THE ENVIRONMENTAL STATUS OF THE ORANGE RIVER MOUTH AS REFLECTED BY THE FISH COMMUNITY

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WRC Report No 505/1/98
ISBN 1 86845 388 X

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Final Report

PARTICIPANTS

Funding and material help by Cape Nature Conservation (CNC) and the Water Research Commission (WRC).

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SUMMARY

Fish-wise the Orange River Estuary is neither particularly rich in estuarine species nor is it important as a nursery area, which reflects the history of the estuary. The major concern during an inevitable future regime of low flows in winter and less-low (certainly not large) flows in summer is therefore the health of the riverine fish community. The extent to which the large seasonal fluctuation in flows is necessary and can be simulated is problematical. The low flows during the study period appeared to be adequate to sustain the riverine fish community, but seasonality of flow (especially the summer increase associated with rainfall runoff) is necessary to stimulate breeding in some of the species. The long-term effect of flow-reduction on some marginal species is bound to be negative.

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1. INTRODUCTION

The Lesotho Highland Water Scheme has major environmental implications for the Orange River. It has been predicted by consultants BKS (McKenzie and Roth, 1994) that *if the scheme is completed*, then there will be a considerable shortfall of water at the mouth, amounting to an average of more than 842 million m^3 per year. This should be compared with an original flow of 11500 million m^3 per year which has already been reduced to 6500 million m^3 per year. This would result in a river mouth that is practically dry for years on end apart from exceptional floods. In addition the flow pattern has changed drastically from one of large flows in summer and negligible flows in winter to one of reduced flows in summer and increased flow in winter. Consequently the mouth stopped closing in winter. When it did close in the winter of 1994 this was the first occasion in 16 years. Due to the unseasonal offtake of water by towns, agriculture (notably in spring before the rivers waters would swell naturally), hydroelectricity and interbasin transfer (existing and potential), the natural flow pattern is lost. It is questionable to what extent management of flow from reservoirs could ameliorate this situation.

The massive floods which appear once every decade or more are probably important in dictating the nature of the system.

There will be other related effects to the bird-rich salt-marsh, to the overall salinity regime of the estuary and the drying-out of extended stretches in the middle and lower reaches of the river. There are therefore potentially catastrophic effects on the Orange River ecosystem unless adequate plans are made based on a suitable knowledge of the present biota and of ecosystem function.

As the river mouth/estuary is the ultimate part of the ecosystem, where manipulative effects will accumulate, the Orange River Environmental Task Group has requested that baseline information on the plants, birds and fish of the mouth area be acquired as soon as possible for incorporation in a model which will allocate *sufficient* water to maintain the mouth area in a *suitable* condition.

Estimates resulting from the Instream Flow Requirements Workshop in Fishhoek during April 1996 (Venter and Van Veelen, 1996) suggest that a minimum of 197 million m^3 under drought conditions, and a preferred minimum flow of 294 million m^3 of water per year under "normal" conditions would be acceptable to maintain the river mouth ecosystem, at a potential selling value of at least R1.50 per m^3 were it to be sold as potable water. While a study of the fish cannot give monetary answers, we can certainly provide an idea of the potential effects of freshwater loss and saltwater intrusion on the fish populations in the estuary and to some extent upstream.

Rationale

The following extracts from Orange River Environmental Task Group (1989) explain the rationale for this study:

"The following environmental management objectives were formulated:

- *Conservation of bird life, which includes conservation of the supporting ecosystem.*

- *Re-establishment of the saltmarsh on the southern bank of the ORM (Orange River Mouth) -system, which is cut off from the system by the access road to the beach.*
- *Control of salinisation of the ORM-system, which is anticipated to become a critical factor during low-flow or no-flow conditions. Under these conditions the salinity of especially the groundwater may exceed the human tolerance.*

The identified remedial and control measures to manage the ORM-system can be summarised as follows:

- *The control of the status of the mouth by means of regulated flow to the system.*
- *Periodic water flushing of the system to restore the freshwater regime.*
- *Controlled inundation of the saltmarsh.*
- *Maintaining the present status of the oxidation pond system.*
- *Installation of culverts and stormwater pipes under the access road to provide unrestricted flow access to the saltmarsh.*

In order to achieve the above objectives and measures, proposed management strategies were formulated. These strategies distinguish between management under ideal conditions, viz. years of average to above average streamflow, and the management of the system under absolute minimum conditions, which represent extreme drought conditions.

The management strategies formulate the guidelines to assess environmental water requirements. Since only limited data are available these assessed water requirements should be considered preliminary estimates and are subject to updating once more substantial data can be obtained. The minimum annual environmental water requirement for the two management conditions is as follows:

Under ideal conditions, 244 million m^3 per year (this was updated to 294 million m^3 per year minimum under "normal" conditions - Venter and Van Veelen, 1996).

Under absolute minimum conditions, 100 million m^3 per year (this was updated to 197 million m3 per year minimum under drought conditions).

It is also important to stress that the above water requirements represent the minimum water requirements under these two management conditions. Should the inflow to the system exceed the defined minimum requirements, it is essential to note that there are specific control measures built into the management strategies which should be complied with, such as the annual inundation of the saltmarsh. These control measures are deemed to be essential to ecosystem independent of the annual flow rate through the system.

A continuous monitoring programme was seen as a crucial part of the implementation of the management strategies outlined in the report. Suggestions with regard to parameters *that should be monitored are also included. It has been proposed that the responsibility for the planning and implementation of this programme should be referred to the ORETG or an appointed sub-committee"*

Consequently the present study of the fish community in the mouth area is intended to give an insight into the environmental water quality, past, present and future.

Aims

i) to provide a description of the present state of the river mouth environment as indicated by the fish community composition and condition (with an accent on the freshwater, but including estuarine and marine components), bearing in mind the effects of both seasonal and tidal effects,

ii) to prepare a proposal on environmental management requirements on river and mouth in order to maintain or improve the status of the mouth,

iii) to indicate future research needs.

Key questions

i) what is the fish community composition in terms of freshwater, estuarine and marine components?

ii) what is the condition of river-dependent fish populations?

iii) to what extent do the fish populations appear to have suffered from river regulation to date?

iv) what is the prognosis for the condition of the fish community of the river mouth, given alternative scenarios?

v) what further research inputs are needed?

Definition of an estuary (Day, 1981)

"An estuary is a partially closed coastal body of water which is either permanently or temporarily open to the sea and within which there is a measurable variation of salinity due to the mixture of sea water with fresh water derived from land drainage."

This definition is very broad, but Day split estuaries into three further categories, namely:

"1. Normal estuaries

Most estuaries are normal or 'positive' in the sense that there is an increase in salinity from the head where the river enters, towards the sea. Further, there is a net flow seaward over a full tidal cycle. Normal estuaries may be subdivided according to the degree of stratification or mixing of salt and fresh water.

1a. Saltwedge estuaries. These are normal estuaries with a wedge of sea water on the bottom and a layer of fresh water flowing out at the surface but no mixing between the two. Such a condition is rare if not entirely theoretical, but possibly occurs in some tranquil fjords.

1b. Highly stratified estuaries. These are normal estuaries with a layer of sea water flowing in along the bottom, a layer of fresh water flowing out at the surface and *between the two is a layer of mixed water separated by marked haloclines. Most fjords belong to this class.*

1c. Partially mixed estuaries. These are normal estuaries in which the vertical salinity gradient shows varying degrees of mixing or stratification between the outward-flowing surface layer and the inward-flowing bottom layer. Many estuaries belong to this class including the Thames and the Mersey in England, the Seine, Scheldt and Elbe in Europe, and the Hudson and Chesapeake in the United States.

1d. Vertically homogeneous estuaries. These are normal estuaries with the salinity decreasing from the mouth towards the head without a vertical gradient in salinity at any point. There may, however, be differences in salinity across the width of an estuary with the net current flowing landward along one side and seaward along the other. The lack of a vertical salinity gradient is due to a turbulent mixing which often occurs in the strong tidal currents near the mouth of a shallow estuary. Many South African estuaries are homogeneous near the mouth but become partially mixed or even highly stratified in the calm upper reaches. The Bashee, Swartkops, Knysna and Breede estuaries show these features.

2. Hypersaline estuaries.

These have a reversed or 'negative' salinity gradient with the salinity increasing from sea water values at the mouth to hypersaline values in the upper reaches where the water level is below mean sea level, so that the net flow is landward. Such conditions occur during severe droughts. The Laguna Madre in Texas is a classical example. St. Lucia in Zululand becomes hypersaline periodically and Milnerton Lagoon near Cape Town becomes hypersaline every summer.

3. Closed or blind estuaries.

These are estuaries which are temporarily closed by a sandbar across the sea mouth. At such times there is no tidal range and thus no tidal currents. Fresh water enters from the river and the circulation is dependent on the residual river current and the stress of the wind on the water surface. According to the ration between evaporation and seepage through the bar on the one hand, and fresh water inflow and precipitation on the other, salinity will vary. The estuary may become hypersaline, it may retain its normal value when the mouth is closed or it may become hyposaline."

Results will show that the category of the Orange River Mouth varies with season and between years. Furthermore, its category has changed with time due to cultural influences.

Historic and current flow regime

Historically the river had scouring, flushing floodwaters reaching the mouth during summer, with great variability of flow both within and between years. In winter the flow often was so low that the mouth closed, making the estuary blind but apparently not hypersaline. The flow volume at Vioolsdrif, the nearest monitoring station to the mouth, was 350 million m^3 per year in 1993 (data courtesy of the Dept. of Water Affairs and Forestry), which means that the flow is already close to the lower level of 244 million m^3 per year, but well above the absolute minimum level of 100 million m^3 per year. Furthermore there is a quasi-natural seasonality about the flow (Figure 4) which may be at least partially lost as flow volume decreases as a result of upstream activity.

2. MATERIALS AND METHODS

Study area

The Orange River estuary was considered to be that part of the river in which tidal influence occurred. For practical purposes this was taken to be the lower 35km of river from Brandkaros to the sea (Figures 1 and 2). Although saline waters did not reach Brandkaros during the study period, there was a slight (about 10 cm) but noticeable change in water level due to tidal ebb and flow.

The natural position of the mouth during the study period was at the southernmost point, eroding against the dyke built by Alexkor for their access road to the mouth area. The artificial position of the mouth, i.e. where the berm was breached by Alexkor at intervals from about June 1993 to January 1994 was always in the middle of the berm, whereafter it migrated southward.

Choice of stations

Stations were chosen firstly to reflect a gradation from freshwater with minimal estuarine influences (Brandkaros 35 km upstream from the mouth) to estuarine and marine influences and secondly according to accessibility. Stations (Figures 1 and 2) were more abundant nearer the mouth. Stations are characterised as follows:

1.	Brandkaros	riverine	sandy banks.
2.	Bokdroldraai	riverine	sandy banks, used only once.

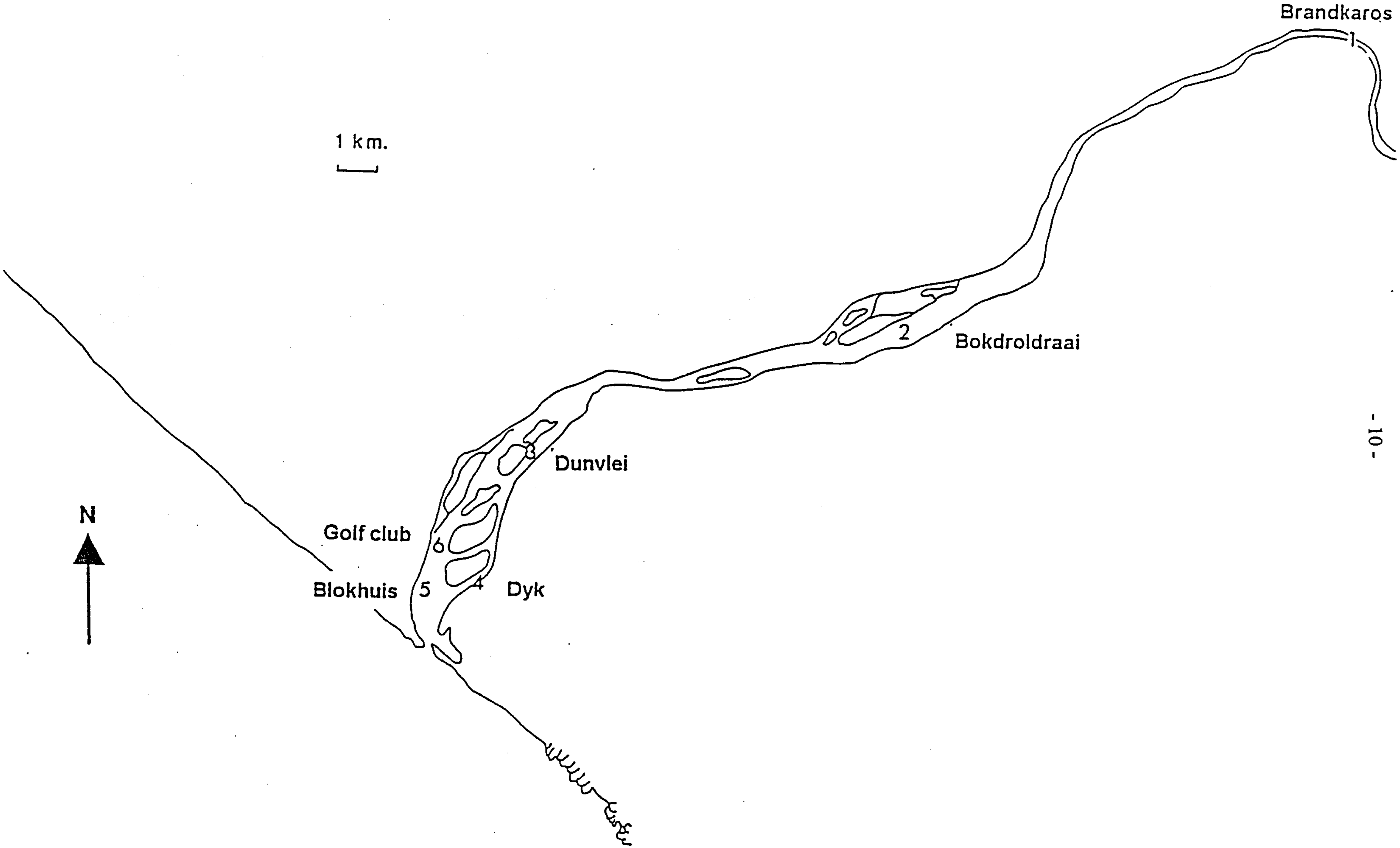


Figure 1. The lower Orange River up to 35 km from the mouth, showing all quarterly sampling sites.

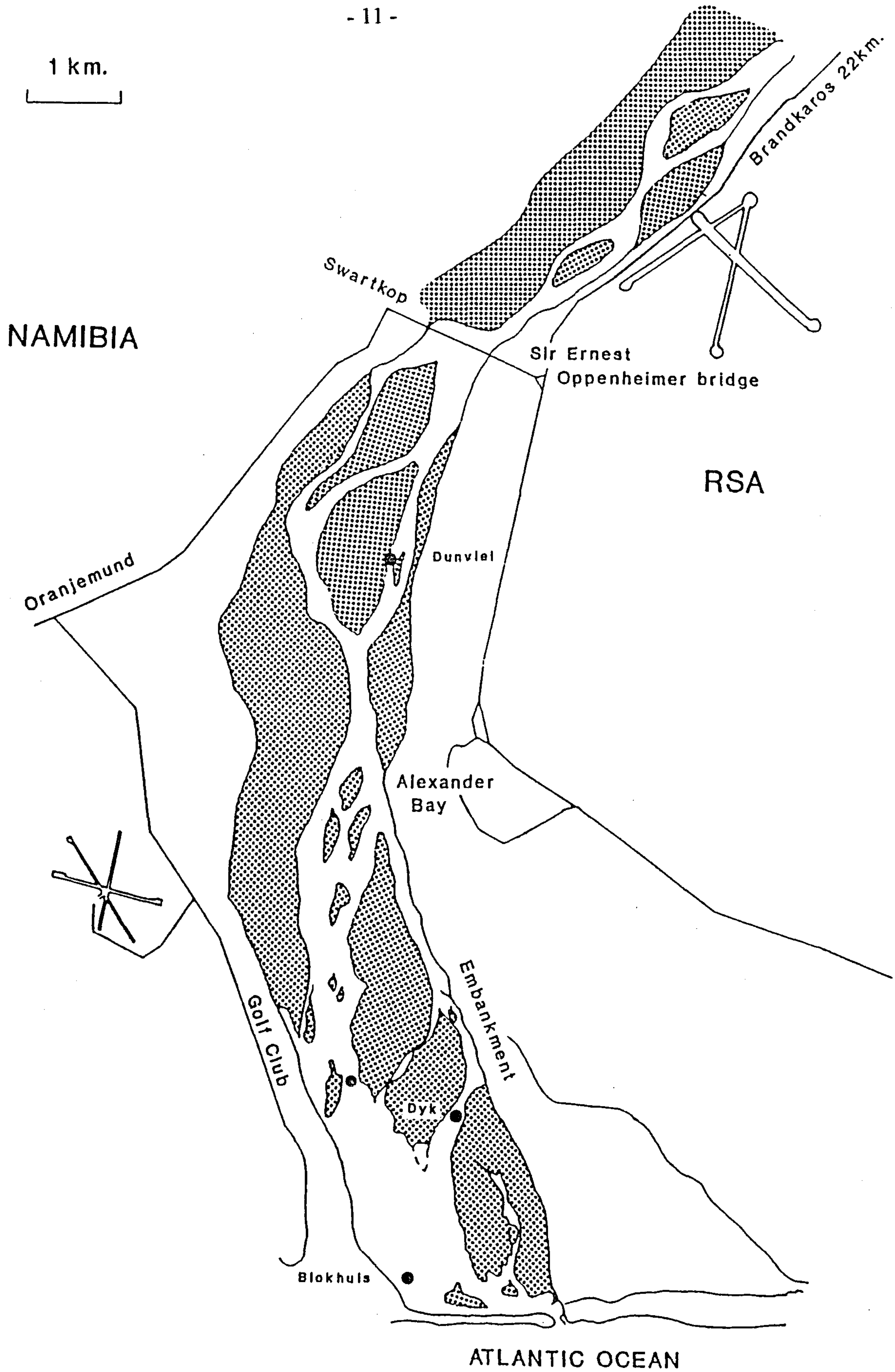


Figure 2. The Orange River estuary up to 12km from the mouth, showing quarterly sampling sites.

3.	Dunvlei	estuarine	reeds, peripheral effects of salinity.
4.	Dyk	estuarine	reeds, near total tidal exchange.
5.	Blokhuis	estuarine	bare shore, total tidal exchange.
6.	Golf Club	estuarine	bare shore, total tidal exchange.

In order to explore the extent of tidal influences (pattern of sea water penetration) within the estuarine area a different set of stations was used (see Figure 3).

Routine Procedure:

i) Determine position of each station, consider accessibility and time constraints - first visit only.

ii) Determine time schedule for each day - sampling at one station per day in order to cover as much of the tidal cycle as possible.

iii) Setting of gill nets and supplementary netting by means of fine-meshed seine net and throw-net.

iv) Taking of salinity (conductivity) and temperature measurements.

v) Recording of each fish according to protocol - date, time, sampling method, species, mass, length, sex.

vi) Computer storage of all data at the UOFS.

vii) Data reduction and reporting.

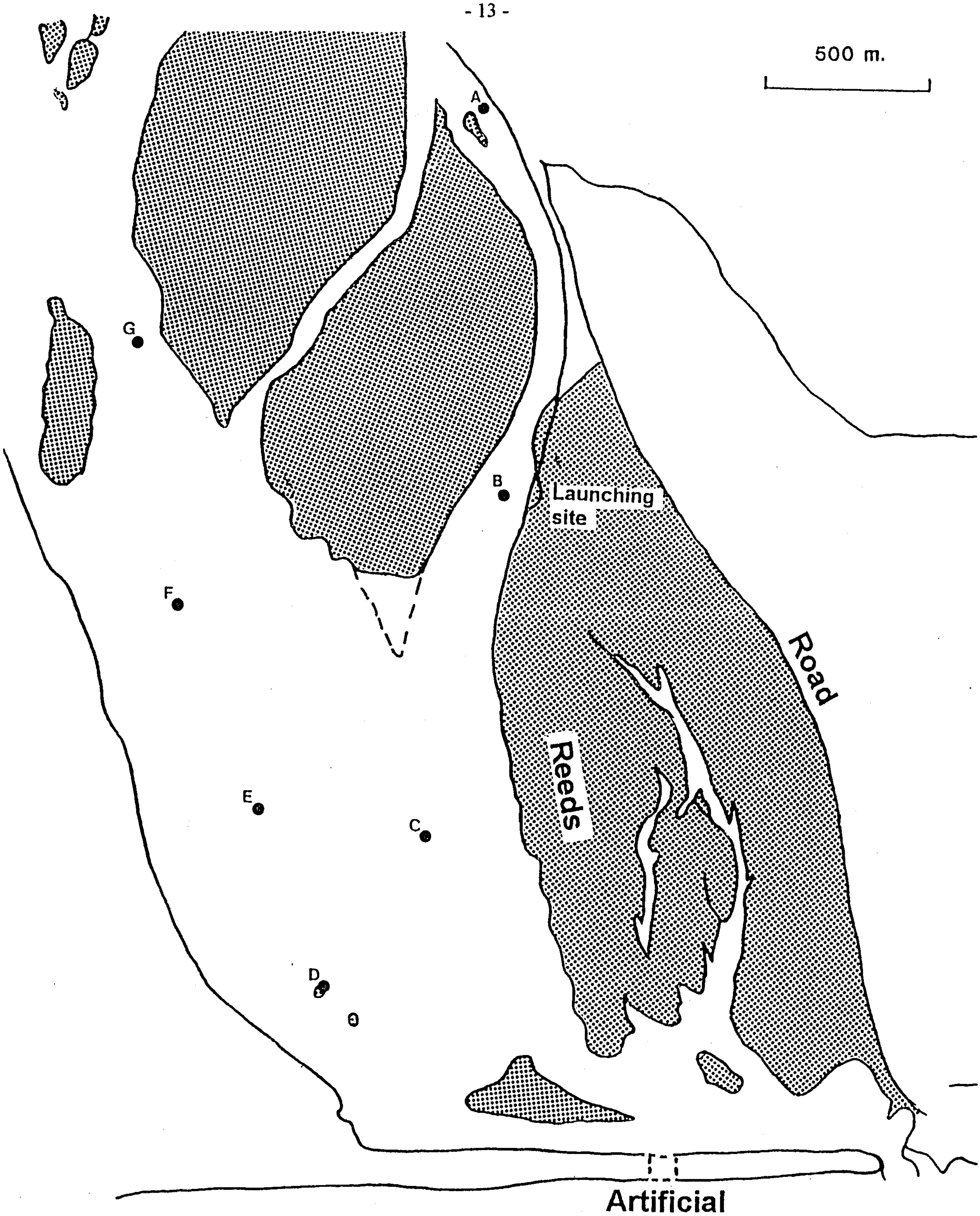


Figure 3. The Orange River in the proximity of the mouth, showing sampling sites used to investigate total influence. The position of the mouth throughout the study varied from the point of artificial breaching to the "natural" position at the southern end of the berm.

Sampling regime

Field surveys were carried out quarterly during approximately the following periods: 26/3 to 12/4/1993, 25/6 to 10/7/1993, 25/9 to 4/10/1993 and 10/1 to 21/1/1994.

3. RESULTS

Salinity patterns as related to river-flow and tide

Over the study period, monthly flow (taken at Vioolsdrif, the nearest measuring station to the mouth - DWAF data) varied between a low of 5 million m^3 (ca. 2 m^3 per sec) in October 1993 and 160 million m^3 (ca. 60 m^3 per sec) in January 1994 (Figure 4). The latter month's peak flows reached the mouth directly after final sampling. Flows during sampling were therefore approximately 15, 11, 4 and 60 m^3 per sec respectively. Total flow for the year 1993 was approximately 350 million m^3. Seen in the light of untested suggestion (Venter and Van Veelen, 1996) that 294 million m^3 per year would suffice to maintain the mouth's ecosystem, flow during the study period wasn't much higher. The suggestion of 197 million m^3 per year as minimum under drought conditions requires a more critical evaluation in the field.

Depth changed up to 30 cm due to tidal influence at Brandkaros, 35 km from the sea. In contrast, salinity changes due to marine inflow were found only within 5 km of the sea (Table 1). Concentrations upstream of 5 km from the sea merely reflect river levels, though these were as high as 0,94 mS per cm at Brandkaros and 1.00 mS per cm at Dunvlei during January 1994 before seasonal flows increased. These can be compared

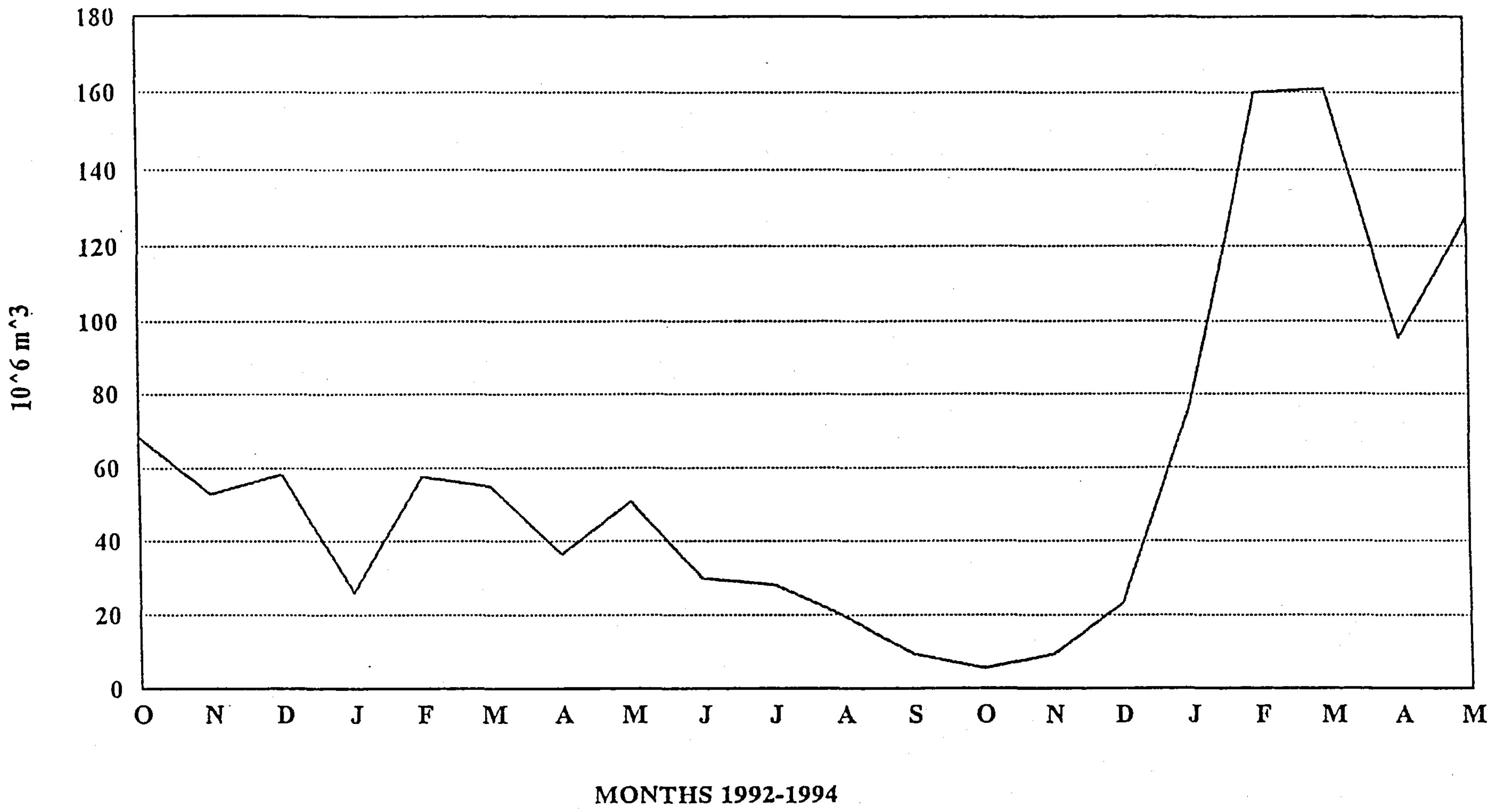


Figure 4. Monthly flow-volume of the Orange River at Vioolsdrif (28° 45' 39" S, 17° 43' 49" E) which lies approximately 200 km from the mouth for the study period.

Table 1 Surface conductivity and temperature range at each station for all seasons.

CONDUCTIVITY (mS/cm)

DATE	BRA	BOK	DUN	DYK	BLO	GCL	SEA
Mar./Apr. 93	0.49-0.53	0.47	0.49	7.3-46.0	11.3-46.9	--------	--------
July 93	0.50-0.60	--------	--------	3.3-32.2	6.3-45.1	--------	--------
Sep. 93	--------	--------	--------	14.2-44.9	21.7-46.3	16.0-44.3	--------
Jan. 94	0.94	--------	1.00	5.7-39.9	5.3-42.1	2.6-36.5	43.9

TEMPERATURE (°C)

DATE	BRA	BOK	DUN	DYK	BLO	GCL	SEA
Mar./Apr. 93	21-24.8	21.1	18.5-19	12.1-20.4	16.6-20.8	--------	--------
July 93	16.4-18.4	--------	--------	19.8-21.2	15.6-21.2	--------	--------
Sep. 93	--------	--------	--------	11.6-18.2	10.5-15.0	12.2-15.0	12
Jan. 94	26.0	--------	19.1-19.8	16.0-22.3	15.8-21.6	16.6-23.2	16.4

(BRA=Brandkaros, BOK=Bokdroldraai, DUN=Dunvlei, DYK=Dyke, BLO=Blokhuis, GCL=Golf Club, SEA= Sea near mouth.)

with values of about 1.00 mS per cm for water flowing into Gariep Dam historically (Stegmann, 1974).

Temperature dropped by as much as 10^{o} C between Brandkaros and the sea (Table 1). Tidal temperature influences were obviously similar to tidal salinity influences, due to the colder seawater flowing in a wedge below the freshwater up to about 5 km from the sea.

For a more detailed insight into salinity and temperature changes with tide see the map of the stations A to G (Figure 3) and Figures 5 to 8 for values at top and bottom, during low and high tide, 30 September 1993. All stations were within 3 km of the sea.

It is evident that the seawater wedge pushed in below the freshwater beyond 3km at both high and low tides. At the surface, pure seawater pushed in at least 2.5km (Station F), as reflected by both salinity and temperature profiles.

Fish community diversity

A checklist of the fish species found during the study (Table 2) shows only *Cyprinus carpio* as a new freshwater record (compared with Bethune and Roberts, 1990) for the Lower Orange River. We in turn did not find *Barbus hospes*, *B. trimaculatus*, *Tilapia sparrmanii* or *Austroglanis sclateri* which were not expected near the mouth anyway.

The freshwater species were dominated by *Labeo capensis* and *B. aeneus.*

B. kimberleyensis, Clarias gariepinus and *Oreochromis mossambicus* were less common.

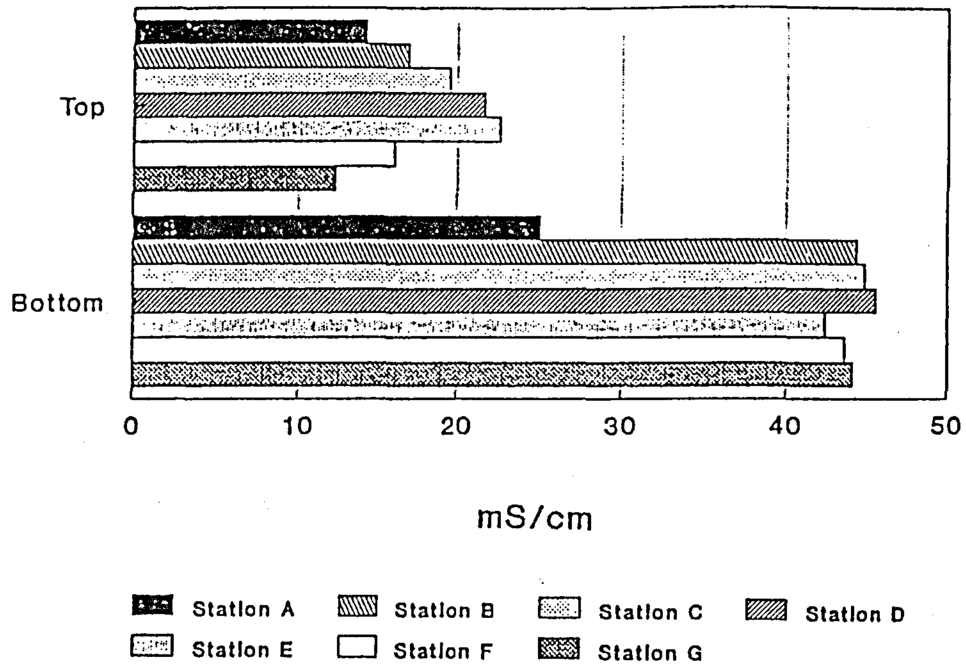


Figure 5. Conductivity at Orange River Mouth on 30 September 1993 at low tide.

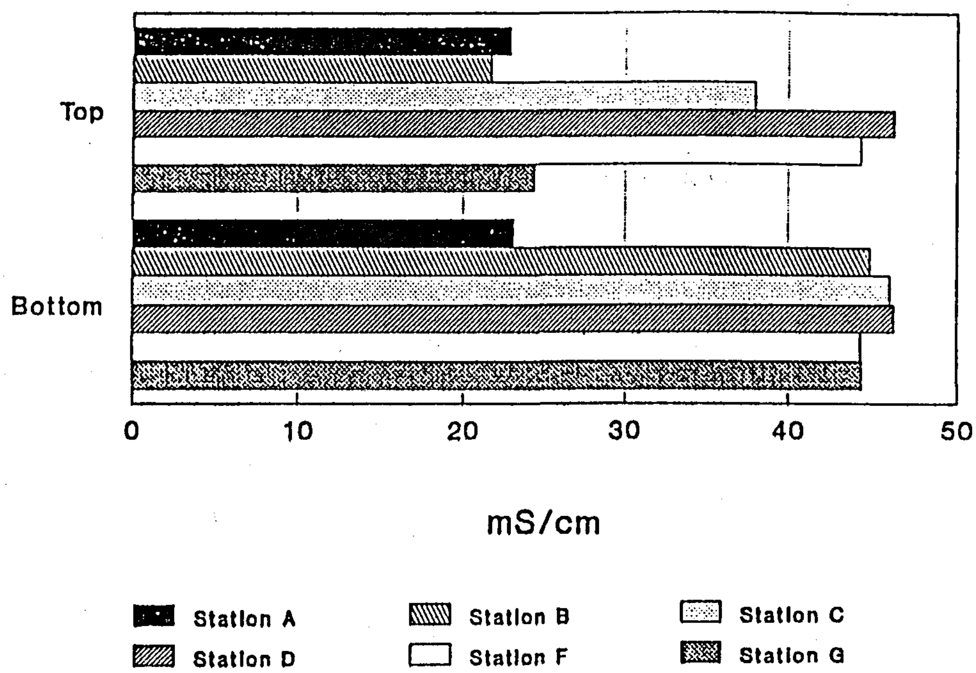


Figure 6. Conductivity at Orange River Mouth on 30 September 1993 at high tide.

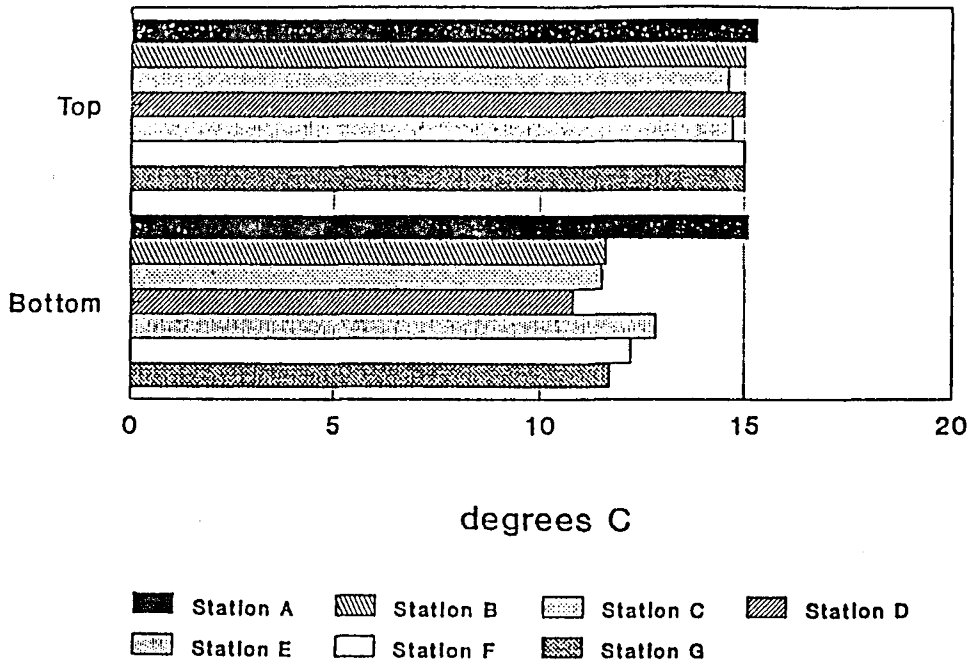


Figure 7. Temperature at Orange River Mouth on 30 September 1993 at low tide.

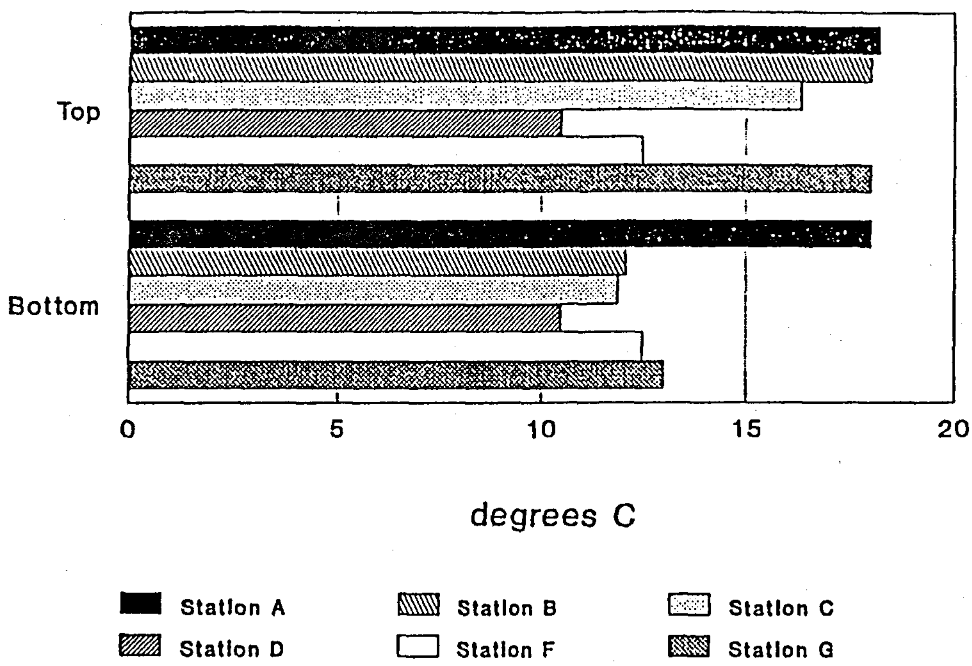


Figure 8. Temperature at Orange River Mouth on 30 September 1993 at high tide.

Table 2 Checklist of the fishes of the Orange River.

* present, R rare, E endemic, V vulnerable, A alien

FISHES	LOWER ORANGE [1]	THIS STUDY
Cyprinidae		
Barbus aeneus	*	*
Barbus anoplus	*	
Barbus hospes	E R	
Barbus kimberleyensis	*	*
Barbus paludinosus	*	*
Barbus trimaculatus	*	
Cyprinus carpio		*
Labeo capensis	*	*
Mesobola brevianalis	*	*
Austroglanidae		
Austroglanis sclateri	R	
Clariidae		
Clarias gariepinus	*	*

Cichlidae		
Oreochromis mossambicus	*	*
Pseudocrenilabrus philander	*	*
Tilapia sparrmanii	*	
Pomatomidae		
Pomatomus saltator		*
Sparidae		
Diplodus trifasciatus		*
Lithognathus lithognathus		*
Mugilidae		
Mugil cephalus		*
Liza richardsoni		*
Sciaenidae		
Argyrosomus inodorus		*
Carangidae		
Lichia amia		*
Clupeidae		
Gilchristella aestuaria		*

[1] Bethune and Roberts (1990)

The marine specimens caught were only one or two individuals per species and are therefore merely records, while the estuarine species were almost solely represented by *Mugil cephalus* and *Liza richardsoni*, with minnows *Gilchristella aestuaria* and *Mesobola brevianalis* less obvious but common nevertheless.

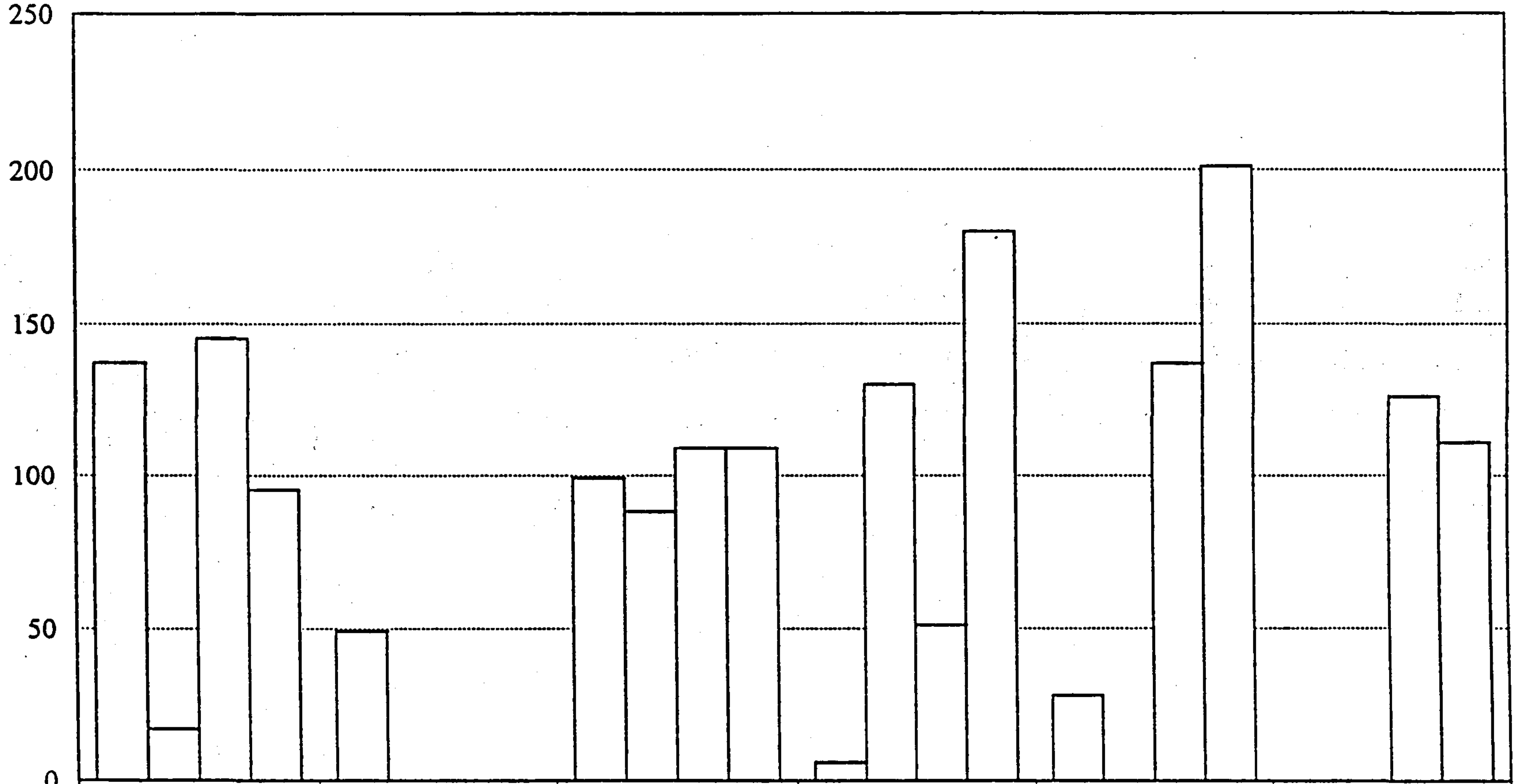
Distribution of fish species

Although not all stations were sampled by gillnet in each season (Figure 9), there was always good coverage of river (Station 1), reed beds (Station 3) and saline estuary (Stations 4 to 6). In winter (July) the mouth was closed, raising water levels to the extent that access to the area near the mouth was compromised. As a result samples from this area could not be taken.

Distribution of the five most common species caught in gillnets, namely *L. capensis*, *B. aeneus*, *O. mossambicus*, *M.cephalus* and *L. richardsoni* (Figures 10 to 14 and Appendix Tables 1 to 4) indicates a lack of any obvious pattern of seasonality.

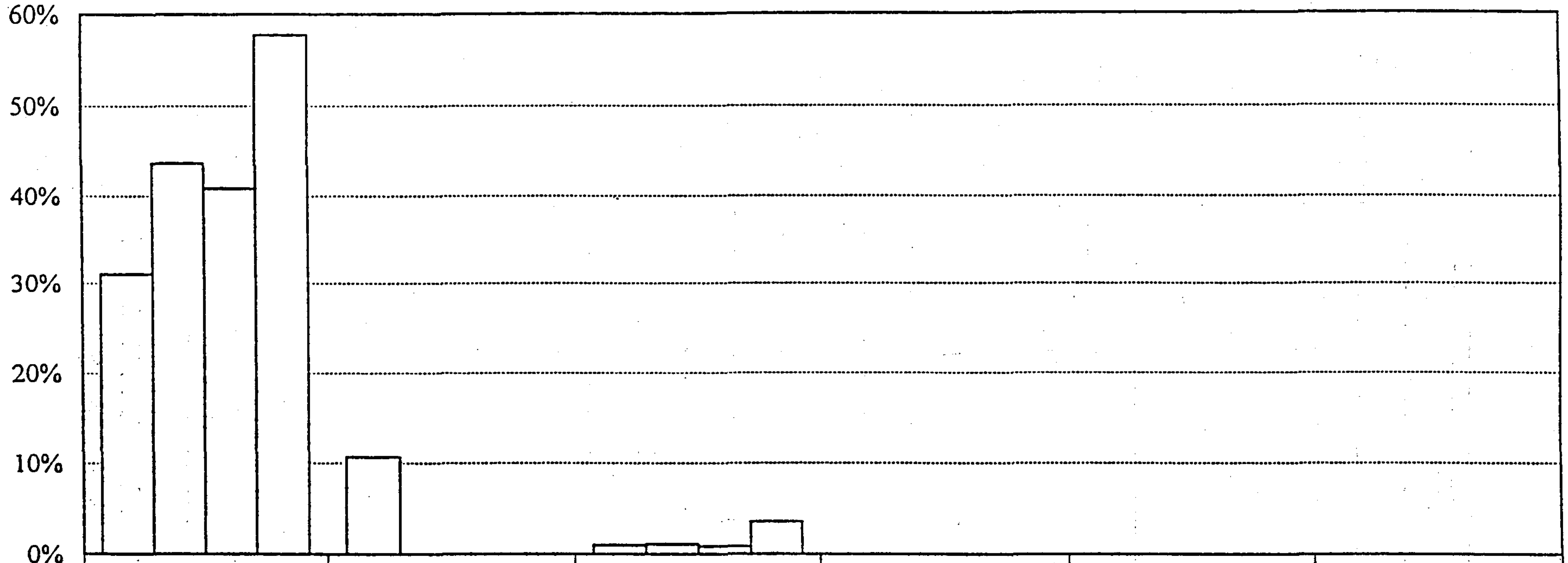
While *B.aeneus* was clearly an upper estuary species, and *L. richardsoni* preferred the most saline waters near the mouth, *M. cephalus* and *O. mossambicus* were most common in the mid-estuarine waters of intermediate salinity. This is borne out clearly in the Cluster Analysis (Figure 15) which has four identifiable clusters, namely "strongly riverine" (*L. capensis*), "upper estuary" (*B. aeneus*, *B. kimberleyensis* and *C. gariepinus*), "mid-estuary" (*O. mossambicus* and *M. cephalus*) and "mouth" (*L. richardsoni*).

Seasonally the gillnetted community at each station clustered according to salinity (Figure 16). The four clusters were, from top to bottom respectively, "fresh" (upper six cases),



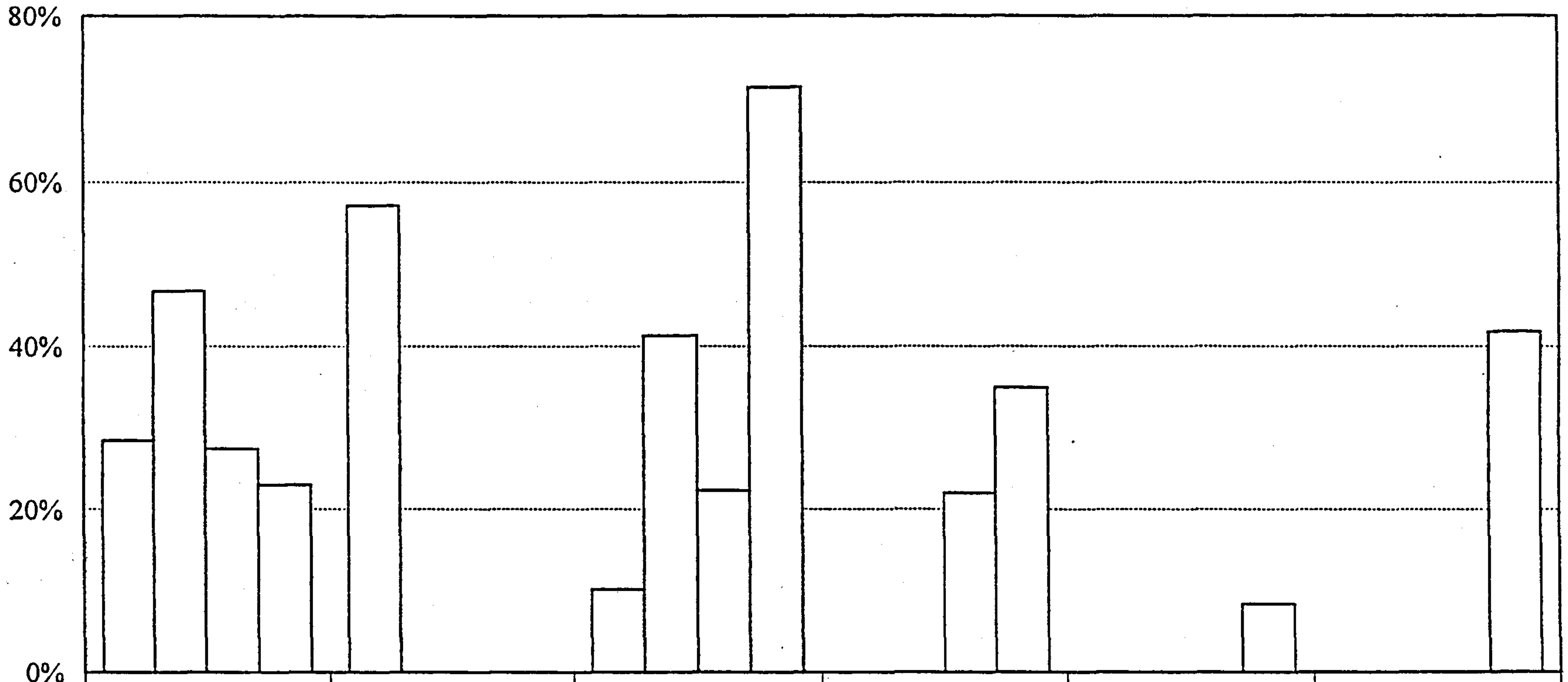
Stations	1	2	3	4	5	6
Autumn	137	49	99	6	28	ND
Winter	17	ND	88	130	ND	ND
Spring	145	ND	109	51	137	126
Summer	95	ND	109	180	201	111

Figure 9. The number of individuals collected at each station for each season using gillnets.



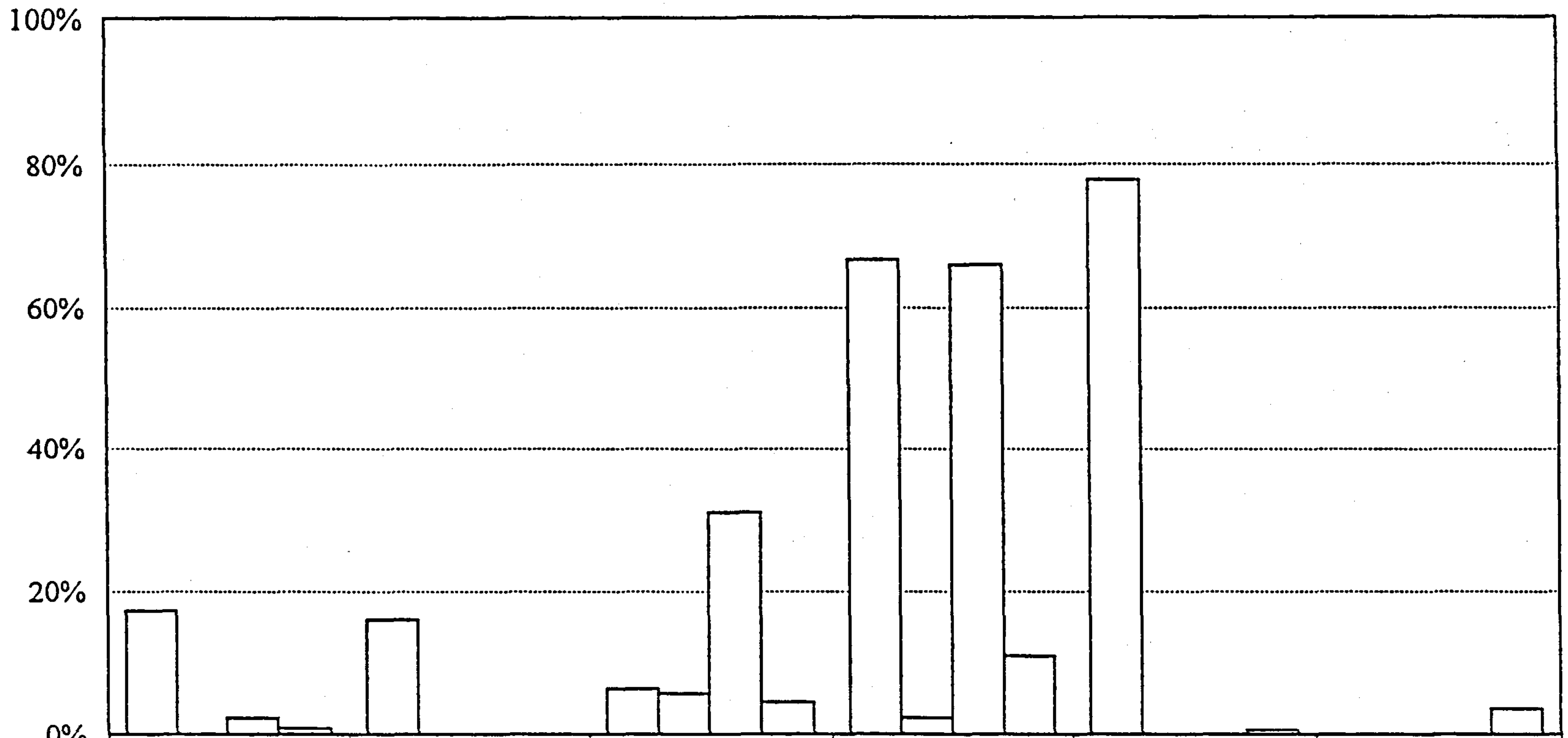
Stations	1	2	3	4	5	6
Autumn	31%	10.7%	1%	0%	0%	0%
Winter	43.7%	ND	1.1%	0%	ND	ND
Spring	40.8%	ND	0.9%	0%	0%	0%
Summer	57.7%	ND	3.6%	0%	0%	0%

Figure 10. Relative abundance of *L. capensis* at each station for each season, expressed as a percentage of the total catch.



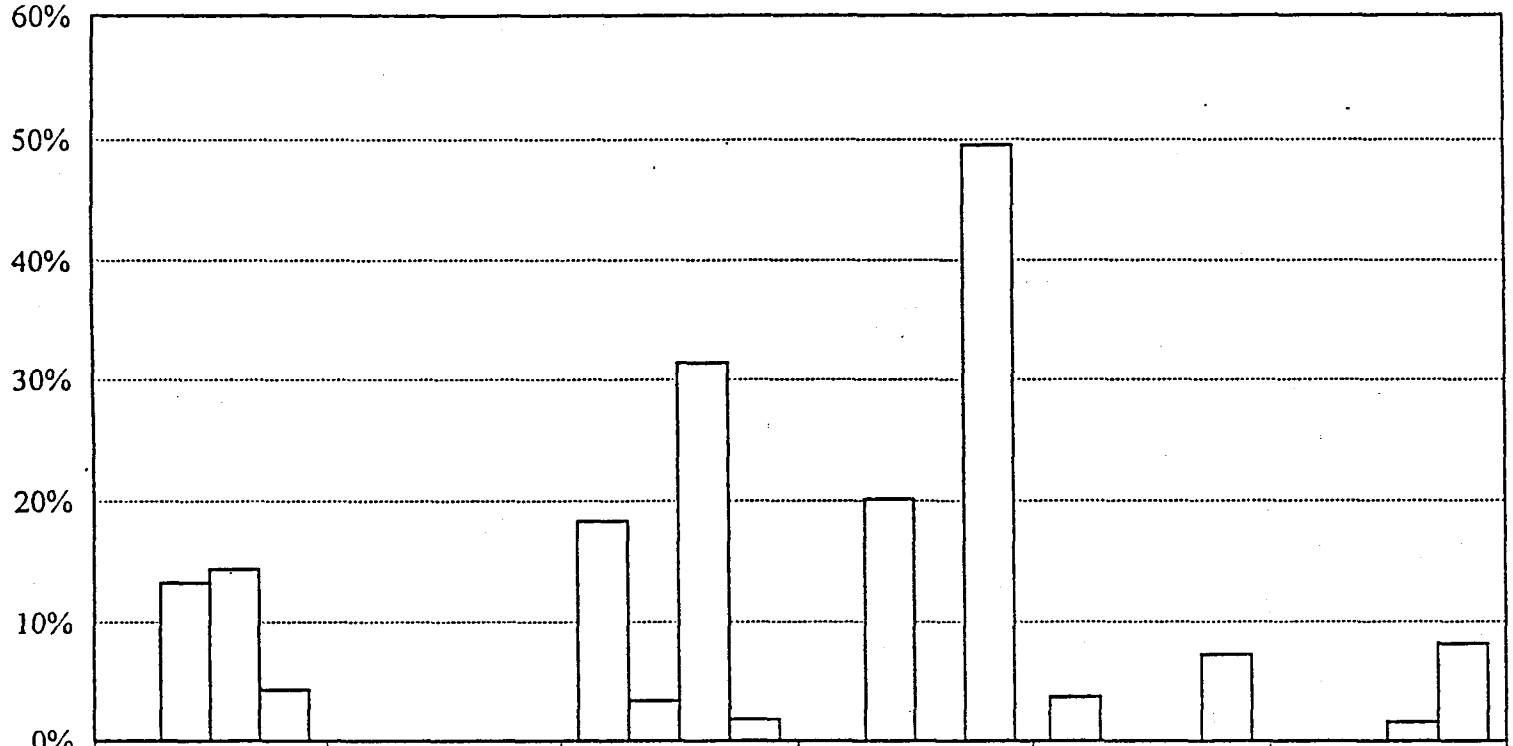
Stations	1	2	3	4	5	6
Autumn	28.5%	57.1%	10.1%	0%	0%	ND
Winter	46.7%	ND	41.3%	0%	ND	ND
Spring	27.5%	ND	22.3%	22%	0%	0%
Summer	23%	ND	71.4%	35%	8.3%	41.8%

Figure 11. Relative abundance of *B. aeneus* at each station for each season, expressed as a percentage of the total catch.



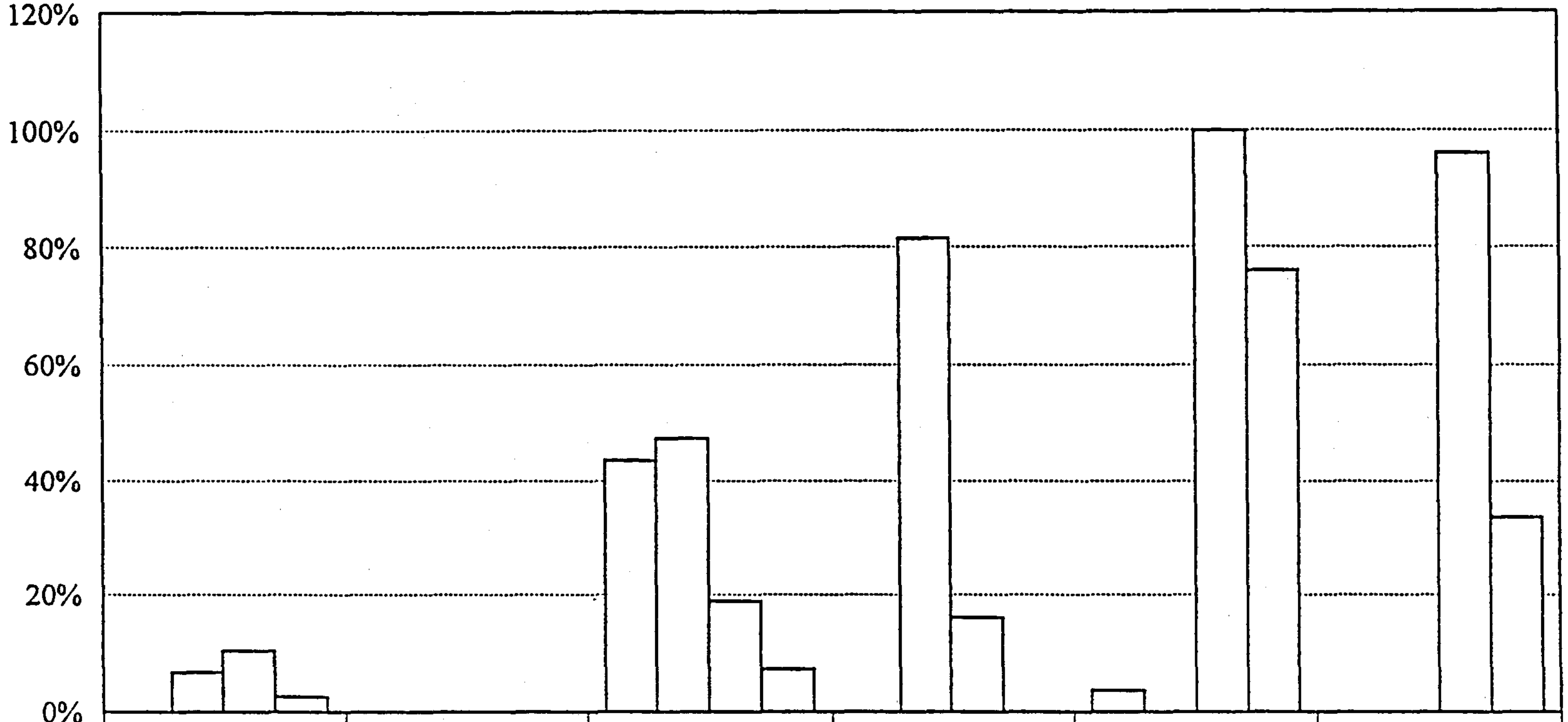
Stations	1	2	3	4	5	6
Autumn	17.3%	16.1%	6.4%	66.7%	77.8%	ND
Winter	0%	ND	5.7%	2.33%	ND	ND
Spring	2.3%	ND	31%	66%	0%	0%
Summer	0.9%	ND	4.5%	11%	0.6%	3.6%

Figure 12. Relative abundance of *O. mossambicus* at each station for each season, expressed as a percentage of the total catch.



Stations	1	2	3	4	5	6
Autumn	0%	0%	18.3%	0%	3.7%	ND
Winter	13.3%	ND	3.4%	20.1%	ND	ND
Spring	14.4%	ND	31.3%	0%	0%	1.6%
Summer	4.3%	ND	1.8%	49.5%	7.3%	8.2%

Figure 13. Relative abundance of *M. cephalus* at each station for each season, expressed as a percentage of the total catch.



Stations	1	2	3	4	5	6
Autumn	0%	0%	43.6%	0%	3.7%	ND
Winter	6.7%	ND	47.4%	81.4%	ND	ND
Spring	10.4%	ND	18.8%	16%	99.9%	96%
Summer	2.6%	ND	7.3%	0%	76%	33.6%

Figure 14. Relative abundance of *L. richardsonii* at each station for each season, expressed as a percentage of the total catch.

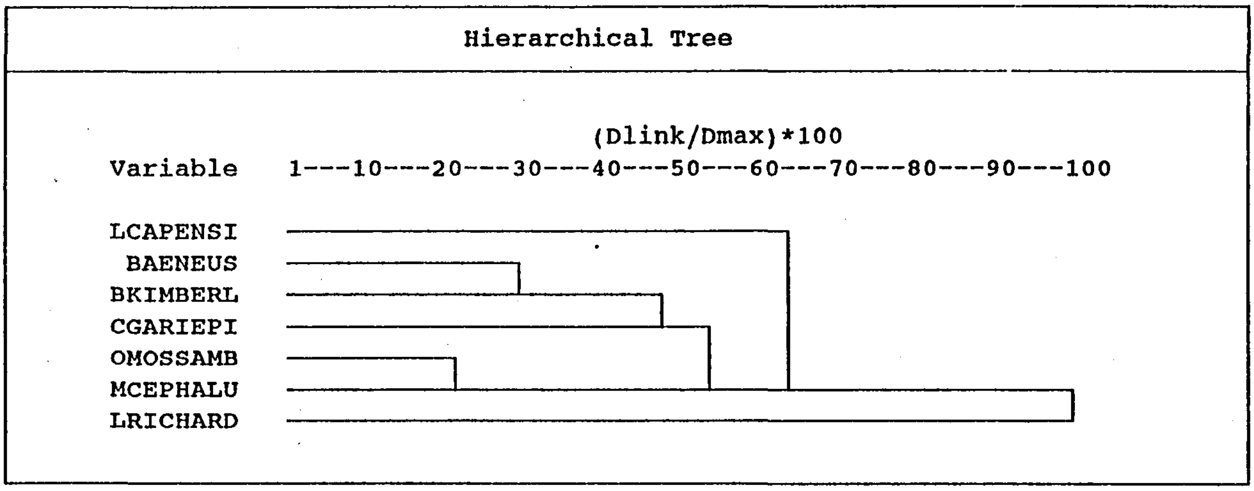


Figure 15. The seven commonest gillnetted species from all samples clustered according to co-abundance.
Distance metric: 1-Pearson r
Joining rule: Unweighted pair-group average.

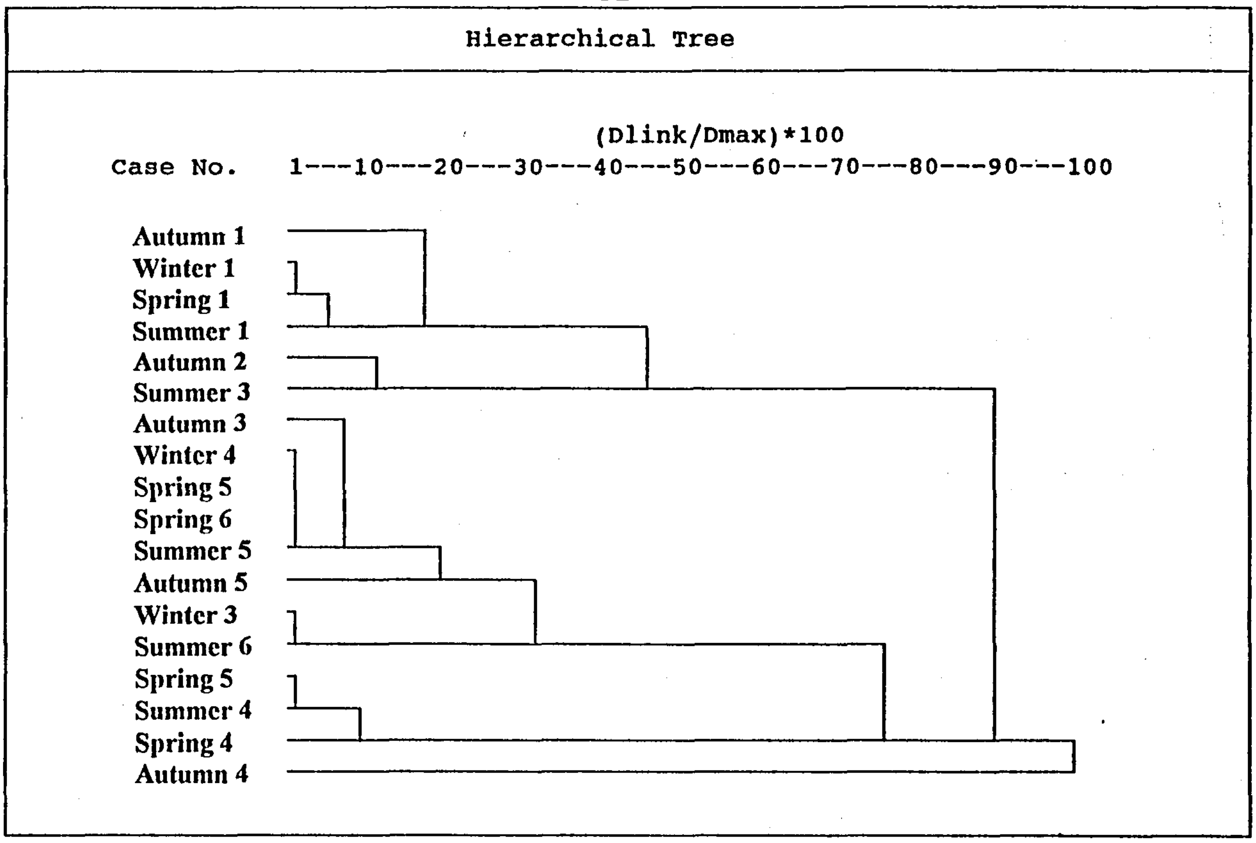


Figure 16. Stations clustered according to co-abundance of the seven commonest gillnetted species in each season.
Distance metric: 1-Pearson r.
Joining rule : Unweighted pair-group average.

"mid-estuary to mouth" (next eight cases), "upper estuary" (next three cases) and "upper estuary" (the bottom case) which was based on only six individuals and is therefore not statistically reliable.

Condition of fish populations

Condition is variously measurable. We have used length/mass ratio as a broad indicator (Figures 1 to 28 in Appendix). There is no particular evidence of poor condition in any species. The sampling regime was not sufficiently rigorous to allow the identification of year classes, which is not important because the highly variable nature of river flow between and within years would tend to produce a mish-mash of year class patterns. Condition is therefore not as important as numbers within each species.

4. DISCUSSION

Salinity patterns, related to river-flow and tide

The Orange River estuary according to Day's (1981) categories would be classed as a blend between a "normal partially mixed estuary" and a "closed or blind estuary". The former refers to it having an inward-flowing bottom layer of water that is saline, an outward-flowing upper layer that is fresh, with a degree of mixing. The latter refers to it being temporarily closed by a sandbar across the sea mouth which prevents a tidal range and tidal currents; according to the ratio between evaporation and seepage through the bar on the one hand, and freshwater inflow and precipitation on the other, salinity will vary.

Pristinely, the estuary would suffer enormous, or devastating, flows in summer, which would tend to flush out the estuary, taking much of its biota out to sea. In winter, particularly in dry years, the flow would become a trickle or cease and the mouth would close.

The next stage of estuarine function, from the start of modification of flow by humans to the present, saw increasing attenuation of summer flows due to damming upstream, and increased winter flows due to water-releases from dams for urban, agricultural and hydroelectrical purposes. Only in exceptional flood years (the most recent being 1988) have flows resumed something of their pristine pattern. These might be called the "resetting" floods, which "reset" the ecosystem by restoring refuge pools ("kuile") through scouring, clearing channels and making new channels. The value of these floods to the ecosystem is probably great and vital to maintaining it.

In the latter part of this period, 1978 to 1994, the mouth did not close once. The estuary therefore became a "normal partially mixed estuary". However in the winter of 1994 the bar once more formed across the mouth due to low flows in the river. The bar was breached artificially at least three times to prevent flooding of facilities important to the human communities on either side of the mouth.

This last action stress the fact that the estuary has become a managed water body. In the past, a dyke was built to cut off the estuary from the golf course to the north, while another larger dyke was built to cut off the southern branch of the estuary. The area gained to the south was put to farming, sewage works and mining. Managers of the estuary will use the formation of the bar and related rise in water level to flood the northern salt marsh.

That the estuary is now a registered transborder wetland of international importance according to the Ramsar convention (Cowan, 1995) does not preclude the managing of the estuary.

The future will be that more dams will be built on the Orange River system (according to the Orange River Development Replanning Study, Department of Water Affairs and Forestry), thus leading to greater potential management options, allowing:

a.) that more water be taken out of the system (for agriculture, urban use and interbasin transfer) and

b.) that water will continue to be released for urban and agricultural needs downstream as far as the mouth itself, including demands by Namibia.

It is important to note that "the natural environment" or "the ecosystem" of the river will be different from what it once was in pristine times, but there will certainly always be water at the mouth for the "natural environment".

The information gathered regarding the fish community should be seen in the light of the management future.

Fish community diversity

The fish community has four components, namely **mouth, mid-estuary**, **upper estuary** and **strongly riverine**. The mouth component, including the greatest variety of species, all marine, is restricted to the proximity of the mouth as pure seawater is to be found only as far as about two km from the mouth at high tide. *Liza richardsoni* dominated this community. It is a species well-known for its ability to enter estuaries.

The mid-estuary component, two to five km from the sea was dominated by *Mugil cephalus* and *Oreochromis mossambicus*, although the former has marine and the latter freshwater origins.

Of the two freshwater components upper estuary and riverine, only *Labeo capensis* (riverine) appeared to avoid even mildly saline water. The *Barbus* spp. and *C. gariepinus* in the upper estuary were less selective but were more common in freshwater.

The predominance of the introduced indigenous *O. mossambicus* in the mixed-saline area suggests that, by its ability to live in saline water, it is able to utilise resources in that area which other cichlids cannot. It is known to be present in the river upstream at least as far as above the Vioolsdrif weir (Benade, pers.comm.).

Historically, apart from *O. mossambicus*, the community appears to have changed little in the last three decades since major regulation started (Cambray, 1984; Benade, 1993). O'Keeffe *et al.* (1994) expressed concern only about the future of *Barbus hospes*, a minnow which is described as rare in the Red Data Book for Fishes (Skelton, 1987).

Prognostication depends on the modification to, and management of, the river upstream, as well as of the management of the sandbar across the mouth. The following scenarios should be considered. Scenario 3 is close to the way the system will probably be managed. Given the information gained about the fish community of the mouth it is clear that no species will be threatened. The ecosystem therefore appears to be sufficiently robust, as a result of a long history of extreme conditions, to be able to tolerate the management proposed.

Scenarios

Scenario 1

Pristine - unfortunately lost. Compare with those below.

Scenario 2

The river upstream is managed solely for its users excluding the environment and no allowance is made for simulated seasonal patterns which broadly approximate the natural pattern. Flow volumes will be much as they are at present, the Gariep/Vanderkloof Dams providing water for hydroelectricity generation especially in winter, for urban needs throughout the year, for agriculture all year but notably in spring, and for inter basin transfer which will have its greatest effect by reducing overall flows.

Scenario 3

The above with an attempt to simulate a quasi-natural flow pattern and manipulate mouth-closure and opening. This would be a highly managed system but the ecosystem would have the best chance of functioning optimally. Flow volume and pattern will be something like that suggested by the Orange River Instream Flow Requirements Workshop (Venter and Van Veelen, 1996), as shown in Tables 3 and 4. The effect on the biota should be monitored on a long-term basis.

Table 3 Management principles for the Orange River Mouth (from Venter and Van Veelen, 1996)

MONTH OF YEAR	TYPES OF FLOW NEEDED
July to September	* Back-flooding for inundation of salt-marsh. * Lowest flow during August and September to initiate mouth closure.
October to April	* Need enough water to keep mouth open. * Open mouth will create habitat for inter-tidal birds. * Maintenance floods needed once every five years. * Periodic maintenance floods for reseeding of plants, to reduce salinity, clear sediments. * During extended drought periods no maintenance floods are necessary. * The major maintenance floods should occur between January and March.
May to June	* Low-flow months for proper germination of seedlings.

Table 4 Environmental requirements (Mm3) for the Orange River and Orange River Mouth for normal (upper part) and drought conditions (lower part).

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
32.1	31.1	35.4	32.1	32.8	32.1	31.1	24.1	15.6	9.4	9.4	9.1	294.3
32.1	31.1	13.4	13.4	12.2	32.1	31.1	10.7	5.2	2.7	2.7	10.4	197.1

5. CONCLUSIONS

In answer to the original five key questions:

1. The fish community is clearly divided into a small **mouth** component of marine fishes dominated by *Liza richardsoni*, a **mid-estuary** component in mixed-saline waters dominated by *Mugil cephalus* and the introduced *Oreochromis mossambicus*, an **upper estuary** component of *Clarias gariepinus* and *Barbus* spp. and a purely freshwater **riverine** component comprised of *Labeo capensis*.
2. The condition of the river-dependent fish population within 35 km of the sea are healthy.
3. The fish populations appear, on the basis of evidence collected, to be uncompromised by increased management of flow.
4. According to a highly managed scenario, the prognosis for the fish community is good, but long-term monitoring will be needed to test this statement.
5. Further research inputs are necessary, firstly to monitor the effects of the managed river in order to improve management guidelines and secondly to understand the ecosystem better given its Ramsar status.

6. ACKNOWLEDGEMENTS

Mrs. Marie Watson and Messrs. Chris de Vries, Berndt van Rensburg and Niekie Lambrechts for data collation and reduction.

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Appendix

Table 1 Fishes collected at each station, lower Orange River, during March/April 1993.

	RIVER		REEDS		ESTUARY	
STATION	BRAND-KAROS	BOKDROL-DRAAI	DUNVLEI	DYK	BLOKHUIS	TOTAL
Labeo capensis	56	6	1	0	0	63
Barbus aeneus	16	18	10	0	0	44
Oreochromis mossambicus	31	9	0	3	0	43
Mesobola brevianalis	36	7	0	0	0	43
Pseudocreni-labrus philander	6	0	3	0	0	9
Cyprinus carpio	0	1	0	0	0	1
Barbus kimberleyensis	0	1	4	2	0	7
Mugil cephalus	0	0	22	0	1	23
Clarias gariepinus	0	0	9	0	0	9
Diplodus trifasciatus	0	0	0	0	1	1
Pomatomus saltator	0	0	0	0	5	5
Liza richardsonii	0	0	43	0	1	44

Table 2 Fishes collected at each station, lower Orange River, during July 1993

	RIVER	REEDSWAMP		
STATION	**BRAND KAROS**	**DUNVLEI**	**DYK**	**TOTAL**
Labeo capensis	7	1	0	8
Barbus aeneus	6	35	0	41
Liza richardsonii	1	42	100	143
Oreochromis mossambicus	0	5	3	8
Argyrosomus hololepidotus	0	0	1	1
Barbus kimberleyensis	1	2	0	3
Mugil cephalus	2	3	26	31

<u>Table 3</u> Fishes collected at each station, lower Orange River, during September 1993.

	RIVER	REEDS		ESTUARY		
STATION	BRAND-KAROS	DUNVLEI	DYK R.M.	BLOKHUIS	GOLF CLUB	TOTAL
Barbus aeneus	103	69	11	0	0	183
Oreochromis mossambicus	35	42	39	20	0	136
Mugil cephalus	27	142	126	2	2	299
Barbus kimberleyensis	4	7	2	0	0	13
Liza richardsonii	18	22	8	136	121	285
Barbus paludinosus	0	1	0	0	0	1
Labeo capensis	135	3	0	0	0	138
Clarias gariepinus	1	9	0	0	0	10
Mesobola brevianalis	42	0	0	0	0	42
Pseudocrenilabrus philander	6	4	0	0	0	10
Lithognathus lithognathus	0	0	0	1	0	4

Table 4 Fishes collected at each station, lower Orange River, during January 1994

	RIVER		REEDS	ESTUARY		
STATION	BRAND-KAROS	DUNVLEI	DYK R.M.	BLOKHUIS	GOLF CLUB	TOTAL
Barbus aeneus	27	81	74	15	47	244
Barbus kimberleyensis	4	10	0	0	1	15
Labeo capensis	68	4	0	0	0	72
Clarius gariepinus	3	1	1	0	0	5
Oreochromis mossambicus	1	5	22	1	4	33
Pomatomus saltator	6	0	6	2	11	25
Lithognathus lithognathus	0	0	0	10	0	10
Mugil cephalus	4	2	98	13	8	125
Liza richardsonii	3	8	0	137	38	186
Argyrosomus hololepidotus	0	0	0	0	1	1
Lichia amia	0	0	0	1	0	1
Gilchristella aestuaria	1	0	0	0	0	1

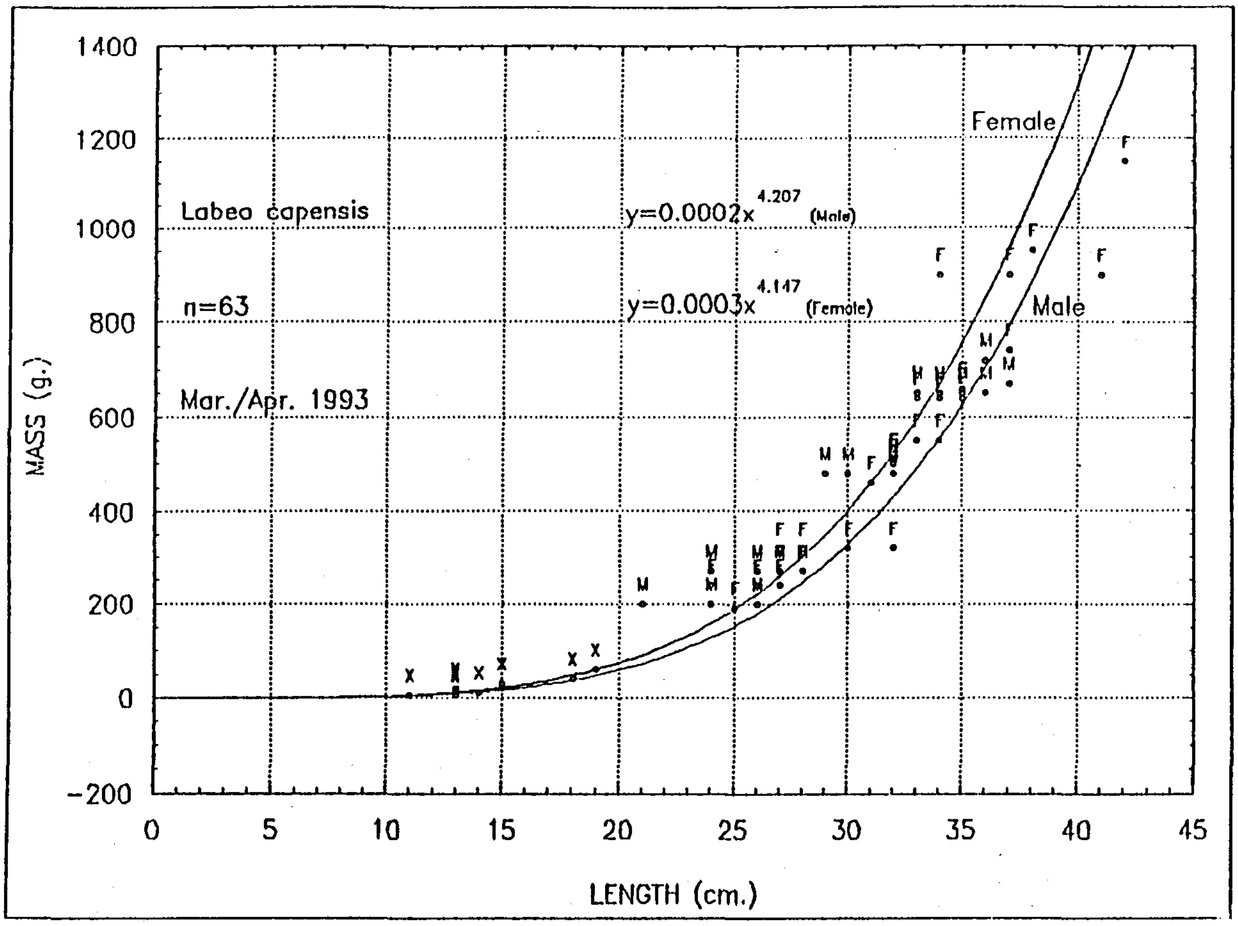


Figure 1. The mass/length relationship of *L. capensis* individuals collected at all stations during March/April 1993.

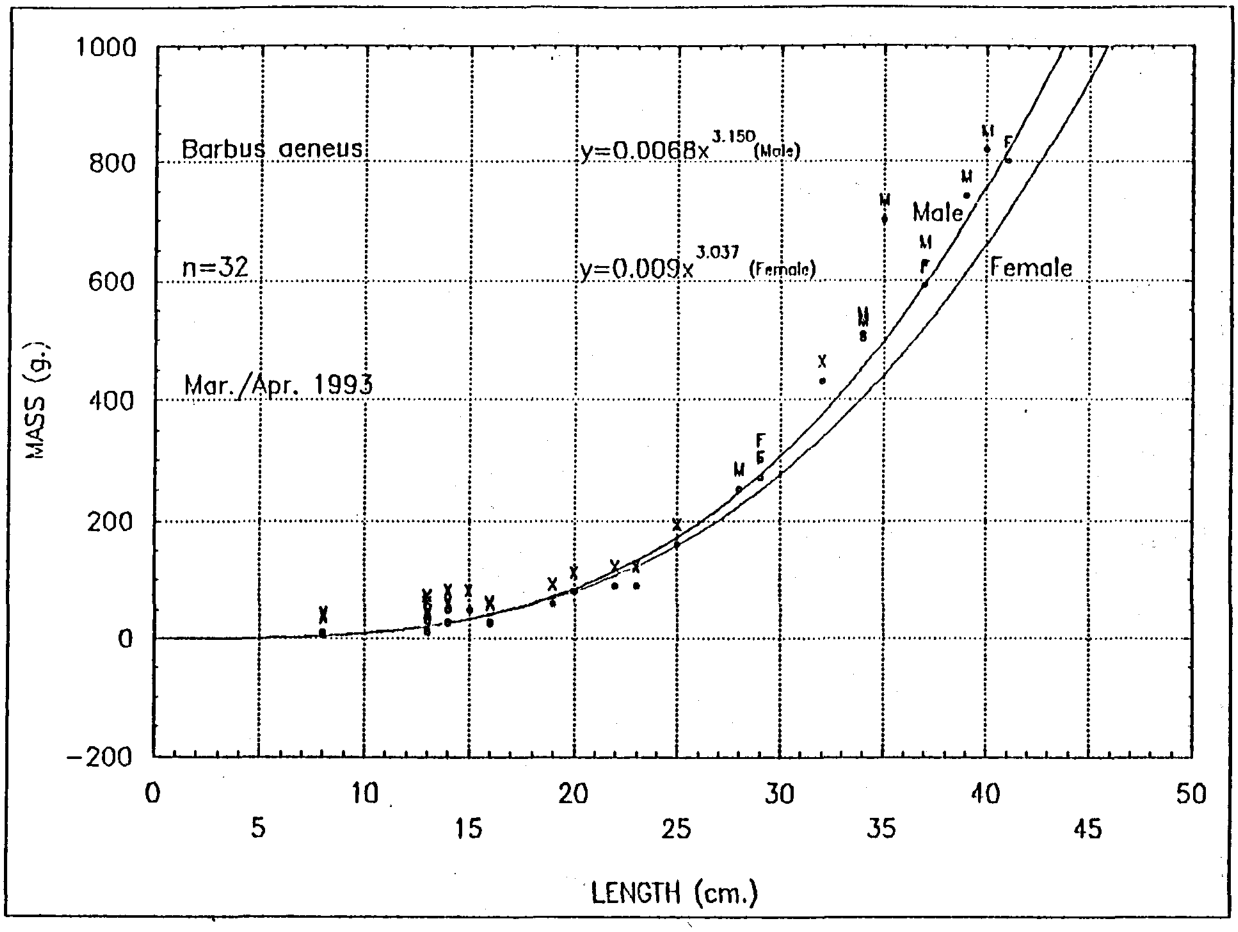


Figure 2. The mass/length relationship of *B. aeneus* individuals collected at all stations during March/April 1993.

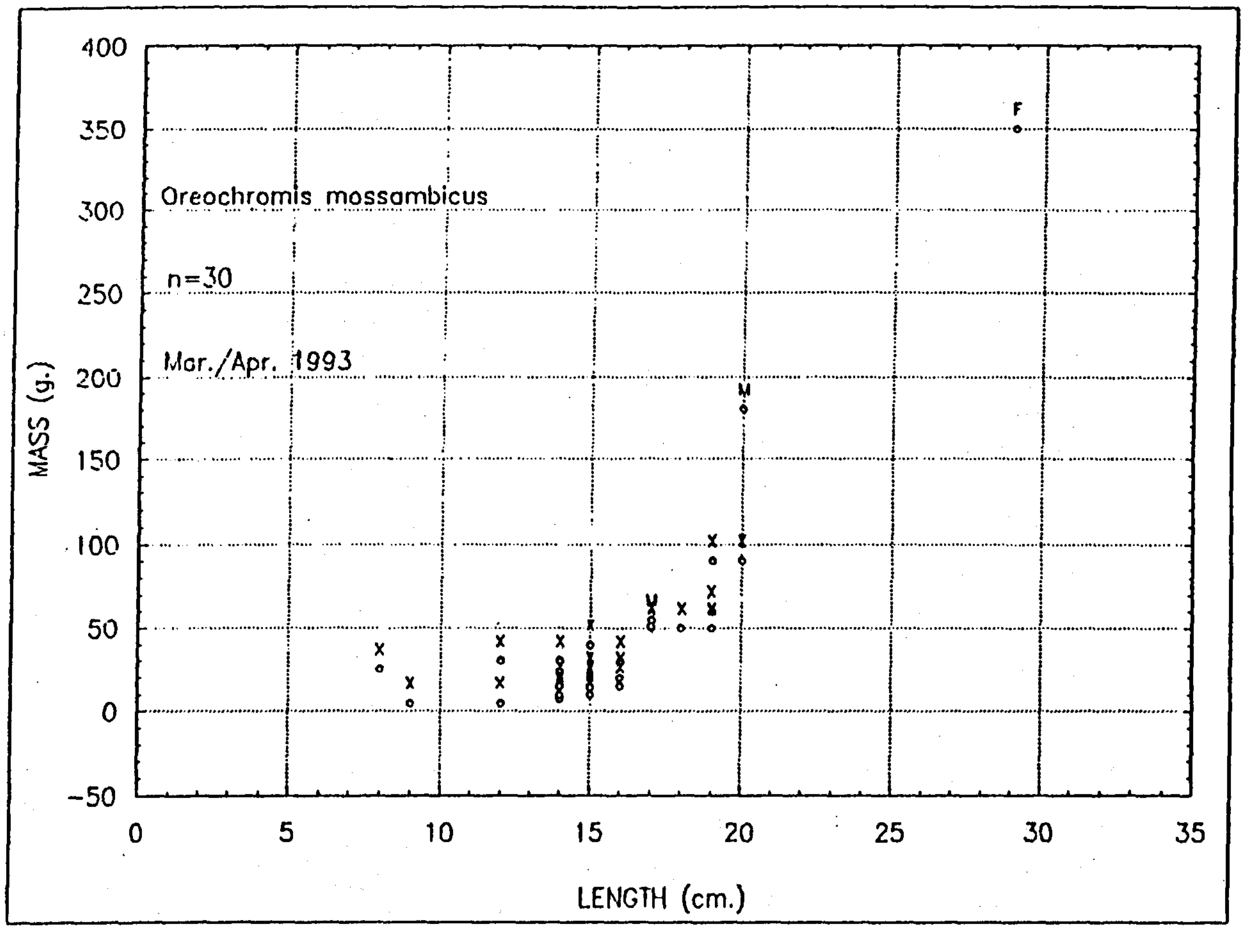


Figure 3. The mass/length relationship of *O. mossambicus* individuals collected at all stations during March/April 1993.

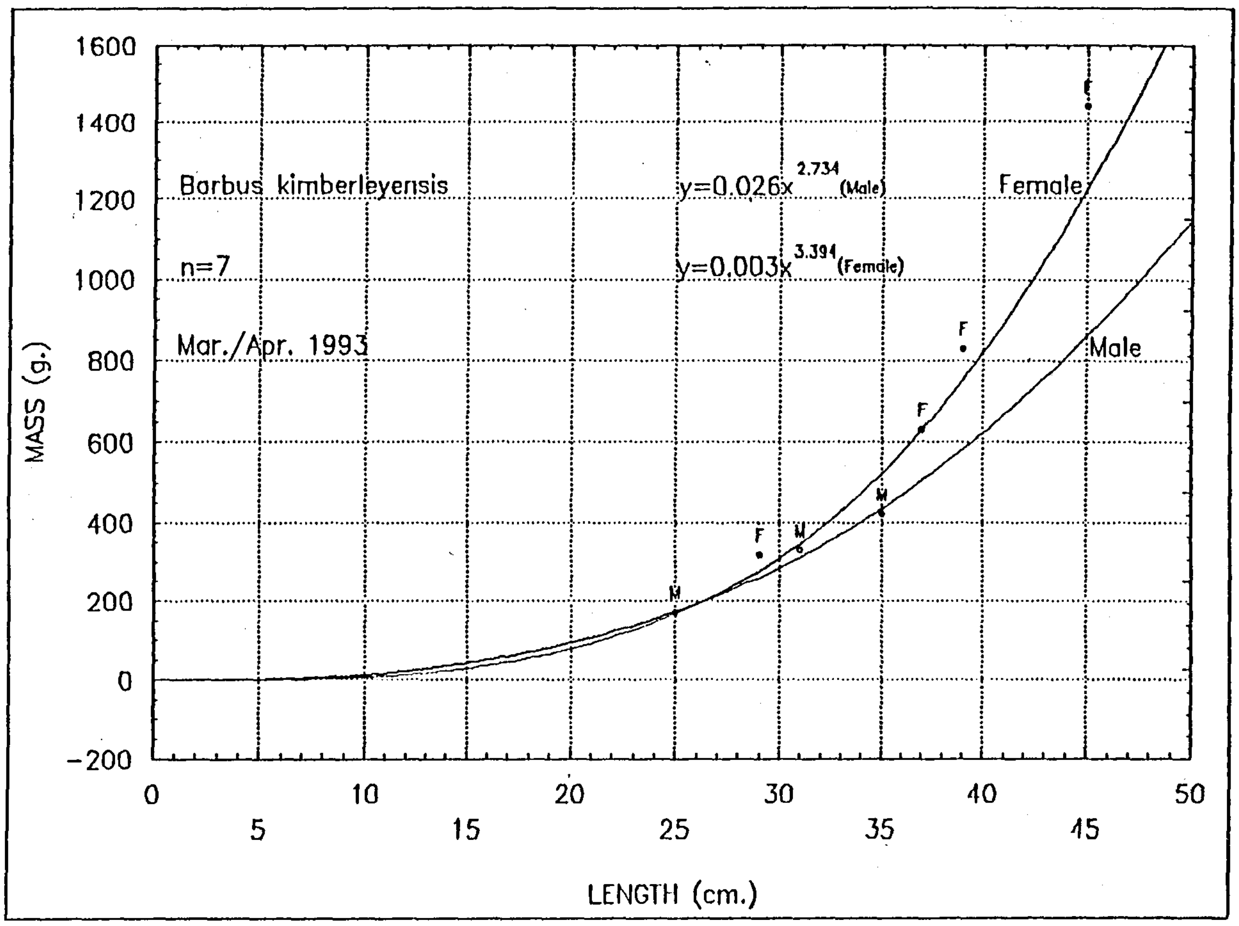


Figure 4. The mass/length relationship of *B. kimberleyensis* individuals collected at all stations during March/April 1993.

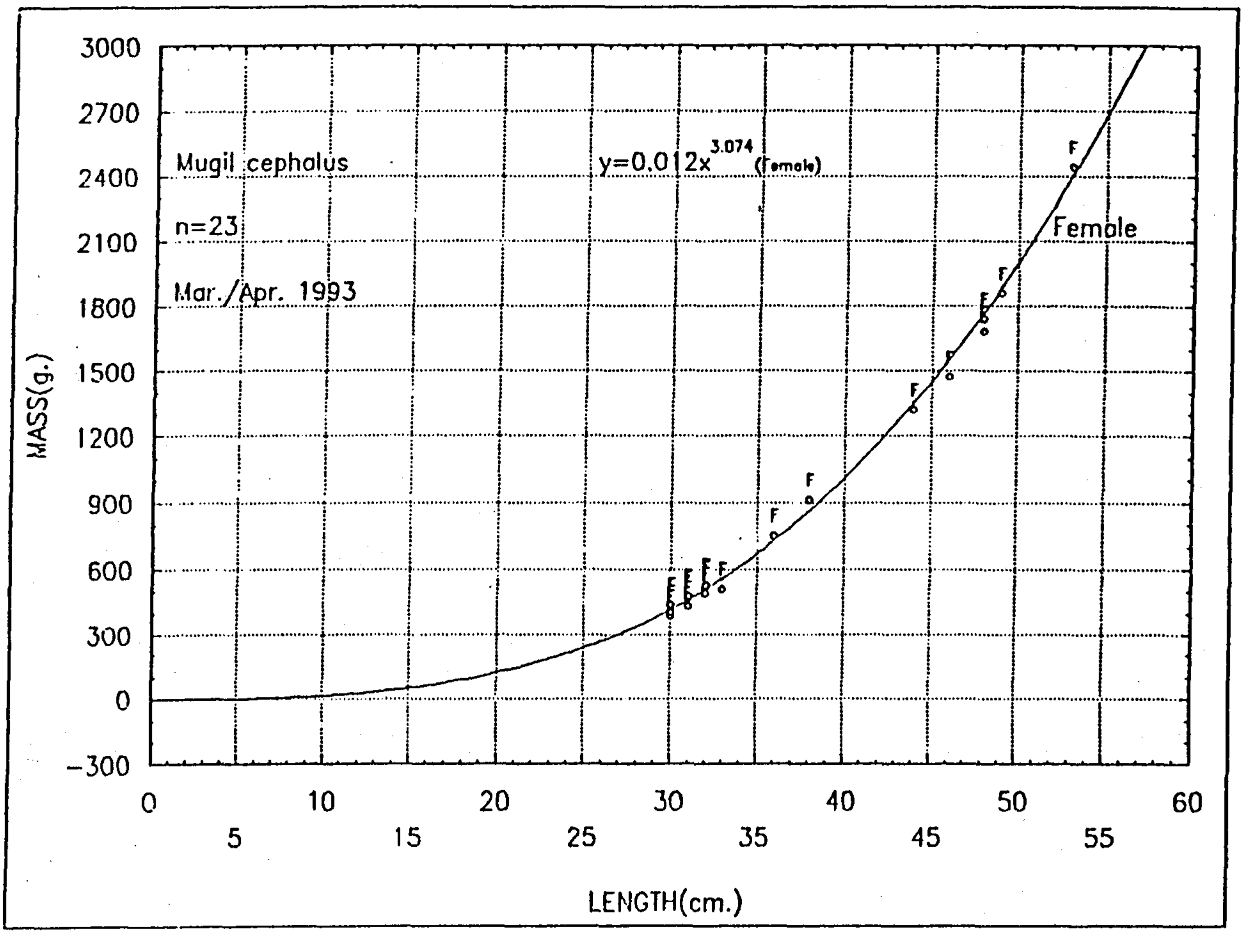
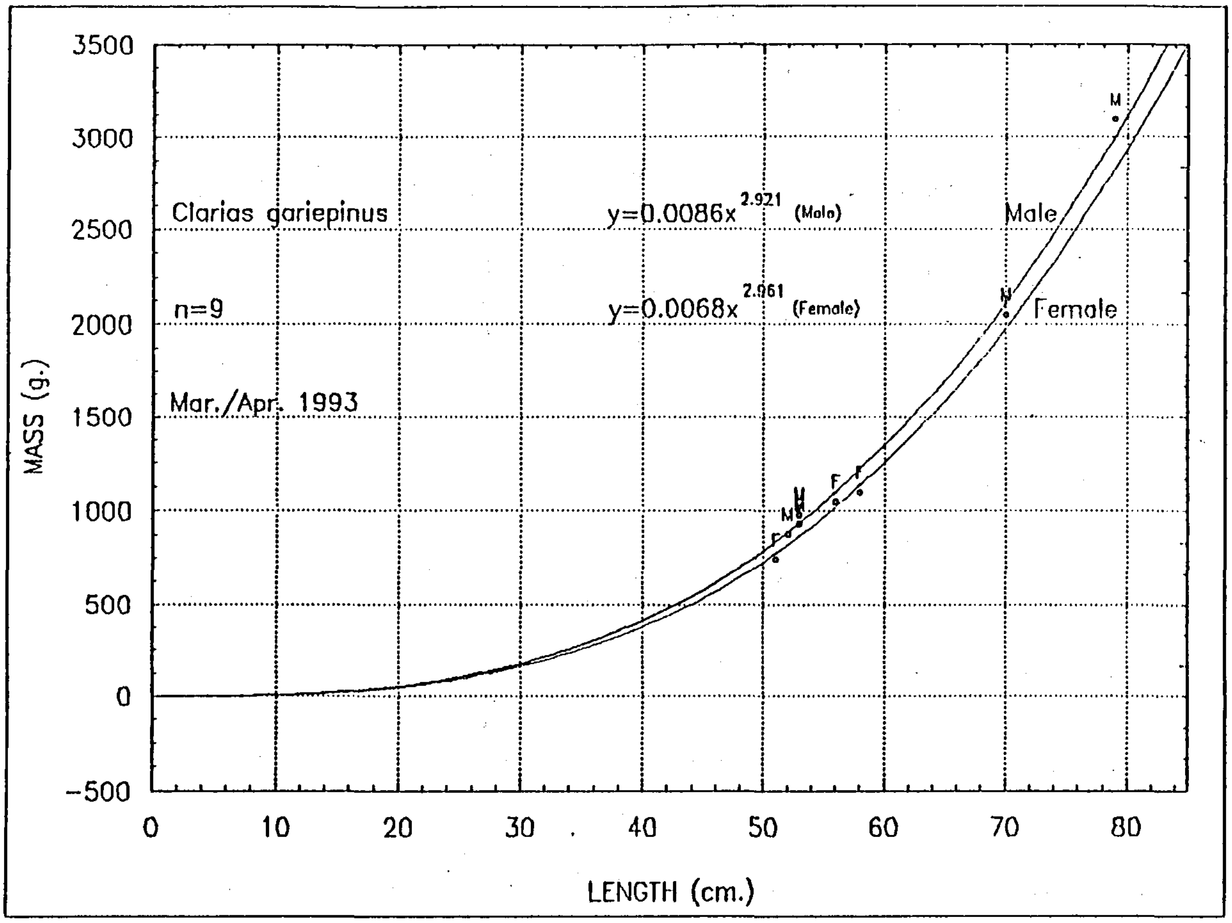


Figure 5. The mass/length relationship of *M. cephalus* individuals collected at all stations during March/April 1993.



<u>Figure 6.</u> The mass/length relationship of *C. gariepinus* individuals collected at all stations during March/April 1993.

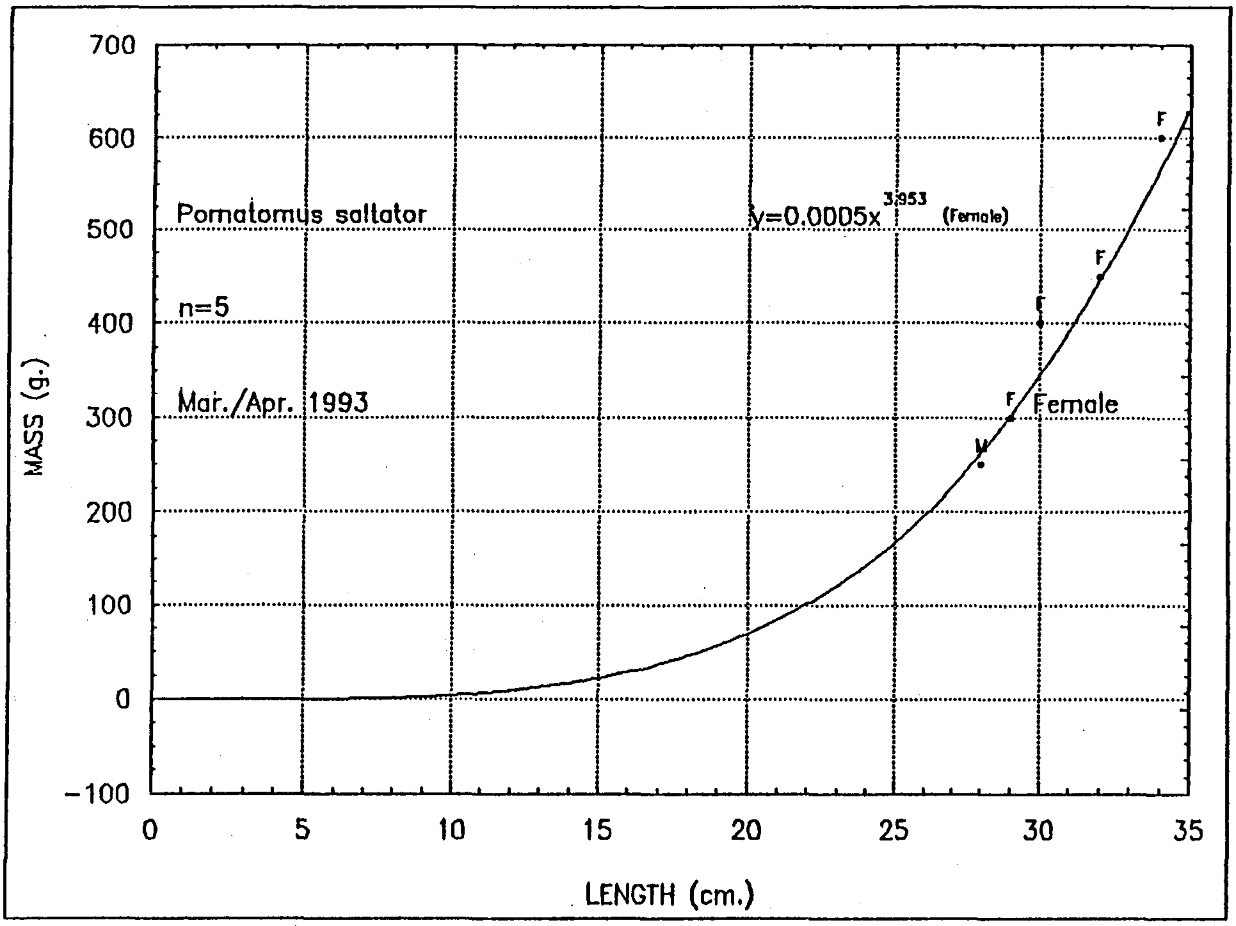


Figure 7. The mass/length relationship of *P. saltator* individuals collected at all stations during March/April 1993.

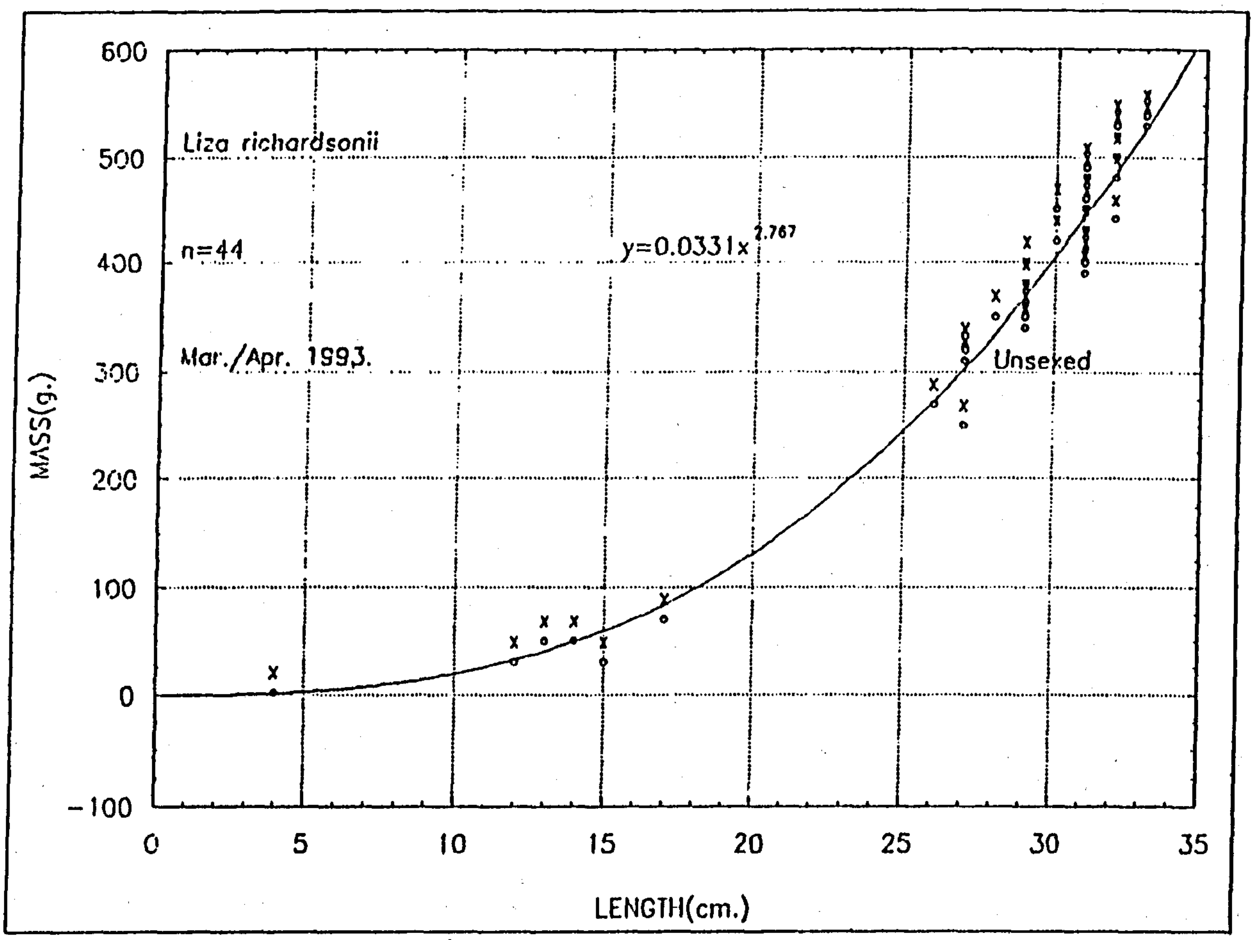


Figure 8. The mass/length relationship of *L. richardsonii* individuals collected at all stations during March/April 1993.

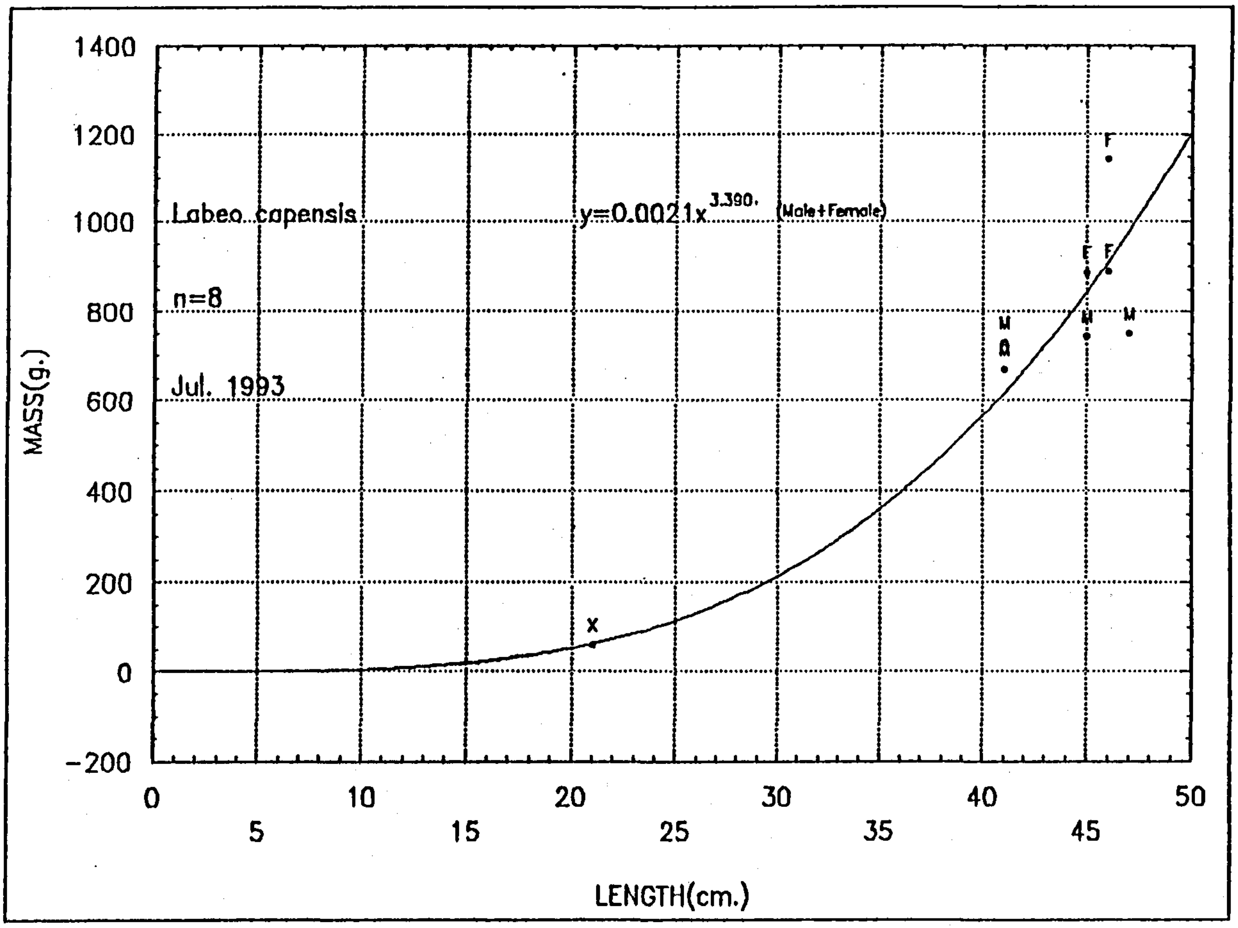


Figure 9. The mass/length relationship of *L. capensis* individuals collected at all stations during July 1993.

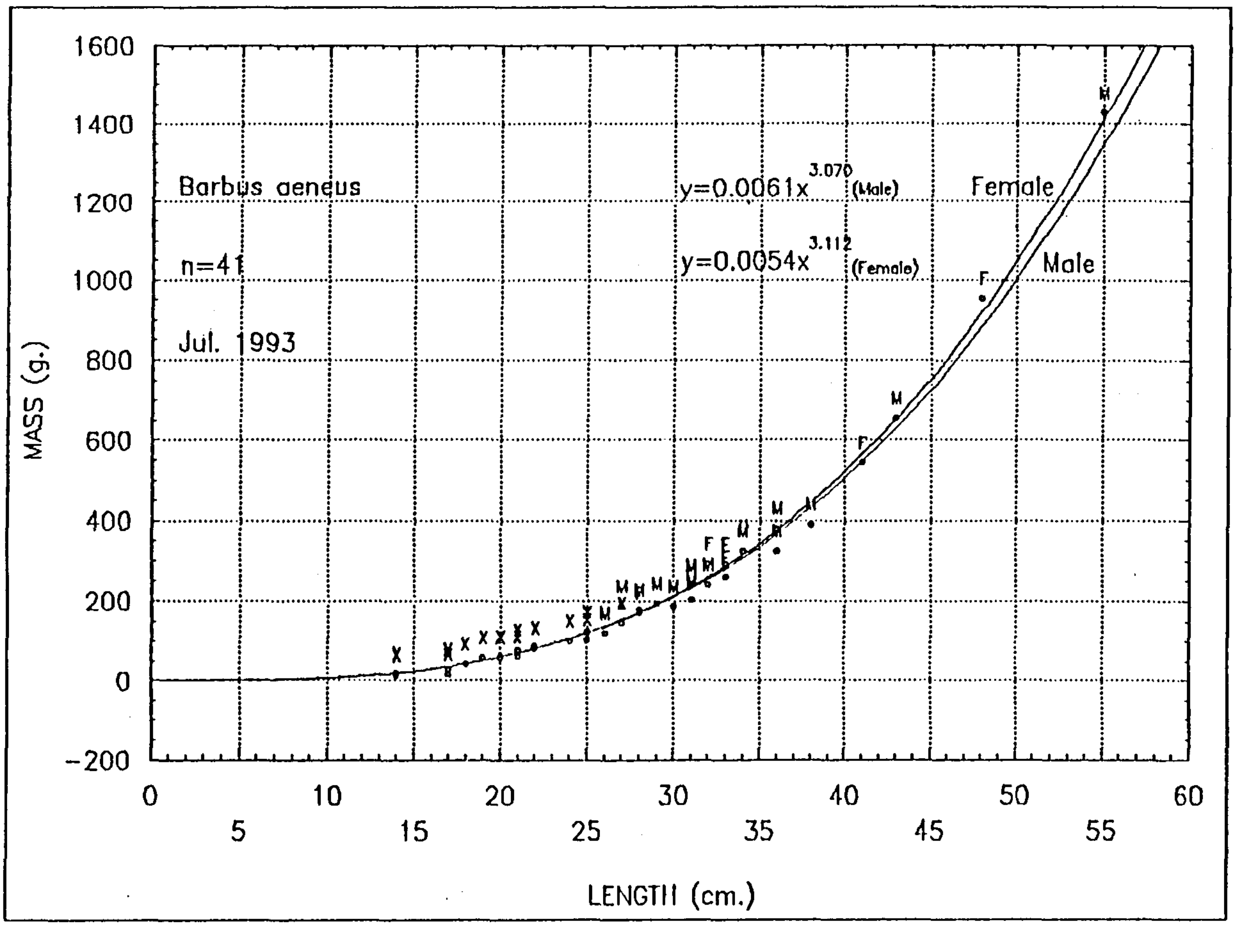


Figure 10. The mass/length relationship of *B. aeneus* individuals collected at all stations during July 1993.

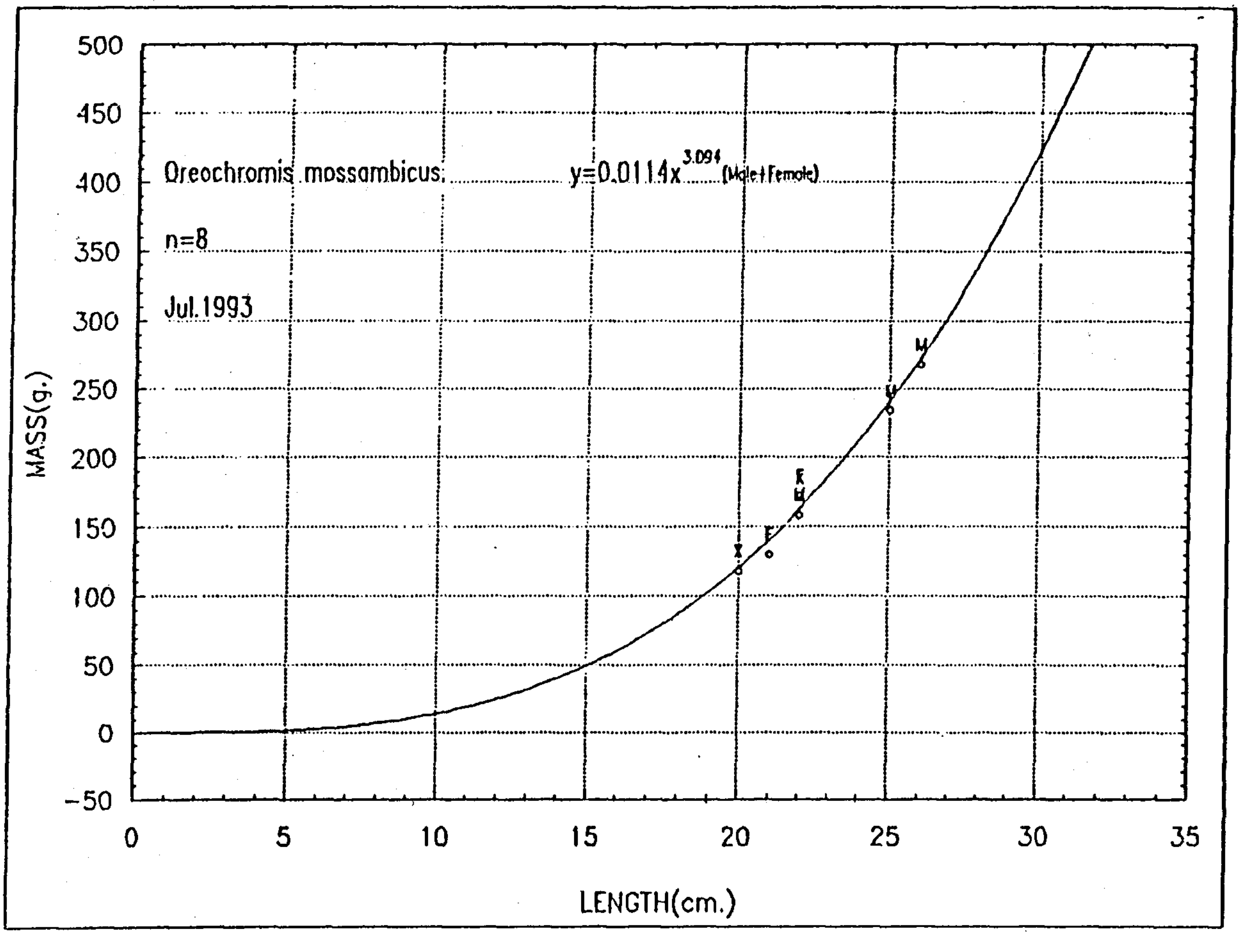


Figure 11. The mass/length relationship of *O. mossambicus* individuals collected at all stations during July 1993.

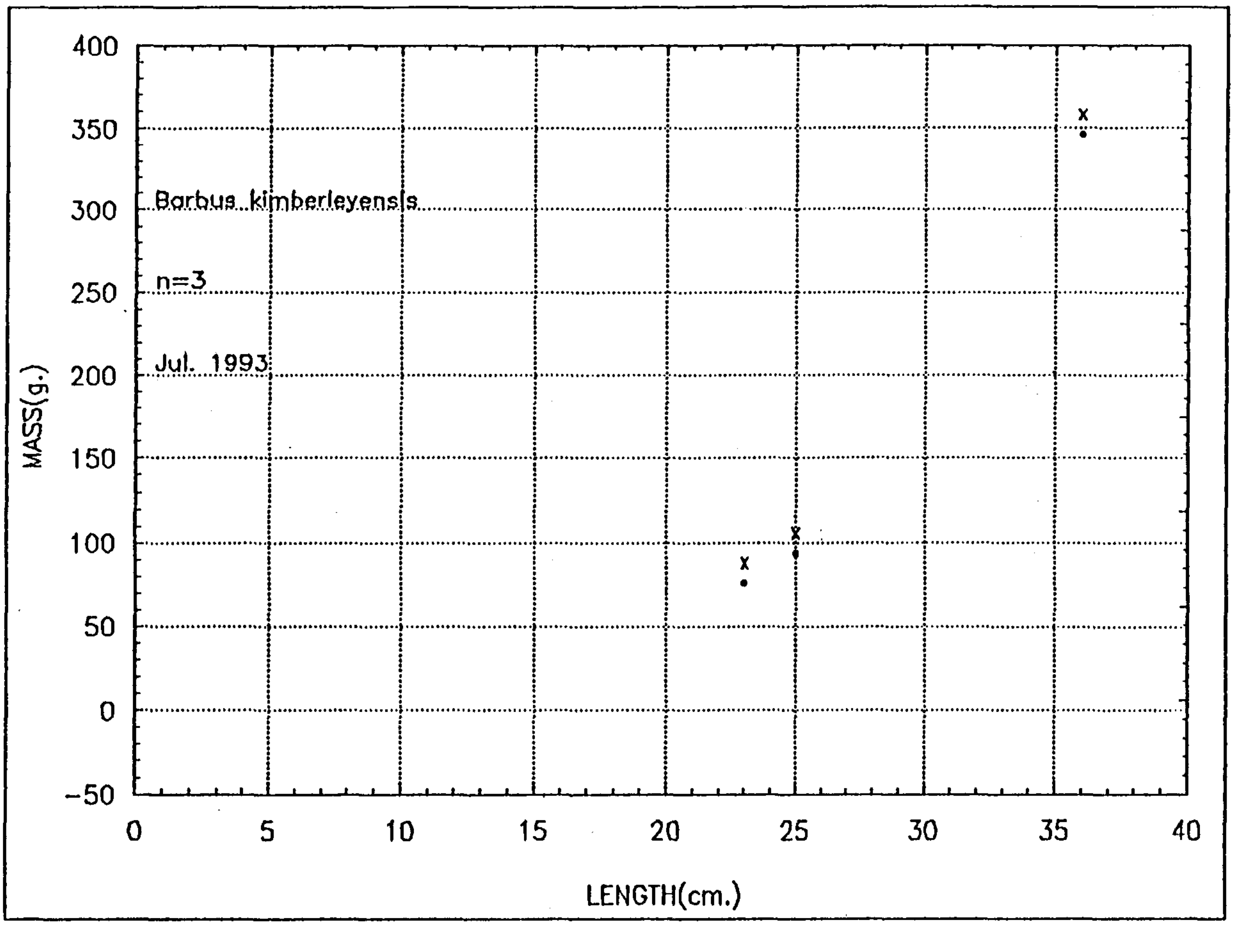


Figure 12. The mass/length relationship of *B. kimberleyensis* individuals collected at all stations during July 1993.

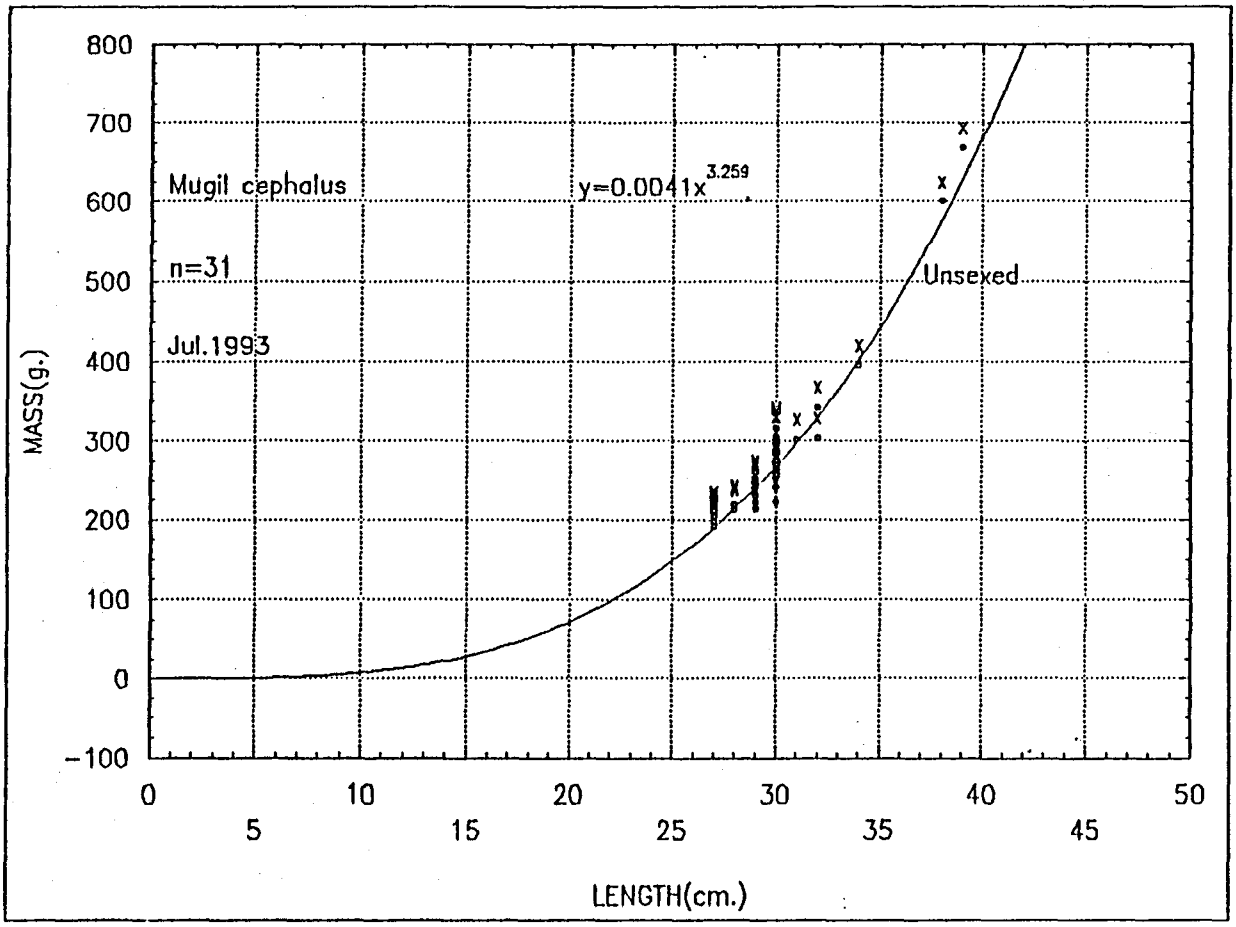


Figure 13. The mass/length relationship of *M. cephalus* individuals collected at all stations during July 1993.

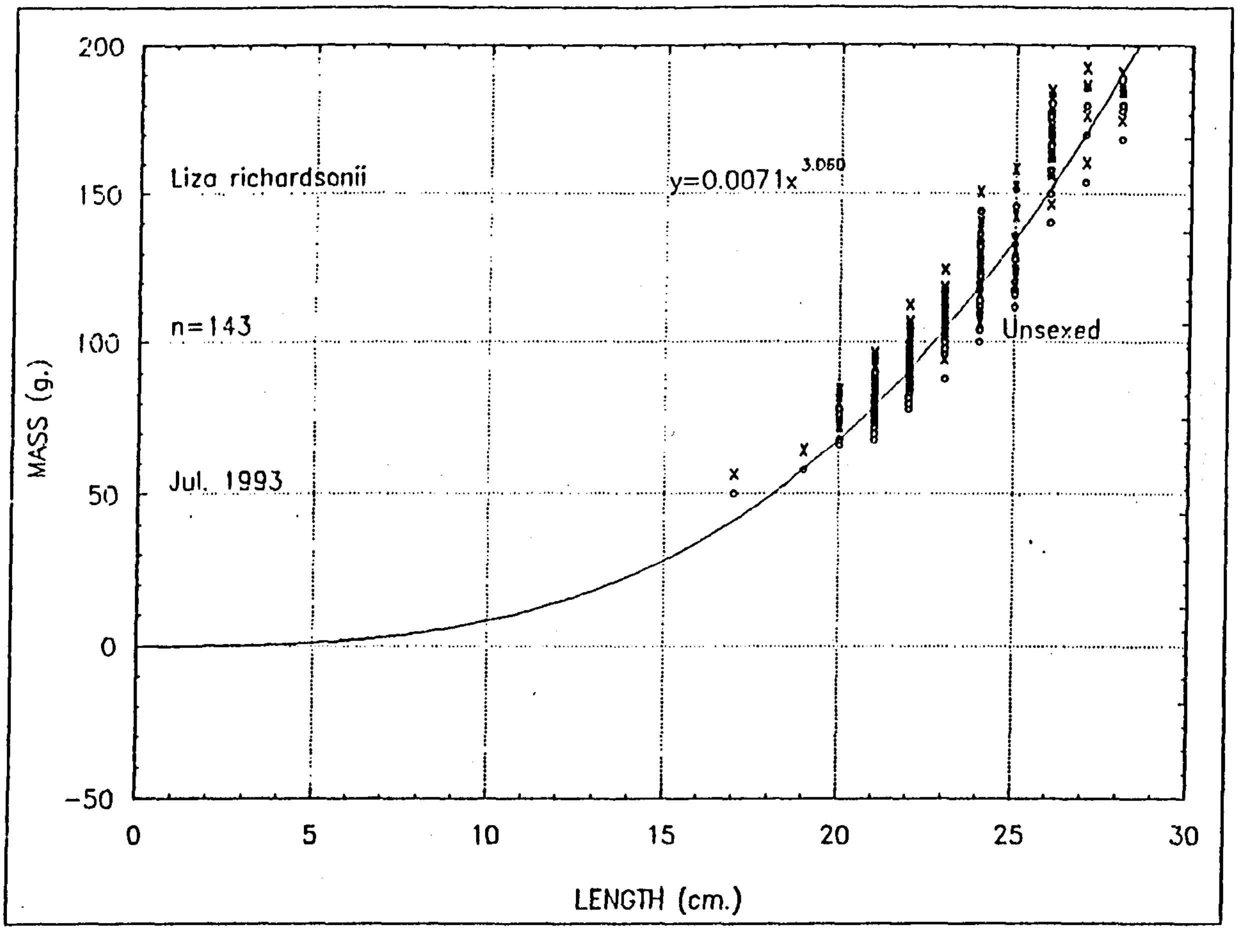


Figure 14. The mass/length relationship of *L. richardsonii* individuals collected at all stations during July 1993.

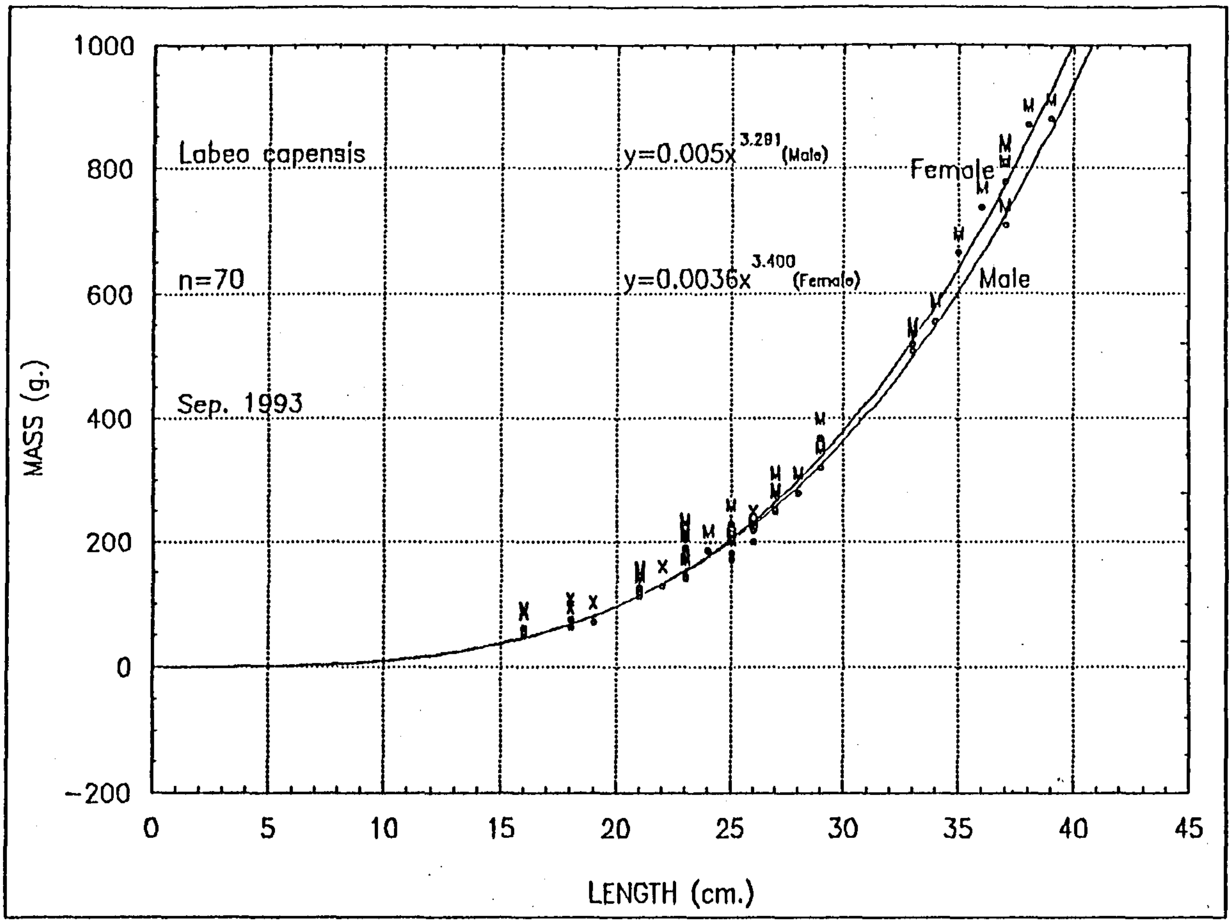


Figure 15. The mass/length relationship of *L. capensis* individuals collected at all stations during September 1993.

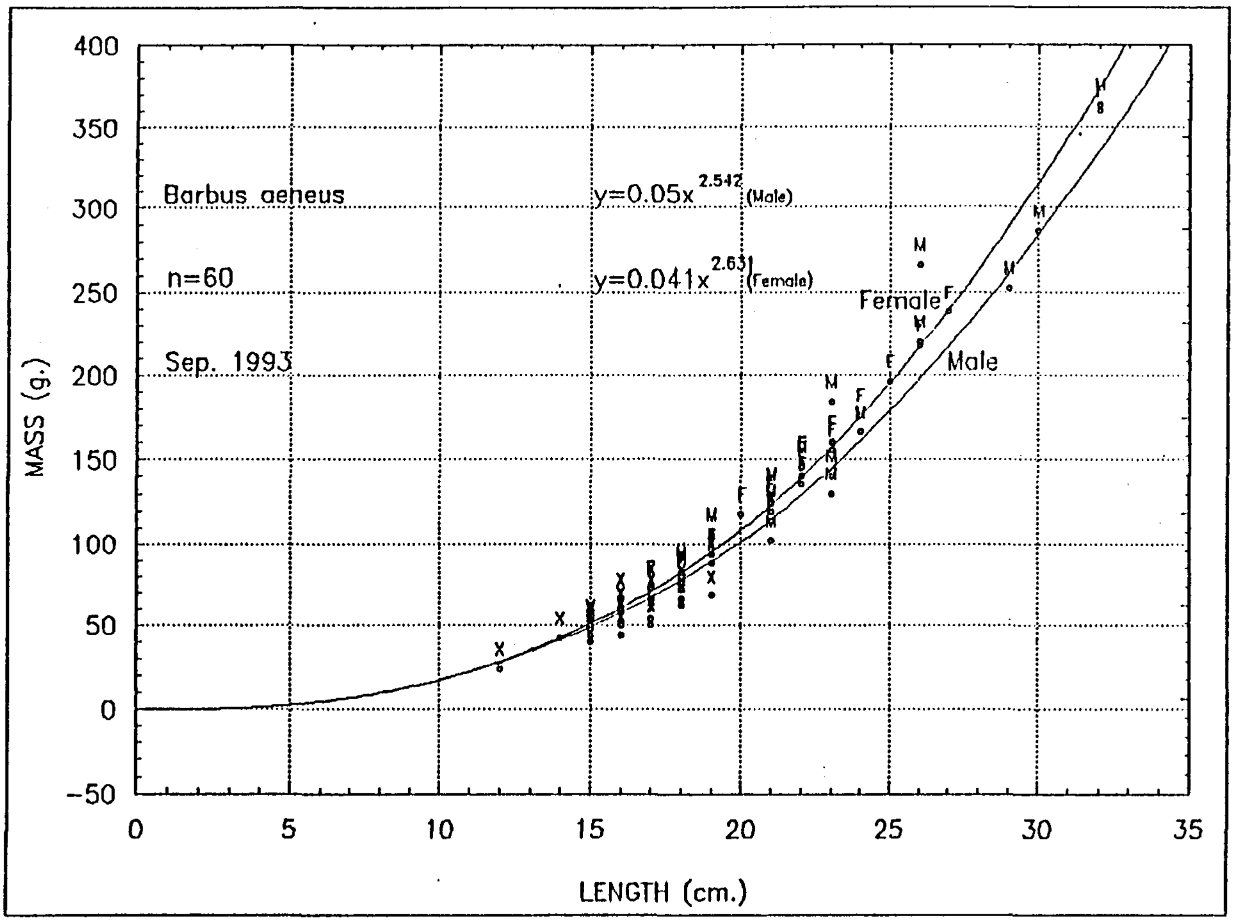


Figure 16. The mass/length relationship of *B. aeneus* individuals collected at all stations during September 1993.

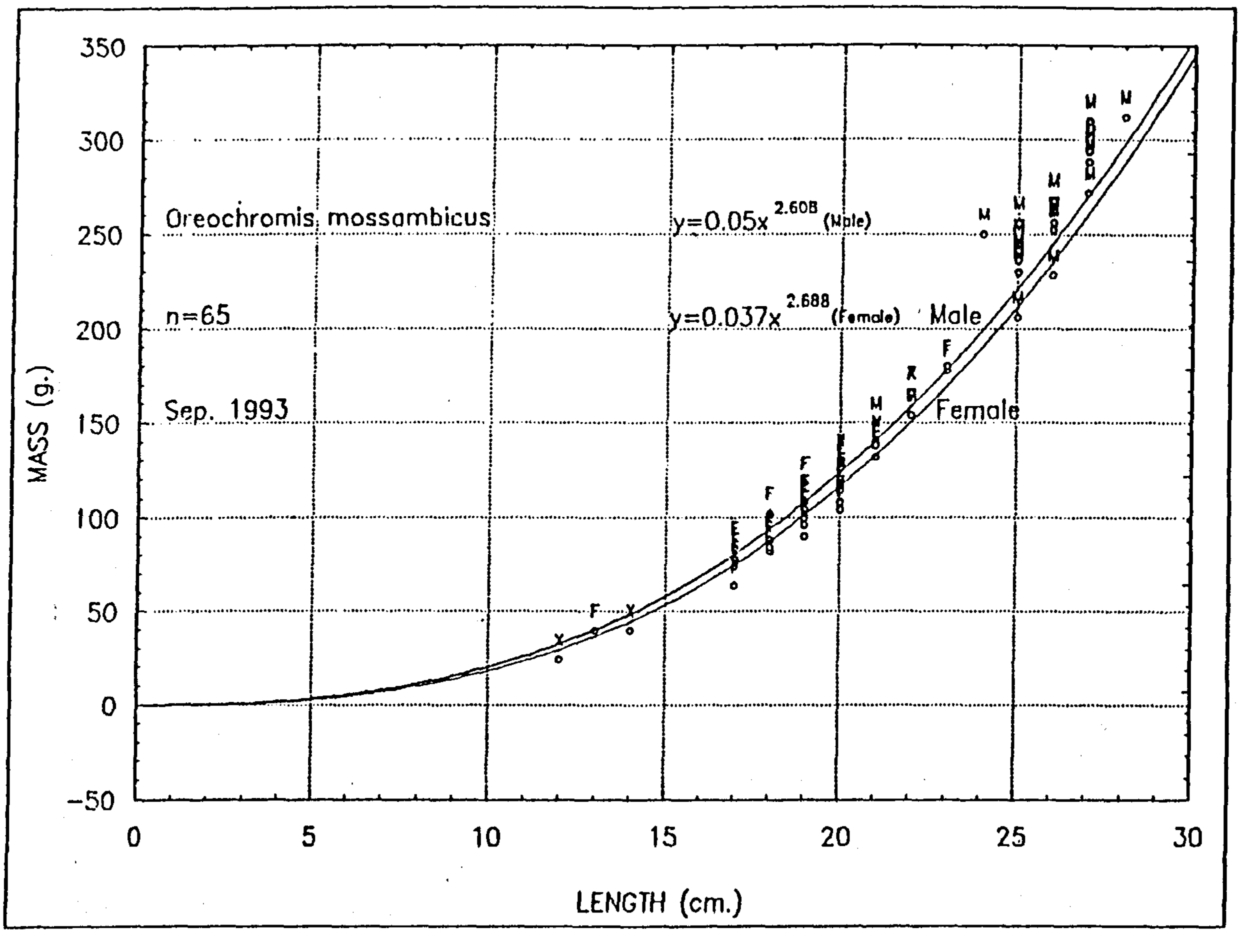


Figure 17. The mass/length relationship of *O. mossambicus* individuals collected at all stations during September 1993.

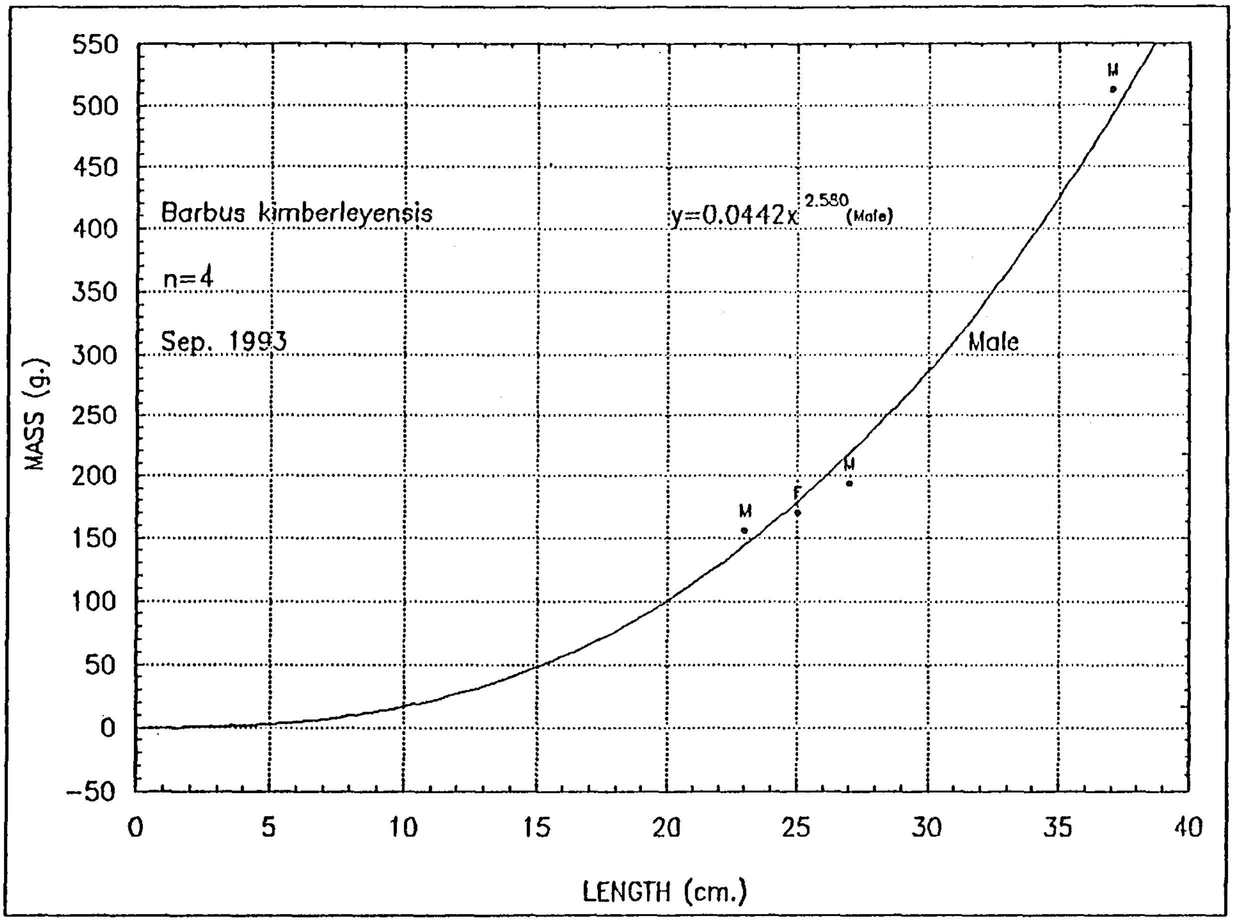


Figure 18. The mass/length relationship of *B. kimberleyensis* individuals collected at all stations during September 1993.

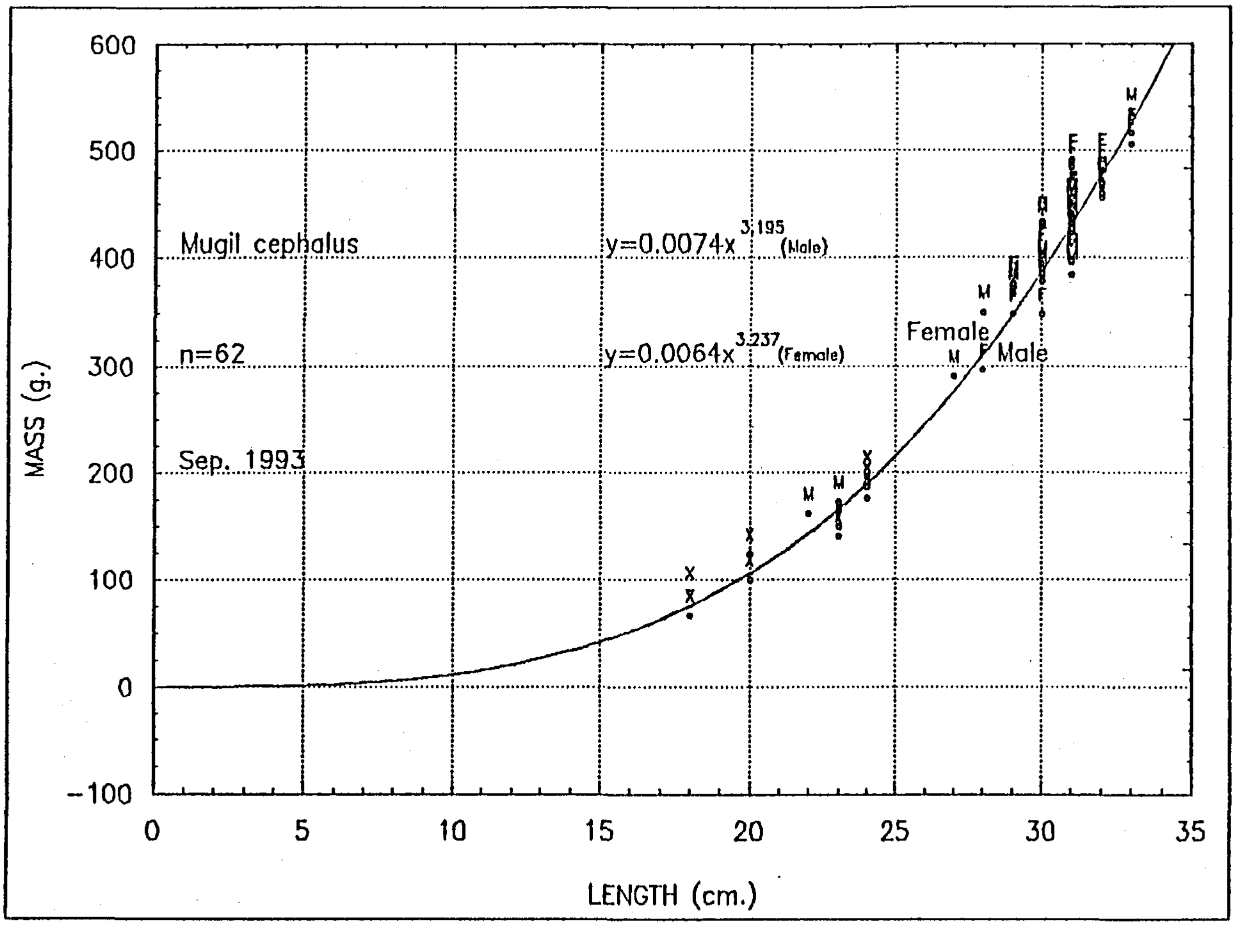


Figure 19. The mass/length relationship of *M. cephalus* individuals collected at all stations during September 1993.

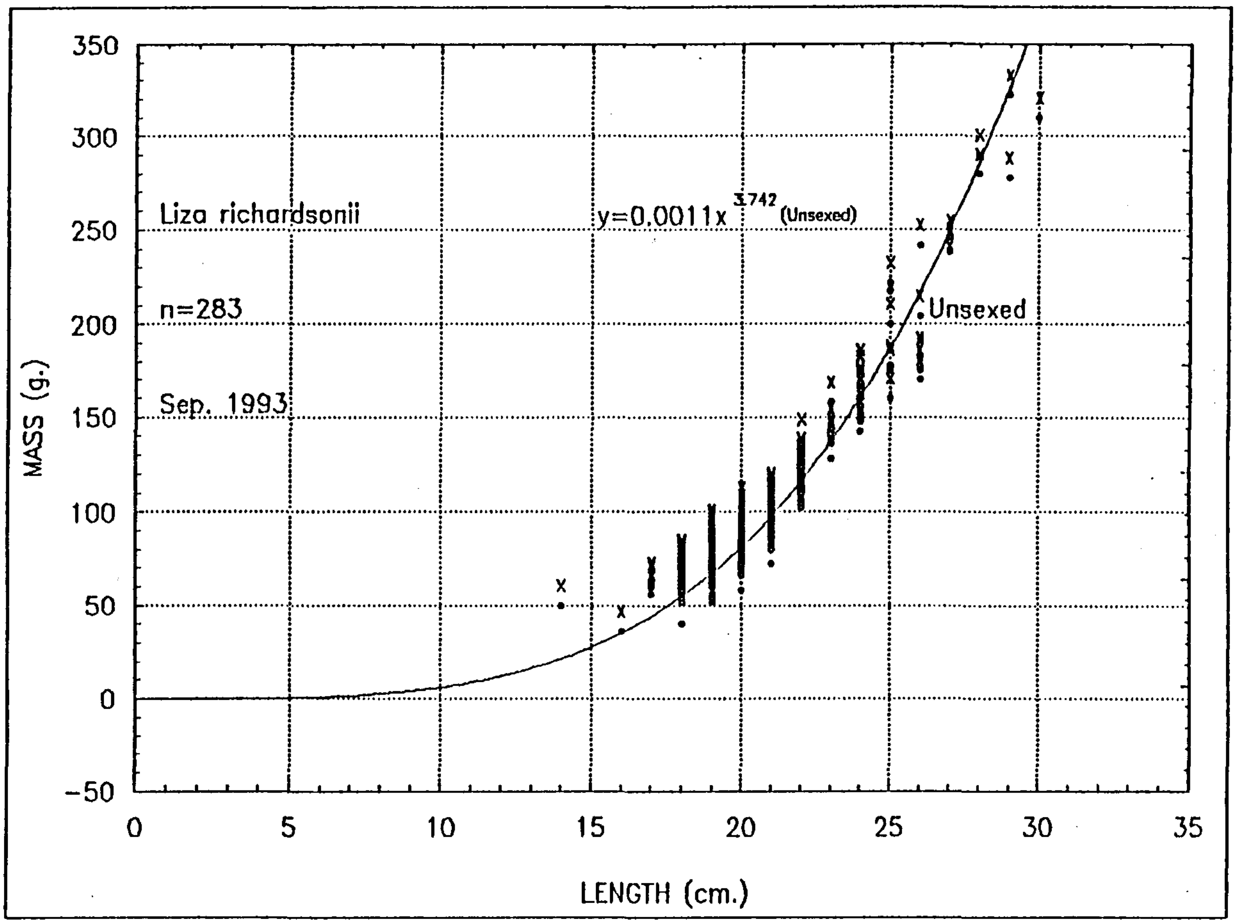


Figure 20. The mass/length relationship of *L. richardsonii* individuals collected at all stations during September 1993.

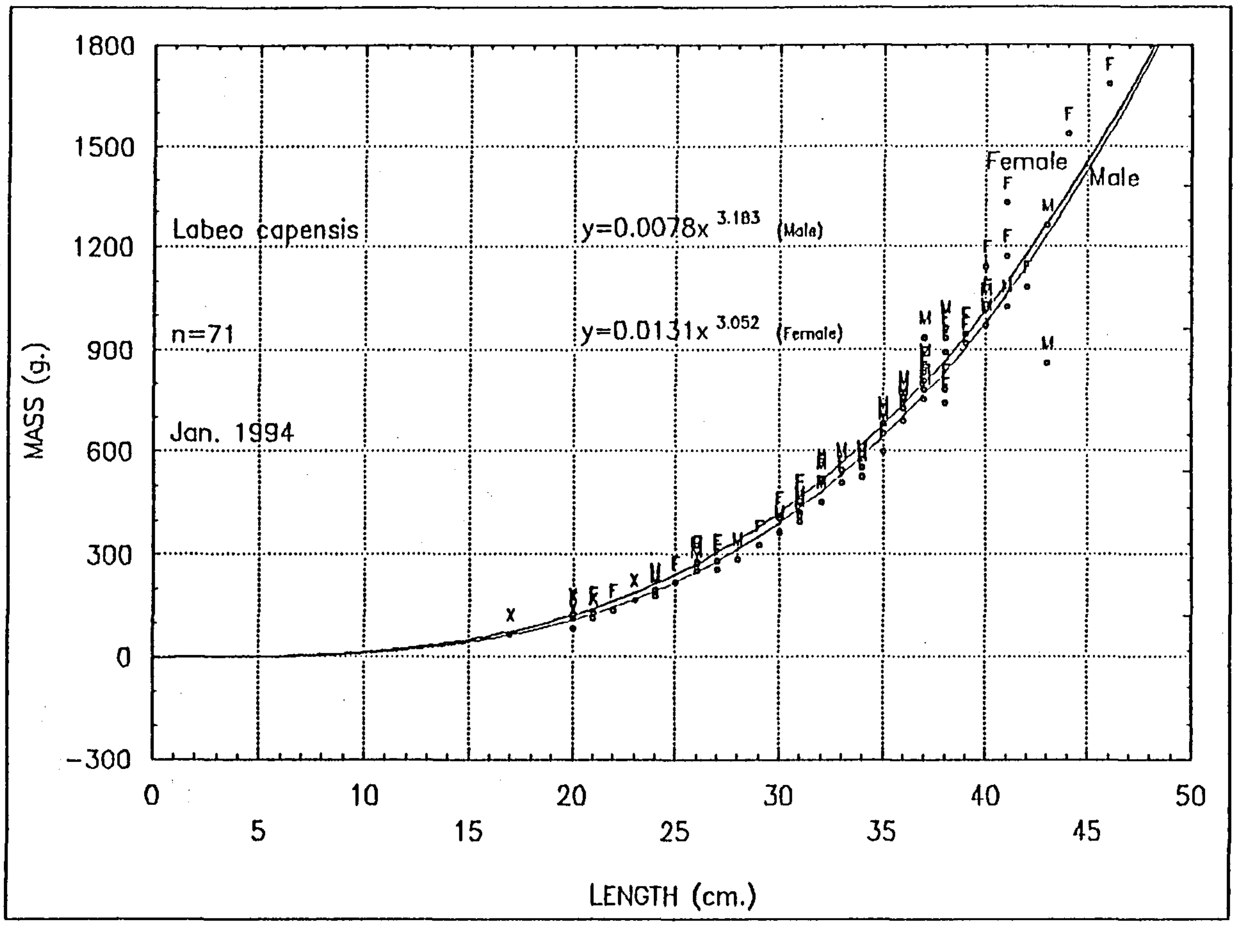


Figure 21. The mass/length relationship of *L. capensis* individuals collected at all stations during January 1994.

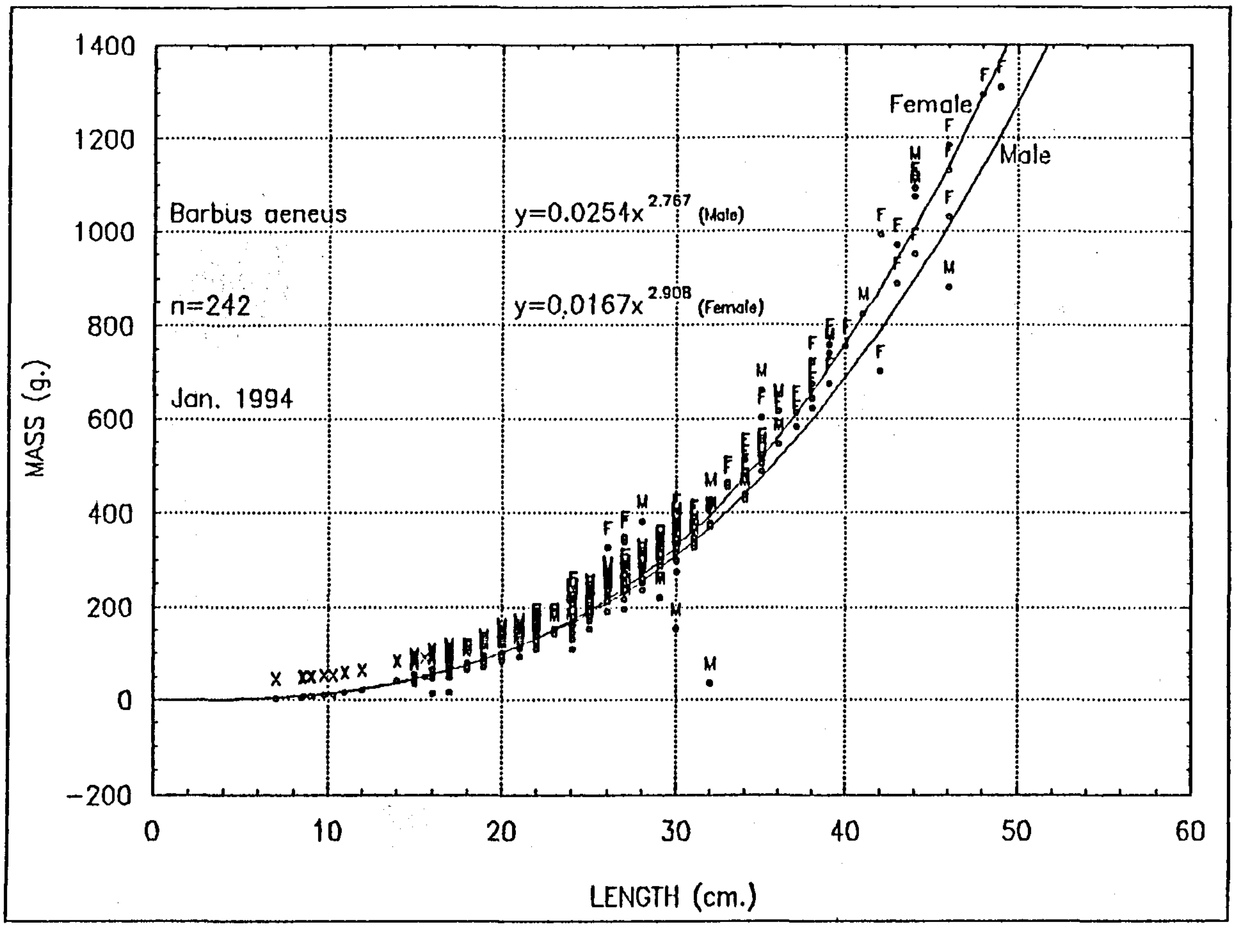


Figure 22. The mass/length relationship of *B. aeneus* individuals collected at all stations during January 1994.

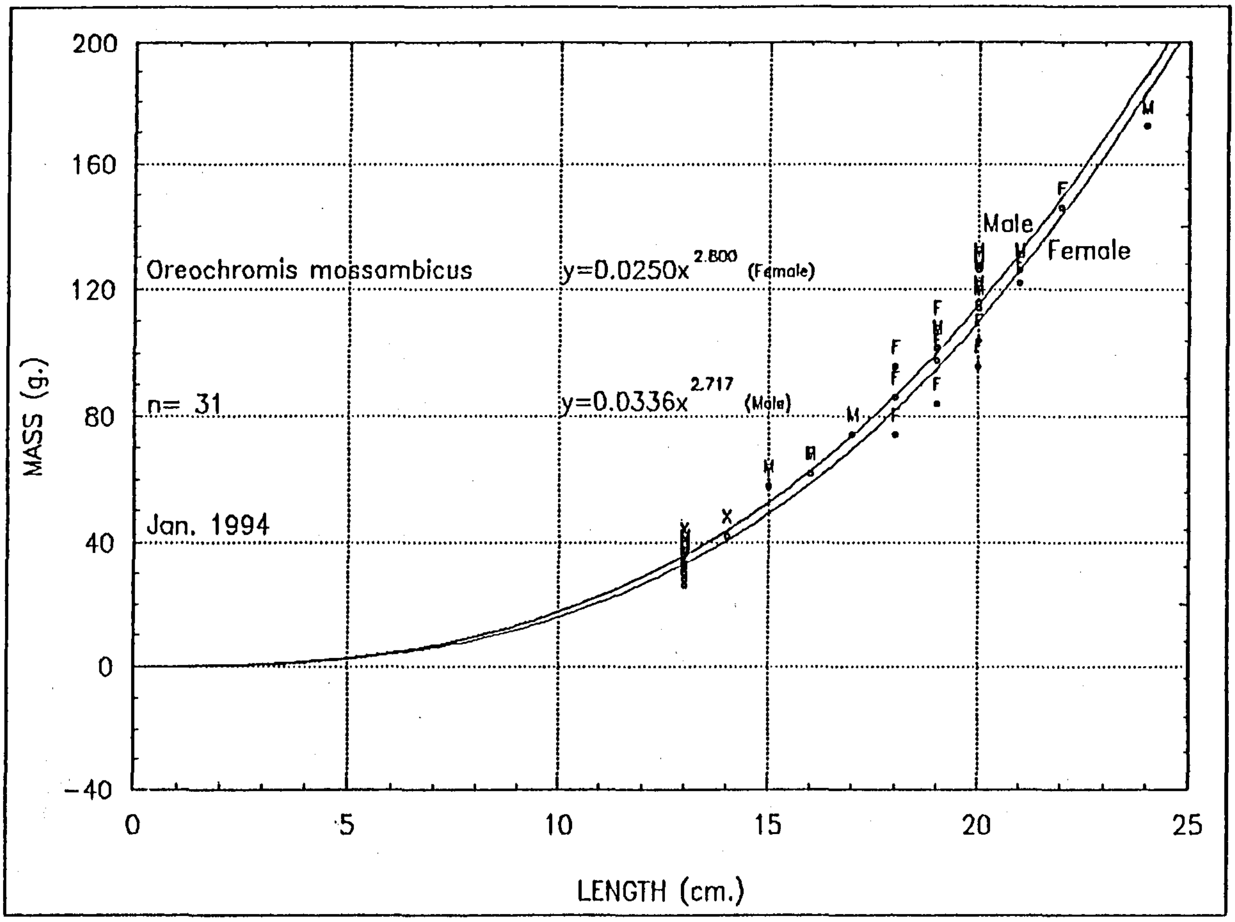


Figure 23. The mass/length relationship of *O. mossambicus* individuals collected at all stations during January 1994.

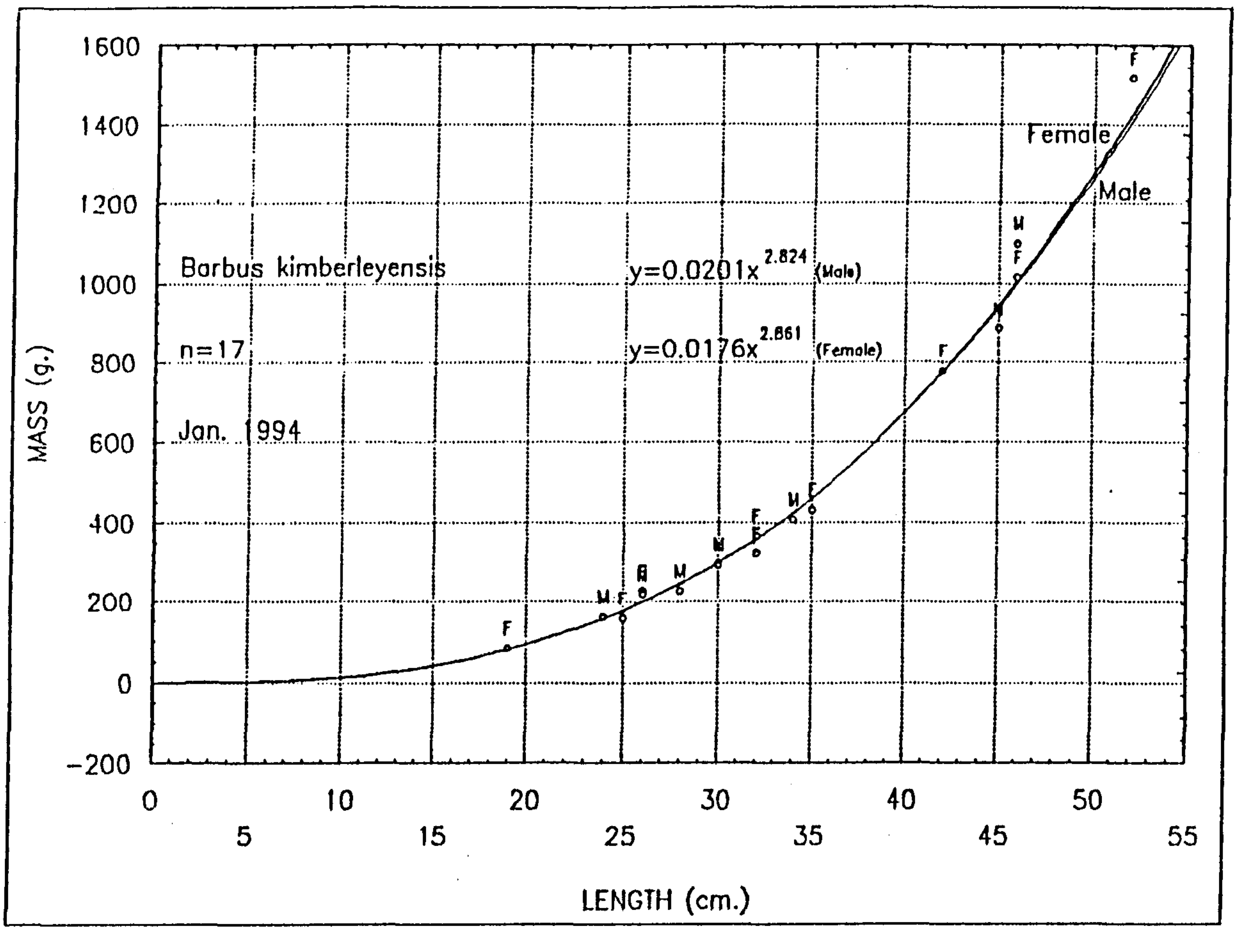


Figure 24. The mass/length relationship of *B. kimberleyensis* individuals collected at all stations during January 1994.

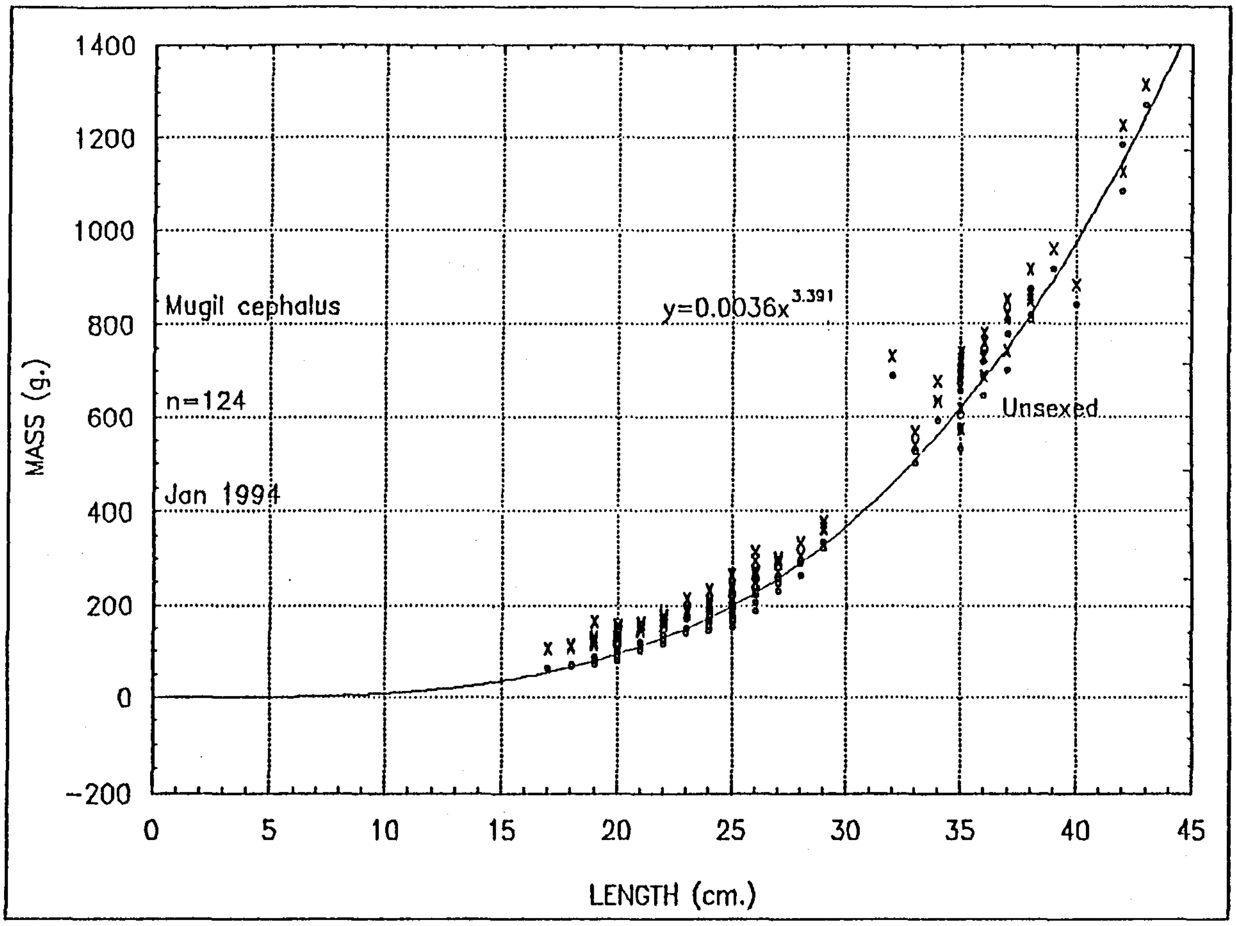


Figure 25. The mass/length relationship of *M. cephalus* individuals collected at all stations during January 1994.

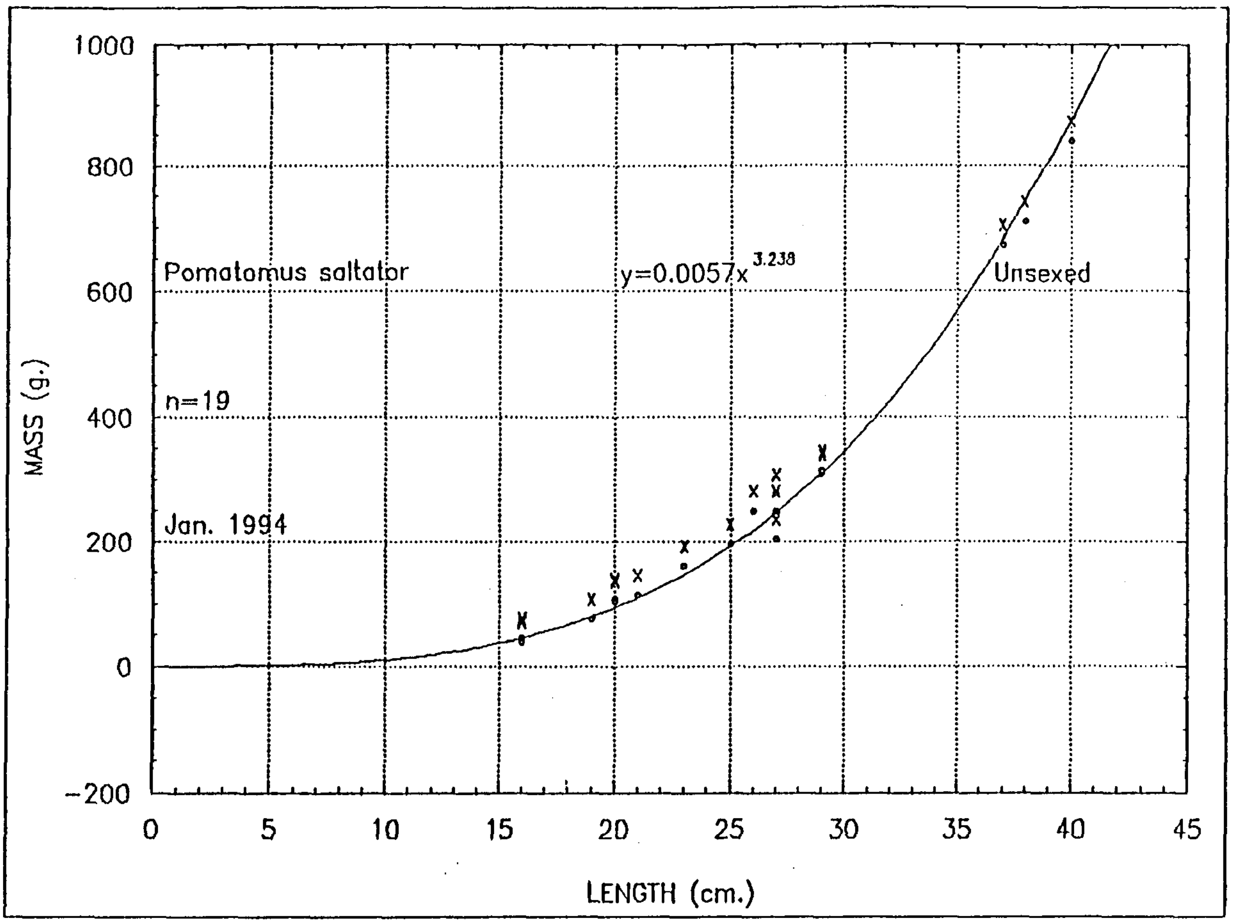


Figure 26. The mass/length relationship of *P. saltator* individuals collected at all stations during January 1994.

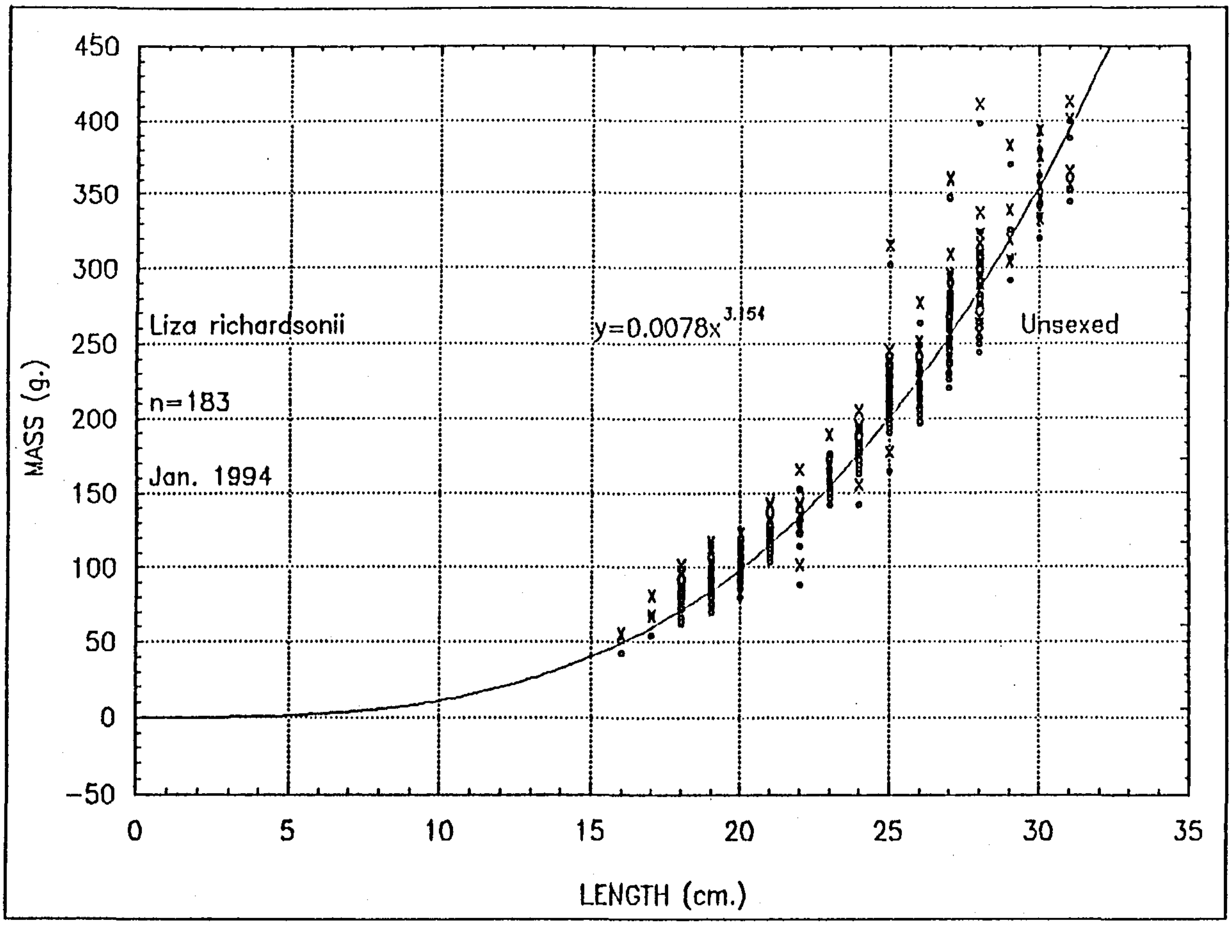


Figure 27. The mass/length relationship of *L. richardsonii* individuals collected at all stations during January 1994.

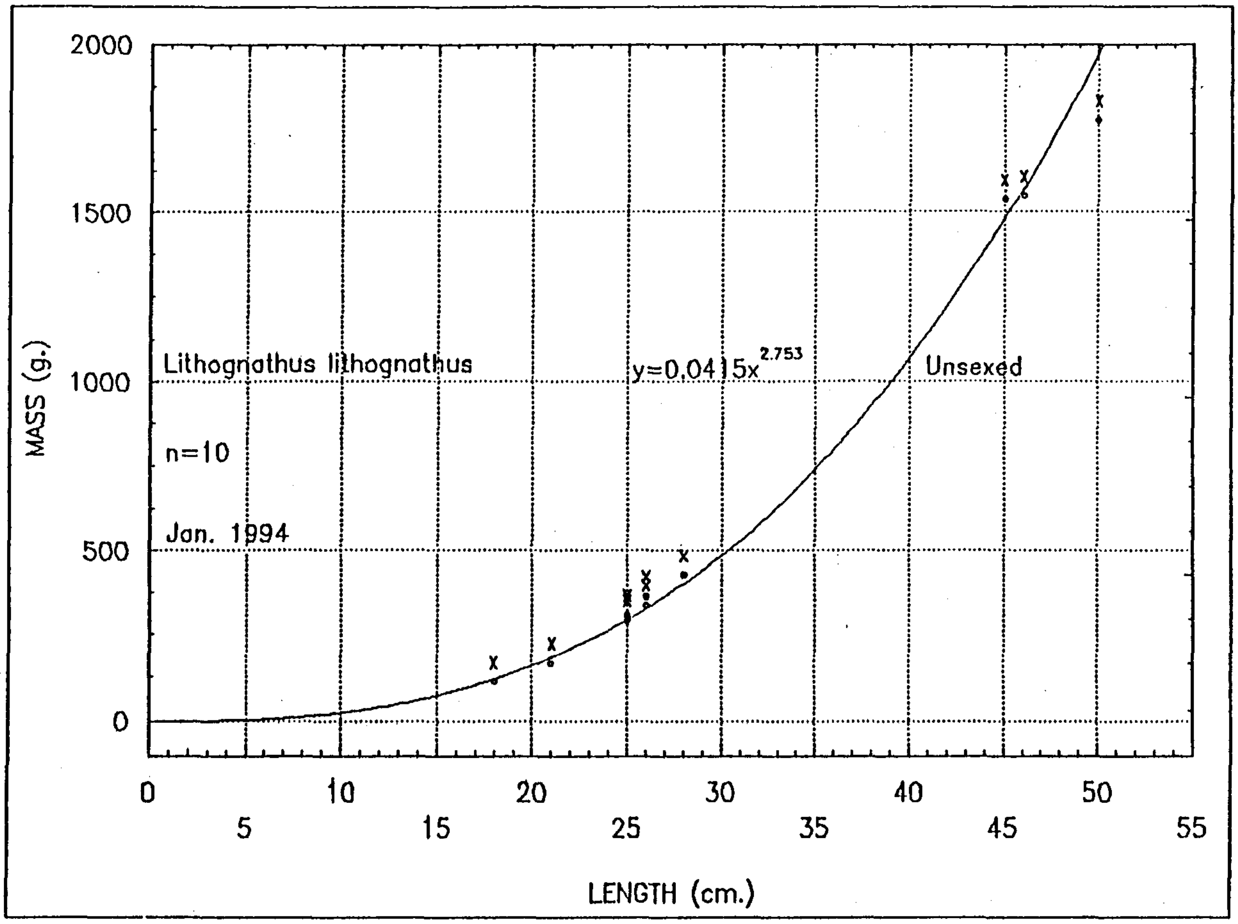


Figure 28. The mass/length relationship of *L. lithognathus* individuals collected at all stations during January 1994.