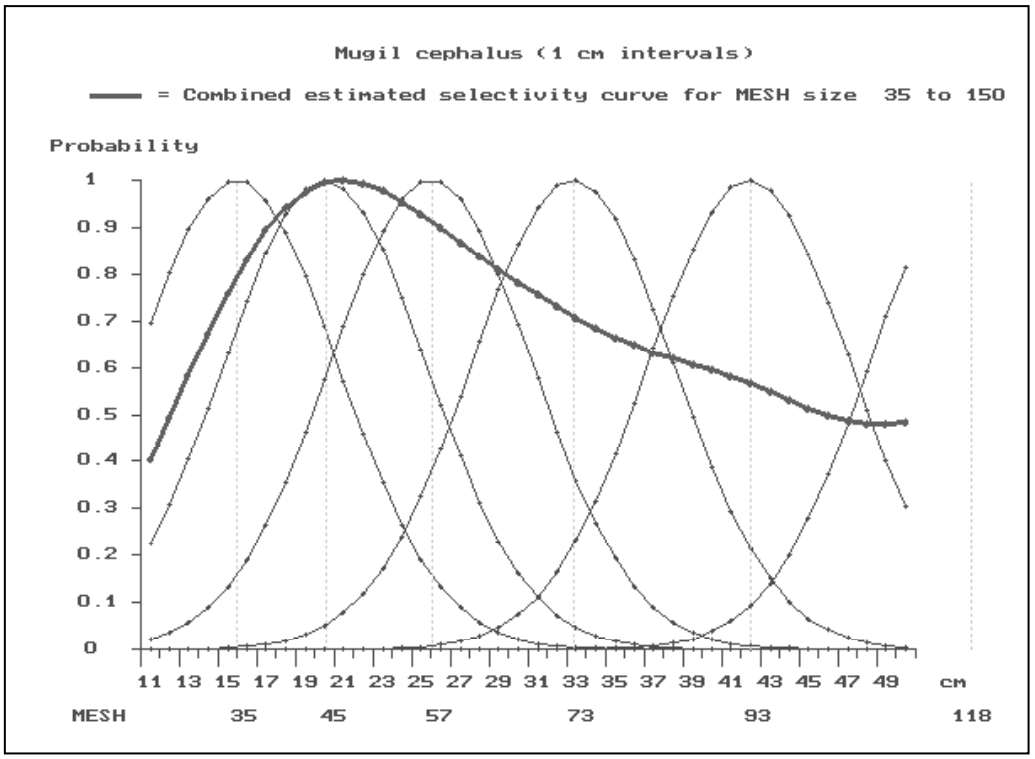


Figure 5.17
Mean catch per unit effort (CPUE) given as mass (kg) per setting for multifilament gill nets (22-150 mm mesh size) during surveys in the Lower Orange River during 1995 - 2001. Numbers given in the figure indicate sample sizes. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2).

To study the gill net catches in various mesh sizes, the multifilament gill catches were divided into the three mesh size intervals 22 - 33 mm, 45 - 73 mm and 93 - 150 mm. The average catches in numbers of fish were highest in the 45 - 73 mm interval (3.3 - 91.3 fish/setting). The average catches in mass were high for both the 45 - 73 mm and 93 - 150 mm interval (0.9 - 16.0 kg/setting and 1.8 - 16.6 kg/setting, respectively) (**table 5.25**, **5.26** and **5.27**).

The average catches in numbers of fish were significantly higher at Off-Road Club than at any of the other stations for all three mesh size intervals, with the exception that no differences were found between the Off-Road Club and River Mouth at the 22 - 33 mm interval, and between the Off-Road Club and River Mouth or Houms River at the 93 - 150 mm interval (t-tests with Bonferroni corrections, all $p < 0.01$) (**table 5.25**, **5.26** and **5.27**). Average catches in mass were also significantly higher at the Off-Road Club than at other stations in 9 of 18 station and mesh size interval combinations (t-tests with Bonferroni corrections, all $p < 0.01$) (**table 5.25**, **5.26** and **5.27**).

The average catches in numbers of fish were significantly lower at Daberas Pump Station than at any of the other stations for the two smallest mesh size intervals (22 - 33 mm and 45 - 73 mm), with the exception that no differences was found between Daberas Pump Station and Sebrasfontein (t-tests with Bonferroni corrections, all $p < 0.01$) (**table 5.25**, **5.26** and **5.27**). The catches were also significantly lower in mass than at the River Mouth, Off-Road Club, Grootpenseiland and Houms River at the 45 - 73 mm interval, but they were higher at the Daberas Pump Station than at the Off-Road Club at the 22 - 33 mm interval (t-tests with Bonferroni corrections, all $p < 0.01$) (**table 5.25**, **5.26** and **5.27**).

Table 5.25. *Total number and biomass of fish caught, the percentage of the total catch and number of settings for the smallest mesh size interval (22 - 35 mm mesh size) at the different sampling stations during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Mean catch per unit effort (CPUE) given as number of fish and biomass per setting is also given. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2). sd = standard deviation.*

Station	Total catch in number and biomass					CPUE number		CPUE biomass	
	n	%	kg	%	Settings	n/setting	sd	kg/setting	sd
River Mouth	130	9.5	6.83	14.0	30	14.4	15.54	0.76	1.16
Off-Road Club	508	37.1	25.02	51.4	30	56.4	67.54	2.78	4.20
Daberas Pump Station	16	1.2	1.41	2.9	24	2.2	3.21	0.20	0.56
Sebrasfontein	20	1.5	0.79	1.6	15	4.4	5.73	0.17	0.32
Grootpenseiland	263	19.2	7.07	14.5	55	15.9	14.97	0.43	0.55
Gariep Motors	339	24.7	5.12	10.5	65	17.4	20.40	0.26	0.25
Houms River	94	6.9	2.43	5.0	28	11.2	10.23	0.29	0.34
All stations combined	**1370**	**100**	**48.66**	**100**	**247**	**18.5**	**31.01**	**0.66**	**1.74**

Table 5.26. *Total number and biomass of fish caught, the percentage of the total catch and number of settings for the medium mesh size interval (45 - 73 mm mesh size) at the different sampling stations during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Mean catch per unit effort (CPUE) given as number of fish and biomass per setting is also given. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2). sd = standard deviation.*

Station	Total catch in number and biomass					CPUE number		CPUE biomass	
	n	%	kg	%	Settings	n/setting	sd	kg/setting	sd
River Mouth	356	19.3	81.0	21.7	36	33.0	34.88	7.5	8.32
Off-Road Club	822	44.6	144.2	38.7	30	91.3	77.86	16.0	12.45
Daberas Pump Station	29	1.6	7.6	2.0	29	3.3	3.45	0.9	1.28
Sebrasfontein	36	2.0	9.1	2.4	15	8.0	8.15	2.0	2.66
Grootpenseiland	231	12.5	47.0	12.6	54	14.3	12.16	2.9	2.81
Gariep Motors	215	11.7	40.9	11.0	63	11.4	10.05	2.2	1.99
Houms River	155	8.4	42.9	11.5	32	16.2	11.30	4.5	4.95
All stations combined	**1844**	**100**	**372.5**	**100**	**259**	**23.7**	**39.86**	**4.8**	**7.29**

Table 5.27. *Total number and biomass of fish caught, the percentage of the total catch and number of settings for the largest mesh size interval (93 - 150 mm mesh size) at the different sampling stations during multifilament gill net surveys in the Lower Orange River during 1995 - 2001. Mean catch per unit effort (CPUE) given as number of fish and biomass per setting is also given. Setting = 12 hours of fishing with one standard gill net (area = 50 m^2). sd = standard deviation.*

Station	Total catch in number and biomass					CPUE number		CPUE biomass	
	n	%	kg	%	Settings	n/setting	sd	kg/setting	sd
River Mouth	62	14.4	67.8	16.2	29	7.1	9.12	7.8	8.80
Off-Road Club	145	33.7	139.6	33.4	28	17.3	19.10	16.6	14.13
Daberas Pump Station	18	4.2	28.9	6.9	22	2.7	3.19	4.4	5.34
Sebrasfontein	15	3.5	21.6	5.2	15	3.3	3.78	4.8	7.35
Grootpenseiland	59	13.7	60.6	14.5	40	4.9	5.44	5.1	5.57
Gariep Motors	42	9.8	24.6	5.9	45	3.1	4.89	1.8	2.76
Houms River	89	20.7	74.8	17.9	30	9.9	12.18	8.3	9.14
All stations combined	**430**	**100**	**418.0**	**100**	**209**	**6.9**	**10.69**	**6.7**	**9.07**

6 Discussion

6.1 Species diversity

A total of 19 fish species were collected during the study period of which 13 were freshwater species. Hay *et al.* (1999) listed 17 freshwater species for the Lower Orange River. Three of the species not recorded during this study were *Tilapia rendalli* (alien species), *Labeo umbratus* and *Labeobarbus cf. kimberleyensis* (hybrid). These three species were only recorded by Hay (1991) in the Fish River, the northern tributary of the Lower Orange River. Further, a *Labeo* hybrid (*Labeo capensis* x *Labeo umbratus*) was also identified by Hay (1991) in the Hardap Dam in the Fish River, but with no records from the Lower Orange River.

A total of six species was recorded since 2001 in the section surveyed of which three species were marine and three freshwater. The marine species were the silver kob, *Argyrosomus inodorus*, the elf, *Pomatomus saltatrix* and the white steenbras *Lithognathus lithognathus*. The three freshwater species were the yellowfish hybrid *Labeobarbus kimberleyensis* x *Labeobarbus aeneus*, the redbreast tilapia, *Tilapia rendalli* and the moggel, *Labeo umbratus*. These species were not very important during these surveys according to the Index of Relative Importance.

6.1.1 The Lower Orange River

All gears combined

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).

Labeo capensis and *Labeobarbus aeneus* dominated the catches during the study period. These two species contributed to 63% of the total IRI, 29% of the total number of fish caught and 61% of the total biomass. These two species were also found by Benade (1993) to be very common in the system. *Labeo capensis*, considered a large species, was, indeed, recorded in higher numbers than some small sized species as *Mesobola brevianalis, Barbus hospes, Barbus trimaculatus* and *Barbus paludinosus.*

Considering the three IUCN Red List species, *Barbus hospes* had a slightly higher IRI (2.9%) than *Labeobarbus kimberleyensis* (2.1%), with *Austroglanis sclateri* occurring in low numbers and with a low IRI (0.02%). *Barbus hospes* can be considered abundant in the system, which also was documented by Cambray (1984). Cambray (1984) documented very few numbers of *Labeobarbus kimberleyensis*, with only nine individuals from a total of 6361 fish recorded (0.14%). Low numbers were also recorded by Benade (1993). Compared to those earlier studies, higher numbers of *Labeobarbus kimberleyensis* were recorded in the present study (208 fish; 1.2% of the total number of fish recorded). The abundance of *Austroglanis sclateri* could be under estimated due to its preference for rapids. These habitats are very difficult to survey which may be the reason for the low numbers sampled. Only small individuals were recorded further contributing to the low IRI calculated.

Of the two alien species, *Oreochromis mossambicus* seem to be the one that may have a significant effect on the system with large numbers recorded during the study period (11% of the total catch in numbers). This is considerably higher than the numbers documented by Cambray (1984) (2% of the total number sampled). Very few individuals of *Cyprinus carpio* were sampled, and this species is presently not considered a threat to the fish communities in the river. This species was not recorded by Cambray (1984) from the Lower Orange River, although it was recorded from the Middle Orange River. Benade (1993), however, sampled 14 individuals from the Lower Orange River, including five from the estuary.

Catches in multifilament gill nets

Labeobarbus aeneus and *Labeo capensis* dominated the gill net catches with a combined IRI of 90%. This dominance was both in number as well as in biomass. These two species also dominated the gill net catches according to Benade (1993). High numbers of *Labeo capensis* was recorded during gill net surveys in the Fish River, but *Labeobarbus aeneus* was replaced by the hybrid *Labeobarbus cf. kimberleyensis* (Hay 1991). *Labeobarbus aeneus* is only present in the lower section of the Fish River (Hay 1991). *Labeo capensis* was also the dominant species in Hardap Dam as well as in Naute Dam, both situated in the Fish River (Schrader 1992). *Labeo umbratus*, a species not sampled during the study period, was sampled in the upper reaches of the Fish River (Hay 1991). It was very common in the gill net catches in Hardap Dam in the upper reaches of

the Fish River (Schrader 1986). This species was also found to be absent from the Lower Orange River by Cambray (1984). According to Skelton (2001), *Labeo umbratus* prefers slow flowing waters and may thrive in reservoirs, which may be the reason why the species is absent or in low numbers in the Lower Orange River. *Labeo capensis* x *Labeo umbratus* hybrids have also been recorded from Hardap Dam, but neither from the lower reaches of the Fish River nor from the Orange River (Schrader 1986).

Labeobarbus kimberleyensis, listed as near threatened on the IUCN Red List, was relatively common in the gill net catches in the present study, and was the fifth most numerous species sampled with the gill nets. Of the two other Red List species, very few individuals of *Barbus hospes* and no individuals of *Austroglanis sclateri* were collected.

The alien species *Cyprinus carpio* is mainly caught in gill nets rather than with the other gears, although very few individuals were recorded during this study. *Oreochromis mossambicus* was the fourth most common species sampled with the gill nets, but was caught in much lower numbers than when using the other gear types.

Catches in other gears

More species were recorded with the other gears than with the gill nets. This was due to the selectivity of the methods used and the areas surveyed, as gill nets cannot be used to survey all habitat types, especially shallow habitats and rocky areas. Small sized species were also only recorded when using the variety of other gear types than gill nets. The smallest gill net mesh size used was too large to sample the small species in the river system.

The other gears used supplemented the gill net catches and was important for species diversity aspects. *Mesobola brevianalis* for instance, was not sampled with the gill nets, but was the second most important species in terms of IRI within the other gear types used. It was also the second most numerous species recorded with these gear types.

Large numbers of juveniles of the alien species *Oreochromis mossambicus* were sampled, indicating successful recruitment in the system, further signifying potential negative effects on indigenous species. Small individuals of the near threatened, *Labeobarbus kimberleyensis*, were also recorded. This is important as this species is known to have a low rate of turnover, hence the classification as a near threatened species. Without the use of the other gear types, these smaller individuals might have been unrecorded in the system. The other red data species, *Barbus hospes* and *Austroglanis sclateri*, could only be studied using the other gear types as only seven individuals were recorded with the gill nets.

Overall, smaller and immature individuals were recorded from all the different fish species, stressing the importance of these gear types for the identification of recruitment in the system.

6.1.2 At the different stations

Multifilament gill nets

Labeo capensis dominated the catches in the upper parts of the Orange River, whereas *Labeobarbus aeneus* dominated the catches closer to the river mouth. Also the catches in the estuary were dominated by this species. The reasons for this change in the dominant species closer to the river mouth are, however, not clear.

Labeo capensis, Labeobarbus aeneus and *Labeobarbus kimberleyensis* were the only species sampled at all the gill net stations. *Clarias gariepinus* was also recorded from all the gill net stations except at the Off-Road Club station situated in the estuary. The highest number of species was recorded at Off-Road Club in the estuary, and included three marine species. This station was in a backwater habitat with no current, which may have contributed to the high number of species.

The marine species contributed less than 2% at the River Mouth station and less than 10% at the Off-Road Club station. The freshwater fish were therefore dominating the gill net catches in the estuary during the study period.

As indicated, the IUCN Red List species *Barbus hospes* was not targeted with the gill nets, with only few individuals recorded at Grootpenseiland, Gariep Motors and Houms River stations. *Austroglanis sclateri* was not recorded in the gill nets at all. *Labeobarbus kimberleyensis*, was slightly more common at Grootpenseiland than at the other stations. Based on the relative high number of Red List species and individuals recorded, this area may be identified as a potential protected area

When considering the alien species, *Oreochromis mossambicus* was abundant in the gill net catches at the Off-Road Club station in the estuary. It was also abundant in the pools in the Fish River (Hay 1991). The reason for this higher abundance in the estuary should be studied as the estuary is declared a Ramsar site, and it will be important to identify any negative effects this species may have on the protected habitats and indigenous fish species.

Other gears

The important species recorded with other gears were different from the gill net catches at some of the stations. Six different species were the most important species at the ten different stations. At the River Mouth station, dominated by the freshwater species in the gill net catches, the situation is reversed with *Liza richardsoni*, a marine species by far the most important species in catches with other gears at this site (IRI = 75%). This is an indication that the juveniles are congregating in this area and can be seen as a nursery area for this species. This was also found by Cambray (1984). The number of marine species increased from three in the gill net catches to five in the catches with the other gear types. The marine species *Atherina breviceps*, the Marine sp. and the Gobiidae are all small species, and it is unlikely that these will be recorded with the gill net mesh sizes used during this study.

The alien species *Oreochromis mossambicus* has a wide distribution in the lower Orange River as it was recorded at all the stations sampled with other gears, with high numbers at Gariep Motors and Houms River stations. This species was not very common during the surveys done by Cambray in 1984, indicating an increase in abundance since then. Schrader (1993) showed an increase in abundance with a rise in water level of Hardap Dam, stating that recruitment was linked to this increase in the water level of the dam. The other alien species, *Cyprinus carpio*, was not considered of any importance when using the other gear types. This species is, therefore, presently not considered a threat to the indigenous species in the system.

Barbus hospes was distributed throughout the system, but with very low numbers in the estuary. Although listed on the IUCN Red List, it is considered abundant in the Lower Orange River as well as in the Lower Fish River (Hay *et al.* 1997a).

6.1.3 Estuary (the Ramsar site) versus river

Multifilament gill nets

The marine species contributed very little to the gill net catches in the estuary, with a total IRI of only 1.5%. *Liza richardsoni* was the most important of the marine species recorded in this area. No marine species were recorded from the rest of the river. *Labeobarbus aeneus* was the most important species in the estuary, with *Labeo capensis* the second most important species. For the rest of the river, *Labeobarbus aeneus* was replaced by *Labeo capensis* as the most important species. Although the reason for this is not known, habitat preferences may be a factor that led to this change in the importance of the species. The freshwater discharge will determine the water quality in the estuary, which again will affect the species composition. It is expected that the species composition will vary according to the water quality parameters and even the season.

The alien species *Oreochromis mossambicus* was more important according to the IRI in the estuary than in the rest of the river. It is known that this species can tolerate very high salinities. Breeding may even take place, and a healthy population can be maintained in such high salinities (van Zyl *et al.* 1997). It is, therefore, important to monitor this species to determine its effect on the fish population in especially the estuary.

The IUCN Red List species *Labeobarbus kimberleyensis* was more commonly sampled in the rest of the river than in the estuary. It is expected that the larger specimens may prefer the riverine conditions as indicated by Skelton (2001). Cambray (1984) pointed out that the turbidity might limit the abundance of this visually orientated species. *Barbus hospes* was only sampled with the gill nets in the riverine section of the study area and in low numbers. *Austroglanis sclateri* was not sampled with gill nets at all. This is attributed to the small size, preventing large numbers of these species to be caught in the gill nets.

Other gears

As expected, more species of especially the small sized species were recorded with other gear types than gill nets. The estuary was dominated by a marine species, *Liza richardsoni*, followed by *Labeobarbus aeneus*. The riverine section was dominated by *Labeo capensis*, like in the gill net catches. *Mesobola brevianalis* was also abundant in the riverine section, most probably due to habitat preferences. According to Skelton (2001),

this species prefers well-aerated, open waters in flowing rivers. This species is considered rare in the Okavango River (Hay *et al.* 2000), the Zambezi and Chobe Rivers (Hay *et al.* 2002) and in the Kwando River (Næsje *et al.* 2004).

Similar to the gill net catches, marine species were restricted only to the estuary, with no specimens recorded from the riverine section. *Liza richardsoni* contributed more to abundance than to mass, indicating the presence of small specimens, most likely juveniles. This species is therefore probably using the estuary as a nursery area rendering this area as important in the recruitment of this species.

Tilapia sparrmanii, Barbus paludinosus, Pseudocrenilabrus philander and *Clarias gariepinus* are the other species also present in the Okavango, Zambezi and Chobe Rivers. *Pseudocrenilabrus philander*, relatively common in the Lower Orange River, is also abundant in these northern rivers. *Tilapia sparrmanii* and *Barbus paludinosus*, low in numbers in the Lower Orange River were found to be much more regularly sampled in the Okavango, Zambezi and Chobe Rivers (Hay *et al.* 2000, 2002).

Oreochromis mossambicus was more abundant in the riverine section than in the estuary, differing from the gill net catches. This species, when considering also the gill net catches, seems to be increasing in abundance in the system when comparing with the results from Cambray (1984). *Cyprinus carpio* again was very low in number, with only one specimen recorded from the riverine section.

The IUCN Red List species *Labeobarbus kimberleyensis* is not considered important when using the other gear types, both in the estuary as well as in the riverine section. It contributed more to mass than to abundance. The preference for deeper, fast flowing habitats might be the reason for the low numbers sampled using these gear types as it is difficult to sample the preferred habitats. Only gill nets are effective in deeper, faster flowing areas. *Barbus hospes* seem to prefer the riverine section, with only three specimens sampled from the estuary. This was also noted by Cambray (1984), further stating that this species benefited from the regulated flow of the Orange River, although this was questioned by Benade (1993). *Austroglanis sclateri* was only sampled from the river section ant not from the estuary.

6.2 Body length distribution and gill net selectivity

6.2.1 Body length distribution in gill nets and other gears

There is a definite size difference of the sampled fish between the gill nets and the other gear types used, with smaller fish being sampled with the other gears than with gill nets. This was also observed during surveys in the Okavango River (Hay *et al.* 2000), the Zambezi and Chobe Rivers (Hay *et al.* 2002) and the Kwando River (Næsje *et al.* 2004). The habitats surveyed by the different gears and gear selectivity contributed towards this difference. The mean lengths of fish caught both by gill nets and other gears in the Orange River in the present study were larger than those caught in the Zambezi and Chobe Rivers (Hay *et al.* 2002). Modal lengths of fish caught in gill nets were larger in the Okavango River (9.0-9.9 cm) than in the Lower Orange River, Zambezi/Chobe Rivers and Kwando River (8.0-8.9 cm in all these rivers) (this study, Hay *et al.* 2000, 2002, Næsje *et al.* 2004).

6.2.2 Body length at maturity

Only four species had minimum length at maturity of less than 7 cm. These were *Mesobola brevianalis, Barbus trimaculatus, Barbus hospes* and *Pseudocrenilabrus philander. Pseudiocrenilabrus philander* had a smaller minimum length at maturity than the population in the Zambezi and Chobe Rivers (Hay *et al.* 2002). The males were smaller than in the Okavango River (Hay *et al.* 2000), but larger than in the Kwando River (Næsje *et al.* 2004). The situation was reversed for the females, with a larger minimum length at maturity than in the Okavango River, but smaller than in the Kwando River. The length at which 50% of the recorded *Pseudiocrenilabrus philander* were mature was larger in the Lower Orange River than for the populations from the Okavango and Zambezi/Chobe Rivers. The length at 50% maturity for males could not be calculated in the Lower Orange River, but the minimum length was smaller than for the populations from the two northern rivers. *Labeo capensis* had smaller lengths at 50% maturity for both sexes from the area of this study compared to those from Hardap Dam in 1988, as did *Oreochromis mossambicus* (Schrader 1992). Benade (1993) reported larger lengths at sexual maturity for *Labeo capensis* than for this study, whilst similar lengths were reported from Hardap Dam in the Fish River (Van Zyl *et al.* 1995).

6.2.3 Life history and gill net selectivity

Labeo capensis was abundantly caught in all types of gears including the gill nets. It was also the most commonly sampled species during a previous survey in the middle and lower Orange River (Skelton and Cambray 1981). There was a size difference between the gill nets and the other gears, with smaller specimens sampled with the other gears. This species was sampled with all the different mesh sizes of the gill nets used. It was also sampled with all mesh sizes in Hardap Dam (35 to 150 mm), with the highest number and mass per setting for the 93 mm mesh size (for the period 1983-1985). In a previous study in the Lower Orange River, the highest number of fish per setting was caught by the 73 mm mesh size, and the highest mass per setting by the 93 mm mesh size (Schrader 1992). Similar catches were recorded for the Naute Dam in the Fish River (Schrader 1992).

Labeobarbus aeneus, similar to *Labeo capensis*, was abundantly sampled with all gear types. Also smaller specimens were recorded with the other gear types. Skelton and Cambray (1981) mentioned that this species was nowhere sampled in great numbers, which is different from the results from this survey. This discrepancy may be either in the methodology used or there has been an increase in abundance since the surveys of Skelton and Cambray (1981). The methodology used by Skelton and Cambray (1981), however, included several types of fishing gear to prevent gear selectivity. It, therefore, appears that there has been an increase in abundance since those years. Benade (1993) also commented on the high abundance of this species in the Orange River System. No comparison can be made with Hardap Dam as this species is replaced by the hybrid *Labeobarbus cf. kimberleyensis*.

Mesobola brevianalis was very common in the catches of the other gears, but with no specimens sampled with the gill nets due to its small size. This species was also regularly sampled by Skelton and Cambray (1981), Cambray (1984) and Benade (1993). Hay (1991) also reported on the high number sampled in the lower parts of the Fish River. This species is absent from the upper reaches of the Fish River. Although considered rare in the Okavango River (Hay *et al.* 2000), the Zambezi and Chobe Rivers (Hay *et al.* 2002) and the Kwando River (Næsje *et al.* 2004), it appears to be more common in the Kunene River (C. J. Hay *pers. obs.*).

The alien species *Oreochromis mossambicus* can also be considered abundant in the Lower Orange River, with large numbers sampled in all the different gear types. This species was only sampled at one site in 1980 (Skelton and Cambray 1981), with only few individuals recorded by Cambray (1984). Benade (1993) did not record its presence during his surveys. This species was not caught in the 118 and 150 mm mesh sizes during this study, with the highest catch per setting in number of fish and mass in the 73 mm mesh size. During the period 1985 to 1988, the highest catch per setting in number of fish for Hardap Dam was in the 93 mm mesh size and in mass in the 118 mm mesh size (Schrader 1993).

The importance of *Clarias gariepinus* was mainly due to mass contribution rather than a high number of fish caught. This was true for all the different gear types. Smaller specimens were recorded with the other gears than with the gill nets. Although low numbers were sampled during earlier surveys (Skelton and Cambray 1981, Cambray 1984), *Clarias gariepinus* is not considered rare. This species was more abundant in the gill net catches in the Fish River (Hay 1991) than in the Lower Orange River. It could be that the pool habitats in the Fish River were more suitable for this species. Catches of *Clarias gariepinus* from Hardap Dam were also very low compared to the other species (Schrader 1992). Benade (1993) reported that this species was substantially more abundant in post-flood catches from the estuary. This study indicated that the gill net catches were evenly matched between the estuary and the riverine habitats, but that the catches with the other gears featured much higher catches in the river than those from the estuary. The highest number of fish caught per setting was in the 93 mm mesh size, whereas the largest mass was caught in the 150 mm mesh size. This corresponds to the Hardap dam, where both the highest number of fish and largest mass per setting was caught in the 150 mm mesh size (Schrader 1992).

Barbus hospes was recorded more often by using other gears than gill nets. This is mainly due to the small size of this species. Large individuals may be sampled with the smallest mesh sizes. The serrated dorsal spine can also be a reason for some of the catches in the gill nets. The species was not found to be common by Skelton and Cambray (1981). Cambray (1984), however, recommended that this species should be removed from the red data list. The present study does indicate this

species to be common, but the restricted distribution justifies the presence on the IUCN Red List. Very few specimens were recorded in the estuary, which, like emphasized by Cambray (1984), may be due to the different habitats or that the species cannot tolerate high salinities.

Liza richardsoni was important in the catches from the estuary, and then especially for the other gear types than gill nets. The restricted distribution decreases the importance when considering the entire study area. Cambray (1984), though, recorded one individual more than 40 km from the river mouth. This species has been found at Daberas pump station also more than 60 km from the river mouth (Hay *pers. obs.*). The length frequency of the other gears indicates that there were a large number of juveniles in the catches from the estuary. As indicated earlier, the estuary serves most probably as a nursery area for this species (Van der Elst 1985).

Barbus trimaculatus was recorded with all gear types, with a higher IRI percentage in the other gears than in the gill nets. This is due to the small size of the species, with catches only in the two smallest mesh sizes of the gill nets. Mainly mature individuals were recorded with the gill nets. This species can be considered common, although this was not the situation in the Lower Orange River during the survey done by Skelton and Cambray (1981). It is also not considered common in the lower reaches of the Fish River, where the pool habitats might not be suitable (Hay 1991). This species is closely related to *Barbus poechii* (Skelton 2001) from the Okavango, Zambezi, Chobe and Kwando Rivers. *Barbus trimaculatus* is, however, present in the Kunene River (Hay *et al.* 1997b, 1999).

Labeobarbus kimberleyensis was more important in the gill net catches than in the other gear types. There was also a size difference in the catches between these two gear types. This is probably due to habitat preferences, or it could be size related. The contribution was always higher in mass than in number of fish. Very few specimens were collected by Cambray (1984) and Skelton and Cambray (1981). Benade (1993) also reported on the low numbers sampled. Although it is difficult to compare abundance with earlier years as the methodology is not standardized, it appears that this species was more regularly sampled during this study than earlier, and several individuals smaller than 10 cm were collected during this study. *Labeobarbus kimberleyensis* was collected in all the different mesh sizes, with the 45 mm mesh size with the highest number of fish per setting and the 93 and 118 mm mesh size with the highest mass per setting. The largest specimen caught was larger than those reported by Cambray (1984), but smaller than reported by Skelton and Cambray (1981).

Pseudocrenilabrus philander was not recorded with the gill nets mainly due to the small size of the species. It was, however, recorded with gill nets in the Okavango River (Hay *et al.* 2000), the Zambezi and Chobe Rivers (Hay *et al.* 2002) and the Kwando River (Næsje *et al.* 2004), although in low numbers. This species was very common in catches with other gear types, especially in numbers, similar to the catches from the rivers in the north. Reports from earlier years also commented on the high abundance of this species in the Lower Orange River. *Pseudocrenilabrus philander* is important for the subsistence fishery in the Okavango River (Hay *et al.* 2000). The maximum body length was larger in all the rivers in the north of Namibia compared with catches from the Lower Orange River.

The alien species *Cyprinus carpio* had a very low IRI (0.3%) for the study period. It was more important in mass than in number of fish due to the large individuals collected. Very few specimens were recorded during earlier surveys (Skelton and Cambray 1981, Cambray 1984, Benade 1993). Catches from Hardap Dam also resulted in very few specimens sampled. The habitats from the Lower Orange River do not provide favourable sites for this species, and it does not at present pose a threat to the indigenous fish species. Only the larger mesh sizes recorded this species, with the highest number of fish and mass per setting sampled in the 150 mm mesh size, similar to the catches from Hardap Dam (Schrader 1992).

Mugil cephalus, a marine species, was only recorded in the estuary, both with gill nets and other gear types. It was slightly more important in the gill nets than in the other gears. The specimens caught with the other gears were all juveniles, whereas the majority of the specimens caught with gill nets had body lengths larger than the minimum size at maturity. Skelton (2001) reported that juveniles may enter estuaries during the winter months. *Mugil cephalus* was recorded with all mesh sizes except the two smallest and the largest mesh sizes. This species was also reported from the estuary by Benade (1993).

Barbus paludinosus is not considered very common in the system, with only two individuals caught using gill nets. The rest were collected using the other gear types. Large individuals may be caught with the small mesh sizes, or the serrated dorsal fin may get hooked to the gill nets, which happened during surveys in the northern rivers. The species was also not considered common by Skelton and Cambray (1981), Cambray (1984) and Benade (1993). This species was, however, very common in the pool habitats of the lower sections of the Fish River (Hay *et al.* 1997a).

Tilapia sparrmanii is considered not common in the Lower Orange River, with only 43 specimens recorded during this study. The species was mainly sampled using the other gear types. *Tilapia sparrmanii* was the most important species listed for the Zambezi and Chobe Rivers (Hay *et al.* 2002) using the other gears, and the third most important in the Okavango River (Hay *et al.* 2000). It was also recorded in the gill net catches in these rivers. The maximum body length was much larger for the Zambezi and Chobe Rivers (Hay *et al.* 2002) than for the Okavango (Hay *et al.* 2000) and Lower Orange Rivers. The highest number of fish and largest mass per setting were recorded with the 35 mm mesh size during this study. In the Zambezi and Chobe Rivers, the largest number of fish per setting was recorded with the 22 mm mesh size and the largest mass with the 57 mm mesh size.

Austroglanis sclateri was only sampled with the other gear types than gill nets and not in large numbers. This was mainly habitat related as this species was only recorded in rocky habitats, mainly rapids. It was also not commonly found during previous surveys (Skelton and Cambray 1981, Cambray 1984, Benade 1993). According to Skelton (2001), recent assessments showed that the species was more common than previously thought. Sedimentation and water abstraction are the main threats to this species.

Athrina breviceps was not commonly recorded and was not collected with the gill nets. It is a marine species and was collected only in the estuary. It is tolerant of low salinities and can complete its life cycle within the estuary (van der Elst 1985).

Lichia amia was only caught using gill nets and was not very common in the catches. It is a marine species and was only sampled in the estuary. It has no commercial value, but is important for recreational fishermen (van der Elst 1985).

6.3 Catch per unit effort (CPUE)

The catch per unit effort in the multifilament gill nets was much higher in mass (3.9 kg per setting) for the Orange River than for any of the other Namibian rivers surveyed with similar methods (1.44 kg per setting in the Okavango River, 1.87 kg per setting in the Zambezi/Chobe Rivers and 1.23 kg per setting in the Kwando River, Hay *et al.* 2000, 2002, Næsje *et al.* 2004). In number of fish per setting, the catches were higher in the Orange River (17 fish per setting) than in the Kwando River (10 fish per setting), but lower than in the Okavango River (28 fish per setting) and Zambezi/Chobe Rivers (89 fish per setting) (Hay *et al.* 2000, 2002, Næsje *et al.* 2004).

6.3.1 Catch per unit effort in different mesh sizes

Mean catch per unit effort given as number of fish per setting decreased with an increase in mesh size. In contrast, mean catch per unit effort given as mass per setting increased with increasing mesh size. A similar relationship was observed for the Kwando River (Næsje *et al.* 2004), but not for the Zambezi/Chobe rivers (Hay *et al.* 2002), where both the number and mass decreased with mesh size.

6.3.2 Catch per unit effort at different stations

Similar to the Okavango and Zambezi/Chobe Rivers (Hay *et al.* 2000, 2002), a difference in catch per unit effort among stations was observed in the Lower Orange River. The Off-Road Club had the highest catch per unit effort in number of fish per setting as well as in mass. This was followed by the River Mouth Station. Both these stations are situated in the estuary. The highest catch per unit effort for the stations in the river was Houms River, both in mass and number of fish per setting.

6.4 IUCN Red List species

Labeobarbus kimberleyensis seem to have increased in abundance since the early 1980's. However, earlier authors commented on the difficulty in distinguishing specimens smaller than 10 cm between this species and

Labeobarbus aeneus. The length frequencies indicate successful recruitment, with also large individuals collected during the survey, indicating a relatively stable population. The large size at maturity, however, places this species in the near threatened category, and in future steps should be taken to protect this species.

Barbus hospes was found to be common in the system with successful recruitment taking place. The status on the Red List as of least concern should remain due to the restricted distribution of this species.

Very few individuals of the species *Austroglanis sclateri* were collected during this study, which may be partly due to its preference for rocky habitats, mainly rapids. These habitats are very difficult to monitor and the numbers are probably under estimated. The South African Institute for Aquatic Biodiversity is presently doing a detailed study of this species along the entire Orange River that will improve our understanding of the status of this species.

6.5 Alien species

Oreochromis mossambicus was abundantly sampled throughout the river, indicating a drastic increase in abundance since the early 1980's. Recruitment had also been extremely successful with large numbers of juvenile fish recorded. It is expected that this abundance will increase in future, which may be detrimental to the native fish population, especially for *Tilapia sparrmanii*.

The other alien species, *Cyprinus carpio*, does not seem to pose a threat to the native fish population as very few individuals were recorded during this study. The riverine conditions do not seem to benefit this species, with very poor recruitment observed.

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Appendixes

RESULTS FROM ALL STATIONS COMBINED (APPENDIX 1-7)

Appendix 1. *Scientific and English common names of species caught during surveys (multifilament gill nets, monofilament gill nets and other gears) in the Lower Orange River during 1995 - 2001, classified by family.*

Family number	Family	Scientific name	English common name	Habitat (fresh water/ marine)
1	Cyprinidae (barbs, yellowfish, labeos)	*Labeobarbus aeneus*	Smallmouth yellowfish	Fresh water
		Labeobarbus kimberleyensis	Largemouth yellowfish	Fresh water
		Barbus trimaculatus	Threespot barb	Fresh water
		Barbus hospes	Namaqua barb	Fresh water
		Barbus paludinosus	Straightfin barb	Fresh water
		Labeo capensis	Orange river mudfish	Fresh water
		Mesobola brevianalis	River sardine	Fresh water
		Cyprinus carpio	Common carp	Fresh water
2	Clariidae (air-breathing catfish)	*Clarias gariepinus*	Sharptooth catfish	Fresh water
3	Cichlidae (cichlids)	*Oreochromis mossambicus*	Mozambique tilapia	Fresh water
		Pseudocrenilabrus philander	Southern mouthbrooder	Fresh water
		Tilapia sparrmanii	Banded tilapia	Fresh water
4	Mugilidae (Mullets)	*Liza richardsoni*	Southern mullet	Marine
		Mugil cephalus	Flathead mullet	Marine
5	Austroglanididae (Rock catfishes)	*Austroglanis sclateri*	Rock catfish	Fresh water
6	Atherinidae (Silversides)	*Atherina breviceps*	Cape silverside	Marine
7	Gobiidae (Gobies)	*Gobiidae sp.*	Goby	Marine
8	Carangidae (Kingfishes, yellowtails, pompanos, queenfishes, garrick, rainbow runner)	*Lichia amia*	Garrick	Marine

Appendix 2. *Mean, minimum and maximum body lengths (cm) for fish caught with multifilament gill nets, monofilament gill nets and other gears during surveys in the Lower Orange River during 1995 - 2001. Only specimens that were length measured are included (n = number of specimens length measured).*

Family	Species	Mean length	Minimum length	Maximum length	n
Cyprinidae	*Barbus paludinosus*	4.72	2	7	148
	Barbus trimaculatus	6.99	3	11	958
	Labeobarbus aeneus	16.02	2	64	2404
	Barbus hospes	4.47	2	9	775
	Labeobarbus kimberleyensis	22.64	3	62	211
	Labeo capensis	11.95	2	46	3139
	Mesobola brevianalis	3.76	1	7	1065
	Cyprinus carpio	40.83	3	76	18
Clariidae	*Clarias gariepinus*	33.96	5	150	284
Cichlidae	*Oreochromis mossambicus*	9.50	1	30	1045
	Pseudocrenilabrus philander	4.10	2	8	693
	Tilapia sparrmanii	8.02	2	15	43
Gobiidae	*Gobiidae sp.*	10.00	10	10	1
Mugilidae	*Mugil cephalus*	11.97	3	50	89
	Liza richardsoni	7.77	2	31	661
Austroglanididae	*Austroglanis sclateri*	8.04	2	16	68
Atherinidae	*Atherina breviceps*	4.23	2	7	31
Carangidae	*Lichia amia*	19.33	12	25	21
-	*Marine sp.*	3.54	3	5	56
Total		**10.82**	**1**	**150**	**11710**

Appendix 3. *The relative importance (IRI) of all species caught by multifilament gill nets and other gears at all stations combined during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to appendix 1.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeo capensis*	4416	24.8	285.04	31.2	56	81.2	4547	34.68
1	*Labeobarbus aeneus*	2564	14.4	273.18	29.9	57	82.6	3660	27.92
1	*Mesobola brevianalis*	2841	16.0	1.76	0.2	52	75.4	1218	9.29
3	*Oreochromis mossambicus*	2019	11.4	44.47	4.9	42	60.9	987	7.53
2	*Clarias gariepinus*	286	1.6	175.37	19.2	32	46.4	965	7.36
1	*Barbus hospes*	1305	7.3	1.51	0.2	35	50.7	381	2.90
4	*Liza richardsoni*	1664	9.4	18.62	2.0	21	30.4	347	2.64
1	*Barbus trimaculatus*	924	5.2	4.36	0.5	42	60.9	345	2.63
1	*Labeobarbus kimberleyensis*	208	1.2	60.00	6.6	25	36.2	280	2.14
3	*Pseudocrenilabrus philander*	1055	5.9	0.90	0.1	31	44.9	271	2.07
1	*Cyprinus carpio*	18	0.1	32.04	3.5	8	11.6	42	0.32
4	*Mugil cephalus*	86	0.5	13.09	1.4	11	15.9	31	0.23
1	*Barbus paludinosus*	170	1.0	0.20	0.0	19	27.5	27	0.21
3	*Tilapia sparrmanii*	43	0.2	0.47	0.1	12	17.4	5	0.04
5	*Austroglanis sclateri*	68	0.4	0.51	0.1	4	5.8	3	0.02
-	*Marine sp.*	68	0.4	0.03	0.0	3	4.4	2	0.01
6	*Atherina breviceps*	31	0.2	0.02	0.0	5	7.3	1	0.01
8	*Lichia amia*	21	0.1	2.20	0.2	1	1.5	1	0.00
7	*Gobiidae sp.*	1	0.0	0.02	0.0	1	1.5	0	0.00
	SUM	**17788**	**100**	**914**	**100**			**13111**	**100**

Appendix 4. *The relative importance (IRI) of all species caught by* ***multifilament gill nets*** *(22-150 mm) at* ***all stations*** *combined during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeobarbus aeneus*	1616	44.35	267.96	31.93	346	48.39	3691	53.32
1	*Labeo capensis*	905	24.84	261.67	31.18	324	45.31	2538	36.67
2	*Clarias gariepinus*	123	3.38	151.08	18.00	85	11.89	254	3.67
1	*Labeobarbus kimberleyensis*	167	4.58	54.11	6.45	118	16.50	182	2.63
3	*Oreochromis mossambicus*	284	7.79	37.91	4.52	83	11.61	143	2.06
1	*Barbus trimaculatus*	358	9.82	2.66	0.32	60	8.39	85	1.23
4	*Liza richardsoni*	110	3.02	16.39	1.95	22	3.08	15	0.22
1	*Cyprinus carpio*	17	0.47	32.04	3.82	12	1.68	7	0.10
4	*Mugil cephalus*	23	0.63	12.83	1.53	16	2.24	5	0.07
8	*Lichia amia*	21	0.58	2.20	0.26	7	0.98	1	0.01
3	*Tilapia sparrmanii*	11	0.30	0.31	0.04	8	1.12	0	0.01
1	*Barbus hospes*	7	0.19	0.04	0.01	5	0.70	0	0.00
1	*Barbus paludinosus*	2	0.05	0.00	0.00	2	0.28	0	0.00
	SUM	**3644**	**100**	**839**	**100**			**6922**	**100**

Appendix 5. *The relative importance (IRI) of all species caught by* ***other gears*** *at* ***all stations*** *combined during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeo capensis*	3511	24.82	23.38	31.36	97	64.24	3609	41.10
1	*Mesobola brevianalis*	2841	20.09	1.76	2.37	82	54.30	1219	13.88
3	*Oreochromis mossambicus*	1735	12.27	6.56	8.80	65	43.05	907	10.32
2	*Clarias gariepinus*	163	1.15	24.28	32.57	39	25.83	871	9.92
1	*Labeobarbus aeneus*	948	6.70	5.22	7.01	90	59.60	817	9.30
1	*Barbus hospes*	1298	9.18	1.47	1.97	47	31.13	347	3.95
3	*Pseudocrenilabrus philander*	1055	7.46	0.90	1.20	60	39.74	344	3.92
1	*Barbus trimaculatus*	566	4.00	1.70	2.28	76	50.33	316	3.60
4	*Liza richardsoni*	1554	10.99	2.23	2.98	25	16.56	231	2.63
1	*Labeobarbus kimberleyensis*	41	0.29	5.88	7.89	16	10.60	87	0.99
1	*Barbus paludinosus*	168	1.19	0.19	0.26	20	13.25	19	0.22
5	*Austroglanis sclateri*	68	0.48	0.51	0.68	5	3.31	4	0.04
4	*Mugil cephalus*	63	0.45	0.26	0.34	7	4.64	4	0.04
3	*Tilapia sparrmanii*	32	0.23	0.16	0.21	12	7.95	3	0.04
-	*Marine sp.*	68	0.48	0.03	0.04	7	4.64	2	0.03
6	*Atherina breviceps*	31	0.22	0.02	0.02	7	4.64	1	0.01
7	*Gobiidae sp.*	1	0.01	0.02	0.02	1	0.66	0	0.00
1	*Cyprinus carpio*	1	0.01	0.00	0.00	1	0.66	0	0.00
	SUM	**14144**	**100**	**75**	**100.**			**8782**	**100**

RESULTS FROM MULTIFILAMENT GILL NET CATCHES AT THE DIFFERENT STATIONS (APPENDIX 6-12)

Appendix 6. *The relative importance (IRI) of all species caught by* ***multifilament gill nets*** *at the* ***River Mouth station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeobarbus aeneus*	432	78.83	95.36	61.30	66	69.47	9735	87.88
1	*Labeo capensis*	58	10.58	15.18	9.76	30	31.58	642	5.80
2	*Clarias gariepinus*	30	5.47	35.94	23.11	21	22.11	632	5.70
1	*Labeobarbus kimberleyensis*	8	1.46	3.95	2.54	8	8.42	34	0.30
4	*Mugil cephalus*	7	1.28	4.18	2.68	6	6.32	25	0.23
3	*Oreochromis mossambicus*	5	0.91	0.43	0.28	4	4.21	5	0.05
1	*Barbus trimaculatus*	5	0.91	0.04	0.02	3	3.16	3	0.03
4	*Liza richardsoni*	3	0.55	0.49	0.32	2	2.11	2	0.02
	SUM	**548**	**100**	**156**	**100**			**11078**	**100**

Appendix 7. *The relative importance (IRI) of all species caught by* ***multifilament gill nets*** *at the* ***Off-Road Club station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeobarbus aeneus*	715	48.47	97.35	31.52	66	75.00	6000	56.14
1	*Labeo capensis*	307	20.81	83.43	27.01	58	65.91	3152	29.49
3	*Oreochromis mossambicus*	171	11.59	21.70	7.03	26	29.55	550	5.15
2	*Clarias gariepinus*	32	2.17	41.82	13.54	18	20.45	321	3.01
4	*Liza richardsoni*	107	7.25	15.90	5.15	20	22.73	282	2.64
1	*Labeobarbus kimberleyensis*	43	2.92	17.08	5.53	25	28.41	240	2.24
1	*Cyprinus carpio*	11	0.75	20.17	6.53	6	6.82	50	0.46
4	*Mugil cephalus*	16	1.08	8.66	2.80	10	11.36	44	0.41
1	*Barbus trimaculatus*	46	3.12	0.39	0.13	8	9.09	29	0.28
8	*Lichia amia*	21	1.42	2.20	0.71	7	7.95	17	0.16
3	*Tilapia sparrmanii*	6	0.41	0.13	0.04	4	4.55	2	0.02
	SUM	**1475**	**100**	**309**	**100**			**10688**	**100**

Appendix 8. *The relative importance (IRI) of all species caught by* ***multifilament gill*** *nets at the* ***Daberas Pump station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeobarbus aeneus*	41	65.08	9.89	26.10	27	36.00	3282	77.35
2	*Clarias gariepinus*	8	12.70	18.35	48.41	6	8.00	489	11.52
1	*Labeo capensis*	12	19.05	9.13	24.08	8	10.67	460	10.84
1	*Labeobarbus kimberleyensis*	2	3.17	0.53	1.41	2	2.67	12	0.29
	SUM	**63**	**100**	**38**	**100**			**4244**	**100**

Appendix 9. *The relative importance (IRI) of all species caught by* ***multifilament gill nets*** *at the* ***Sebrasfontain station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeobarbus aeneus*	27	38.03	6.02	19.10	15	33.33	1904	45.81
1	*Labeo capensis*	23	32.39	5.42	17.19	9	20.00	992	23.86
2	*Clarias gariepinus*	7	9.86	16.40	52.04	5	11.11	688	16.55
1	*Labeobarbus kimberleyensis*	12	16.90	2.60	8.25	10	22.22	559	13.45
1	*Cyprinus carpio*	1	1.41	1.07	3.40	1	2.22	11	0.26
1	*Barbus trimaculatus*	1	1.41	0.01	0.02	1	2.22	3	0.08
	SUM	**71**	**100**	**32**	**100**			**4156**	**100**

Appendix 10. *The relative importance (IRI) of all species caught by* ***multifilament gill nets*** *at the* ***Grootpenseiland station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeo capensis*	214	38.70	52.64	45.89	82	55.03	4655	58.78
1	*Labeobarbus aeneus*	169	30.56	24.23	21.13	65	43.62	2255	28.47
1	*Labeobarbus kimberleyensis*	60	10.85	16.86	14.70	41	27.52	703	8.88
3	*Oreochromis mossambicus*	38	6.87	5.63	4.91	20	13.42	158	2.00
1	*Barbus trimaculatus*	59	10.67	0.44	0.38	14	9.40	104	1.31
2	*Clarias gariepinus*	8	1.45	4.56	3.98	7	4.70	25	0.32
1	*Cyprinus carpio*	3	0.54	10.33	9.01	3	2.01	19	0.24
1	*Barbus hospes*	1	0.18	0.01	0.00	1	0.67	0	0.00
1	*Barbus paludinosus*	1	0.18	0.00	0.00	1	0.67	0	0.00
	SUM	**553**	**100**	**115**	**100**			**7920**	**100**

Appendix 11. *The relative importance (IRI) of all species caught by* ***multifilament gill nets*** *at the* ***Gariep Motors station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeo capensis*	192	32.21	43.70	61.90	96	55.49	5223	71.17
1	*Labeobarbus aeneus*	117	19.63	12.52	17.74	60	34.68	1296	17.66
1	*Barbus trimaculatus*	202	33.89	1.49	2.10	24	13.87	499	6.81
3	*Oreochromis mossambicus*	53	8.89	6.79	9.61	23	13.29	246	3.35
1	*Labeobarbus kimberleyensis*	15	2.52	2.80	3.97	14	8.09	52	0.72
2	*Clarias gariepinus*	7	1.17	2.94	4.16	6	3.47	18	0.25
1	*Barbus hospes*	5	0.84	0.03	0.05	3	1.73	2	0.02
3	*Tilapia sparrmanii*	3	0.50	0.15	0.21	3	1.73	1	0.02
1	*Cyprinus carpio*	1	0.17	0.19	0.26	1	0.58	0	0.00
1	*Barbus paludinosus*	1	0.17	0.00	0.00	1	0.58	0	0.00
	SUM	**596**	**100**	**71**	**100**			**7338**	**100**

Appendix 12. *The relative importance (IRI) of all species caught by* ***multifilament gill nets*** *at the* ***Houms River station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeo capensis*	99	29.29	52.18	43.44	41	45.56	3313	44.18
1	*Labeobarbus aeneus*	115	34.02	22.59	18.80	47	52.22	2759	36.79
2	*Clarias gariepinus*	31	9.17	31.07	25.87	22	24.44	857	11.42
1	*Labeobarbus kimberleyensis*	27	7.99	10.30	8.57	18	20.00	331	4.42
1	*Barbus trimaculatus*	45	13.31	0.30	0.25	10	11.11	151	2.01
3	*Oreochromis mossambicus*	17	5.03	3.36	2.80	10	11.11	87	1.16
3	*Tilapia sparrmanii*	2	0.59	0.03	0.03	1	1.11	1	0.01
1	*Cyprinus carpio*	1	0.30	0.28	0.23	1	1.11	1	0.01
1	*Barbus hospes*	1	0.30	0.01	0.01	1	1.11	0	0.00
	SUM	**338**	**100**	**120**	**100**			**7499**	**100**

RESULTS FROM OTHER GEARS AT THE DIFFERENT STATIONS (APPENDIX 13-22)

Appendix 13. *The relative importance (IRI) of all species caught by* ***other gears*** *than gill nets at the* ***River Mouth station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
4	Liza richardsoni	1550	63.39	1.94	47.27	23	74.19	8211	74.63
1	Labeobarbus aeneus	62	2.54	1.06	25.77	12	38.71	1096	9.96
1	Mesobola brevianalis	336	13.74	0.32	7.73	10	32.26	693	6.30
1	Labeo capensis	132	5.40	0.13	3.25	13	41.94	363	3.30
3	Oreochromis mossambicus	74	3.03	0.21	5.13	9	29.03	237	2.15
1	Barbus trimaculatus	86	3.52	0.22	5.43	6	19.35	173	1.57
4	Mugil cephalus	59	2.41	0.11	2.78	6	19.35	101	0.91
-	Marine sp.	68	2.78	0.03	0.68	7	22.58	78	0.71
6	Atherina breviceps	31	1.27	0.02	0.42	7	22.58	38	0.35
1	Barbus paludinosus	36	1.47	0.03	0.82	1	3.23	7	0.07
3	Pseudocrenilabrus philander	4	0.16	0.00	0.10	3	9.68	3	0.02
7	Gobiidae sp.	1	0.04	0.02	0.42	1	3.23	1	0.01
1	Barbus hospes	3	0.12	0.00	0.03	3	9.68	1	0.01
3	Tilapia sparrmanii	3	0.12	0.01	0.18	1	3.23	1	0.01
	SUM	**2445**	**100**	**4.1**	**100**			**11002**	**100**

Appendix 14. *The relative importance (IRI) of all species caught by* ***other gears*** *than gill nets at the* ***Off-Road Club*** *station during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeobarbus kimberleyensis*	3	2.83	1.86	53.49	2	33.33	1877	29.27
1	*Labeo capensis*	7	6.60	0.64	18.51	3	50.00	1256	19.58
1	*Barbus trimaculatus*	22	20.75	0.15	4.44	2	33.33	840	13.09
1	*Labeobarbus aeneus*	15	14.15	0.37	10.57	2	33.33	824	12.85
3	*Pseudocrenilabrus philander*	17	16.04	0.01	0.40	2	33.33	548	8.54
3	*Oreochromis mossambicus*	27	25.47	0.01	0.27	1	16.67	429	6.69
4	*Liza richardsoni*	4	3.77	0.29	8.20	2	33.33	399	6.22
4	*Mugil cephalus*	4	3.77	0.14	4.05	1	16.67	130	2.03
1	*Barbus paludinosus*	5	4.72	0.00	0.05	1	16.67	79	1.24
2	*Clarias gariepinus*	1	0.94	0.00	0.02	1	16.67	16	0.25
1	*Mesobola brevianalis*	1	0.94	0.00	0.01	1	16.67	16	0.25
	SUM	**106**	**100**	**3.5**	**100**			**6414**	**100**

Appendix 15. *The relative importance (IRI) of all species caught by* ***other gears*** *than gill nets at the* ***Hohenfels station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Barbus hospes*	111	38.01	0.12	22.32	5	71.43	4310	32.09
1	*Labeobarbus aeneus*	27	9.25	0.18	32.94	7	100.0	4219	31.41
1	*Mesobola brevianalis*	61	20.89	0.03	5.53	6	85.71	2264	16.86
1	*Labeo capensis*	9	3.08	0.08	14.56	5	71.43	1260	9.38
1	*Barbus trimaculatus*	11	3.77	0.03	4.83	6	85.71	737	5.49
3	*Oreochromis mossambicus*	30	10.27	0.05	9.13	1	14.29	277	2.06
1	*Barbus paludinosus*	32	10.96	0.04	7.79	1	14.29	268	1.99
3	*Pseudocrenilabrus philander*	8	2.74	0.01	1.28	1	14.29	57	0.43
2	*Clarias gariepinus*	1	0.34	0.01	1.30	1	14.29	23	0.17
3	*Tilapia sparrmanii*	2	0.68	0.00	0.33	1	14.29	15	0.11
	SUM	**292**	**100**	**0.55**	**100**			**13430**	**100**

Appendix 16. *The relative importance (IRI) of all species caught by* ***other gears*** *than gill nets at the* ***Daberas Pump*** *station during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeo capensis*	447	40.90	2.49	10.79	10	62.50	3231	32.84
2	*Clarias gariepinus*	13	1.19	16.51	71.53	7	43.75	3182	32.34
1	*Mesobola brevianalis*	270	24.70	0.10	0.44	9	56.25	1414	14.37
1	*Labeobarbus aeneus*	133	12.17	0.43	1.87	9	56.25	790	8.02
1	*Barbus hospes*	146	13.36	0.13	0.56	6	37.50	522	5.31
1	*Labeobarbus kimberleyensis*	4	0.37	3.14	13.61	4	25.00	349	3.55
3	*Oreochromis mossambicus*	41	3.75	0.22	0.95	7	43.75	206	2.09
1	*Barbus trimaculatus*	32	2.93	0.05	0.22	7	43.75	138	1.40
3	*Pseudocrenilabrus philander*	3	0.27	0.00	0.02	2	12.50	4	0.04
1	*Barbus paludinosus*	3	0.27	0.00	0.01	2	12.50	3	0.04
1	*Cyprinus carpio*	1	0.09	0.00	0.00	1	6.25	1	0.01
	SUM	**1093**	**100**	**23.1**	**100**			**9838**	**100**

Appendix 17. *The relative importance (IRI) of all species caught by* ***other gears*** *than gill nets at the* ***Sendelingsdrif station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Mesobola brevianalis*	210	79.85	0.26	28.69	2	100.0	10854	62.12
3	*Oreochromis mossambicus*	4	1.52	0.42	47.03	1	50.00	2428	13.90
1	*Labeo capensis*	30	11.41	0.10	11.55	2	100.0	2296	13.14
1	*Labeobarbus aeneus*	12	4.56	0.10	11.72	2	100.0	1629	9.32
1	*Barbus trimaculatus*	3	1.14	0.01	0.51	2	100.0	165	0.95
1	*Barbus paludinosus*	3	1.14	0.00	0.26	1	50.00	70	0.40
1	*Barbus hospes*	1	0.38	0.00	0.23	1	50.00	31	0.17
	SUM	**263**	**100**	**0.89**	**100**			**17472**	**100**

Appendix 18. *The relative importance (IRI) of all species caught by* ***other gears*** *than gill nets at the* ***Sebrasfontain station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	Labeo capensis	841	37.15	5.79	51.99	19	90.48	8065	59.67
1	Mesobola brevianalis	624	27.56	0.55	4.95	13	61.90	2013	14.89
1	Barbus hospes	506	22.35	0.79	7.12	10	47.62	1403	10.38
1	Labeobarbus aeneus	95	4.20	0.82	7.34	17	80.95	934	6.91
2	Clarias gariepinus	31	1.37	2.50	22.47	6	28.57	681	5.04
3	Oreochromis mossambicus	92	4.06	0.57	5.09	6	28.57	261	1.93
1	Barbus trimaculatus	40	1.77	0.06	0.58	11	52.38	123	0.91
1	Barbus paludinosus	27	1.19	0.04	0.38	4	19.05	30	0.22
3	Pseudocrenilabrus philander	5	0.22	0.00	0.04	4	19.05	5	0.04
1	Labeobarbus kimberleyensis	3	0.13	0.01	0.05	2	9.52	2	0.01
	SUM	**2264**	**100**	**11**	**100**			**13517**	**100**

Appendix 19. *The relative importance (IRI) of all species caught by* ***other gears*** *than gill nets at the* ***Grootpenseiland station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeo capensis*	1022	41.26	3.46	44.15	20	80.00	6833	55.12
1	*Labeobarbus aeneus*	284	11.47	0.81	10.34	17	68.00	1483	11.96
2	*Clarias gariepinus*	75	3.03	1.67	21.35	9	36.00	877	7.08
3	*Oreochromis mossambicus*	128	5.17	0.72	9.20	15	60.00	862	6.95
1	*Barbus hospes*	347	14.01	0.27	3.49	9	36.00	630	5.08
1	*Mesobola brevianalis*	232	9.37	0.07	0.88	15	60.00	615	4.96
1	*Barbus trimaculatus*	159	6.42	0.36	4.57	12	48.00	528	4.26
3	*Pseudocrenilabrus philander*	134	5.41	0.19	2.47	15	60.00	473	3.82
1	*Barbus paludinosus*	49	1.98	0.06	0.70	4	16.00	43	0.35
5	*Austroglanis sclateri*	29	1.17	0.15	1.86	2	8.00	24	0.20
1	*Labeobarbus kimberleyensis*	12	0.48	0.04	0.56	5	20.00	21	0.17
3	*Tilapia sparrmanii*	6	0.24	0.03	0.43	3	12.00	8	0.06
	SUM	**2477**	**100**	**7.84**	**100**			**12397**	**100**

Appendix 20. *The relative importance (IRI) of all species caught by* ***other gears*** *than gill nets at the* ***Sambok River station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeo capensis*	699	42.31	8.98	79.19	8	100.0	12150	69.63
1	*Labeobarbus aeneus*	239	14.47	0.69	6.12	8	100.0	2059	11.80
3	*Pseudocrenilabrus philander*	307	18.58	0.18	1.55	7	87.50	1762	10.10
1	*Mesobola brevianalis*	95	5.75	0.03	0.23	7	87.50	523	3.00
3	*Oreochromis mossambicus*	215	13.01	0.70	6.18	2	25.00	480	2.75
1	*Barbus trimaculatus*	21	1.27	0.04	0.35	7	87.50	142	0.81
2	*Clarias gariepinus*	21	1.27	0.23	1.98	3	37.50	122	0.70
5	*Austroglanis sclateri*	27	1.63	0.34	3.03	2	25.00	117	0.67
1	*Barbus hospes*	17	1.03	0.01	0.11	4	50.00	57	0.33
3	*Tilapia sparrmanii*	6	0.36	0.06	0.50	2	25.00	21	0.12
1	*Labeobarbus kimberleyensis*	2	0.12	0.08	0.74	1	12.50	11	0.06
1	*Barbus paludinosus*	3	0.18	0.00	0.02	2	25.00	5	0.03
	SUM	**1652**	**100**	**11**	**100**			**17448**	**100**

Appendix 21. *The relative importance (IRI) of all species caught by* ***other gears*** *than gill nets at the* ***Gariep Motors station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
3	*Oreochromis mossambicus*	679	32.90	0.84	30.22	10	62.50	3945	35.23
1	*Mesobola brevianalis*	599	29.02	0.24	8.64	9	56.25	2118	18.92
1	*Barbus trimaculatus*	131	6.35	0.63	22.44	11	68.75	1979	17.67
1	*Labeo capensis*	217	10.51	0.49	17.62	8	50.00	1407	12.56
3	*Pseudocrenilabrus philander*	250	12.11	0.17	6.23	9	56.25	1032	9.22
1	*Barbus hospes*	126	6.10	0.11	3.92	4	25.00	251	2.24
1	*Labeobarbus aeneus*	34	1.65	0.12	4.18	6	37.50	218	1.95
2	*Clarias gariepinus*	8	0.39	0.13	4.71	6	37.50	191	1.71
1	*Tilapia sparrmanii*	12	0.58	0.05	1.74	3	18.75	44	0.39
1	*Barbus paludinosus*	8	0.39	0.01	0.30	3	18.75	13	0.11
	SUM	**2064**	**100**	**2.8**	**100**			**11198**	**100**

Appendix 22. *The relative importance (IRI) of all species caught by* ***other gears*** *than gill nets at the* ***Houms River station*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
3	*Oreochromis mossambicus*	445	29.91	2.82	30.12	13	68.42	4107	37.05
3	*Pseudocrenilabrus philander*	327	21.98	0.32	3.42	17	89.47	2272	20.50
1	*Mesobola brevianalis*	413	27.76	0.17	1.84	10	52.63	1558	14.05
2	*Clarias gariepinus*	13	0.87	3.24	34.60	6	31.58	1120	10.11
1	*Labeo capensis*	107	7.19	1.21	12.92	9	47.37	952	8.59
1	*Labeobarbus aeneus*	47	3.16	0.64	6.89	10	52.63	529	4.77
1	*Barbus trimaculatus*	61	4.10	0.15	1.62	12	63.16	361	3.26
1	*Labeobarbus kimberleyensis*	17	1.14	0.75	8.02	2	10.53	96	0.87
1	*Barbus hospes*	41	2.76	0.02	0.25	5	26.32	79	0.71
5	*Austroglanis sclateri*	12	0.81	0.02	0.18	1	5.26	5	0.05
1	*Tilapia sparrmanii*	3	0.20	0.01	0.09	2	10.53	3	0.03
1	*Barbus paludinosus*	2	0.13	0.00	0.05	1	5.26	1	0.01
	SUM	**1488**	**100**	**9.4**	**100**			**11085**	**100**

RESULTS FROM THE ESTUARY VERSUS THE RIVER (APPENDIX 13-22)

Appendix 23. *The relative importance (IRI) of all species caught by* ***multifilament gill nets and other gears in the estuary (station 1 and 2)*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeobarbus aeneus*	1224	26.76	194.14	41.13	17	65.38	4439	39.4
4	*Liza richardsoni*	1664	36.38	18.62	3.95	20	76.92	3102	27.53
1	*Labeo capensis*	504	11.02	99.38	21.06	16	61.54	1974	17.52
3	*Oreochromis mossambicus*	277	6.06	22.35	4.74	12	46.15	498	4.42
2	*Clarias gariepinus*	63	1.38	77.76	16.48	6	23.08	412	3.66
1	*Mesobola brevianalis*	337	7.37	0.32	0.07	11	42.31	315	2.79
4	*Mugil cephalus*	86	1.88	13.09	2.77	10	38.46	179	1.59
1	*Barbus trimaculatus*	159	3.48	0.80	0.17	9	34.62	126	1.12
1	*Labeobarbus kimberleyensis*	54	1.18	22.89	4.85	5	19.23	116	1.03
1	*Cyprinus carpio*	11	0.24	20.17	4.27	3	11.54	52	0.46
-	*Marine sp.*	68	1.49	0.03	0.01	3	11.54	17	0.15
6	*Atherina breviceps*	31	0.68	0.02	0	5	19.23	13	0.12
3	*Pseudocrenilabrus philander*	21	0.46	0.02	0	5	19.23	9	0.08
1	*Barbus paludinosus*	41	0.9	0.04	0.01	2	7.69	7	0.06
8	*Lichia amia*	21	0.46	2.20	0.47	1	3.85	4	0.03
3	*Tilapia sparrmanii*	9	0.2	0.14	0.03	3	11.54	3	0.02
1	*Barbus hospes*	3	0.07	0.00	0	3	11.54	1	0.01
7	*Gobiidae sp.*	1	0.02	0.02	0	1	3.85	0	0
	SUM	**4574**	**100**	**472**	**100**			**11266**	**100**

Appendix 24. *The relative importance (IRI) of all species caught by* ***multifilament gill nets and other gears in the river (station 3 to 10)*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	Labeo capensis	3912	29.6	185.67	42.02	41	95.35	6830	41.64
1	Labeobarbus aeneus	1340	10.14	79.05	17.89	41	95.35	2673	16.3
1	Mesobola brevianalis	2504	18.95	1.45	0.33	41	95.35	1838	11.21
2	Clarias gariepinus	223	1.69	97.61	22.09	25	58.14	1383	8.43
3	Oreochromis mossambicus	1742	13.18	22.12	5.01	31	72.09	1311	8
1	Barbus hospes	1302	9.85	1.51	0.34	33	76.74	782	4.77
1	Barbus trimaculatus	765	5.79	3.56	0.8	34	79.07	521	3.18
3	Pseudocrenilabrus philander	1034	7.83	0.88	0.2	27	62.79	504	3.07
1	Labeobarbus kimberleyensis	154	1.17	37.11	8.4	21	48.84	467	2.85
1	Barbus paludinosus	129	0.98	0.16	0.04	17	39.53	40	0.24
1	Cyprinus carpio	7	0.05	11.87	2.69	6	13.95	38	0.23
3	Tilapia sparrmanii	34	0.26	0.33	0.07	9	20.93	7	0.04
5	Austroglanis sclateri	68	0.51	0.51	0.11	4	9.3	6	0.04
	SUM	**13214**	**100**	**442**	**100**			**16400**	**100**

Appendix 25. *The relative importance (IRI) of all species caught by* ***multifilament gill nets in the estuary (station 1 and 2)*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeobarbus aeneus*	1147	56.7	192.71	41.5	132	72.13	7083	71.39
1	*Labeo capensis*	365	18.04	98.60	21.23	88	48.09	1889	19.04
2	*Clarias gariepinus*	62	3.06	77.76	16.74	39	21.31	422	4.25
3	*Oreochromis mossambicus*	176	8.7	22.13	4.77	30	16.39	221	2.22
1	*Labeobarbus kimberleyensis*	51	2.52	21.03	4.53	33	18.03	127	1.28
4	*Liza richardsoni*	110	5.44	16.39	3.53	22	12.02	108	1.09
4	*Mugil cephalus*	23	1.14	12.83	2.76	16	8.74	34	0.34
1	*Cyprinus carpio*	11	0.54	20.17	4.34	6	3.28	16	0.16
1	*Barbus trimaculatus*	51	2.52	0.43	0.09	11	6.01	16	0.16
8	*Lichia amia*	21	1.04	2.20	0.47	7	3.83	6	0.06
3	*Tilapia sparrmanii*	6	0.3	0.13	0.03	4	2.19	1	0.01
	SUM	**2023**	**100**	**464**	**100**			**9922**	**100**

Appendix 26. *The relative importance (IRI) of all species caught by* ***multifilament gill nets in the river (station 3 to 10)*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeo capensis*	540	33.31	163.06	43.5	236	44.36	3408	55.6
1	*Labeobarbus aeneus*	469	28.93	75.25	20.08	214	40.23	1971	32.17
1	*Labeobarbus kimberleyensis*	116	7.16	33.09	8.83	85	15.98	255	4.17
2	*Clarias gariepinus*	61	3.76	73.32	19.56	46	8.65	202	3.29
1	*Barbus trimaculatus*	307	18.94	2.23	0.6	49	9.21	180	2.94
3	*Oreochromis mossambicus*	108	6.66	15.78	4.21	53	9.96	108	1.77
1	*Cyprinus carpio*	6	0.37	11.87	3.17	6	1.13	4	0.07
1	*Barbus hospes*	7	0.43	0.04	0.01	5	0.94	0	0.01
3	*Tilapia sparrmanii*	5	0.31	0.18	0.05	4	0.75	0	0
1	*Barbus paludinosus*	2	0.12	0.00	0	2	0.38	0	0
	SUM	**1621**	**100**	**375**	**100**			**6129**	**100**

Appendix 27. *The relative importance (IRI) of all species caught by* ***other gears in the estuary (station 1 and 2)*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
4	*Liza richardsoni*	1554	60.92	2.23	29.35	25	67.57	6099	68.83
1	*Labeobarbus aeneus*	77	3.02	1.43	18.8	14	37.84	826	9.32
1	*Labeo capensis*	139	5.45	0.78	10.25	16	43.24	679	7.66
1	*Mesobola brevianalis*	337	13.21	0.32	4.19	11	29.73	517	5.84
1	*Barbus trimaculatus*	108	4.23	0.38	4.97	8	21.62	199	2.25
3	*Oreochromis mossambicus*	101	3.96	0.22	2.9	10	27.03	185	2.09
1	*Labeobarbus kimberleyensis*	3	0.12	1.86	24.53	2	5.41	133	1.5
4	*Mugil cephalus*	63	2.47	0.26	3.36	7	18.92	110	1.25
-	*Marine sp.*	68	2.67	0.03	0.37	7	18.92	57	0.65
6	*Atherina breviceps*	31	1.22	0.02	0.23	7	18.92	27	0.31
3	*Pseudocrenilabrus philander*	21	0.82	0.02	0.24	5	13.51	14	0.16
1	*Barbus paludinosus*	41	1.61	0.04	0.47	2	5.41	11	0.13
1	*Barbus hospes*	3	0.12	0.00	0.02	3	8.11	1	0.01
7	*Gobiidae sp.*	1	0.04	0.02	0.23	1	2.7	1	0.01
3	*Tilapia sparrmanii*	3	0.12	0.01	0.09	1	2.7	1	0.01
2	*Clarias gariepinus*	1	0.04	0.00	0.01	1	2.7	0	0
	SUM	**2551**	**100**	**7.6**	**100**			**8862**	**100**

Appendix 28. *The relative importance (IRI) of all species caught by* ***other gears in the river (station 3 to 10)*** *during surveys in the Lower Orange River during 1995 - 2001. The IRI takes into account the number of individuals (No.), mass (kg) and frequency of occurrence (Freq.) of the individuals caught. Values are given in absolute values and as percentage of total catch. Fam. = number designation for family classification according to* ***appendix 1****.*

Fam.	Species	No.	%	Mass	%	Freq.	%	IRI	%
1	*Labeo capensis*	3372	29.09	22.60	33.75	81	71.05	4465	41.78
1	*Mesobola brevianalis*	2504	21.60	1.45	2.16	71	62.28	1480	13.85
2	*Clarias gariepinus*	162	1.40	24.28	36.26	38	33.33	1255	11.75
3	*Oreochromis mossambicus*	1634	14.09	6.34	9.46	55	48.25	1137	10.63
1	*Labeobarbus aeneus*	871	7.51	3.80	5.67	76	66.67	879	8.22
1	*Barbus hospes*	1295	11.17	1.47	2.19	44	38.60	516	4.82
3	*Pseudocrenilabrus philander*	1034	8.92	0.88	1.31	55	48.25	494	4.62
1	*Barbus trimaculatus*	458	3.95	1.32	1.97	68	59.65	353	3.31
1	*Labeobarbus kimberleyensis*	38	0.33	4.02	6.01	14	12.28	78	0.73
1	*Barbus paludinosus*	127	1.10	0.16	0.24	18	15.79	21	0.20
5	*Austroglanis sclateri*	68	0.59	0.51	0.76	5	4.39	6	0.06
3	*Tilapia sparrmanii*	29	0.25	0.15	0.22	11	9.65	5	0.04
1	*Cyprinus carpio*	1	0.01	0.00	0.00	1	0.88	0	0.00
	SUM	**11593**	**100**	**67**	**100**			**10687**	**100**

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