DISTRIBUTION PATTERNS OF FISHES IN THE HEAD REGION OF A TURBID EASTERN CAPE ESTUARY.

Thesis submitted in fulfilment of the requirements for the degree of
Master of Science

by
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Contents

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Abstract

Two and a half years of data were collected from the Great Fish River and estuary using seine nets and gill nets to determine the fish species composition within these regions. The head region of the Great Fish River estuary was found to have a rich fish fauna, with the euryhaline marine fish component totally dominating the catch in all three regions. *Gilchristella aestuaria* was the single most common species and several euryhaline marine species were captured in freshwater for the first time. Physical parameters were also measured in an effort to ascertain the possible factors which may affect the distribution and length frequency of the most common species within this area. Salinity was found to be the single most important factor affecting the species composition, and the sampling area was consequently divided into three regions, viz. river (<1‰), head (1-4‰) and estuary (>4‰). In addition, it was determined that river flow rate during the month prior to sampling also had a profound effect on species composition in all three regions. Based on the available evidence it is suggested that for most species this is related to conductivity levels rather than flow *per se*.

Introduction

Aims and objectives

1) To determine the ichthyofaunal species composition in the head region of the Great Fish River estuary.
2) To determine the effect of salinity, temperature and turbidity variables on the distribution patterns of the most abundant fish taxa within the sampling area.
3) To determine the length frequency relationships for the most common species.
4) To identify other factors that appear to influence the distribution of fishes within the sampling area.

Background information

South African estuaries have been the subject of much ichthyological research over the past two decades. Studies on the recruitment of fishes into estuaries have shown that the juveniles of different species recruit at different times of the year, the bulk of which enter estuaries during spring and summer (Beckley 1983, Beckley 1984, Harrison & Whitfield 1990). It has been noted that there is a marked decrease in species numbers with increase in latitude (Whitfield 1994a). Certain species are limited to the cooler southern and western Cape waters, while the tropical and sub-tropical species extend southwards to differing degrees, usually according to temperature. It has also been shown that within estuaries a gradation of species occurs regardless of the salinity gradient prevailing in the system (Ter Morshuizen & Whitfield 1994). However, fish densities within estuaries have been related to salinity (Cyrus & Blaber 1992), with major declines in species diversity occurring at salinity levels above 50 ‰ (Whitfield *et al.* 1981). In most systems the greatest species diversity occurs in the lower reaches, whereas the middle reaches usually have the highest fish densities (Plumstead *et al.* 1985, Plumstead *et al.* 1989, Ter Morshuizen & Whitfield 1994). The upper reaches generally show a decrease in both species numbers and densities (Beckley 1984, Plumstead *et al.* 1985, Ter Morshuizen & Whitfield 1994).

Studies on turbidity, predation and the diets of estuarine fishes have revealed that turbidity and food distribution are key factors in determining the distribution and feeding strategies of species in South African estuaries (Blaber & Blaber 1980, Whitfield 1980, Cyrus & Blaber 1987a & b, Cyrus 1992, Hecht & van der Lingen 1992). Pelagic visual predators are more effected by elevated turbidities than demersal macrobenthos feeders, as the former have a reduced reaction time (Hecht & van der Lingen 1992). High turbidity levels would therefore offer protection from visual predators, favouring juvenile fishes (Blaber & Blaber 1980, Cyrus & Blaber 1987a & b) and predators such as *Argyrosomus japonicus* that can detect prey by means of chemo- and mechano-reception (van der Elst 1988, Whitfield *et al.* 1994). Blaber & Blaber (1980) went so far as to suggest that elevated turbidities are the most important factor attracting juvenile fishes into estuarine environments.

Despite the large amount of information available on fishes in South African estuaries (Blaber 1978, Blaber & Blaber 1980, Beckley 1983, Beckley 1984, Whitfield *et al.* 1989, Hecht & van der Lingen 1992, Whitfield *et al.* 1994, Whitfield 1994b), there is a lack of information on fish assemblages at the freshwater/estuarine interface. This is in spite of the warning by Rogers *et al.* (1984) that estuarine researchers need to give attention to the freshwater areas adjacent to estuaries due to their importance in the overall functioning of the estuary and their acute vulnerability to human activities. Bok (1983) recorded 11 fish species (six freshwater, two estuarine and three marine) in the ebb and flow region of the Kowie system and Rayner (1993) found 15 species (four freshwater, two estuarine and nine marine) at a Keiskamma ebb and flow site. Preliminary seine net sampling at the ebb and flow of the Great Fish River by Griffiths (unpubl.) in 1992 revealed the presence of large numbers of juvenile *Argyrosomus japonicus* (16-297 mm SL). This finding is significant since it assisted in separating *A. japonicus* from *A. inodorus*, both of which were incorrectly identified as *A. hololepidotus* (Griffiths & Heemstra 1995), and were previously thought to use inshore marine areas as primary nursery grounds (Wallace *et al.* 1984). This again confirms the present lack of information on the fishes at the head, or ebb and flow, of South African estuaries.

Study area

Arising in the Karoo, the 650 kilometre long Great Fish River is a sixth order system that drains a catchment of more than 30 000 km^2 (O'Keeffe 1989). The river enters the Indian Ocean about half way between Port Elizabeth and East London at 33° 28'S and 27°

10'E. Prior to 1975, the river was known to have had a highly variable flow regime. Periods of zero surface flow frequently occurred, causing the river to form a series of discrete pools, and closure of the mouth was recorded in 1965 and 1966 (Reddering & Esterhuysen 1982). However, in 1975 the erratic flow of this system was stabilised by the provision of water from the Orange River via an 85 km long tunnel. For the period 1978 to 1991 the mean monthly flow rates exceeded 23 x 10^6 m^3 (Department of Water Affairs and Forestry, unpubl. records), but the mean annual discharge into the estuary has changed little, mainly due to the abstraction of water for irrigation (O'Keeffe & de Moor 1988).

The Great Fish River has a low to average conservation status, compared to its original form (O'Keeffe 1989). Watling & Watling (1983) regarded this river as being unpolluted in terms of metal contaminants, and the metals that are present are of natural rather than anthropogenic sources (Gardner *et al.* 1985). Conductivity levels in the river are high, but these are diluted by water from the Orange River (O'Keeffe & de Moor 1988). In addition, the river is extremely turbid due to the catchment including the highly erodible Beaufort soils (Laurenson 1984).

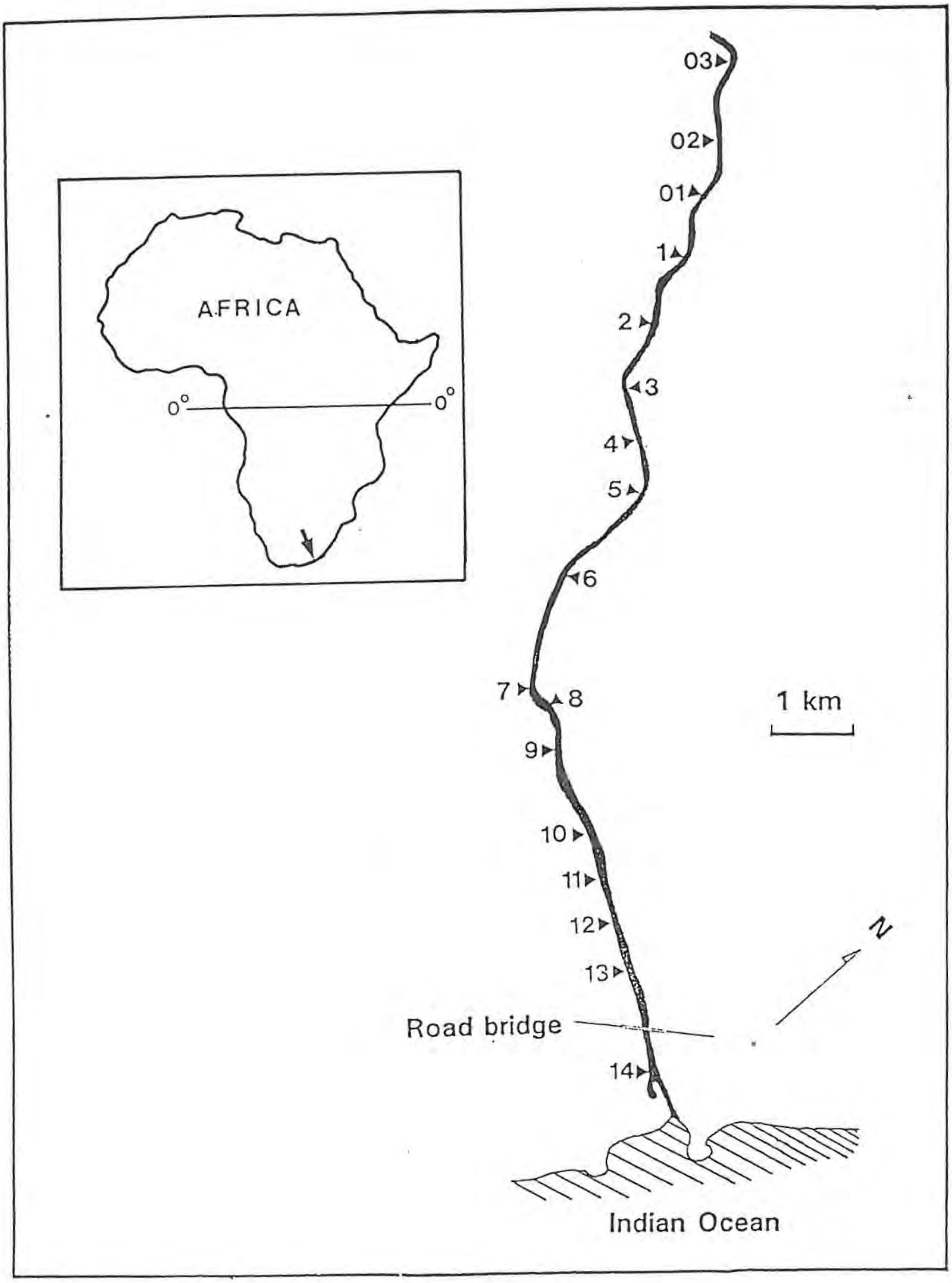
Deposition of sediments is the major geomorphological action in the estuary during non-flood periods, most of the bottom being covered in a thick layer of unconsolidated mud which is prone to erosion when flooding occurs (Reddering & Esterhuysen 1982). Sediment originates mainly from the catchment area, with marine sediments seldom penetrating beyond the first kilometre from the mouth. Sand is deposited in the upper reaches during periods of high flow, whereas low flow results in mud deposition (Reddering & Esterhuysen 1982).

The road bridge that crosses the estuary 1.3 km from the mouth (Fig. 1) is not regarded as having an adverse effect on the tidal circulation (Reddering & Esterhuysen 1982). The estuary is riverine in appearance, with few intertidal mud flats or saltmarshes. The reed *Phragmites australis* lines the banks of the river and upper estuary.

In 1980 the tidal head was about 11 km from the mouth and the furthest extent of saline water ($\geq 1‰$) was only 5 - 7 km from the mouth (Reddering & Esterhuysen 1982). For the period 1992 - 1995 the tidal head was approximately 15 km from the mouth and the furthest extent of saline water ($\geq 1‰$) at spring high tide ranged from 3 - 10 km from the mouth, varying according to river flow rate.

The Great Fish system was selected for this project because it receives a regular freshwater input and is navigable by boat to beyond the head of the estuary. This facilitated comparable sampling in the freshwater reaches above the estuary as well as in the estuary itself, which is not the case in most other Eastern Cape estuaries.

Fig. 1: Map of the Great Fish River system showing the sampling sites and (inset) locator map showing the position of the Great Fish River mouth



Materials & Methods

Bi-monthly sampling on the new-moon low tide occurred from November 1992 until January 1995, providing 14 samples that span three summers and two winters. The sampling regime was divided into three components so that the complete size spectrum of fish in the study area could be determined.

Fish sampling

(a) Small seine net

A seine net of 5 x 1 m and 0.5 mm mesh size was used from September 1994 to January 1995 at sites 03 - 14 (Fig. 1). The small seine net was operated by two people in water less than 75 cm deep, and covered an estimated 25 m^2 per haul.

(b) Large seine net

On all 14 field trips sampling was conducted using a 30 m x 2 m seine net with a 10 mm bar mesh size, fitted with a bag of 5 mm bar mesh size. From November 1992 until July 1994 samples were collected from sites 1 - 8 (Fig. 1). For the last three trips, September 1994 to January 1995, sampling occurred at all 17 sites (Fig. 1). Sites 03 - 8 were sampled on the first day and 9 - 14 on the subsequent day. The net swept an estimated 600 m^2 at each site, and was operated in water no deeper than 1.5 m. This net was used to sample the pelagic, demersal and benthic species in the littoral region over a mud bottom. The large size of the net facilitated the capture of the small and medium size classes of most species.

(c) Gill net

From January 1994 until January 1995 gill nets were laid overnight in the area that had been seined that day, i.e. between sites 03 - 8 on the first night and 9 - 14 on the subsequent night (Fig. 1). The nets were laid by boat at 18H00, checked at midnight and lifted at 06H00. A total of six multifilament nets were used, each 20 x 2 m with a 50 mm bar mesh size. These were set parallel to the shore and in pairs to compensate for possible microhabitat differences.

The selection of the mesh size for the gill nets was based on the work of Marais (1985). Although Marais' results indicated that a larger mesh size was more effective at catching *Argyrosomus japonicus*, it was decided to use 50 mm bar mesh size for the present study as *Elops machnata* was expected to be present in the catch. Since Marais (1985) did not include *E. machnata* in his discussion, it was not possible to determine in advance which mesh would be the best compromise between the narrow bodied *E. machnata* and the deeper bodied *A. japonicus*.

With the exception of the sandy bottom at site 14 (Fig. 1), the three techniques were used exclusively over predominantly muddy substrata. Rocks and submerged macrophytes were absent from all the sites. Consequently, the catches obtained with the two seine nets are conservative, since the unconsolidated mud bottom made sampling very difficult. All samples were preserved on site in 10% formalin. In the laboratory, fish were identified, measured to the nearest mm SL and stored in 60% iso-propyl alcohol.

The grouping of species according to their life-history categories follows the pattern of Whitfield (1994c), a summary of which is presented below (Table 1). Mugilids below 30mm SL were not identified beyond family level. All specimens that could not be identified to species level have been omitted from the life-history category figures as their categories are uncertain.

Table 1: The five major categories of fishes which utilise southern African estuaries (from Whitfield 1994c).

Categories	Description of categories
I	Estuarine species which breed in southern African estuaries. Further subdivided into: Ia. Resident species which have not been recorded spawning in the marine or freshwater environment. Ib. Resident species which also have marine or freshwater breeding populations.
II	Euryhaline marine species which usually breed at sea with the juveniles showing varying degrees of dependence on southern African estuaries. Further subdivided into: IIa. Juveniles dependant on estuaries as nursery areas. IIb. Juveniles occur mainly in estuaries, but are also found at sea. IIc. Juveniles occur in estuaries, but are usually more abundant at sea.
III	Marine species which occur in estuaries in small numbers but are not dependant on these systems.
IV	Euryhaline freshwater species, whose penetration into estuaries is determined primarily by salinity tolerance. Includes some species which may breed in both freshwater and estuarine systems.
V	Catadromous species which use estuaries as transit routes between the marine and freshwater environments. Further sub-divided into: Va. Obligate catadromous species which require a freshwater phase in their development. Vb. Facultative catadromous species which do not require a freshwater phase in their development.

Physico-chemical sampling

A water sample was collected from midwater at each seine net site and adjacent to each gill net fleet whenever the nets were laid, checked or lifted. From November 1992 to July 1993 water samples were also collected from the bottom of the channel adjacent to each seine net sampling site. All water samples were used to obtain temperature, salinity and turbidity readings. Temperature was measured immediately by means of a mercury thermometer, whereas salinity and turbidity were measured in the laboratory using an optical salinometer and turbidimeter respectively. Prior to taking the latter readings the samples were shaken vigorously to resuspend the settled matter.

Stomach content analyses

The stomach contents of all piscivorous fish species (> 150 mm TL) captured during this study were analysed to determine possible predator/prey relationships. The contents of each stomach were identified, counted and weighed, enabling the gravimetric, numerical and frequency of occurrence methods to be applied to the data (Hyslop 1980). All three methods were used to overcome the problems associated with using each method individually. The percentage frequency of occurrence was calculated by taking the number of stomachs in which a particular food item occurred as a percentage of the total number of stomachs containing food. The gravimetric technique tends to emphasise less frequent, but larger, and therefore heavier, items. Although some authors use dry weight it was decided to use wet weight during the present study because it has been shown that for various food items the wet and dry weights correlate highly significantly (Hyslop 1980). Use of the numerical method results in exaggeration of the smaller, more numerous items. In addition, items such as algae cannot be counted in discrete terms. By representing the number of stomachs in which a diet item occurred, regardless of the frequency of that item in each stomach, the frequency of occurrence method gives no indication of the bulk or importance of food items. An Index of Relative Importance (IRI) was applied to the data to provide an overall impression of the relative importance of each food item, as it combines the three methods discussed above. The index is calculated from the formula;

$$IRI = \%F(\%N + \%M)$$

where F, N and M are the percentage contributions of each food item in terms of frequency of occurrence, number and mass respectively (Pinkas *et al.* 1971).

Statistical methods

Temperature, turbidity and salinity were compared between sites, and between sites and the adjacent channel, using a one-way ANOVA (analysis of variance) test. The ANOVA used was the Scheffe method, which is a powerful test, giving considerable certainty to the level of confidence obtained.

Species richness (R) was calculated for the species assemblages in each of the three regions according to the formula

$$R = \frac{s-1}{\log_e N}$$

where s represents the number of species and N the number of specimens captured (Margalef 1958). This method was used as it takes into account the number of species as well as the total number of individuals in each region, and has been used in other southern African estuarine studies (Whitfield *et al.* 1989, Ter Morshuizen & Whitfield 1994), thus facilitating comparisons.

Results & Discussion

Physical parameters

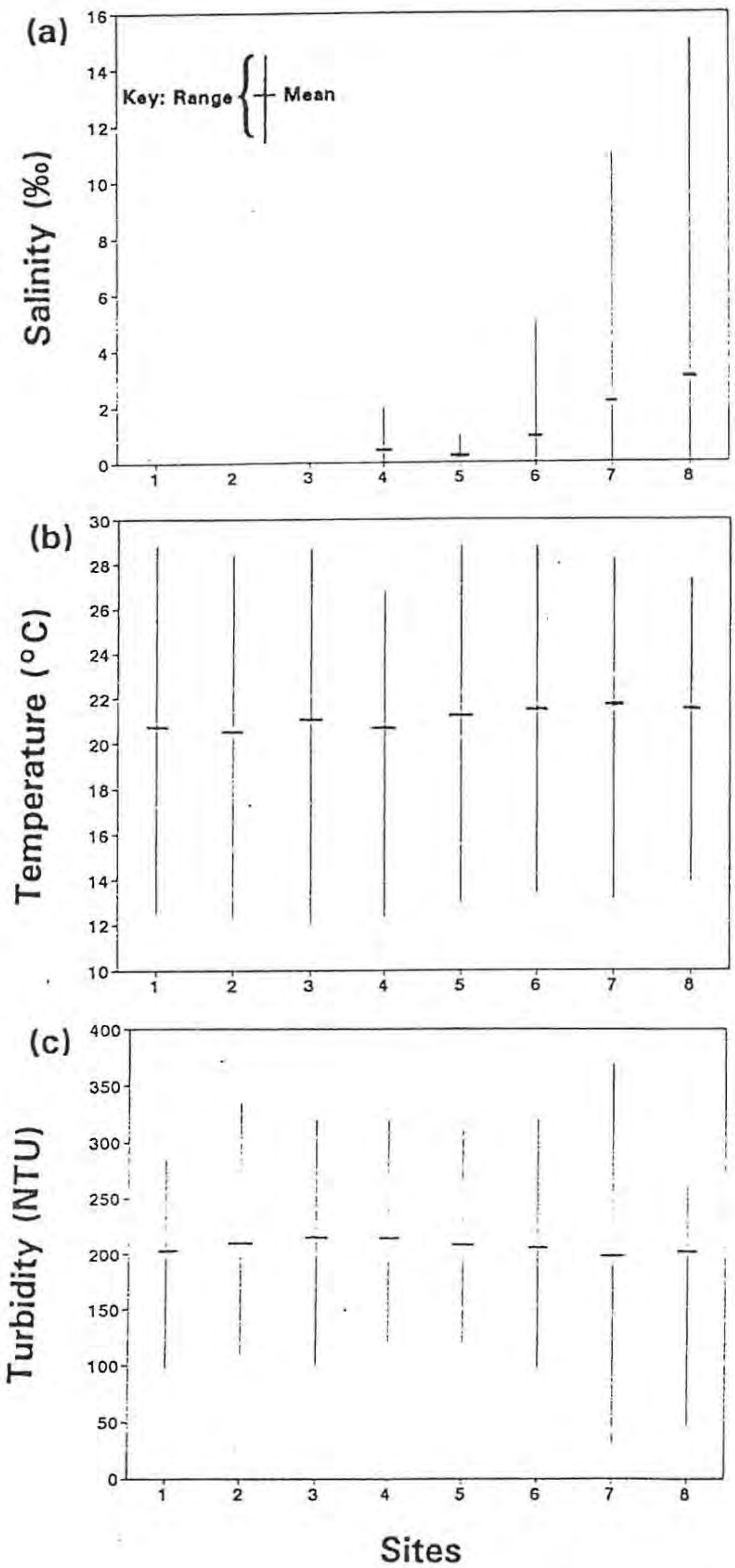
Estuarine researchers have regarded levels of > 10 NTU as turbid (Blaber & Blaber 1980, Cyrus & Blaber 1992). Therefore the turbidities recorded in the Great Fish system, with means in the vicinity of 200 NTU (Fig. 2), can only be described as extreme. A single turbidity of > 1000 NTU was recorded at site 8 in March 1994, and has been omitted from Fig. 2 as it is felt that sediment was collected along with the water sample. Temperature varied between 12 °C in winter and 29 °C in summer (Fig. 2). The ANOVA indicated a lack of significant difference between sites and between sites and the adjacent channel for either turbidity or temperature. Salinity, however, showed a highly significant difference between sites ($p < 0.01$). In addition, salinity showed a significant difference between sites and the adjacent channel ($p < 0.05$), but due to high varience within the samples this issue was not investigated further. Salinity was therefore used as the factor for differentiating between the regions. Measurements of < 1 ‰ were regarded as riverine, from 1 - 4 ‰ as the head of the estuary and > 4 ‰ as estuarine.

Salinity, rather than physical locality, was used to facilitate comparisons between periods of differing river flow. Under river flood conditions the estuary was reduced in size as the increased volume of freshwater discharged was more substantial than the incoming tidal push, conversely, it expanded upstream during low flow periods. Sites 03 to 3 were always riverine, sites 11 to 14 always estuarine and sites 4 to 10 varied according to the flow rate at the time of sampling.

No relationship was evident between either salinity and temperature or turbidity and temperature. A slight negative correlation exists between salinity and turbidity, but this was not statistically significant.

Gill nets were laid and lifted on the high tide with the midnight sample being collected on the low tide. Estuarine and riverine samples showed a decrease in salinity, as is to be expected, over the low tide relative to the high tide. Temperature at all sites dropped by an average 2 °C overnight from 18H00 to 06H00. Turbidity showed no clear trend over the tidal cycle.

Fig. 2: Mean and ranges of sampling site salinities (2a), temperatures (2b) and turbidities (2c) recorded at sites 1 to 8 on the Great Fish system from November 1992 to January 1995



Small seine net fish assemblage

A total of 5510 fishes were captured during this phase of the study, representing at least 23 species (Table 2). Due to their small size, several of the specimens captured were not identified to species level. Riverine samples can be seen to be dominated by the family Mugilidae, the head region by both mugilids and *R. holubi*, and the estuarine samples by *R. holubi* (Table 2). Due to the limited number of samples collected with this gear, i.e. three samples over two seasons, the results should be viewed with caution.

Species analyses

Although the temperatures at which most individuals of the dominant species were captured are mentioned during the discussion of the species, these must be regarded with circumspection. The reason for this is that reproduction within, and recruitment into, Eastern Cape estuaries is known to be seasonal (Whitfield 1983, Whitfield 1989b), and apparent trends of increasing abundance in the summer months may be a reflection of recruitment rather than of thermal preference.

The analyses for individual species most commonly captured using the small seine gear showed some interesting trends.

R. holubi was most abundant at higher salinities (Table 2) and medium turbidities (Fig. 3). The length frequency graphs for *R. holubi* show little, if any, variation between the three zones sampled, the modal size class being 10-14 mm SL in all three regions (Fig. 4).

Mugilidae less than 30 mm SL were abundant throughout the sampling region of the Great Fish system (Table 2).

P. commersonnii showed a trend of increasing numbers from the river to the estuary (Table 2), and with increasing turbidity (Fig. 5). Although 24 - 25 °C is regarded as an optimum for this species in culture situations (Deacon & Hecht 1995) the vast majority were captured between 19 °C and 21 °C. No specimens of *P. commersonnii* smaller than 30 mm SL were captured at any of the riverine sites sampled. In addition, the specimens captured in the river were generally larger than those captured in either the head region or the estuary, and a decline in average size occurred from the river to the estuary.

Table 2: The mean number of fish per haul and ranking of fishes captured in each of the three regions of the Great Fish River system using a small seine net.

Species	Life-history category	River <1 ‰	River ranks	Head 1-4 ‰	Head ranks	Estuary >4 ‰	Estuary ranks
Anguillidae	Va	0.03	23	0.00		0.09	15
Clupeidae							
Gilchristella aestuaria	Ia	0.31	13	0.00		3.55	4
Elopidae							
Elops machnata	IIa	0.69	11	0.00		0.00	
Cyprinidae							
Cyprinus carpio	IV	0.09	19	0.00		0.00	
Labeo umbratus	IV	1.09	7	1.00	6	0.09	15
Poecilidae							
Gambusia affinis	IV	0.28	16	0.00		0.00	

Haemulidae							
Pomadasys commersonnii	IIa	0.78	9	2.00	3	3.45	5
Sparidae							
Acanthopagrus berda	IIa	0.09	19	0.00		0.00	
Lithognathus lithognathus	IIa	0.03	23	0.17	10	4.91	3
Rhabdosargus holubi	IIa	7.28	2	19.5	2	226.45	1
Sciaenidae							
Argyrosomus japonicus	IIb	0.19	17	0.17	10	0.09	15
Monodactylidae							
Monodactylus falciformis	IIa	3.72	3	0.00		0.18	12
Cichlidae							
Oreochromis mossambicus	IV	0.88	8	0.00		0.00	
Mugilidae		39.94	1	21.17	1	38.91	2
Liza dumerilii	IIb	0.06	22	0.17	10	0.18	12
Liza richardsonii	IIc	0.00		1.33	5	2.45	6

Mugil cephalus	Vb	0.31	13	2.00	3	1.18	7
Myxus capensis	Vb	0.72	10	0.00		0.64	10
Gobiidae		2.54	5	0.67	7	0.00	
Caffrogobius nudiceps	Ib	0.00		0.17	10	0.82	8
Glossogobius callidus	Ib	0.69	11	0.00		0.09	15
Psammogobius knysnaensis	Ia?	0.31	13	0.33	9	0.82	8
Redigobius dewaali	IV	2.81	4	0.00		0.00	
Soleidae							
Heteromycteris capensis	IIb	1.72	6	0.00		0.18	12
Solea bleekeri	IIb	0.19	17	0.00		0.00	
Unidentified		0.09	19	0.67	7	0.36	11
Number of sites		32		6		11	
Mean number of fish per haul		64.75		49.35		284.44	

Although *L. lithognathus* was the fourth most common species captured with the small seine net, the species was only common in the estuary (Table 2).

M. falciformis was vastly more abundant in the riverine samples than those of either the head or estuary (Table 2). Studies on Eastern Cape estuaries found this species to be more abundant in the upper reaches of estuaries than either the middle or lower reaches (Beckley 1984, Hanekom & Baird 1984). In addition, this species is known to associate with cover (Beckley 1984, Hanekom & Baird 1984) and the riverine areas of the Great Fish system often had grass growing into the water along the banks near to where sampling occurred. The abundance of small juveniles of this species suggests that they move into this area very rapidly after entering the estuary. Most of the specimens were captured at turbidities of above 200 NTU (Fig. 6).

Although *G. aestuaria* was the fourth most common species to be captured with the small seine net in the estuary, none were captured in the head region and few in the river (Table 2).

L. richardsonii was absent from the riverine samples, but among the most common species captured in the head region and estuary (Table 2).

The head region and lower turbidities were favoured by *M. cephalus* (Table 2, Fig. 7). This species also showed the widest range of sizes, but the modal size class remained in the vicinity of 50 mm SL in all three regions. Juveniles (<30mm FL) of this species are known to recruit into Eastern Cape estuaries during the winter months (Bok 1984). As the small seine net was only used during spring and summer, this species would not be expected in the catches.

L. umbratus showed a clear preference for the river and head regions (Table 2), and was absent from the highest turbidities (Fig. 8). The modal size class for this species was constant in all three regions at 10-19 mm SL.

Fig. 3: The distribution of *Rhabdosargus holubi*, captured with a small seine net in the Great Fish system, in relation to turbidity.

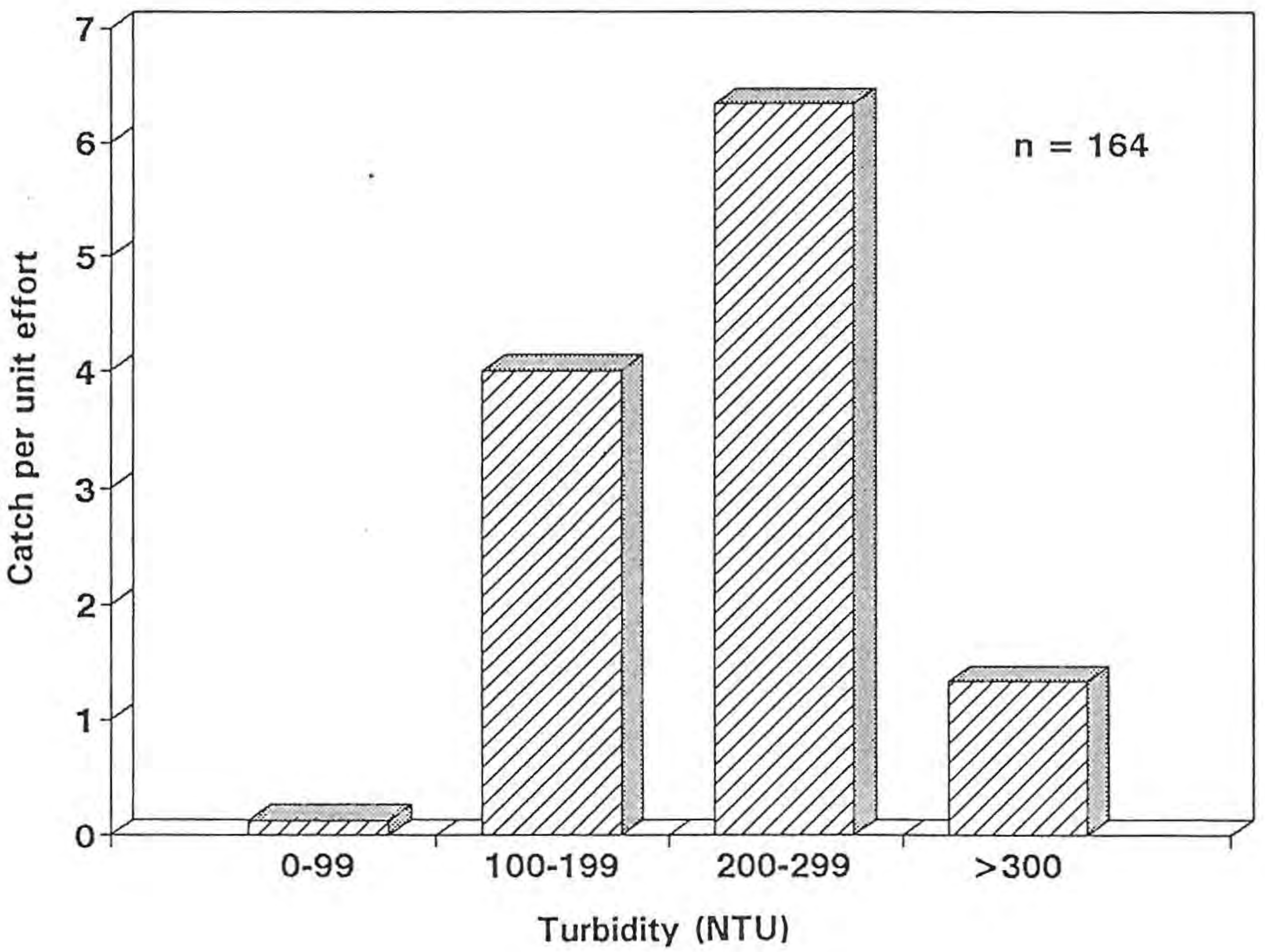


Fig. 4: The length frequency distribution of *Rhabdosargus holubi* captured with a small seine net in the Great Fish (4a), head region (4b) and estuary (4c).

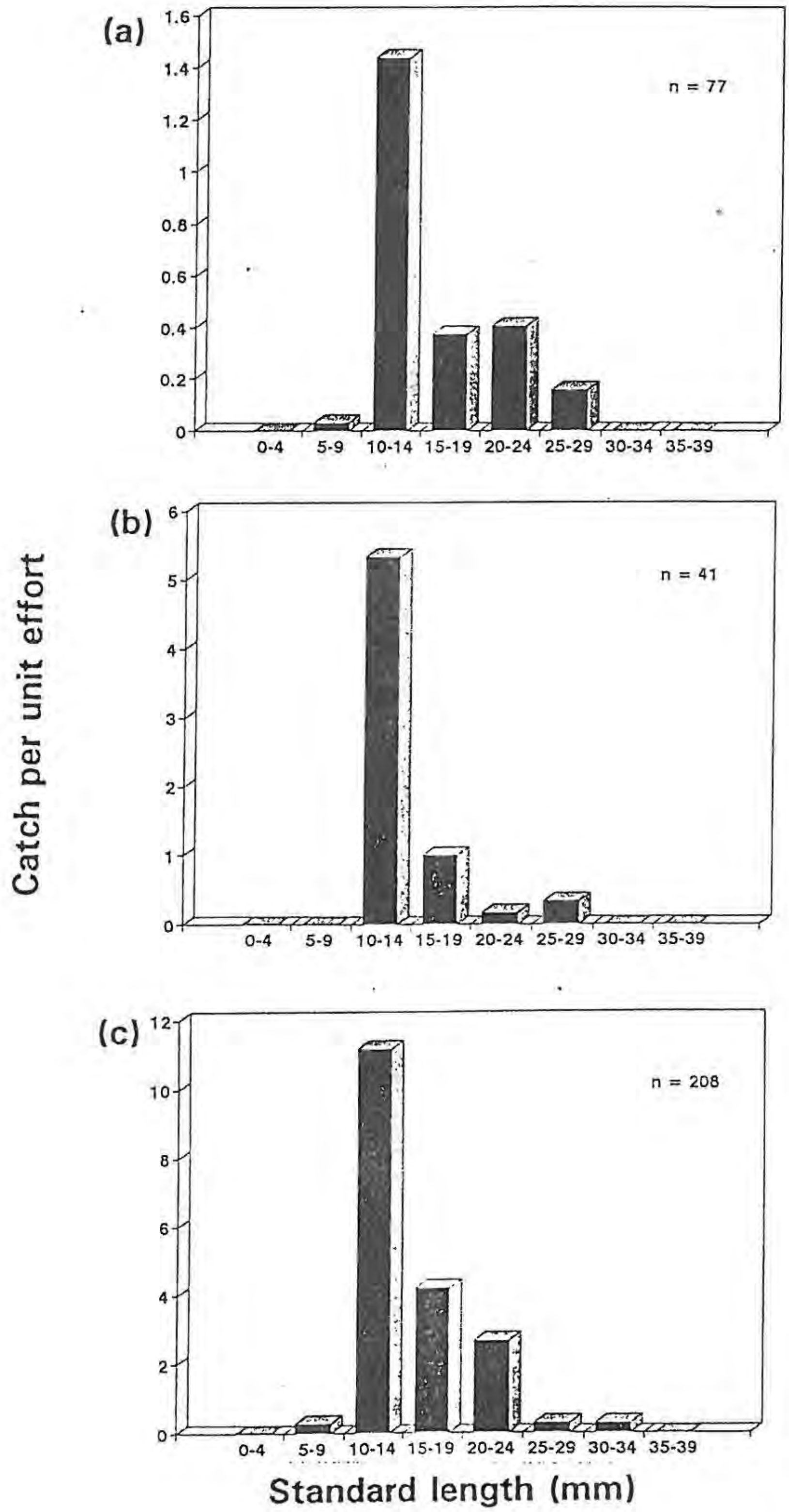


Fig. 5: The distribution of *Pomadasys commersonnii*, captured with a small seine net in the Great Fish system, in relation to turbidity.

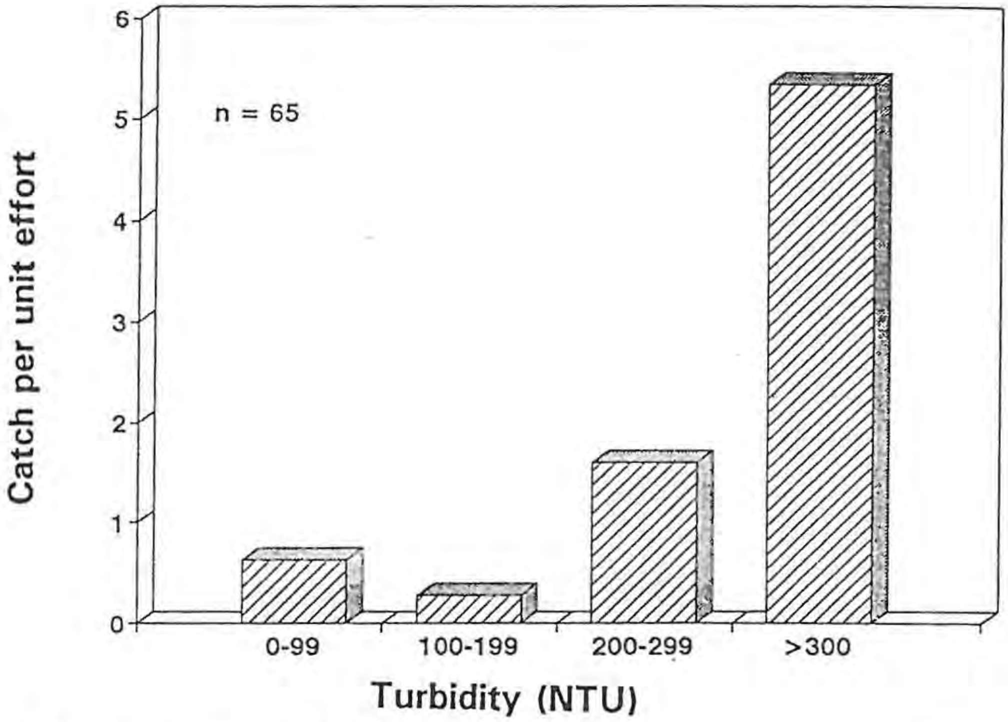


Fig. 6: The distribution of *Monodactylus falciformis*, captured with a small seine net in the Great Fish system, in relation to turbidity.

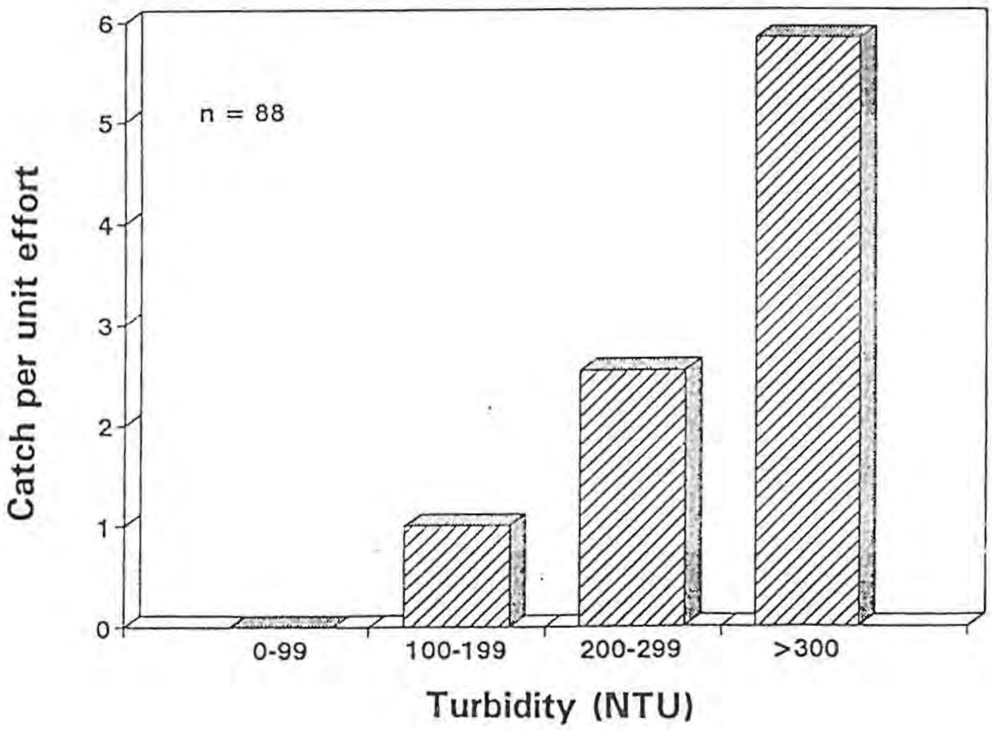


Fig. 7: The distribution of *Mugil cephalus*, captured with a small seine net in the Great Fish system, in relation to turbidity.

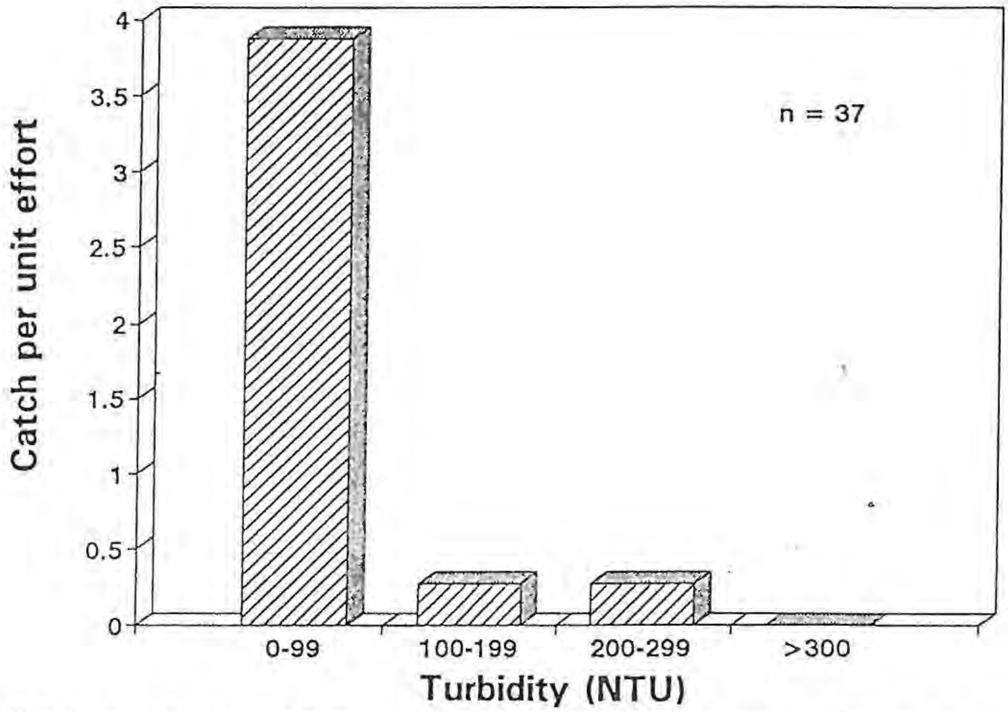
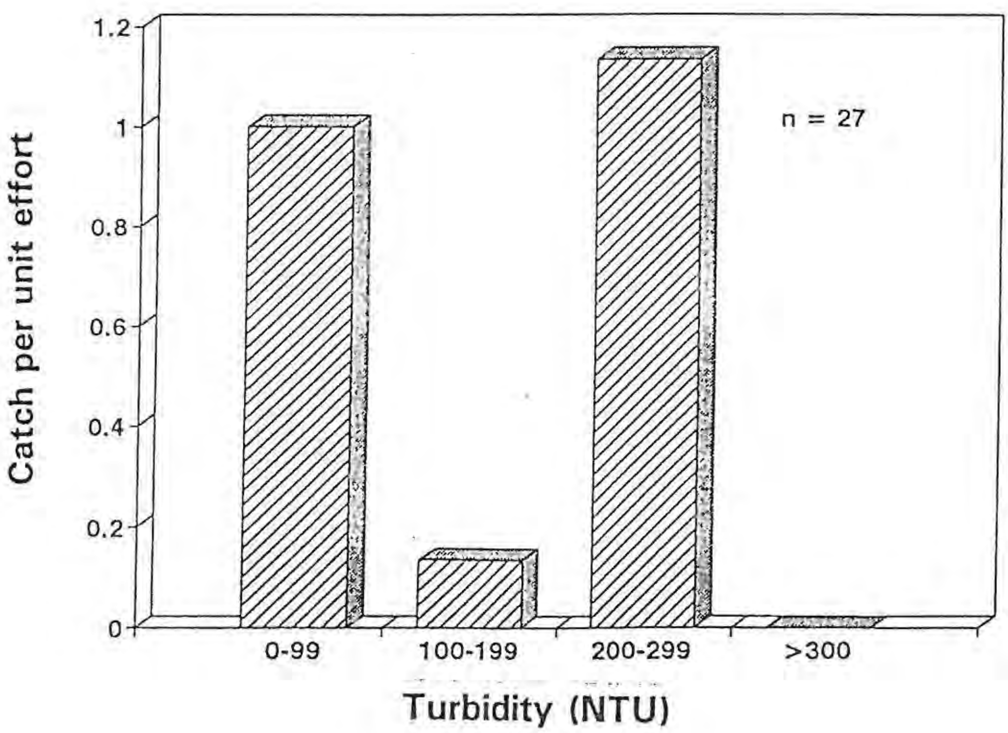


Fig. 8: The distribution of *Labeo umbratus*, captured with a small seine net in the Great Fish system, in relation to turbidity.

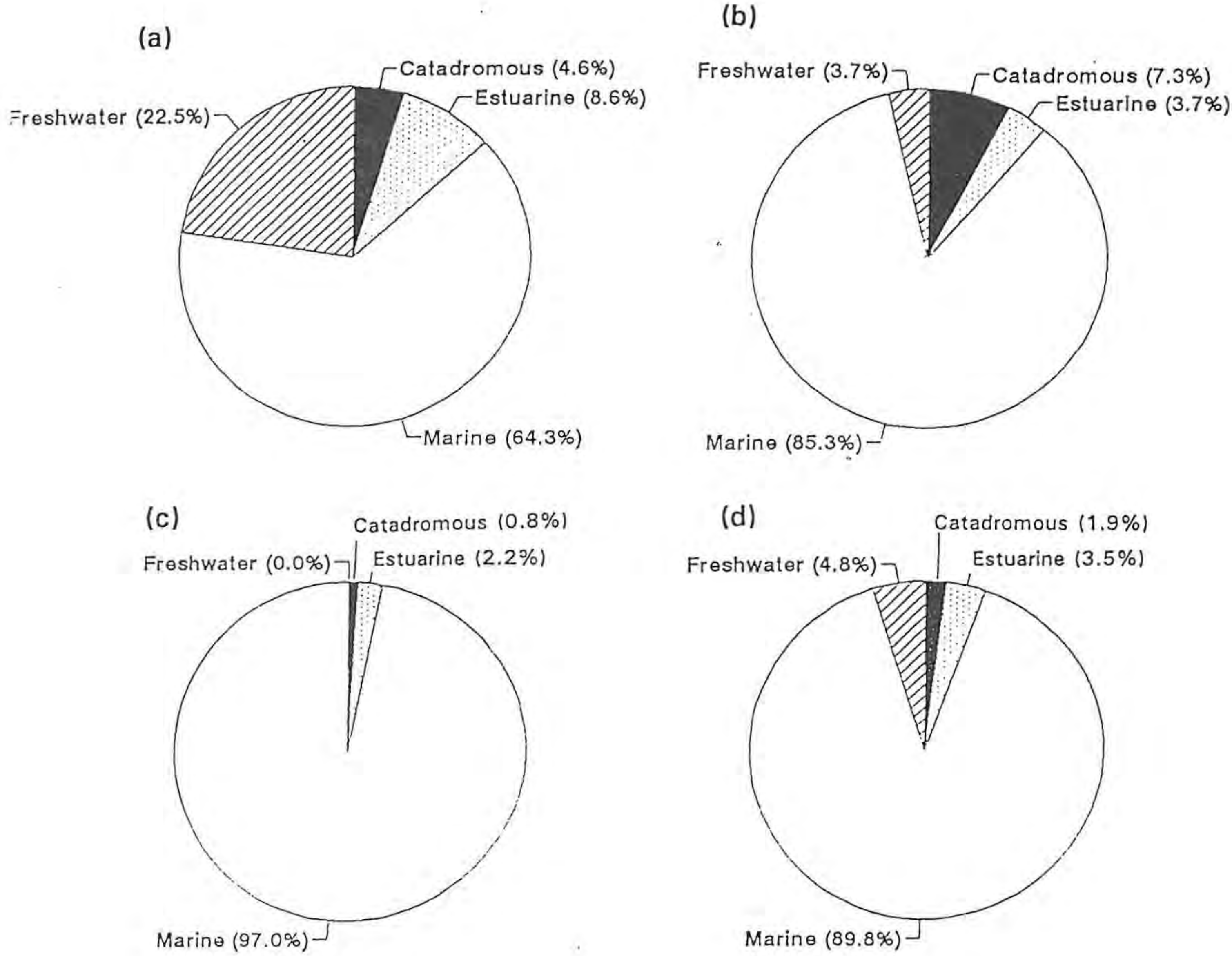


Life-history analysis

River: The euryhaline marine species comprised two thirds of the small seine net catches in the river (Fig. 9a). The most abundant species in this category captured in the riverine samples were *Rhabdosargus holubi, Monodactylus falciformis* and *Heteromycteris capensis*, with *R. holubi* being the most abundant (Table 2). The freshwater species were the second most numerous in the small seine net riverine catches (Fig. 9a), with *Redigobius dewaali* and *Labeo umbratus* being the two most common species (Table 2). The estuarine category comprised less than 10 % of the fishes from the riverine samples (Fig. 9a). Only three of estuarine species, namely *Glossogobius callidus, Psammogobius knysnaensis* and *Gilchristella aestuaria*, were present in the riverine samples (Table 2). Although only two catadromous species were commonly captured during this study, namely *Mugil cephalus* and *Myxus capensis*, they contributed 5 % to the total small seine catch from the river (Fig. 9a).

Head region: The euryhaline marine species again dominated the catch with the small seine net at the head region (Fig. 9b), *R. holubi* again being the single most abundant euryhaline marine species (Table 2). *Pomadasys commersonnii* and *Liza richardsonii* were also abundant at the head region. As in the riverine samples, the catadromous species again represented less than 10 % of the overall total for the head region, where they were the second most abundant category (Fig. 9b). This catch was made up entirely of *M. cephalus*, no *M. capensis* being captured at the head region with the small seine net (Table 2). *Caffrogobius nudiceps* and *P. knysnaensis* were the only estuarine species, and *Labeo umbratus* the only freshwater species, to be captured at the head region of the Great Fish River estuary with the small seine net (Table 2).

Fig. 9: The proportion contributed by each life history category (Whitfield 1994a) to the small seine net catch in the Great Fish River (9a), head region (9b), estuary (9c) and total area sampled (9d)



Estuary: The vast majority of the fish captured in the estuary were *R. holubi*, accounting for the dominance of the euryhaline marine species in the small seine net catch from this region (Fig. 9c). The next most abundant species was *Lithognathus lithognathus*, which was present, but uncommon, in the catches from the head and river (Table 2). Other euryhaline species common in this area were *P. commersonnii* and *L. richardsonii* (Table 2).

Total: When the overall trends are analysed in can be seen that the euryhaline marine species dominated the small seine net catches in all three sampled regions of the Great Fish system (Fig. 9d). The mugilidae <30 mm SL were the most abundant taxa in both the riverine and head regions of the system, but could not be included in the classification due to the family having representatives from at least two of the life-history categories. The single most abundant species is therefore *R. holubi*, which was common in all three regions (Table 2). *P. commersonnii* was the only other species to be reasonably common throughout the sampled area (Table 2). Several of the species were common in one or two of the regions, but totally absent from the others. The freshwater species, with the exception of *L. umbratus*, were only captured in the riverine small seine samples.

On comparing the distribution of these species to their life-history sub-categories a general trend can be observed of decreasing use of the riverine habitat with a decreasing dependence on estuaries. Species such as *Acanthopagrus berda, Elops machnata, L. lithognathus, P. commersonnii* and *M. falciformis* (category IIa) all utilise the riverine region freely, often more so than the head or estuary. Whereas on the other end of the spectrum, *L. richardsonii* (category IIc) was one of the most commonly caught species in the estuary and head regions, but was absent from the riverine small seine samples (Table 2).

Interestingly, the gobiids that were too small to identify accurately were abundant in the riverine and head region samples, but absent from the estuary (Table 2). It is believed that the recorded Goby species all spawn within the estuary (Whitfield 1994c), as well as freshwater in the case of *G. callidus*. Although the larvae of the estuarine species of the genera *Caffrogobius* and *Psammogobius* are known to utilise the nearshore marine surf zone adjacent to estuary mouths for a period of time (Whitfield 1989a), they return to the estuary as post larvae, and the possibility of their presence amoung post-larval juveniles in the riverine regions cannot be excluded.

Large seine net fish assemblage

A total of 36 172 fishes, representing 41 species and 24 families, were captured during this facet of the study (Table 3). The family Mugilidae dominated the catch throughout the sampling area comprising 44 % of the catch. Whitfield *et al.* (1994) found the Great Fish system to have higher densities of Mugilidae than the adjacent Kowie system and suggested that this may be due to the large riverine input of organic matter. Species richness was moderately high in all three sampled regions compared to other Eastern Cape estuaries (Whitfield *et al.* 1989, Ter Morshuizen & Whitfield 1994), and decreased from the river to the estuary. This differs from the usual trend of decreasing species richness from the lower to the upper reaches of estuaries (Plumstead *et al.* 1989, Ter Morshuizen & Whitfield 1994). This may indicate that the Great Fish system differs significantly from other systems in the eastern Cape, or that lack of sampling in other systems has failed to reveal the high species richness associated with the head regions and the rivers above those estuaries.

Table 3: The mean number of fish per haul and ranking of fishes captured in each of the three regions of the Great Fish River system using the large seine net.

Species	Life-history category	River <1 ‰	River ranks	Head 1-4 ‰	Head ranks	Estuary >4 ‰	Estuary ranks
Clupeidae							
Gilchristella aestuaria	Ia	42.26	3	79.52	2	96.96	1
Elopidae							
Elops machnata	IIa	2.21	10	5.70	11	0.13	24
Cyprinidae							
Cyprinus carpio	IV	1.24	13	2.70	14	0.04	29
Labeo umbratus	IV	0.91	18	0.52	21	1.04	14
Clariidae							
Clarias gariepinus	IV	0.23	23	0.00		0.00	
Ariidae							
Galeichthys feliceps	IIb	0.47	21	2.43	16	0.09	25
Hemiramphidae							
Hyporhamphus capensis	Ia	0.01	35	0.00		0.00	
Atherinidae							

Atherina breviceps	Ib	0.00		0.30	24	0.00	
Platycephalidae							
Platycephalus indicus	IIc	0.01	35	0.17	27	0.09	25
Ambassidae							
Ambassis gymnocephalus	Ib?	1.24	13	6.26	9	26.35	5
Teraponidae							
Terapon jarbua	IIa	0.06	26	0.22	25	0.00	
Carangidae							
Caranx sexfasciatus	IIb	0.06	26	0.83	19	0.09	25
Lichia amia	IIa	0.03	28	0.09	30	0.22	20
Leiognathidae							
Leiognathus equula	IIc	0.00		0.04	31	0.00	
Gerreidae							
Gerres acinaces	IIb	0.02	31	0.00		0.00	
Gerres sp.		0.01	35	0.00		0.00	
Haemulidae							
Pomadasys commersonnii	IIa	11.25	4	65.00	4	10.52	8
Pomadasys olivaceum	III	0.00		0.04	31	0.00	
Sparidae							
Acanthopagrus berda	IIa	1.42	12	1.17	18	0.30	18

Lithognathus lithognathus	IIa	0.60	20	3.87	13	6.65	9
Rhabdosargus holubi	IIa	5.25	7	104.87	1	77.13	2
Sciaenidae							
Argyrosomus japonicus	IIb	5.15	8	8.61	7	1.39	13
Johnius dussumieri	IIc	0.02	31	0.00		0.00	
Monodactylidae							
Monodactylus falciformis	IIa	1.20	16	0.35	23	0. 26	19
Cichlidae							
Oreochromis mossambicus	IV	5.56	6	0.39	22	0.04	29
Mugilidae		48.21	1	62.04	5	16.57	6
Crenimugil crenilabis	IIc	0.03	28	0.13	28	0.13	21
Liza dumerilii	IIb	42.78	2	70.35	3	56.30	3
Liza richardsonii	IIc	1.22	15	2.74	15	31.17	4
Liza tricuspidens	IIb	0.07	24	0.00		0.13	21
Mugil cephalus	Vb	7.22	5	12.61	6	10.57	7
Myxus capensis	Vb	4.17	9	0.30	24	4.83	10
Polynemidae							
Polydactylus plebius	III?	0.00		0.13	28	0.00	
Gobiidae							
Caffrogobius multifasciatus	Ib	0.07	24	0.22	25	0.70	16

Caffrogobius nudiceps	Ib	0.02	31	1.65	17	0.91	15
Eleotris fusca	Ia?	0.02	31	0.00		0.00	
Glossogobius callidus	Ib	1.15	17	0.78	20	0.04	29
Oligolepis keiensis	Ia?	0.00		0.00		0.09	25
Psammogobius knysnaensis	Ia?	0.72	19	6.70	8	2.09	12
Redigobius dewaali	IV	0.03	28	0.00		0.00	
Soleidae							
Heteromycteris capensis	IIb	0.26	22	6.22	10	2.61	11
Solea bleekeri	IIb	1.94	11	4.43	12	0.65	17
Tetraodontidae							
Amblyrhynchotes honckenii	III	0.00		0.00		0.09	25
Unidentified		0.00		0.00		0.04	29
Number of sites		95		23		23	
Species richness (R)		3.47		3.35		3.23	

Table 4: The mean and range of temperatures (°C) at which the more common species were captured using the large seine net in the Great Fish system.

Species	Mean	Minimum	Maximum
Ambassis gymnocephalus	21.9	14.0	27.3
Argyrosomus japonicus	21.8	13.9	27.3
Elops machnata	25.1	13.3	27.3
Gilchristella aestuaria	22.8	12.8	28.7
Heteromycteris capensis	17.8	13.9	24.0
Lithognathus lithognathus	21.8	15.0	26.9
Liza dumerilii	23.5	12.8	27.3
Liza richardsonii	20.0	12.8	26.8
Mugil cephalus	23.3	12.0	28.8
Mugilidae	20.7	12.0	28.8
Myxus capensis	22.5	12.0	28.8
Oreochromis mossambicus	22.2	12.0	28.8
Pomadasys commersonnii	22.2	13.1	28.8
Psammogobius knysnaensis	17.6	12.3	26.7
Rhabdosargus holubi	21.7	12.8	27.3
Solea bleekeri	20.4	13.1	28.8
Sampling temperatures	22.2	12.0	28.8

Species analyses

The estuarine *Gilchristella aestuaria* comprised 22.3 % of the total catch making it the most abundant species, consistent with similar studies in other South African estuaries (Beckley 1984, Whitfield *et al.* 1989). This species was most abundant at lower turbidities (Fig. 10), and the mean temperature at which they were caught was 22.2 °C (Table 4). Coinciding with the small seine net (Table 2), the largest numbers of *G. aestuaria* captured with the large seine net were caught in the estuary (Table 3). As copepods were shown to be the main prey item of *G. aestuaria* in the Swartkops system (Talbot & Baird 1985) and Grange *et al.* (1995) found the highest abundance of copepods to occur at salinities of around 8 ‰ in the Great Fish estuary, it was to be expected that the largest densities this species would be in the same region. Talbot (1982) determined that this species suffers 99% mortality by the age of two years in the Swartkops estuary due to bird and fish predation. Thus it is not surprising that the modal class for all three regions was only 40-49 mm SL (Fig. 11). Even so, some specimens were captured in the riverine region of up to 93 mm SL (RUSI 47100), which is greater than the largest size given by Whitehead & Wongratana (1986). In addition to this, specimens from this system are deep bodied (depth in SL = 3.94) similar to those from lake St Lucia (depth in SL = 3.92) (Blaber *et al.* 1981). Blaber *et al.* suggest that abundant food facilitates generous body proportions, and this may, in addition to the protection offered by the turbidity, explain the large size attained by individuals in this system. Grange & Allanson (1995) classified the Great Fish River estuary as being mesotrophic/eutrophic, again confirming the abundance of zooplanktonic food items.

Juvenile *Rhabdosargus holubi* showed no clear preference with respect to turbidity within the sampling area (Fig. 12), which is not consistent with the field and laboratory findings of Cyrus & Blaber (1987a, 1987b) and the findings of Cyrus (1992) in Lake St Lucia. The species was most abundant at temperatures of between 16 °C and 28 °C, with the mean at 21.7 °C (Table 4). This was one of the species found to be clearly more abundant in the estuary (Table 3). Even so, many specimens were recorded in freshwater which is contrary to the conclusion of Blaber (1973), who found freshwater to be lethal at all temperatures between 5 - 35 °C. The latter finding was based on fish transferred directly from sea water (35 ‰) to the experimental salinity, and the abruptness of such a move,

Fig. 10: The distribution of *Gilchristella aestuaria*, captured with a large seine net in the Great Fish system, in relation to turbidity.

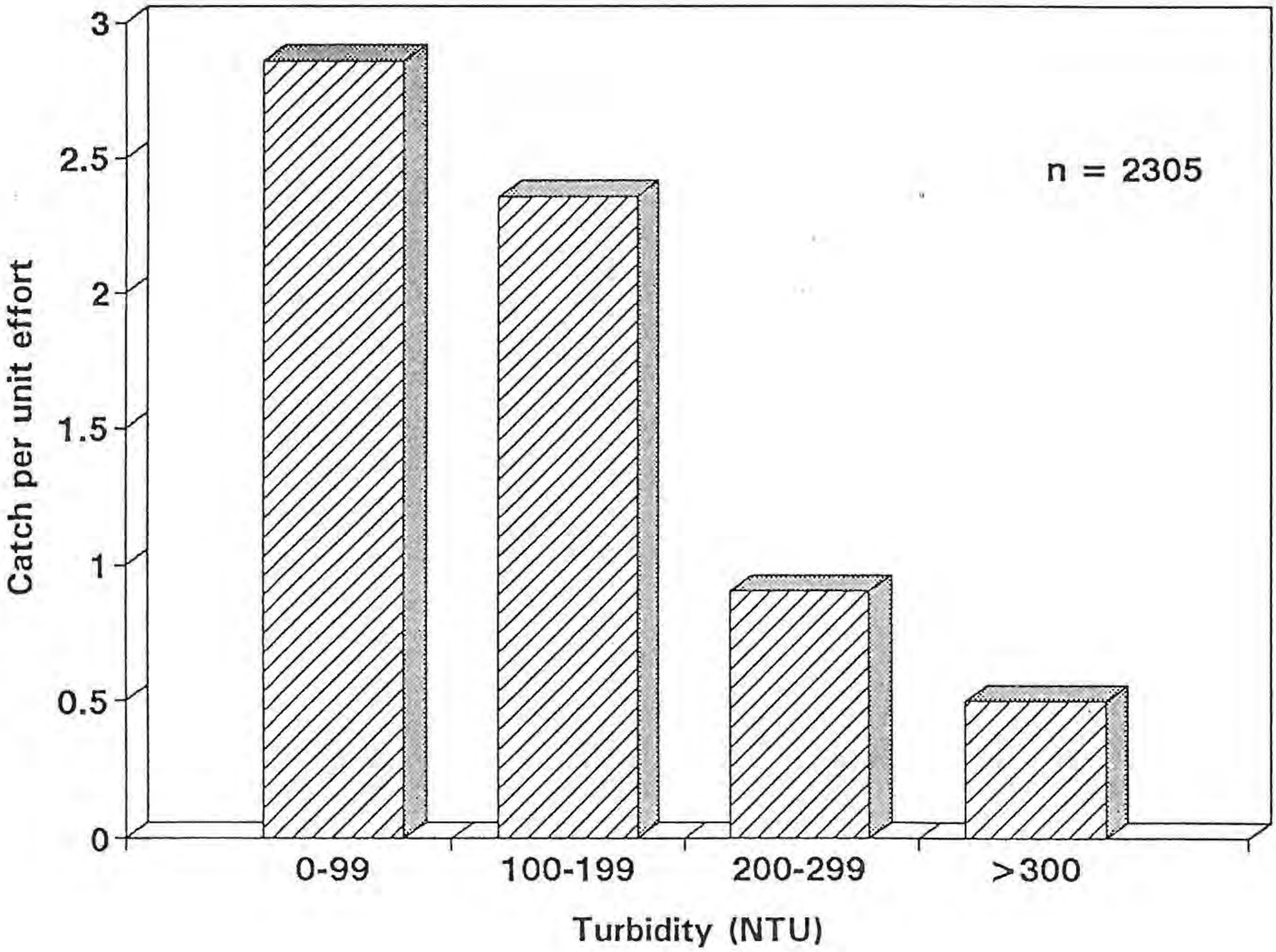


Fig. 11: The length frequency distribution of *Gilchristella aestuaria* captured with a large seine net in the Great Fish River (11a), head region (11b) and estuary (11c).

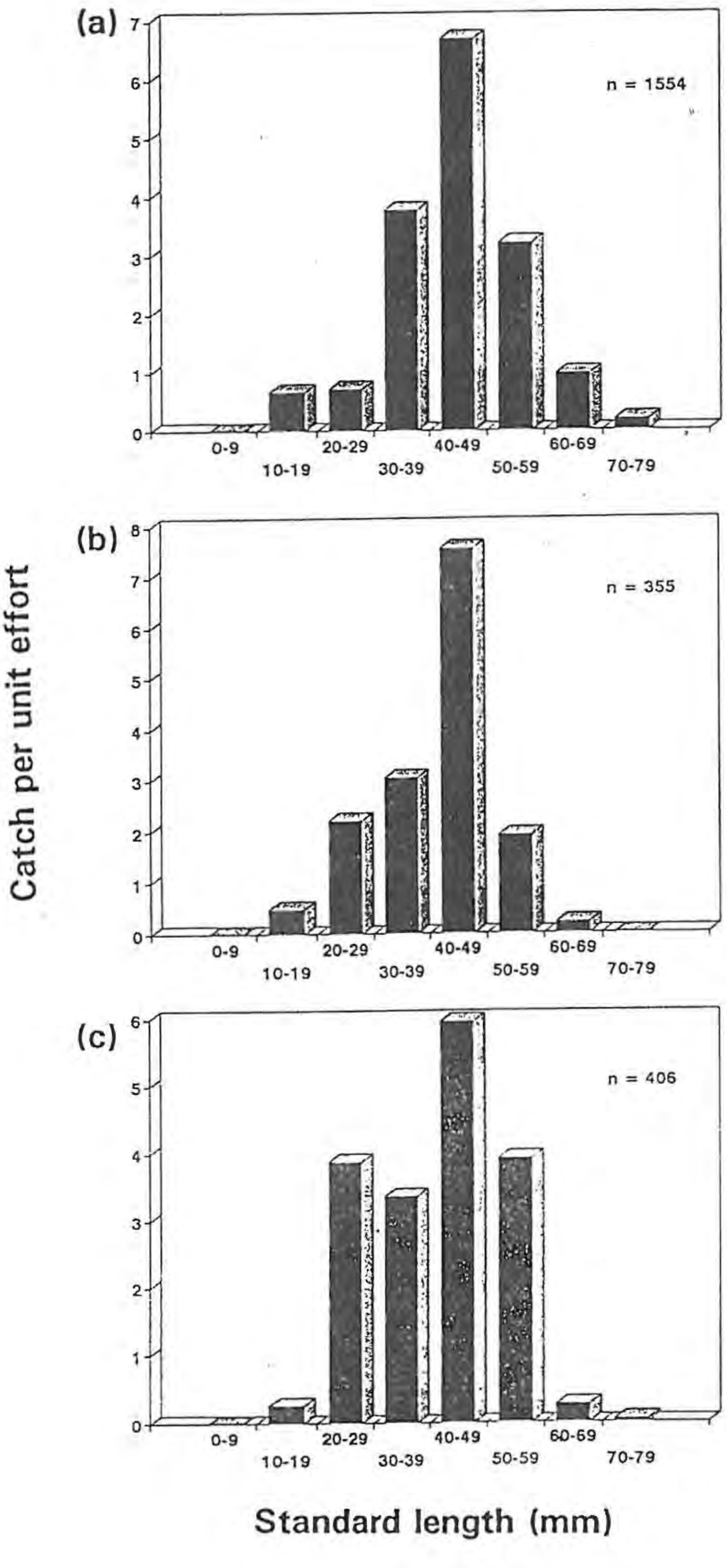
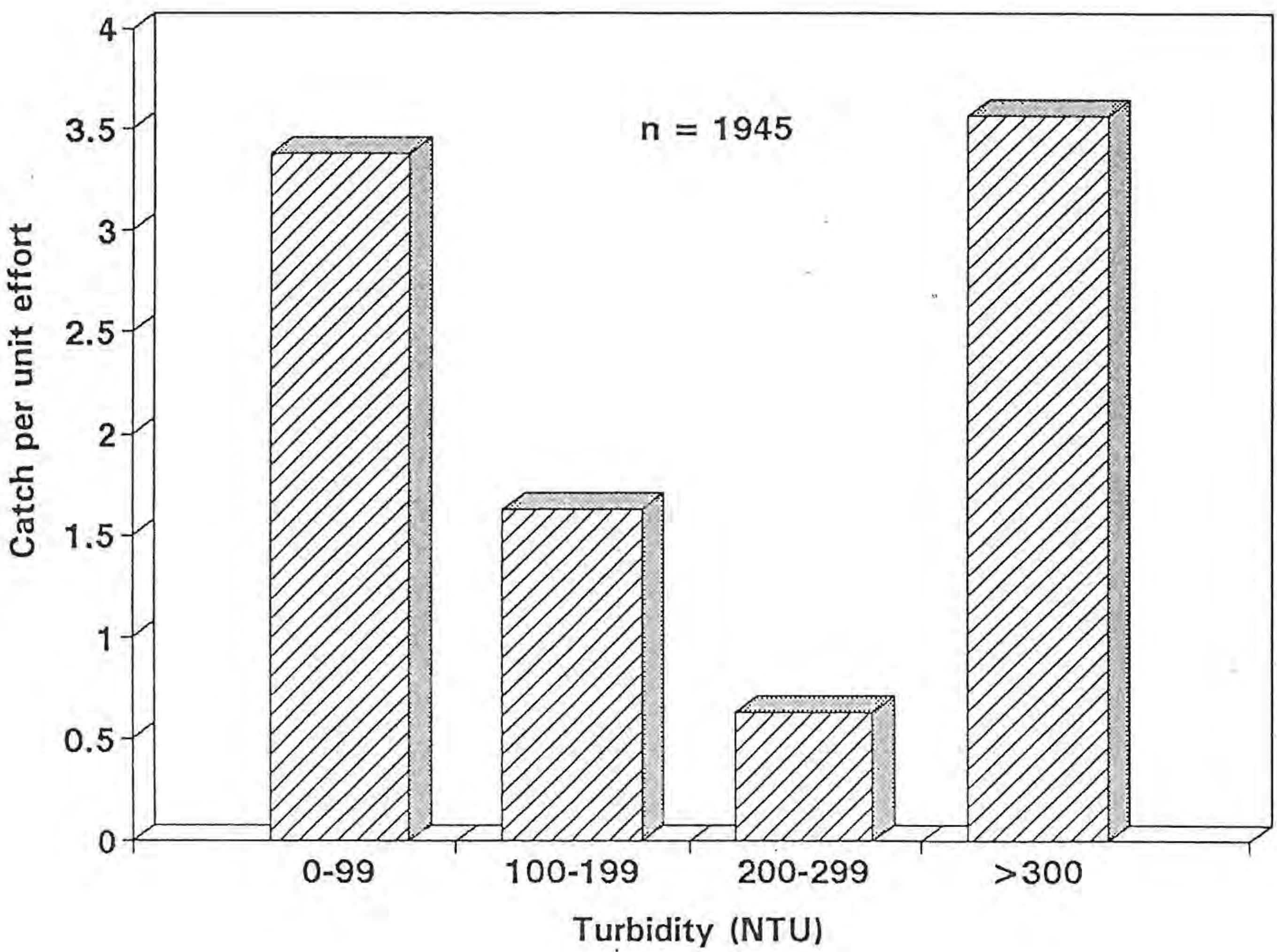


Fig. 12: The distribution of *Rhabdosargus holubi*, captured with a large seine net in the Great Fish system, in relation to turbidity.



rather than the actual values themselves, may have caused the mortalities (Dallas & Day 1993).

R. holubi was most common at sizes of <80 mm SL and no individuals >120 mm SL were captured in the Great Fish River, head region or estuary (Fig. 13). Other workers have shown that this species is dependant on estuaries as a nursery area and moves to sea to join adult populations from about 120 mm (TL) (Beckley 1984). It is therefore assumed that this, rather than gear selectivity, explains the paucity of specimens > 100 mm SL during the present study.

The most common euryhaline marine species captured with the 30 m seine net was *L. dumerilii*. This is one of the few species that was equally common at all sampled salinities (Table 3), but most were caught at temperatures of around 23.5 °C (Table 4). The lowest turbidities were favoured (Fig. 14), consistent with the findings of Cyrus (1992) in Lake St Lucia and Cyrus & Blaber (1987a, 1987b). In terms of size the vast majority were between 30 mm and 90 mm SL (Fig. 15).

Most Mugilidae <30 mm SL were captured at temperatures of around 21 °C (Table 4). Although these juveniles were least common in the estuary, they were well represented in all three sampling regions.

Juvenile *Pomadasys commersonnii* were clearly more plentiful in the head region (Table 3), but no difference was observed in their abundance in terms of temperature. However, this species displayed a bi-modal distribution pattern in terms of turbidity (Fig. 16). The lack of correlation between the distribution of this species and turbidity in the Great Fish system is consistent with the findings of Cyrus & Blaber (1987a, 1987b). The modal class for all three regions was 30-59 mm SL (Fig. 17).

In terms of salinity *L. richardsonii* showed a bimodal distribution pattern, but was most abundant in the estuary (Table 3). The vast majority of specimens were captured between 20 °C and 22 °C and mostly at turbidities < 200 NTU (Fig. 18). This species also showed a bimodal length frequency distribution. Specimens between 30 mm and 89 mm SL were most abundant, with no specimens between 120 mm and 180 mm SL, and a few between 180 mm - 360 mm SL.

Ambassis gymnocephalus was most abundant at the higher salinities (Table 3) and low turbidities (Fig. 19) within the sampled area of the Great Fish system, and was most abundant at temperatures of 20-24 °C.

Fig. 13: The length frequency distribution of *Rhabdosargus holubi* captured with a large seine net in the Great Fish River (4a), head region (4b) and estuary (4c).

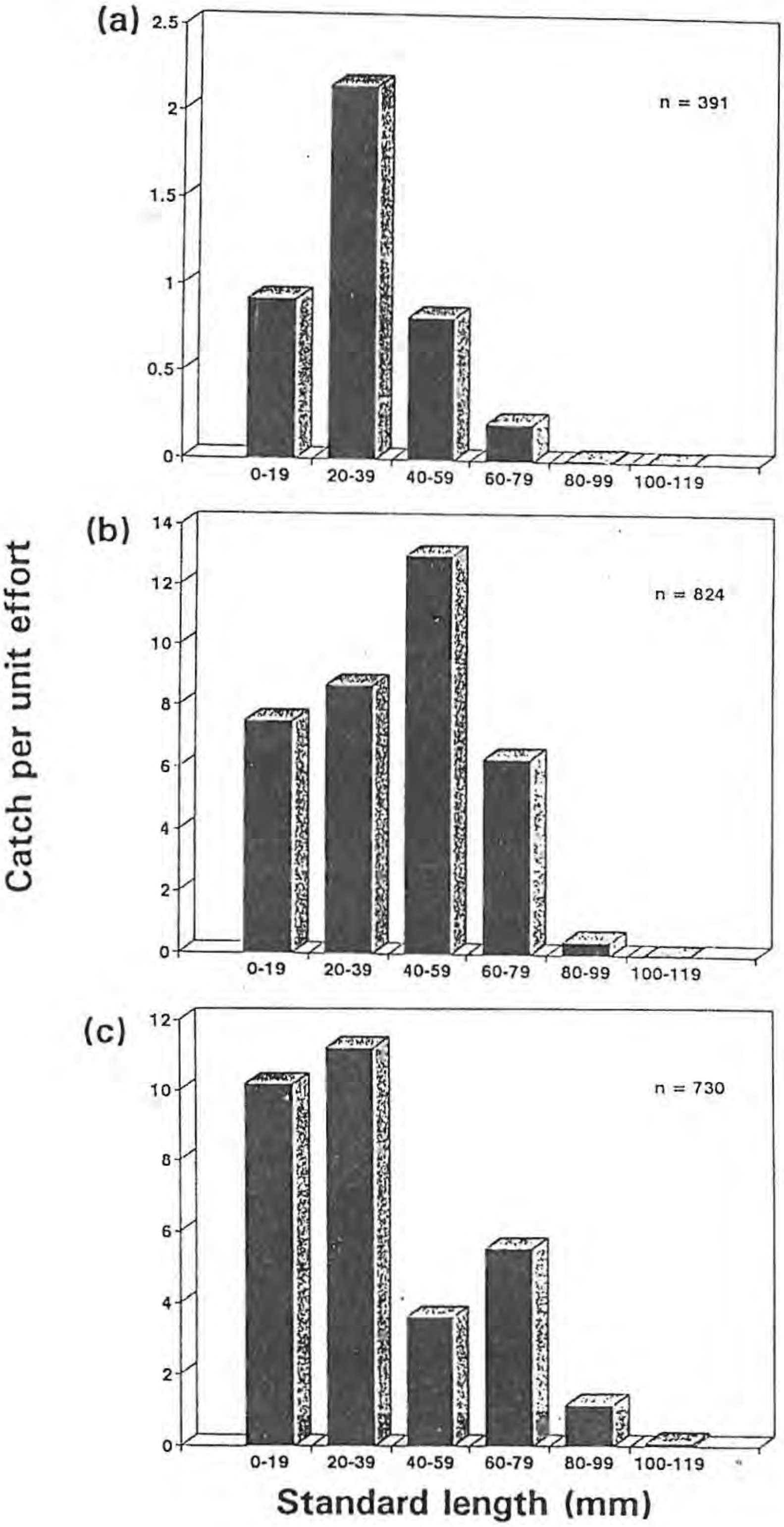


Fig. 14: The distribution of *Liza dumerilii*, captured with a large seine net in the Great Fish system, in relation to turbidity.

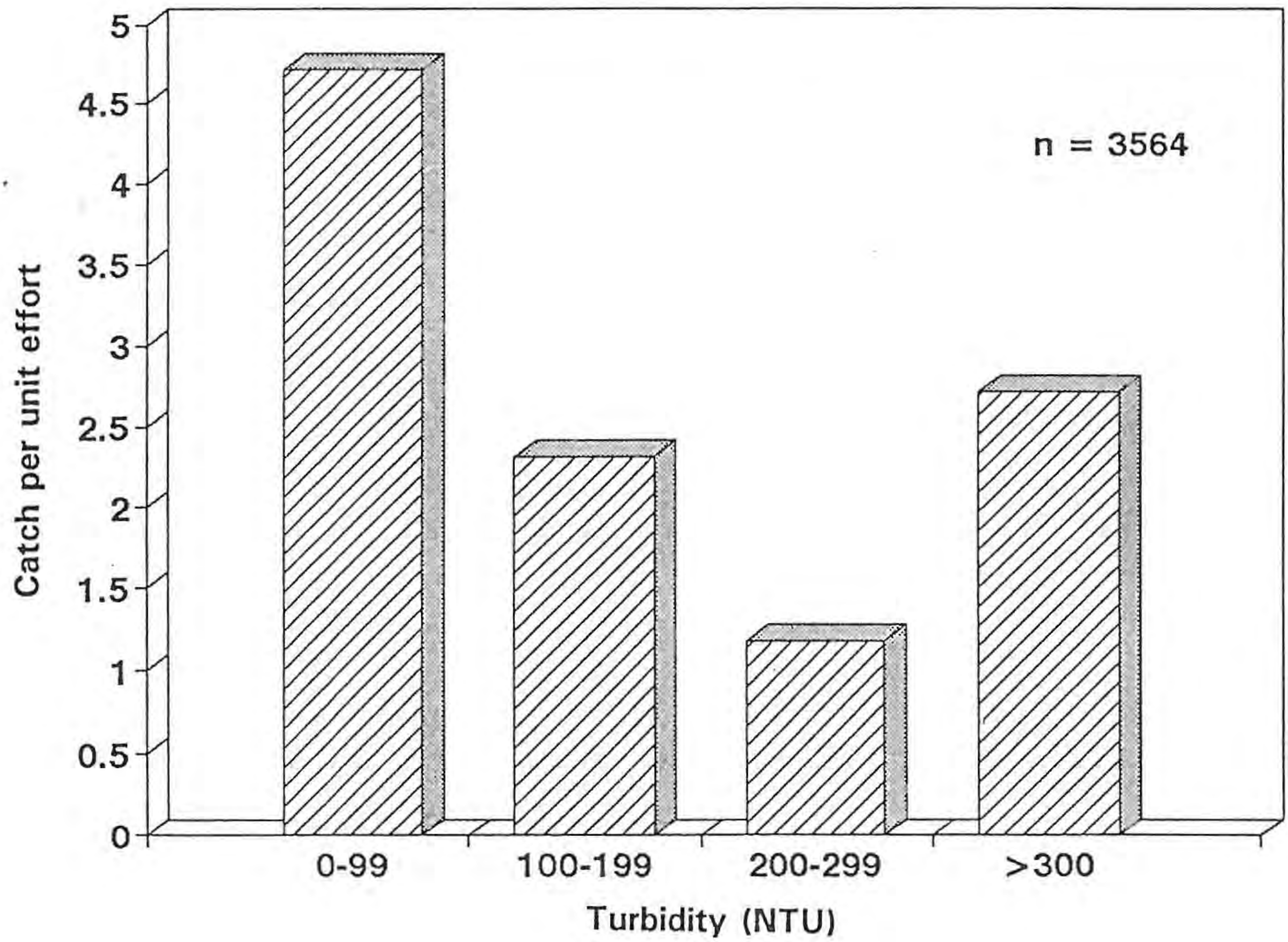


Fig. 15: The length frequency distribution of *Liza dumerilii* captured with a large seine net in the Great Fish River (15a), head region (15b) and estuary (15c).

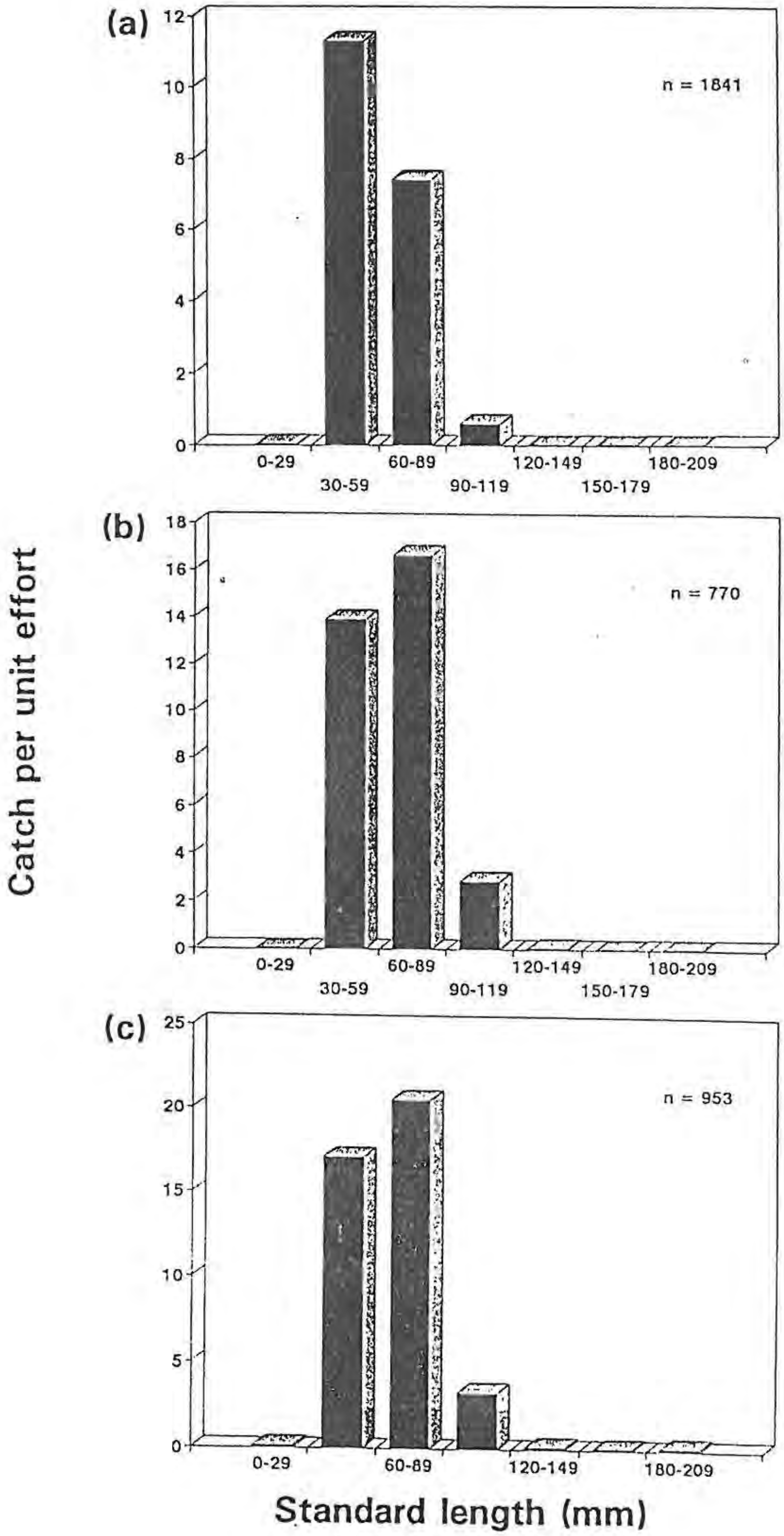


Fig. 16: The distribution of *Pomadasys commersonnii*, captured with a large seine net in the Great Fish system, in relation to turbidity.

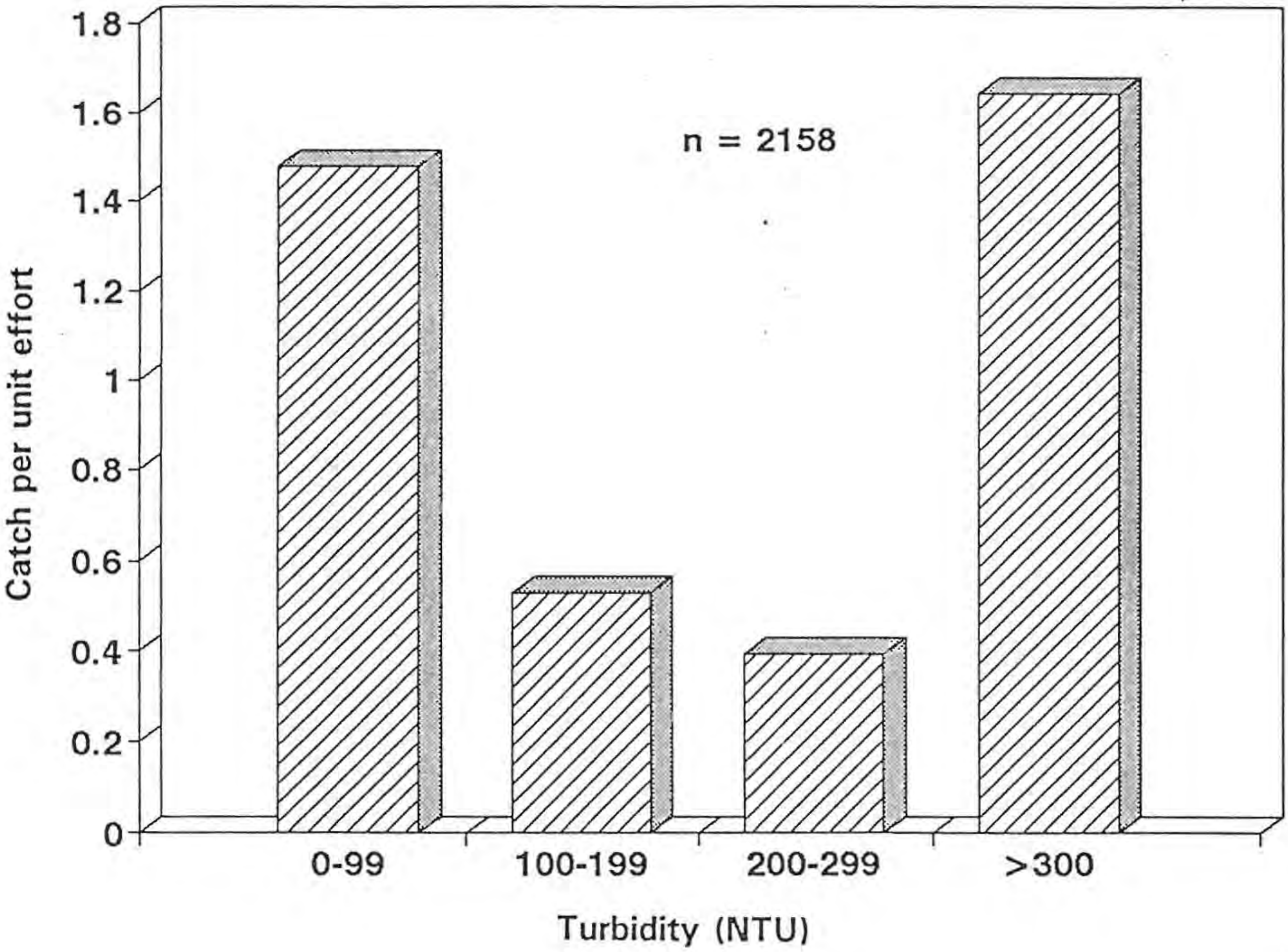


Fig. 17: The length frequency distribution of *Pomadasys commersonnii* captured with a large seine net in the Great Fish River (17a), head region (17b) and estuary (17c).

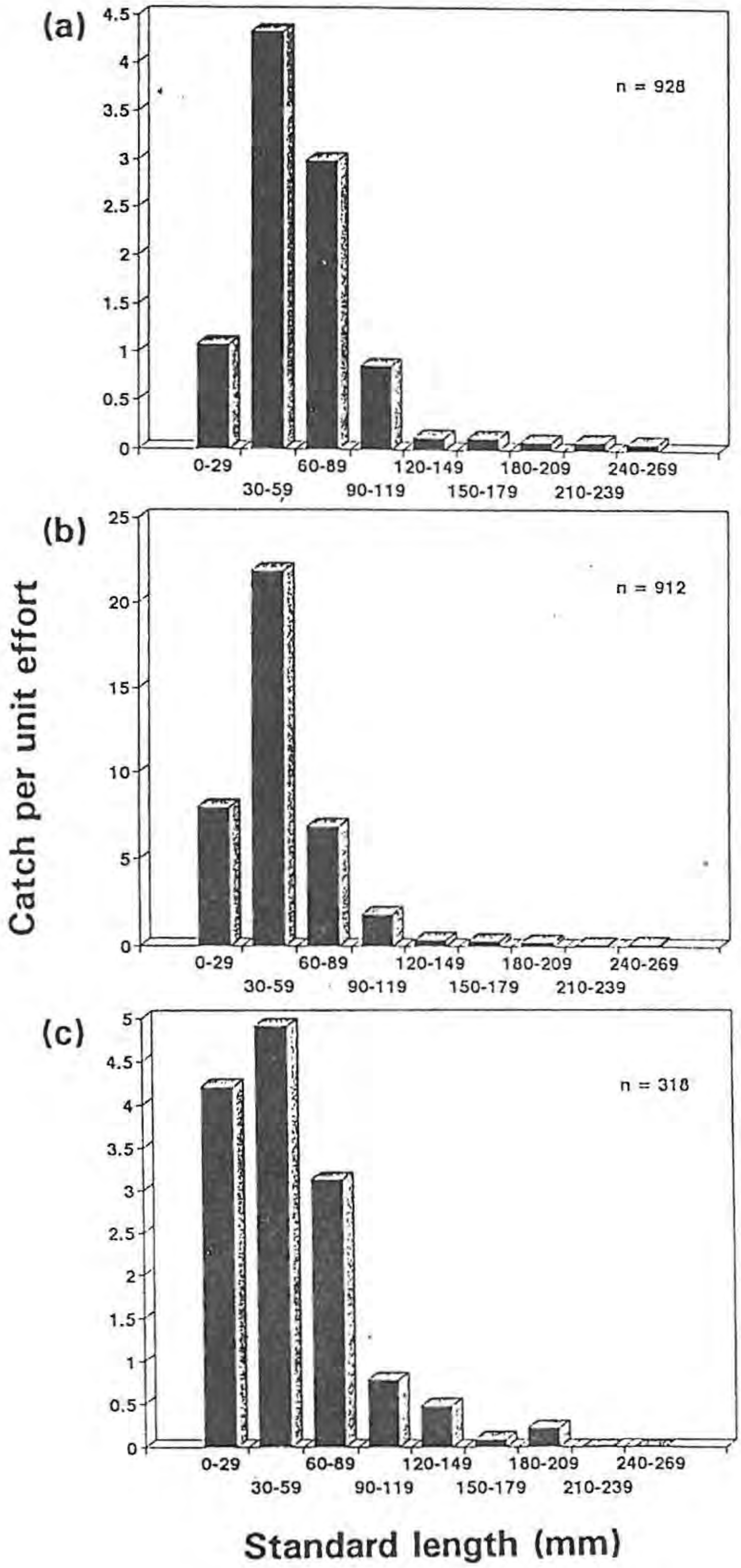


Fig. 18: The distribution of *Liza richardsonii*, captured with a large seine net in the Great Fish system, in relation to turbidity.

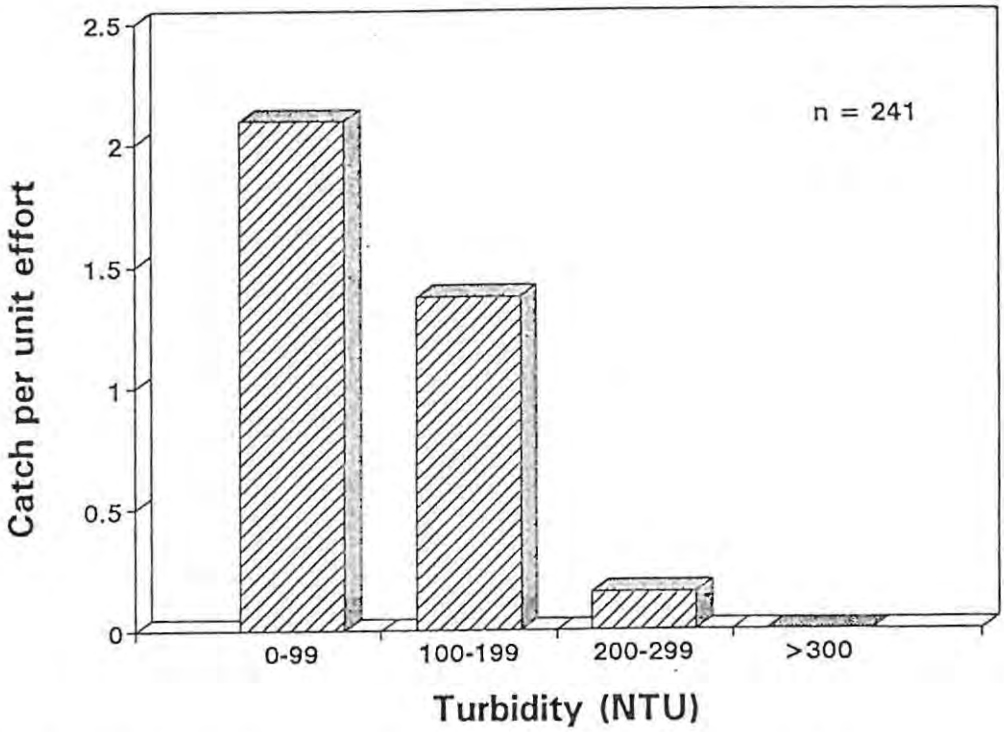
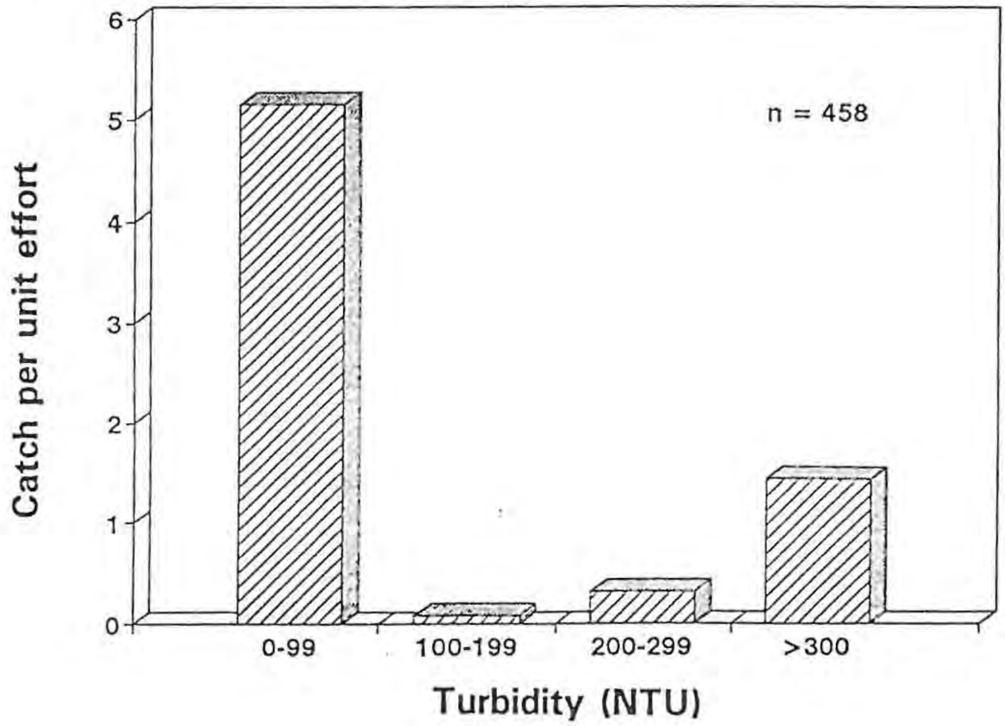


Fig. 19: The distribution of *Ambassis gymnocephalus*, captured with a large seine net in the Great Fish system, in relation to turbidity.



Although plentiful throughout the sampling area *Mugil cephalus* was most plentiful in the estuary (Table 3). Little difference in abundance was noticed in terms of temperature, with the mean at 23 °C. The greatest numbers occurred at lower turbidities (Fig. 20) consistent with the findings of Cyrus & Blaber (1987a), who showed that this species was most abundant at turbidities of 50 - 80 NTU in Lake St. Lucia.

Juvenile *Argyrosomus japonicus* were most plentiful at temperatures of around 21 °C, lower salinities (Table 3) and higher turbidities (Fig. 21). This species was most abundant at the head region (Table 3), which corresponds with the area of highest turbidity. Although relatively abundant in the turbid waters of the Great Fish River and estuary, *A. japonicus* are relatively scarce in clearer estuaries (Hanekom & Baird 1984, Harrison & Whitfield 1990, Whitfield *et al.* 1994) and the surf zone (Bennett 1988, Whitfield 1989a), suggesting that turbid estuaries are an important nursery area for first year juveniles of this species. The modal size class for the river and head region was 30 - 59 mm SL, yet that of the estuary was 120 - 149 mm (Fig. 22). Growth of the modal cohort can be followed through the year, with specimens <30 mm SL being virtually absent after March and <60 mm SL after May (Fig. 23). In addition, specimens >180 mm SL are uncommon in the large seine net catches, suggesting either gear selectivity or a spring and summer recruitment period followed by growth within the sampling area.

The only abundant freshwater species, *Oreochromis mossambicus*, was most abundant in the riverine samples (Table 3), despite its ability to survive highly saline conditions in estuaries (Whitfield & Blaber 1978, Whitfield *et al.* 1981). The species was most plentiful at temperatures of around 22 °C (Table 4) and turbidities of 200 - 300 NTU (Fig. 24).

Fig. 20: The distribution of *Mugil cephalus*, captured with a large seine net in the Great Fish system, in relation to turbidity.

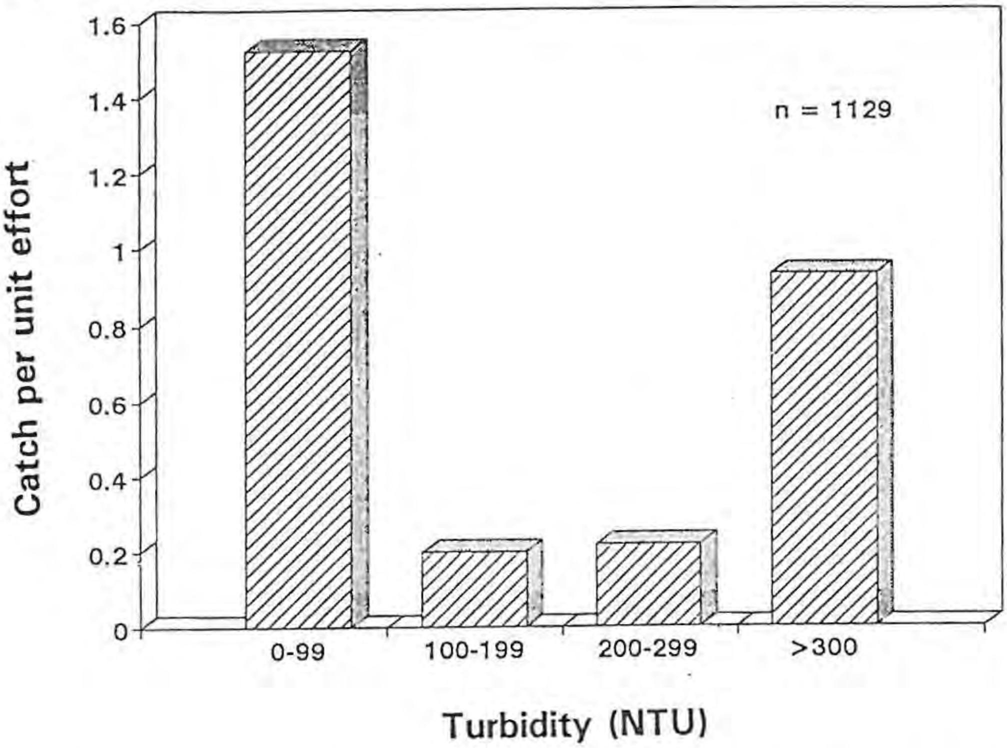


Fig. 21: The distribution of *Argyrosomus japonicus*, captured with a large seine net in the Great Fish system, in relation to turbidity.

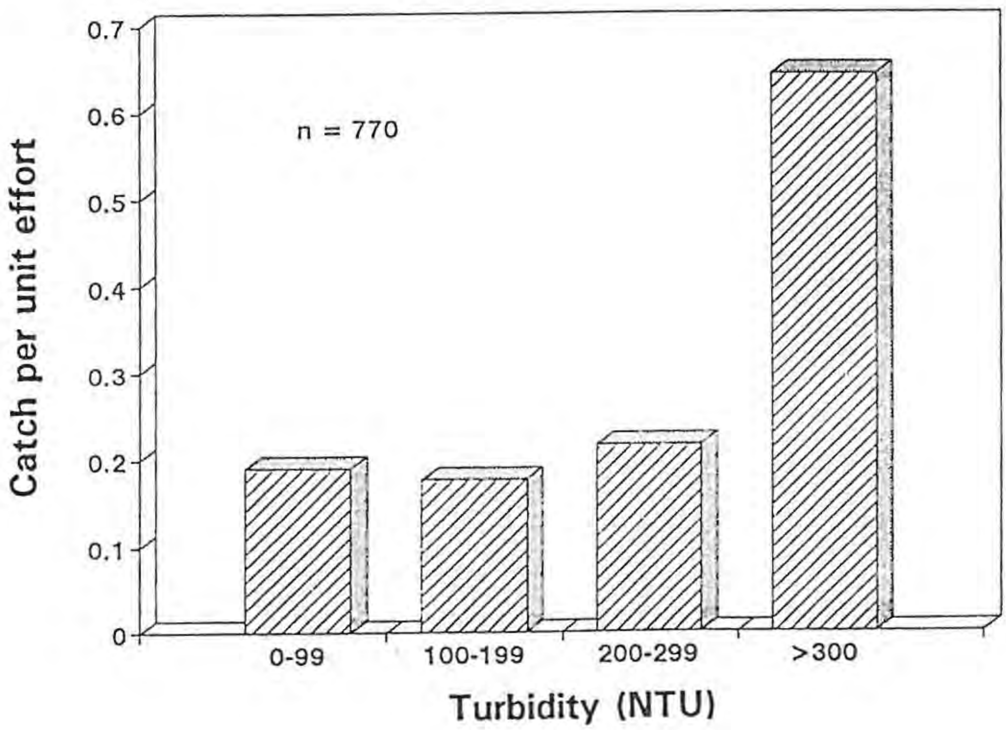


Fig. 22: The length frequency distribution of *Argyrosomus japonicus* captured with a large seine net in the Great Fish River (22a), head region (22b) and estuary (22c).

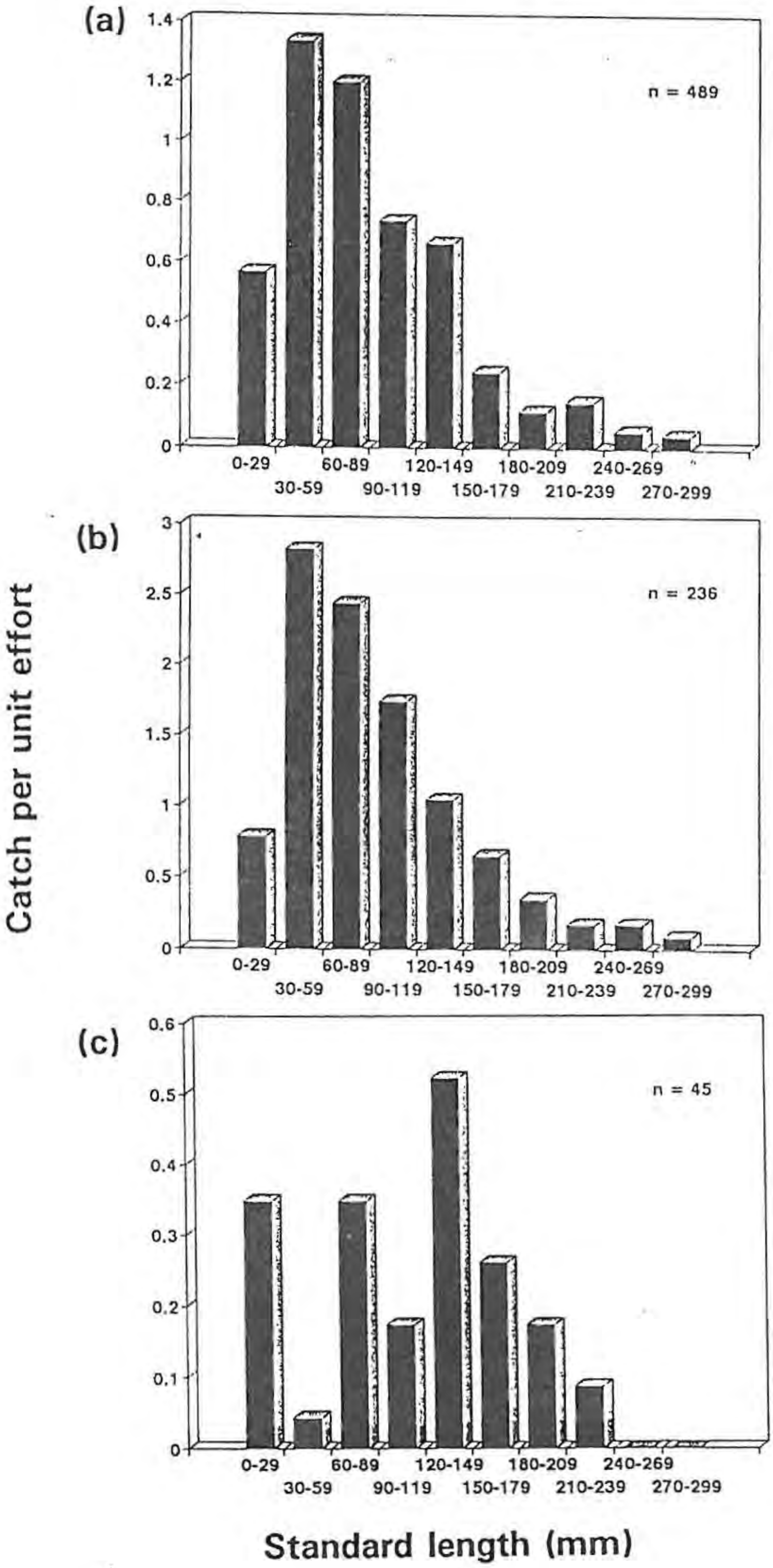


Fig. 23: The length frequency distribution of *Argyrosomus japonicus* captured with a large seine net in the Great Fish River in the months of September (23a), November (23b), January (23c), March (23d), May (23e) and July (23f).

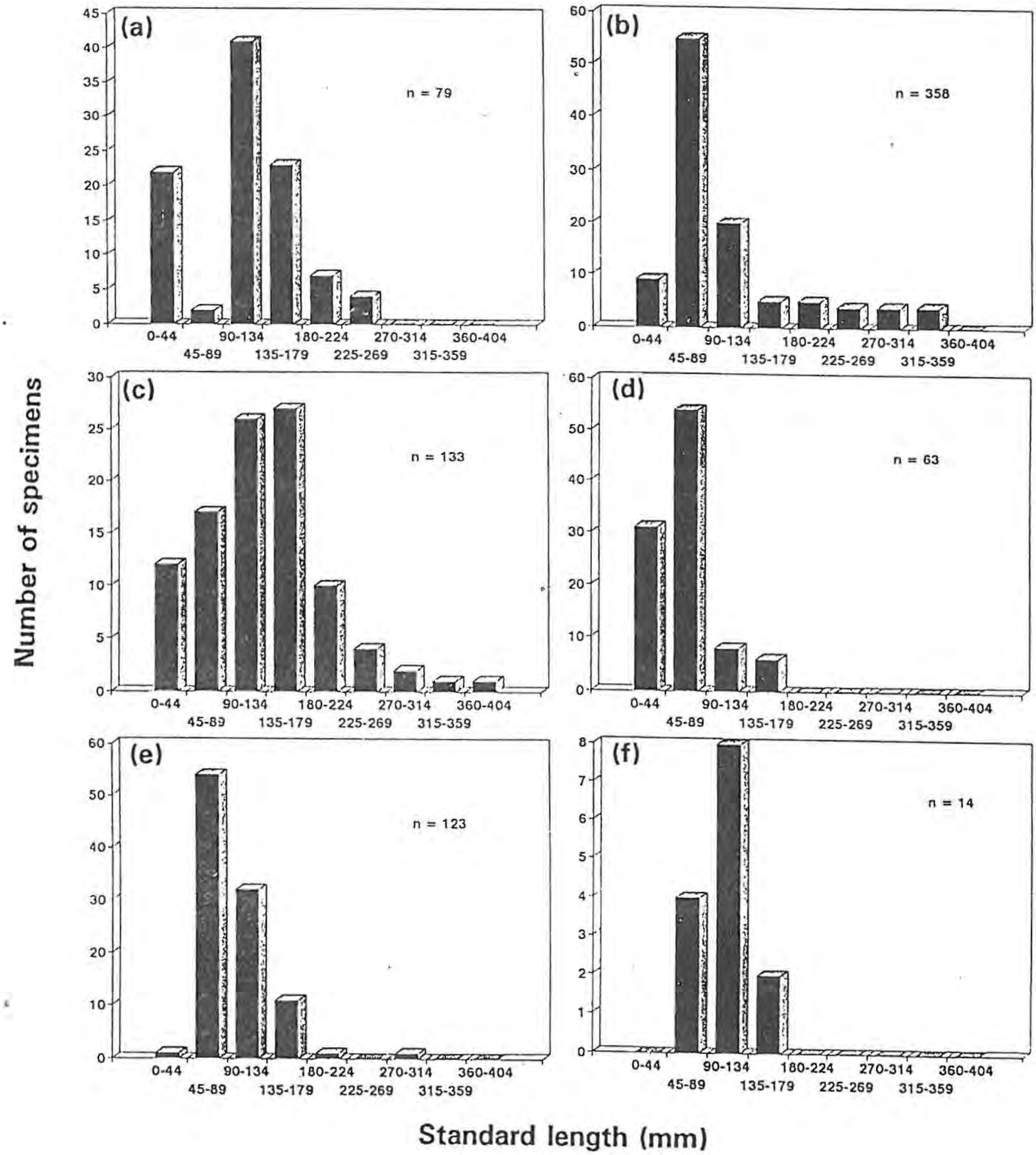
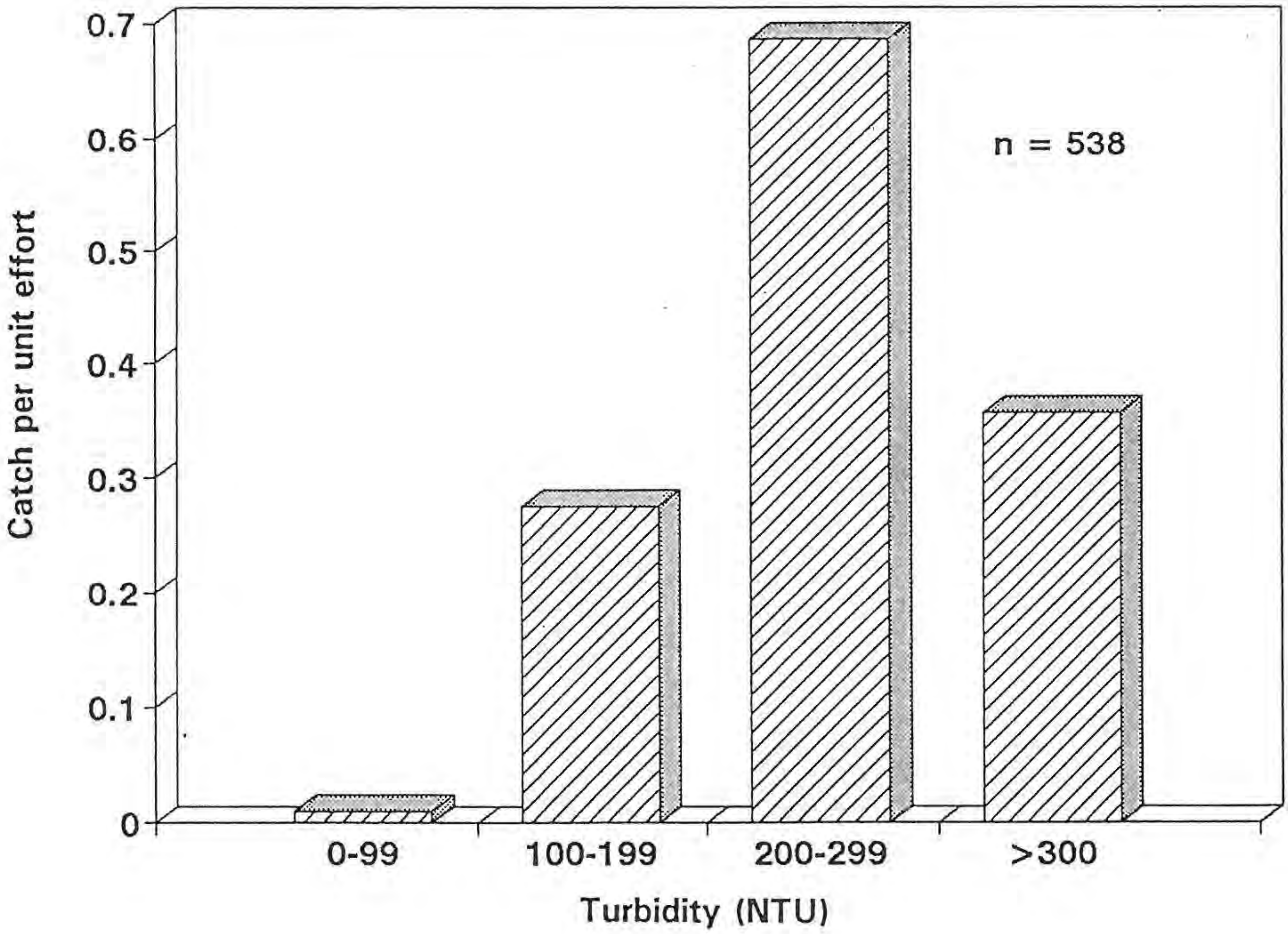


Fig. 24: The distribution of *Oreochromis mossambicus*, captured with a large seine net in the Great Fish system, in relation to turbidity.



Life-history analyses

River: Just over half of the large seine net catch from the river were euryhaline marine species (Fig. 25a), with *Liza dumerilii* being the most abundant species (Table 3). The other euryhaline species common in this area were *Pomadasys commersonnii, Rhabdosargus holubi, Argyrosomus japonicus* and *Elops machnata* (Table 3). The estuarine species accounted for about one third of the riverine large seine net catch (Fig. 25a). *Gilchristella aestuaria* was the only abundant species in this category (Table 3). The two catadromous species, *Mugil cephalus* and *Myxus capensis*,were both common in the riverine samples and together comprised almost 10 % of the total catch for the river (Table 3, Fig. 25a). The only abundant freshwater species in the riverine large seine net catches was *Oreochromis mossambicus* (Table 3).

Head region: The euryhaline marine species dominated the large seine net catch at the head of the Great Fish River estuary (Fig. 25b). *R. holubi, P. commersonnii* and *L. dumerilii* all being very abundant (Table 3). Estuarine species were the second most abundant category (Fig. 25b). The most common estuarine species was *G. aestuaria*, along with *Psammogobius knysnaensis* and *Ambassis gymnocephalus* (Table 3). Of the two catadromous species, only *M. cephalus* was found to be common (Table 3). The freshwater species were not common at the head of the Great Fish system (Fig. 25b).

Estuary: The estuarine samples were again dominated by euryhaline marine species (Fig. 25c), with *R. holubi, L. dumerilii, L. richardsonii* and *P. commersonnii* dominating the catch (Table 3). The estuarine category was again the second most abundant (Fig. 25c), mainly due to *G. aestuaria* and *Ambassis gymnocephalus* (Table 3). The catadromous species were both fairly common in the large seine net catches in the estuary (Fig. 25c, Table 3). Freshwater species were uncommon in the estuarine samples (Fig. 25c), although *Labeo umbratus* was recorded in low numbers (Table 3).

System: The total analyses of the species captured with the large seine net according to life-history categories shows similar trends to that of the small seine net. In both instances the euryhaline marine category was the most abundant in all three regions (Fig. 9 & 25). The common taxa captured in both cases were the mugilidae, *G. aestuaria, R. holubi, P. commersonnii, L. dumerilii* and *Mugil cephalus* (Table 2 & 3).

River flow rates and fish response

Monitoring of the flow rate of the Great Fish River for the month of each sampling trip revealed strong correlations between the flow rate and the species assemblage within the sampling area. This could be done as a direct comparison as each sampling trip occurred at the end of the month and the flow for that month would, presumably, already have affected the fishes in the sampling area. For the sake of comparison flow was divided into low ($<10 \times 10^6\ m^3$), medium ($10 - 20 \times 10^6\ m^3$) and high flow ($>20 \times 10^6\ m^3$) (Table 5).

The data indicate a negative relationship between overall fish abundance and the riverine flow rate, with the most dramatic change occurring between medium and high flow (Table 5). The overall abundance for each region showed a similar trend in the riverine and head region samples, whereas the greatest numbers of fishes were captured in the estuary during medium flow rates (Table 5).

Fig. 25: The proportion contributed by each Life History Category (Whitfield 1994a) to the large seine net catch in the Great Fish River (25a), head region (25b), estuary (25c) and the total (25d)

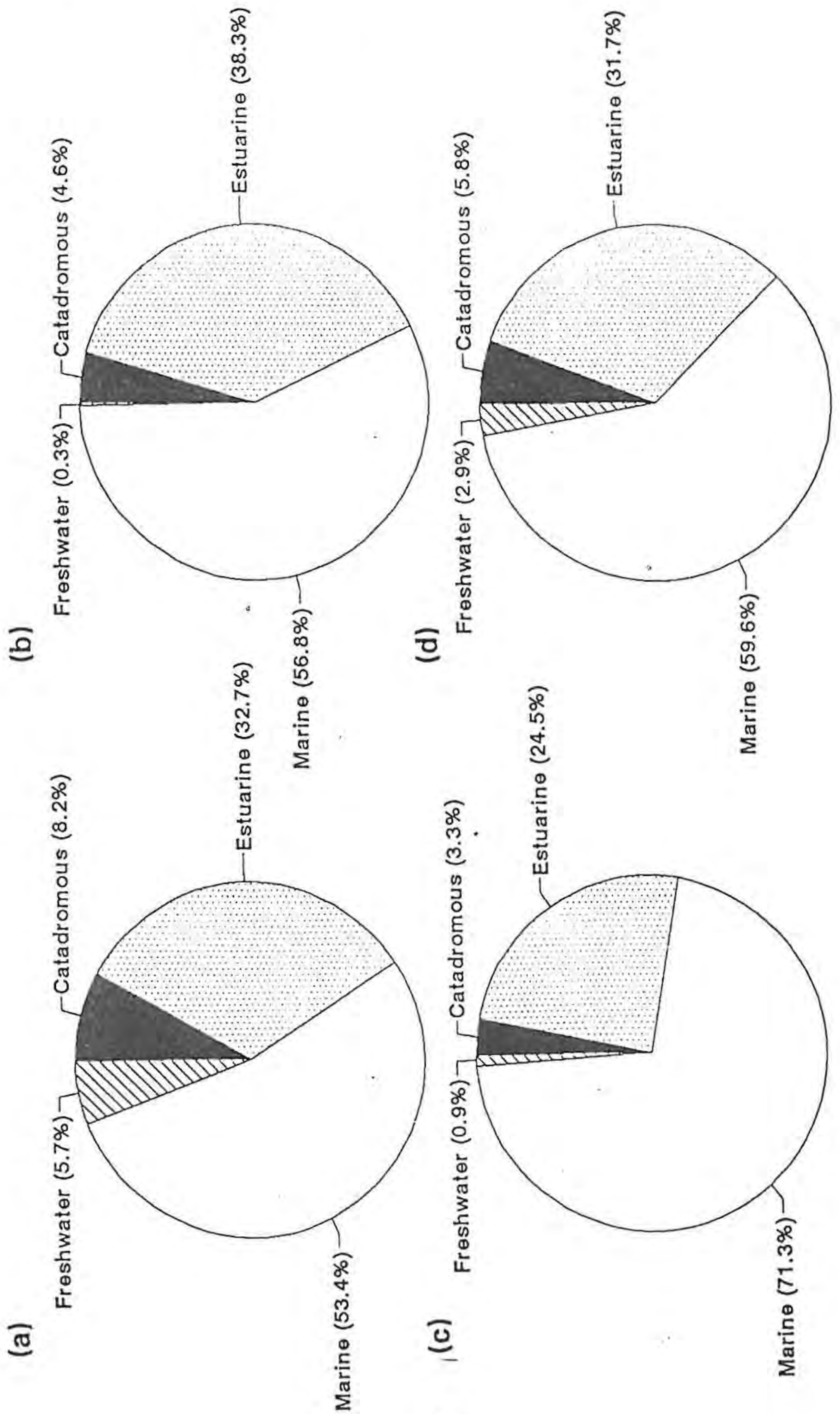


Table 5: Flow rates and conductivity levels in the Great Fish River for the months of sampling from November 1992 to January 1995 (Dept of Water Affairs & Forestry Unpubl. Info.).

Month and Year	Category	Flow rate 10^6 $m^3.month^{-1}$	Conductivity $mS.m^{-1}$
November 1992	medium	16.2	190.6
January 1993	low	9.8	245.5
March 1993	medium	11.3	183.0
May 1993	medium	12.9	217.0
July 1993	medium	12.7	248.0
September 1993	medium	14.3	202.0
November 1993	medium	15.0	164.5
January 1994	high	33.5	127.0
March 1994	high	32.9	98.3
May 1994	medium	13.9	226.3
July 1994	medium	14.6	215.0
September 1994	medium	10.8	219.0
November 1994	low	8.98	212.3
January 1995	high	68.7	74.0

Table 6: The mean number of fish per large seine net haul for each species from the river, head and estuary of the Great Fish River system under low, medium and high flows.

Taxa	LOW FLOW			MEDIUM FLOW			HIGH FLOW		
	River	Head	Estuary	River	Head	Estuary	River	Head	Estuary
Clupeidae									
Gilchristella aestuaria	87.8	493.3	98.4	48.1	5.2	133.6	4.8	11.3	20.8
Elopidae									
Elops machnata	8.3	36.0	0.6	0.6	1.2	0.1	1.5	0.0	0.0
Cyprinidae									
Cyprinus carpio	1.6	2.7	0.2	1.4	3.2	0.0	0.8	0.0	0.0
Labeo umbratus	0.1	0.0	0.0	0.1	0.0	0.0	3.2	2.0	7.0
Clariidae									
Clarias gariepinus	0.2	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Ariidae									
Galeichthys feliceps	0.2	0.7	0.0	0.8	3.2	0.1	0.0	0.0	0.3
Atherinidae									
Atherina breviceps	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.3	0.3
Platycephalidae									
Platycephalus indicus	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0
Ambassidae									
Ambassis gymnocephalus	1.3	17.7	0.2	0.8	4.9	43.5	2.3	0.8	0.0
Teraponidae									

Terapon jarbua	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0
Carangidae									
Caranx sexfasciatus	0.3	6.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Lichia amia	0.1	0.7	0.6	0.0	0.0	0.1	0.0	0.0	0.0
Leiognathidae									
Leiognathus equula	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Gerreidae									
Gerres acinaces	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Haemulidae									
Pomadasys commersonnii	13.5	74.7	13.8	14.6	62.1	19.4	4.4	28.0	1.5
Pomadasys olivaceum	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Sparidae									
Acanthopagrus berda	0.9	0.0	0.6	2.2	1.4	0.4	0.4	0.5	0.0
Lithognathus lithognathus	0.1	0.0	9.4	1.1	1.1	12.5	0.0	0.5	0.0
Rhabdosargus holubi	4.2	69.7	65.0	7.5	56.2	188.8	0.1	5.5	2.8
Sciaenidae									
Argyrosomus japonicus	5.4	19.7	2.4	7.6	7.4	2.3	0.6	0.0	0.3
Monodactylidae									
Monodactylus falciformis	1.1	2.0	0.4	1.6	0.1	0.3	0.6	0.0	0.3
Cichlidae									
Oreochromis mossambicus	4.7	0.0	0.0	4.8	0.5	0.1	8.2	0.0	0.0
Mugilidae	83.9	1.0	32.2	61.0	49.8	43.9	4.1	15.3	30.5
Crenimugil crenilabis	0.0	0.0	0.6	0.1	0.2	0.0	0.0	0.0	0.0

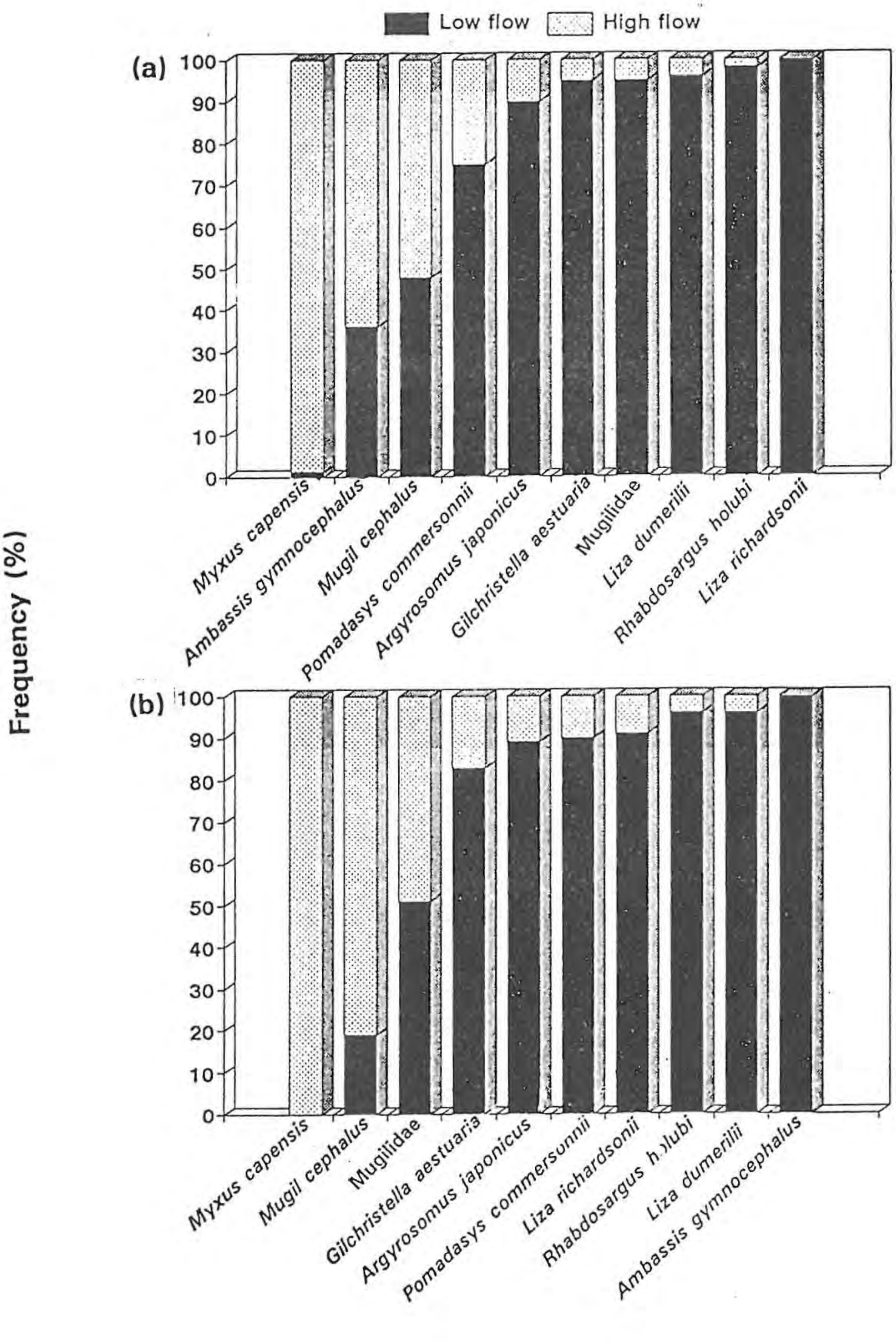
Liza dumerilii	146.3	48.0	206.4	28.6	64.1	41.4	6.0	8.8	8.3
Liza richardsonii	0.1	0.0	48.8	2.3	0.3	36.6	0.0	0.0	4.8
Liza tricuspidens	0.4	0.0	0.4	0.0	0.0	0.1	0.0	0.0	0.0
Mugil cephalus	12.4	2.0	4.8	2.9	7.1	15.4	13.2	20.8	20.8
Myxus capensis	0.1	0.0	0.0	2.7	0.2	8.1	10.4	0.0	0.5
Polynemidae									
Polydactylus plebius	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Gobiidae									
Caffrogobius multifasciatus	0.0	0.0	0.8	0.1	0.1	1.0	0.0	0.3	0.0
Caffrogobius nudiceps	0.0	0.0	0.6	0.0	0.2	3.8	0.0	0.0	0.0
Eleotris fusca	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Glossogobius callidus	0.2	0.3	0.2	1.6	0.4	0.2	1.0	1.8	0.0
Oligolepis keiensis	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Psammogobius knysnaensis	0.1	0.3	1.8	2.3	4.5	8.2	0.0	0.0	0.0
Soleidae									
Heteromycteris capensis	0.1	0.0	1.0	0.5	2.8	10.8	0.0	0.0	0.0
Solea bleekeri	2.5	2.7	0.2	2.5	4.1	2.4	0.7	1.3	0.0
Tetraodontidae									
Amblyrhynchotes honckenii	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0
Unidentified	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Region total	375.9	779.3	490.6	196.4	280.9	573.3	62.6	96.8	97.8
Flow rate mean									

The four most abundant species captured during this study, *G. aestuaria, L. dumerilii, R. holubi* and *P. commersonnii* all showed a decrease in abundance throughout the sampling area during high flows (Table 6, Fig. 26). Most other species showed a similar trend of reduced numbers during high flow periods, but *L. dumerilii*, *R. holubi* and *L. richardsonii* displayed the strongest negative correlation between their abundance and riverine flow rate (Fig. 26).

Several species in the Great Fish River system were more common during the elevated flow periods. These were *L. umbratus, M. cephalus, M. capensis* and *O. mossambicus* (Table 6), all of which are either freshwater or catadromous species. Several species were at their highest relative abundance during periods of medium flow (Table 6). This group includes estuarine species (*A. gymnocephalus*), freshwater species (*C. carpio*) and euryhaline marine species (*R. holubi, H. capensis* and *L. lithognathus*), and may indicate that elevated flows are preferred up to a certain level beyond which they become a limiting factor. Several species showed an intermediate trend with *M. capensis* showing the strongest positive correlation with flow rate (Fig. 26). This species was only present in the estuarine samples (>4‰) during the months of elevated flow (Table 6). During low flow periods *M. capensis* was not even common in the riverine samples, indicating that the elevated flows in the river resulted in this species utilising the estuary (>4‰). Only 2 of the 115 *M. capensis* captured in the estuary during this phase of the study exceded 90 mm SL, indicating that this was not a pre-spawning aggrigation of adults. This, combined with the fact that Whitfield *et al.* 1994 recorded this species in the estuary, contradicts the statement of (Bruton *et al.* 1989) that this species moves into freshwater and stays there for 3-7 years before returning to saline waters to breed. Furthermore, this indicates an interaction between river flow and species distribution that was unrecorded until now.

During flooding the Great Fish system is similar to other large Eastern Cape Rivers because the percentage of the total water volume contributed by translocated water is negligible. Even so, the translocated water has had a major diluting effect on the Great Fish River which had extremely high conductivity levels prior to 1975 (anon. 1995). Marais (1982) regards the duration of flooding events to be more important to estuarine fauna than the absolute values of minimum salinity. In combination with the results from the present

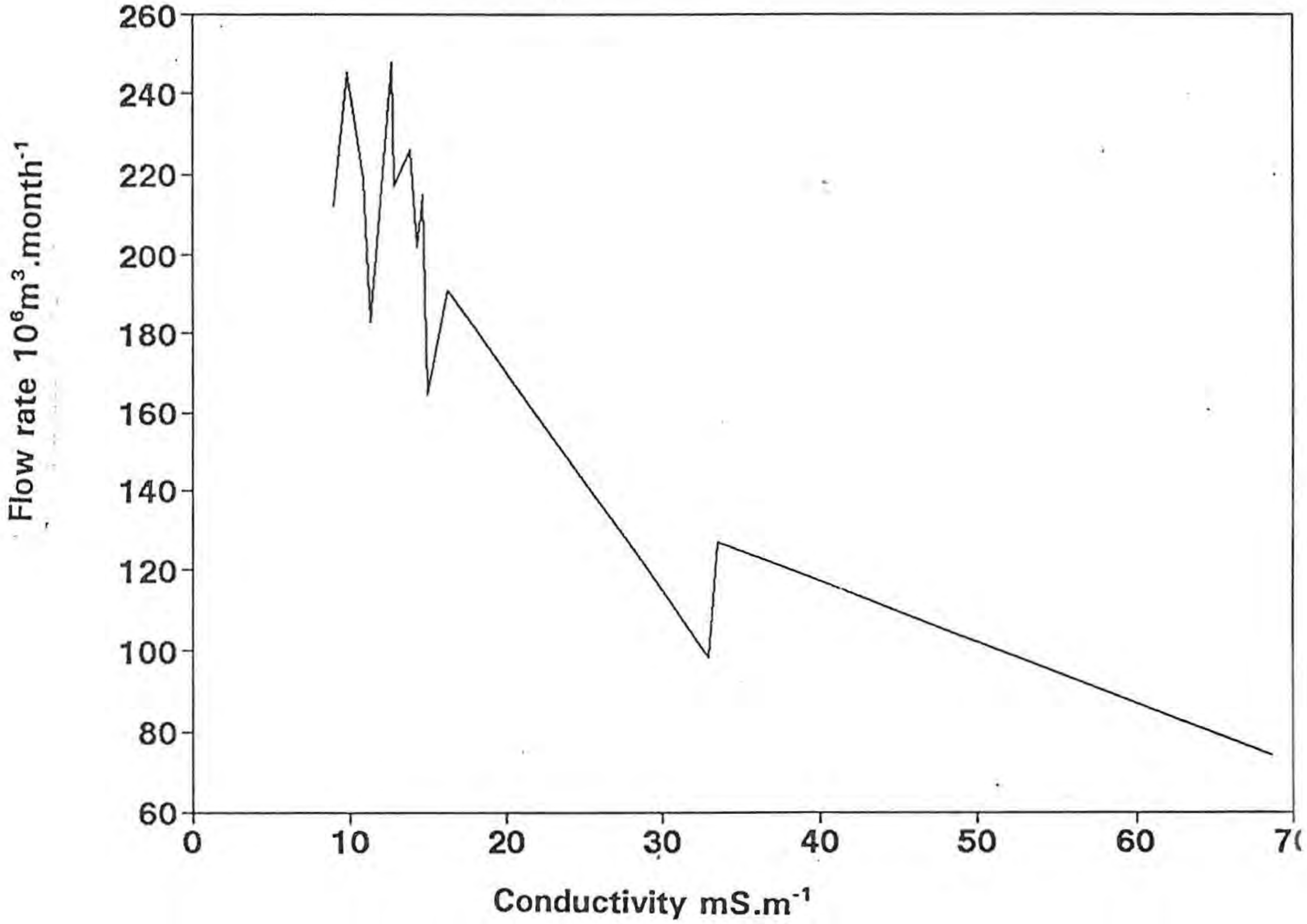
Fig. 26: The change in relative adundance of the most common species captured in the Great Fish River (26a) and the estuary (26b), in relation to high and low river flow rates.



study it would seem that although increased flows result in a decline in abundance of certain species in certain systems, the salinity where sampling occurred, the rate of flow and the duration of the flood all play a role.

An inverse relationship can be observed between river flow rate and conductivity (Table 5, Fig. 27). During periods of low river flow salts leaching into the river cause an increase in conductivity, whereas high flows dilute this effect. As sodium and chloride are two of the salts to be most diluted in this manner (anon. 1995), it is probable that the change in their relative abundance could effect the ability of euryhaline fishes to utilise the river. The salinity of the riverine water is too low to detect a reading on an optical salinometer, yet under low and medium flows the conductivity remains high, indicating the presence of large concentrations of salts. It is also under these conditions that the euryhaline marine species dominate the catches in all three of the sampled regions. With a large increase in flow rate the salts are diluted, the conductivity decreases and the euryhaline marine species are no longer common in the riverine samples. It would seem appear therefore, that there is an indirect link between river flow and marine fish abundance in the Great Fish River system.

Fig. 27: The relationship between flow rate and conductivity in the Great Fish River.



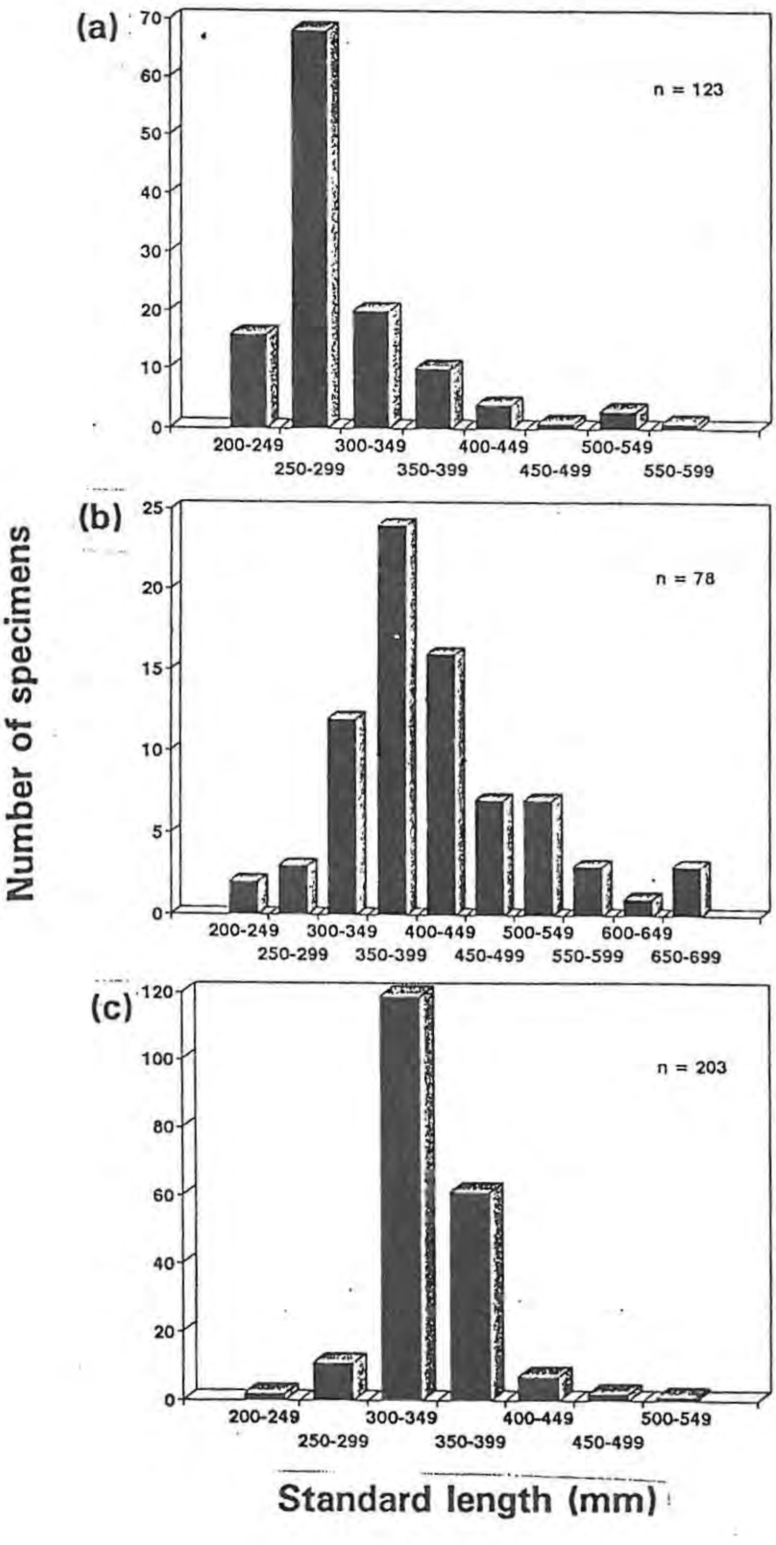
Gill net fish assemblage

A total of 511 fishes representing 15 species were captured by gill netting during this study (Table 7). *Pomadasys commersonnii* was the most abundant species, along with *Argyrosomus japonicus* and *Mugil cephalus* (Table 7). Relative abundances for the three most abundant species is demonstrated in Table 7. *P. commersonnii* was most abundant in the estuarine and head regions during the present study and in the upper Gamtoos estuary (Marais 1983b), whereas they were not common at the head of the Sundays estuary (Marais 1981). However, they were also most abundant at site 4 on the Krom estuary (Marais 1983a), which is the furthest site from the sea but still very saline, indicating that the lower salinity recorded at the head of the Great Fish system is unlikely to be the only reason for this species being abundant there. The abundance of *P. commersonnii* in the Swartkops estuary and their relatively low abundance in the Sundays estuary was attributed to the standing stock of the mudprawn *Upogebia africana* (Marais 1981, 1982). The abundance of *P. commersonnii* in the Great Fish, where *U. africana* also abounds, was therefore to be expected.

A. japonicus was also most abundant at the head during the present study, directly confirming the findings of Marais & Baird (1980) in the Swartkops and Marais (1981) in the Sundays systems. In the clear Krom system this species was evenly distributed throughout the estuary (Marais 1983a), and in the Gamtoos system they were most abundant in the upper estuary (Marais 1983b).

In the Great Fish and Gamtoos (Marais 1983b) systems *M. cephalus* was far more common in the river, where huge numbers were caught on several occasions. Marais (1981) found this species to be more abundant at the upper estuary of the Sundays system than the rest of the estuary or the head. Furthermore, this species was not abundant in the Krom system (Marais 1983a) which is very saline at all four sampling sites. However, in the saline Swartkops estuary this species is most abundant at the site closest to the sea (Marais & Baird 1980), indicating that the distribution of this catadromous species is not only determined by salinity. The overall CPUE and average mass of catch per net for the present study indicate that the greatest catches were made in the head region, followed by the river, and finally the estuary. This is more or less consistent with the findings of Marais (1988), based on gill netting in 14 eastern Cape estuaries, but includes riverine samples. Furthermore, Grange

Fig. 28: The length frequency distributions of *Pomadasys commersonnii* (28a), *Argyrosommus japonicus* (28b) and *Mugil cephalus* (28c) captured with gill nets in the Great Fish system.



et al. (1995) found that as a result of freshwater inflow to the Great Fish estuary, a gradient in food resource availability existed, with higher values being recorded towards the upper reaches. However, salinity increased in the opposite direction, causing the zooplankton community biomass to increase towards the upper reaches, corresponding to the increase in food resources, but declined above the region where salinities were lower than about 8‰. It makes sense therefore that the highest densities of fish should occur where the food resources are highest, and this is at the head region and upper estuary.

When the CPUE results of the gill netting phase of the present study are converted to the same units as used in studies on the Swartkops, Sundays, Krom and Gamtoos systems (Marais & Baird 1980, Marais 1981, Marais 1983a, Marais 1983b respectively), it can be seen that the present catches are very similar to those of the Sundays and Gamtoos (Table 7). This is despite a single mesh size and net area of $80m^2$ being used during the present study, as opposed to a range of 5 mesh sizes and $150m^2$ of netting during the above studies.

As the purpose of gill netting during the present study was to determine the abundance and distribution of piscivorous fish species, and which fish species they were preying on, the gill nets were selected with this in mind. However, it was also noted that the gill nets caught a discrete size range of specimens of each species, confirming the work of Marais (1985). This was demonstrated by the length frequency graphs for the three most abundant species (Fig. 28), but does raise the question - is the catch a reflection of gear selectivity or relative abundance of the size classes? In the case of *M. cephalus* it would seem that gear selectivity is particularly important, as a very narrow size range was captured and the large seine net data indicated that the species was abundant in the smaller size classes that were poorly represented in the gill net catches (Fig. 28). Furthermore, it was noted that the larger the specimen, of a particular species, the further forward on its body it was trapped in the net. In addition, the graph (Fig. 28a) for *P. commersonnii* shows clearly how a particular mesh size catches fish of a discrete size range. The smaller specimens (<100 mm SL) were able to swim through the net, those slightly larger (200 - 300 mm SL) swam into the net and became fouled at the base of the dorsal fin. For specimens over 300 mm SL, as the size of specimens increased the point of entanglement moved forward along the body until the largest specimens (>400 mm SL) were only trapped by the posterior portion of their premaxillae.

No specimens of *Rhabdosargus holubi* were captured during the gill netting phase of the present study, despite this species being one of the most numerous to be caught with the small (Table 2) and large seine nets (Table 3). This again confirms the findings of Beckley (1984) that the larger specimens (> 120 mm TL) are not abundant in the estuarine environment.

An interesting aspect relating to the activity levels of fishes was noted during the present study. During the ebb tide there appeared to be very little audible fish activity in the estuary, which was confirmed by lower gill net catches over that period (± 7,5 hours). However, as soon as the tide turned the activity in the estuary increased dramatically, and this was reflected in increased gill net catches. This could unfortunately not be quantitatively demonstrated due to the nets being checked at midnight, instead of about 23H00 when the tide turned. Since it was observed that the vast majority of fishes collected in the nets at midnight were alive and appeared freshly captured, it is suggested that estuarine fishes are noticeably more active on the rising than the falling tide. This is also confirmed by estuarine anglers (subjective) who maintain that the best fishing time is the first two hours of rising tide.

Table 7: Catch per unit effort (6 hrs^{-1}.80 m^{-2}) using gill nets in each of the three sampled regions of the Great Fish River system.

	River	River rank	Head	Head rank	Estuary	Estuary rank
Elopidae						
Elops machnata	0.08	4	0.00		0.00	
Cyprinidae						
Cyprinus carpio	0.05	6	0.11	7	0.00	
Labeo umbratus	0.03	9	0.00		0.00	
Clariidae						
Clarias gariepinus	0.03	9	0.00		0.00	
Ariidae						
Galeichthys feliceps	0.05	6	0.22	6	0.36	3
Platycephalidae						
Platycephalus indicus	0.03	9	0.00		0.00	
Carangidae						
Lichia amia	0.05	6	0.11	7	0.00	
Haemulidae						
Pomadasys commersonnii	1.58	2	4.44	1	2.82	1
Sparidae						
Acanthopagrus berda	0.03	9	0.00		0.00	
Sciaenidae						

Argyrosomus japonicus	0.75	3	3.22	2	1.73	2
Mugilidae						
Liza richardsonii	0.03	9	0.11	7	0.00	
Liza tricuspidens	0.08	4	0.33	5	0.36	3
Mugil cephalus	5.95	1	2.22	3	0.18	5
Myxus capensis	0.00		0.44	4	0.09	6
Valamugil buchanani	0.00		0.11	7	0.00	
CPUE (fish.6 hrs^{-1}.80 m^{-2})	8.70		11.33		5.55	
CPUE (kg.6 hrs^{-1}.80 m^{-2})	9.44		12.44		5.20	
CPUE (kg.12 hrs^{-1}.150 m^{-2})	35.40		46.65		19.50	
CPUE Sundays River estuary					20.4	
CPUE Gamtoos River estuary					33.3	

Diet of dominant piscivorous fish

The stomach contents of 116 piscivorous fishes were analysed to see which fish species were being most heavily preyed on in each region. A total of 90 *A. japonicus* stomachs were analysed, making this the only species where sufficient stomachs were available for meaningful dietary results to be obtained, and these are demonstrated in Table 8. Only 27 of the 90 *A. japonicus* stomachs did not contain food.

Mysids totally dominated the stomach contents of *A. japonicus* numerically, and were found in more stomachs than any other prey item (frequency of occurrence) (Table 8). However, due to their small size, they were relatively unimportant in the gravimetric analysis and were insignificant when compared to fish in the diet. Nevertheless, the IRI ranked mysids as the most important food item for *A. japonicus* in this system (Table 8). Although *Labeo umbratus* was rated the most important fish prey species by the IRI, this was largely due to their large body size. *G. aestuaria* was the primary prey fish species in terms of % FOO, a finding which is consistent with studies of *A. japonicus* diet in other Eastern Cape systems (Marais 1984).

Almost half of the *A. japonicus* from the river had empty stomachs, as compared to a third from the head region and less than 20% of those from the estuary. The average number of items in a stomach from each of the three regions paralleled this trend, with the riverine fishes having far less food in their stomachs on average (0.65)(items per stomach) than those from either the head region (1.66) or estuary (1.69). One would assume therefore that the largest concentrations of *A. japonicus* between 200 mm and 700 mm SL would be in the estuary and head region and that few would move to the river where they seem to feed less. Although no juvenile *A. japonicus* were discovered in the stomachs of larger specimens during this study they do prey conspecificaly (Marais 1984). Based on this previous finding, it is understandable that juveniles of the species would avoid the head regions and estuary where their larger relatives are more common and rather take refuge in the riverine area. It can be seen from Table 3 and Figure 22 that this is partially true, the bulk of juveniles occurring at the head of the estuary and in the river. Other factors, such as food availability and the nature of the physical environment, would naturally also influence distribution patterns.

Table 8: An analyses of the stomach contents of *Argyrosomus japonicus* from the Great Fish River and estuary, showing the relative importance of different food items.

Prey item	% Numeric	% Gravimetric	% Frequency of occurrence	IRI
Invertebrates				
Callianassa kraussi	0.40	0.20	1.59	0.95
Copepoda	0.54	0.01	4.76	2.62
Mysidacea	78.08	3.82	49.21	4 030.30
Palaemon pacificus	8.29	2.96	17.46	20.42
Upogebia africana	0.13	0.01	1.59	0.22
Fishes				
Eleotris fusca	0.13	8.30	1.59	13.4
Gilchristella aestuaria	2.14	4.08	12.70	79.00
Labeo umbratus	0.40	47.12	4.76	226.20
Mugilidae	0.94	4.31	6.35	33.34
Unidentified	4.81	28.07	42.86	1409.24
Pomadasys commersonnii	0.53	1.10	1.59	2.59

Conclusion

Although other studies have shown that salinity and turbidity are both major factors influencing the distribution of fish species within estuaries (Blaber & Blaber 1980, Cyrus & Blaber 1987b), the lack of a turbidity gradient during the present study precluded the possibility of turbidity effecting the fish species distribution within the sampled area. Turbidity is, however, a factor in determining which species utilise a system (Blaber & Blaber 1980), as well as their abundance (Marais 1988) and feeding strategies within the system (Hecht & van der Lingen 1992).

The euryhaline marine species dominated the entire sampling area (Fig. 9 & 25) in terms of abundance. The tolerance of most species to freshwater conditions was surprising, but is consistent with the opinion of Whitfield *et al.* (1981) that estuarine-associated species are usually more tolerant of low than high salinities.

Many of the species captured during the present study showed an increase in body length from the river to the estuary. This is consistent with the suggestion by North American estuarine researchers that juvenile fish utilise estuarine headwaters first and move down the estuary as they grow; in essence they propose that the estuary 'fills up backward' (Rogers *et al.* 1984).

Catches made with the gill nets and large seine net both indicated that the densities of fish were higher at the head than in either the river or the estuary (Table 3 & 7). This follows the findings of Grange & Allanson (1995) that the highest levels of suspended particulate matter in the Great Fish estuary are in the head region.

Species distribution related strongly to salinity and river flow. Several of the most common species under low and medium flows were uncommon in the same regions under high flows, and the overall trend of decreasing numbers with an increase in river flow was evident. Several estuarine and euryhaline marine species that were captured in freshwater during the present study (Table 3), were not given as being freshwater tolerant by Whitfield *et al.* (1981). Several of these species also succumbed during the Bot River fish kill (Bennett 1985) where low salinity was regarded as a crucial factor. The high conductivity levels recorded in the Great Fish River (Table 5) may well enable species normally incapable of utilising freshwater to utilise the river in this case. In addition, the conductivity levels of the Great Fish River declines dramatically during and immediately following floods (Table 5).

This may be part of the reason why many species only tolerate the riverine region under low and medium flow conditions.

It is clear that the Great Fish system has an extremely abundant, and diverse, fish fauna at the head of the estuary. Comparisons should therefore be made between the head region fish assemblages of this system with its high freshwater inflow and high turbidity, and those in systems with high inflow but low turbidity; low inflow and low turbidity; low inflow and high turbidity, in an effort to determine which is the more important factor. In addition, the conductivity levels must be recorded in these other systems to determine the interplay between flow rate, conductivity and fish species assemblage. The findings of such a research program would have important management implications, particularly in the light of increasing demand for freshwater resources in southern Africa. This follows the suggestion of Cyrus (1991) that we select representative estuaries to receive high conservation attention before it is too late.

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