The fish community of the Berg River estuary and an assessment of the likely effects of reduced freshwater inflows

B.A. Bennett

Zoology Department and Marine Biology Research Institute, University of Cape Town, Rondebosch, 7700 Republic of South Africa

Received 1 May 1993; accepted 6 October 1993

Data concerning the species composition, abundance and distribution of fishes inhabiting the Berg River estuary are presented and used to assess the value of the estuary to fish, and the likely effects of reduced freshwater inflows. A total of 31 species was recorded, eight of which were classified as estuarine residents, 11 as marine estuarine-opportunists, six as marine stragglers and six were freshwater species. *Liza richardsonii*, an opportunist, was the most abundant (54% N) and widely distributed species encountered during the winter and summer seine-net surveys. Three other species (all residents) contributed more than 10% of the total catch; *Atherina breviceps* and *Caffrogobius nudiceps* occurring most abundantly in the lower estuary, and *Gilchristella aestuaria* in the middle estuary. The low number of species compared with estuaries in other regions of the South African coast reflect a well-established marine biogeographical trend. The higher proportions of resident species, entirely dependent species and partially dependent species suggest, however, that west coast estuaries may be more important to the fish that inhabit them than are estuaries in other regions. It is concluded that the fish community of the estuary is already suffering the effects of habitat degradation and that further reductions in freshwater inflows are not desirable.

Data betreffende die spesiessamestelling, talrykheid en verspreiding van visse wat die Bergriviermond bewoon, word aangebied en gebruik in 'n raming van die waarde van die mond vir die bewonende visse, en die moontlike gevolge van verminderde varswaterinvloei. 'n Totaal van 31 spesies is aangeteken, agt waarvan geklassifiseer is as mondinwoners, 11 as mariene trekvisse, ses as mariene swerwers en ses as varswatersoorte. *Liza richardsonii*, 'n trekvis, was die volopste (54% N) en mees wydverspreide spesie wat teëgekom is gedurende die winter- en someropnames. Die ander spesies (almal inwoners) het meer as 10% bygedra tot die totale vangs, met *Atherina breviceps* en *Caffrogobius nudiceps* wat volopste in die laer-, en *Gilchristella aestuaria* in die middelgedeeltes van die strandmeer, voorkom. Die klein aantal spesies weerspieël 'n goed vasgelegde mariene biogeografiese neiging. Die groter proporsie van inwonerspesies, totaal afhanklike en gedeeltelik afhanklike spesies suggereer egter dat Weskusriviermonde belangriker mag wees vir die visse wat hulle bewoon as riviermonde in ander streke. Die gevolgtrekking word gemaak dat die visgemeenskap van die riviermond reeds onder die gevolge van habitatvernieling ly en dat verdere verminderings in varswaterinvloei onwenslik is.

The fish communities inhabiting estuaries on the eastern and southern coasts of South Africa are reasonably well known (see Whitfield 1991 for a bibliography). There are, however, very few data concerning fish inhabiting estuaries and lagoons on the west coast. Millard & Scott (1954) provide brief notes on the species composition and distribution of fish in Milnerton estuary and Whitfield, Beckley, Bennett, Branch, Kok, Potter & Van der Elst (1989) list species associated with *Zostera capensis* beds in Langebaan Lagoon. The only other published information concerning estuarine fish on the west coast is by Day, Blaber & Wallace (1981) who record the presence of species in estuaries as far north as the mouth of the Olifants River.

This study was undertaken in response to a request by the Department of Water Affairs and Forestry for information concerning the likely effects of proposed dams in the catchment on the estuarine fish community of the Berg estuary. Specifically, its aims were to:

1. Identify the fish species occupying the estuary and document their distribution and abundance
2. Identify the species for which the estuary is likely to be an important habitat and establish the value of the estuary relative to other South African estuaries
3. Assess the likely effects of reduced freshwater inflows and suggest the minimum flow requirements of the fish community.

Methods

Study area

The Berg estuary (Figure 1) is situated about 32°46'S, 18°09'E in a winter rainfall area and is fed by the largest river in the western Cape. The catchment area is about 4 000 km^2 and has a mean annual runoff of 693 × 106 m^3. Flow rates are usually 0,2–2,0 m^3s^{-1} during summer and 15–60 m^3s^{-1} during winter, but they may attain 700 m^3s^{-1} during floods (Berg 1993). The estuary meanders over an extensive floodplain and its bed falls only 1 m over the last 50 km; tidal effects are measurable up to 65 km from the sea (Day 1981). The upper 15 km consists of a narrow channel bounded by steep banks covered in riparian woodland. In the middle reaches the river runs through a seasonally flooded plain of between 1,5 and 4 km wide. The floodplain becomes much narrower (<1,5 km) over the lower 15 km and tidal mudflats occur in this region. The mouth has been stabilized between concrete walls and, for the first four kilometres, the channel is dredged to a depth of at least 4 m to allow the passage of purse-seine boats.

Sampling

'Winter' and 'summer' surveys of the fish community of the Berg River estuary were conducted over the periods 9–12 September 1992 and 27 January – 1 February 1993, respectively. On both occasions the surveyed area was between the

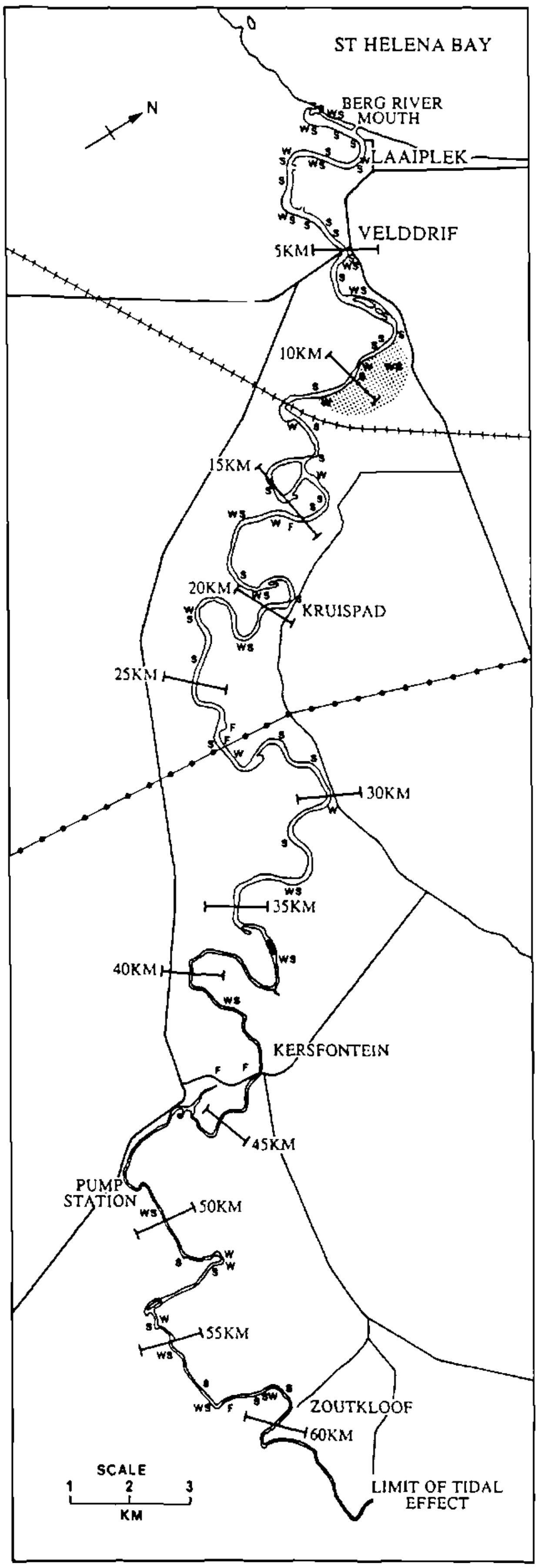

Figure 1 A map of the Berg River estuary (32°46'S, 18°09'E) showing the location of the winter (W), floodplain (F) and summer (S) sampling sites and the places mentioned in the text.

estuary mouth at Laaiplek and the farm Zoutkloof, about 60 km upstream. The winter samples were conducted soon after the cessation of the winter rains while the river was still flowing strongly but after the flooding had abated. The summer sampling was conducted at least five months after the last significant rains and while the river flow was minimal. Water levels at Zoutkloof during the summer survey were about 2,5 m lower than those experienced during the winter and, at the Berg River pump station, they were about 1 m lower. Downstream from Kersfontein, the difference in water levels between the two surveys was less than 0,5 m.

A total of 36 different localities was sampled during the winter survey, including six on the floodplain in pools that had no direct connection with the estuary. Fifty-five localities were sampled during the summer survey, none in pools, as those previously sampled were dry (see Figure 1 for sample locations). Each sample consisted of a haul with a beach seine (30 m long, 12 mm stretched mesh) covering 200–800 m^2. Water clarity was measured with a Secchi disc to within 1 cm, salinity to within 0,5 ppt, and depth and temperature to the nearest 5 cm and 0,5°C, respectively. All fish caught in each seine haul were identified, counted and measured (total length) to within 1 mm.

The 91 samples from the winter and summer surveys were classified heirarchically to show relationships between them as described by Gauch (1982). Dissimilarities between samples were calculated from the catch per haul data for each of the 21 species using the Bray-Curtis similarity index. Samples were clustered in a dendrogram by the group averaging sorting procedure, which joins two groups at their average level of similarity (Field, Clarke & Warwick 1982).

Results

Physical conditions

The physical characteristics of each of the sampling stations during the winter survey are shown in Figure 2. Temperatures varied between 15°C and 21°C, salinity between 0 and 30 ppt, and clarity between 5 and 40 cm. These three measurements within the estuary were strongly affected by the characteristics of the fresh water entering via the river and sea-water at the mouth. In the upper 10 km of the sampling area, the cold and turbid fresh water exerted a strong influence and in the lower reaches the cold, high salinity and clear sea-water ensured that low temperatures and the highest salinity and clarity measurements were recorded within 3 km of the mouth. There was no marked variation in any of these three physical measurements over the intervening section of the estuary. Temperatures varied between 16 and 20°C, tending to increase during the day, salinities were between 0 and 3 ppt and clarity was between 5 and 25 cm.

Conditions in the six pools sampled on the floodplain tended to be similar to each other but different to those in the estuary at equivalent distances from the sea. All the pools were shallow (maximum depth 20–40 cm) and contained clear (clarity 35–45 cm), low salinity (0–1 ppt) water. Temperatures were between 18 and 21°C.

In the summer survey, temperature tended to increase upstream, whereas salinity and clarity decreased. During the incoming tide, the sea-water entering at the mouth was cold

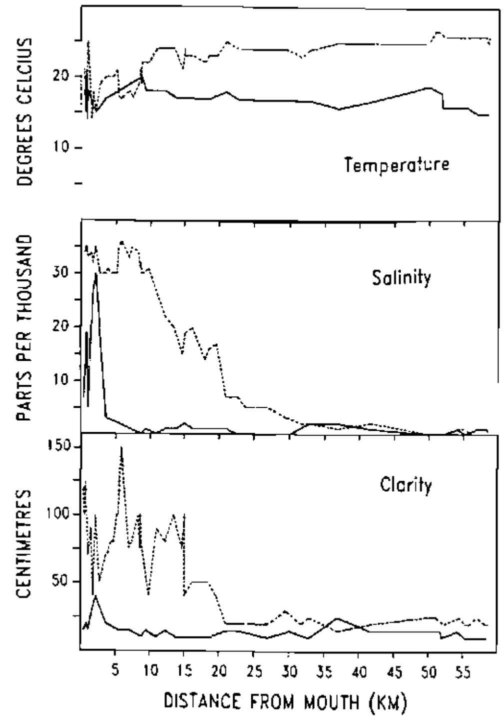

Figure 2 Water temperatures, salinities and clarities at increasing distances from the mouth of the Berg River estuary during the winter (solid line) and summer (broken line) surveys.

(14–15°C) and clear (100–125 cm). This sea-water influence was strongly evident for about 10 km upstream where all of the sampling sites, except those in backwaters off the main channel, had temperatures of <20°C, salinities of >30 ppt and a clarity of >70 cm. Between 10 and 20 km upstream temperatures were 21–23°C, salinities 16–30 ppt and clarity 40–100 cm. The marine influence was further attenuated for the following 10 km upstream where temperatures of 23–25°C, salinities of 3–7 ppt and clarities of 20–30 cm were measured. Above 30 km from the mouth, the water was warm (24–26°C), turbid (15–25cm) and fresh (0–2 ppt).

The fish community

A total of 81 665 fish representing 22 species were caught in 91 seine hauls during the winter and summer surveys (Table 1). The catch per haul of all species combined (899 summer and 895 winter) and the number of species (19 and 17) was similar in both surveys. *Liza richardsonii* was the most abundant species, providing almost 54% of the total catch and *Gilchristella aestuaria, Atherina breviceps* and *Caffrogobius nudiceps* each contributed more than 10%.

The species composition of catches varied quite markedly between the winter and summer surveys. The numerical contribution of *L. richardsonii* during the winter survey was almost double that recorded in the summer and that of

Table 1 The average catch per haul (CPH) and percentage composition (%N) of fish species recorded during winter and summer seine-netting surveys, and during both surveys combined, in the Berg River estuary

	Summer		Winter		Combined	
	CPH	%N	CPH	%N	CPH	%N
Liza richardsonii	362,29	40,31	666,64	74,45	482,69	53,79
Gilchristella aestuaria	144,71	16,10	151,75	16,95	147,49	16,44
Atherina breviceps	221,80	24,68	4,64	0,52	135,89	15,14
Caffrogobius nudiceps	135,56	15,08	40,19	4,49	97,48	10,90
Psammogobius knysnaensis	6,07	0,68	26,69	2,98	14,23	1,59
Clinus superciliosus	8,24	0,92	0,17	0,02	5,04	0,56
Syngnathus acus	3,02	0,34	3,53	0,39	3,22	0,36
Mugil cephalus	1,87	0,21	0,06	0,01	1,15	0,13
Rhinobatos annulatus	0,49	0,05	0,03	0,00	0,31	0,03
Pomatomus saltatrix	0,36	0,04	0,00	0,00	0,22	0,02
Caffrogobius multifasciatus	0,25	0,03	0,14	0,02	0,21	0,02
Solea bleekeri	0,20	0,02	0,00	0,00	0,12	0,01
Amblyrhynchotes honckenii	0,11	0,01	0,00	0,00	0,07	0,01
Cheilodonichthys capensis	0,00	0,00	0,11	0,01	0,04	0,00
Lichia amia	0,04	0,00	0,00	0,00	0,02	0,00
Rhabdosargus globiceps	0,00	0,00	0,03	0,00	0,01	0,00
Oreochromis mossambicus	10,25	1,14	0,08	0,01	6,23	0,69
Micropterus dolomieu	2,00	0,22	0,25	0,03	1,31	0,15
Lepomis macrochirus	0,87	0,10	0,78	0,09	0,84	0,09
Cyprinus carpio	0,58	0,06	0,14	0,02	0,41	0,05
Galaxias zebratus	0,00	0,00	0,17	0,02	0,07	0,01
Gambusia sp.	0,02	0,00	0,00	0,00	0,01	0,00
Catch per Haul	898,75		895,39		897,42	
No. of Hauls	55		36		91	
Total catch (N)	49 431		32 234		81 665	

Psammogobius knysnaensis was four times higher. A larger number of species exhibited the reverse pattern. *A. breviceps, C. nudiceps, Clinus superciliosus* and *Micropterus dolomieu*, for example, were all up to two orders of magnitude more abundant during the summer survey. Only *A. breviceps* and *Syngnathus acus* were caught at about equal rates in both surveys.

Marked differences in the distribution of species within the estuary were evident (Figure 3). Five of the species (*C. superciliosus, S. acus, C. nudiceps, A. breviceps* and *L. richardsonii*) were all most abundant in the lower reaches of the estuary but their upper limits varied. *Clinus superciliosus* was confined to within 5 km of the mouth, whereas *S. acus* and *C. nudiceps* were uncommon above 15 km, *A. breviceps* above 25 km and *L. richardsonii* above 45 km. The latter was the only species of marine origin recorded in the floodplain samples, where it occurred in low numbers (2–29 individuals), in all six of the samples.

Mugil cephalus, P. knysnaensis and *G. aestuaria* were the three common marine species which occurred primarily in the middle reaches of the estuary (Figure 3). Sporadic catches of low numbers of *M. cephalus* were recorded between 10 km from the mouth and the upper limit of the area sampled. This species was, however, most abundant in samples taken between 10 and 30 km. Relatively few *P. knysnaensis* were caught within 5 km of the mouth but large catches were frequently made between 5 and 35 km. None were recorded further upstream. *Gilchristella aestuaria* was recorded throughout the area sampled but was most abundant between 15 and 45 km. Freshwater species were recorded throughout the entire area upstream of 8 km from the mouth, although the majority occurred above 15 km. Most *Cyprinus carpio* were recorded between 20 and 45 km, but *Oreochromis mossambicus* was widely distributed over the area between 15 and 60 km. The abundance of *M. dolomieu* and *Lepomis macrochirus* increased upstream from 20 and 40 km, respectively. *Lepomis macrochirus* also occurred in one of the floodplain samples.

Ten species other than those listed in Figure 3 were caught sporadically and in low numbers. Two of the marine species, *Rhinobatus annulatus* and *Cheilodonichthys capensis*, were confined to samples found within 2 km of the mouth and the remaining six, *Pomatomus saltatrix, Solea bleekeri, Lichia amia, Amblyrhynchotes honckenii, Rhabdosargus globiceps* and *Caffrogobius multifasciatus* occurred between 8 and 35 km. The freshwater *Galaxias zebratus* was taken only in two of the floodplain samples and the single individual of *Gambusia* sp. was caught in the estuary 29,5 km from the mouth.

The distributions described above were the combined result of the occurrence of the species in both the surveys. For a number of the species, however, there were marked differences in distribution between the winter and summer surveys (Figure 3). Clear upstream shifts in the distribution of *S. acus* and *A. breviceps* occurred during the summer. Both species were present only in samples from within 5 km of the mouth during the winter survey, but they were common in samples up to 15 and 25 km, respectively, during summer. A similar pattern was exhibited by *C. superciliosus* which was taken only in one winter sample 0,5 km from the mouth but, during summer, it occurred in most samples up to 5 km. *Caffrogobius nudiceps, P. knysnaensis* and *G. aestuaria*, although not occurring further upstream during the summer, were all relatively more abundant in the upstream areas of the distribution ranges during that survey. *Liza richardsonii*, which occurred throughout

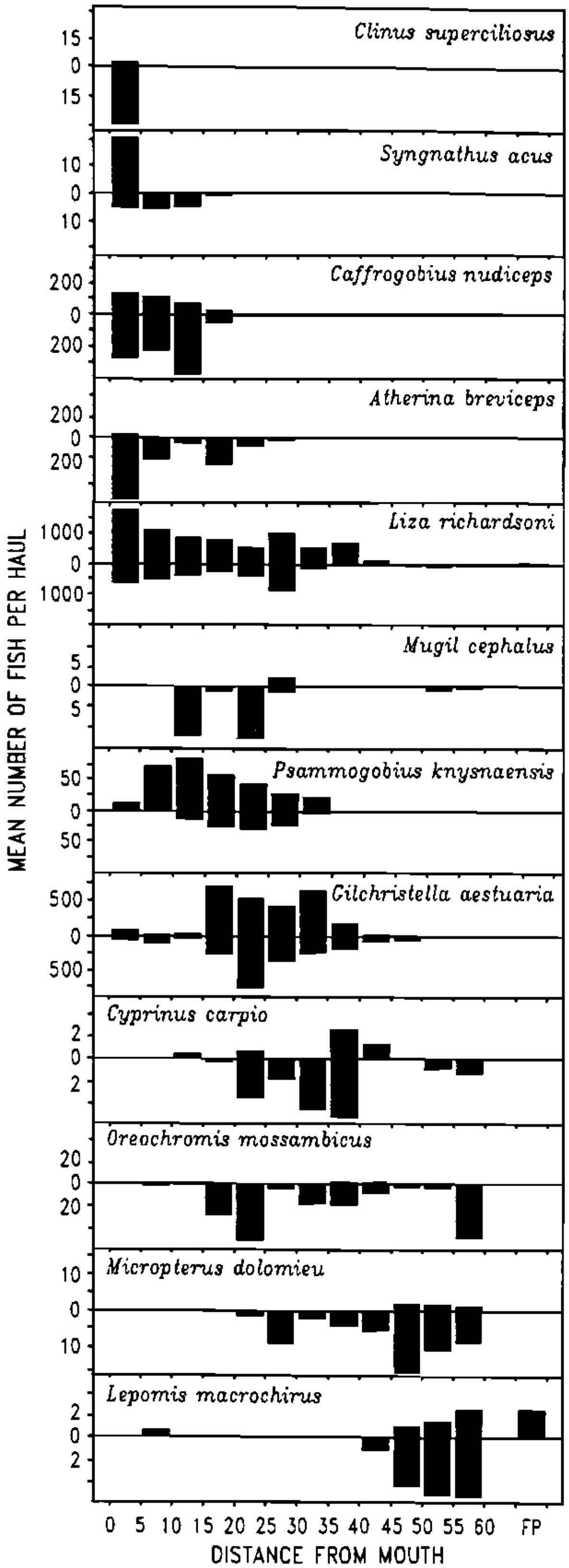

Figure 3 The distribution and density of the 12 most abundant fish species sampled in the Berg River estuary during the winter (upper) and summer (lower) surveys.

the study area during both surveys, was also relatively more abundant upstream during the summer.

Mugil cephalus and the freshwater species shown in Figure 3 were not sufficiently abundant during the winter to make satisfactory comparisons between the two surveys. The limited data available, however, indicate that *M. cephalus*, *C. carpio* and *L. macrochirus* occurred further upstream during the summer whereas *O. mossambicus* and *M. dolomieu* extended their ranges downstream.

Relationships between catches

Relationships between the individual samples according to their species composition and the abundances are shown in Figure 4. The samples form seven separate groups at the 60–65% level of similarity, and consist of three taken primarily during winter and four during summer. The winter groups are of samples taken in the upper reaches of the sampling area 50–60 km from the mouth, samples taken on the floodplain and a much larger group containing the majority of samples taken from between the estuary mouth and 40 km upstream. The summer samples are grouped consecutively according to the distances that were taken along the estuary, namely from 0–15, 15–23, 23–55 and from 55–60 km. The winter 0–40-km group and summer 15-23-km group are more similar to each other than they are to any other group and these two groups are more similar to the summer 0–15-km group than any of the groups from further upstream. The winter 50–60-km group and the floodplain samples are similar to each other, and all the other groups, only at a very low level.

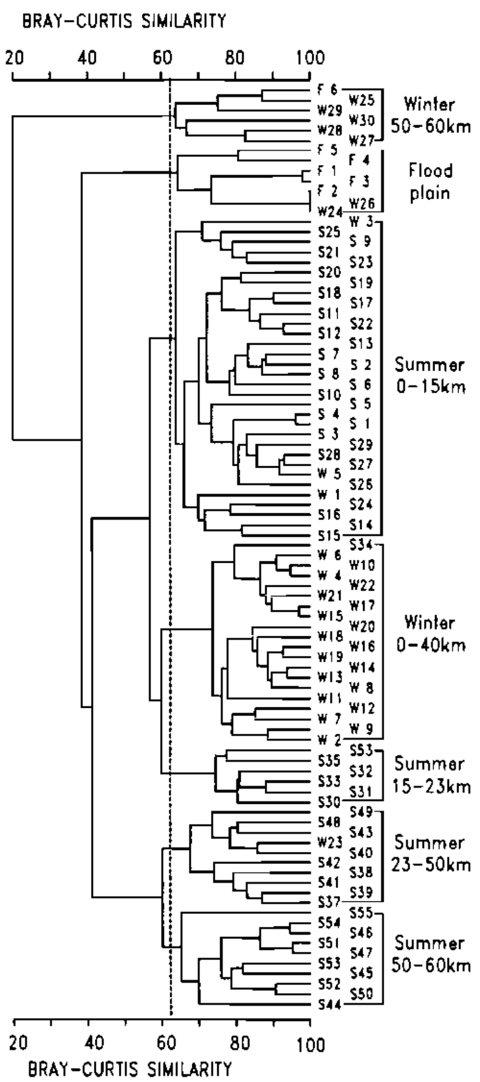

Figure 4 Dendrogram showing the similarities between the 91 seine net samples of fish from the Berg River estuary. The individual winter (W), floodplain (F) and summer (S) samples are numbered consecutively according to their distances from the estuary mouth.

Discussion

Estuaries are extremely important environments for many of the fish species that occupy them. Relative to the sea, estuaries are usually highly productive and have calm, shallow, turbid and warm waters, as well as low densities of piscivorous predators and lowered salinities; all features which result in more rapid growth and/or reduced mortalities among the fish occupying them (Potter, Beckley, Whitfield & Lenanton 1990). These advantages over the marine environment are sufficiently great for a number of South African species to be considered entirely dependent on estuaries during all or part of their life cycles (Wallace, Kok, Beckley, Bennett, Blaber & Whitfield 1984).

Thirty-one fish species have been recorded from the Berg River estuary, 22 during this study, an additional one during a gill net survey (Bennett unpub.), two others by Day *et al.* (1981) and a further six species by reliable fishermen (Table 2). A knowledge of the distribution and abundance of the species in the Berg and other Cape estuaries, as well as data on their origins and breeding biology, allows the subdivision of the species into four groups as suggested by Potter *et al.* (1990):

1. Estuarine residents — species that are able to complete their entire life cycles within estuaries
2. Marine estuarine-opportunists — species that breed in the sea and migrate into estuaries as juveniles where they remain for at least their first year before returning to the sea
3. Marine stragglers — marine species that occur only in the mouth area where salinities approximate sea-water strength
4. Freshwater species — primarily from the upper reaches of the estuary that they have entered via the river.

Only species that fall into the first two groups are able to utilize a large proportion of the range of conditions prevailing in the estuary and may therefore be considered 'true' estuarine species. Three of them, *Gilchristella aestuaria*, *Psammogobius knysnaensis* and *Caffrogobius multifasciatus* are considered by Wallace *et al.* (1984) to be entirely dependent on estuaries throughout their life cycles (category 1) and a further five (*Mugil cephalus*, *Rhabdosargus holubi*, *Lithognathus lithognathus*, *Monodactylus falciformis* and *Lichia amia*), are entirely dependent on estuaries as juveniles (category 2). The remaining nine true estuarine species fall into categories 3 and 4, i.e. they are either largely or partially dependent on estuaries. Eight of the estuarine species, therefore, rely to a large extent on the

Table 2 A list of all species recorded in the Berg River estuary during the present study (1), by Day *et al.* (1981) (2) and by reliable local fishermen (3). The species are subdivided into four groups (estuarine residents, marine estuarine-opportunists, marine stragglers and freshwater species) after Potter *et al.* (1990) and are classified according to their degree of dependence on estuaries as suggested by Wallace *et al.* (1984)

Species	Recorded by	Dependence category
Estuarine residents		
Gilchristella aestuaria	1,2	1
Atherina breviceps	1,2	3
Caffrogobius nudiceps	1,2	5
Psammogobius knysnaensis	1,2	1
Clinus superciliosus	1	5
Syngnathus acus	1,2	4
Caffrogobius multifasciatus	1	1
Solea bleekeri	1	3
Marine estuarine-opportunists		
Liza richardsonii	1,2	4
Pomatomus saltatrix	1,2	4
Galeichthys feliceps	1[1]	4
Mugil cephalus	1,2	2
Rhabdosargus globiceps	1,2	4
Monodactylus falciformis	2	2
Argyrosomus hololepidotus	3	4
Lichia amia	1,2	2
Rhabdosargus holubi	3	2
Lithognathus lithognathus	2	2
Ophisurus serpens	3	3
Marine stragglers		
Cheilodonichthys capensis	1	5
Rhinobatos annulatus	1	5
Amblyrhynchotes honckenii	1	5
Sardinops ocellata	3	5
Trachurus capensis	3	5
Spondyliosoma emarginatum	3	5
Freshwater species		
Galaxias zebratus	1	6
Gambusia sp.[2]	1	6
Lepomis macrochirus[2]	1	6
Micropterus dolomieu[2]	1	6
Cyprinus carpio[2]	1	6
Oreochromis mossambicus[2]	1	6

[1] Gill-net survey, Bennett unpublished

[2] Freshwater species not indigenous to the Berg River catchment

availability of suitable estuarine habitats for their continued survival, and the other nine species are at least partially dependent on this environment.

The 31 species recorded from the Berg River estuary is low relative to the 44 recorded in south-western Cape estuaries (Talbot 1955; Begg 1976; Bennett 1985; Bennett, Hamman, Branch & Thorne 1985; Bennett 1989), the 100 from the south-eastern Cape (Winter 1979; Marais 1981; 1983a; 1983b; Beckley 1983; 1984) and the 242 from Natal (Wallace 1975), suggesting that estuaries on the west coast might be relatively less important to the fish species of that region. However, this eastward increase in the number of species merely reflects the increasing trend in diversity, well-established for fish and a number of other taxa (Smith 1949; Stephenson & Stephenson 1972; Briggs 1974; Bennett 1987). The number of species in the Berg River estuary represents 79% of the total number of coastal species recorded in that region (calculated from distributions in Smith 1949). This percentage compares with values of between 49 and 52% for the other three areas of the South African coast, suggesting that estuaries are very important to coastal fishes of the West coast. Further analysis of the composition of the estuarine species in different areas supports this view. The Berg River estuary has a higher percentage of resident species, 26% as opposed to between 4 and 18% in the three other areas. It also has a higher proportion of species, considered by Wallace *et al.* (1984) to be entirely dependent (26% vs. 25, 22 and 9% in the south-western Cape, south-eastern Cape and Natal, respectively), and partially dependent on estuaries (29% vs. 27%, 25% and 18%).

This relatively high degree of reliance of the local fish fauna on the Berg River estuary indicates that any degradation of this habitat will have worse consequences for the fish on the west coast than similar impacts on estuaries elsewhere in southern Africa. This point has particular significance when one considers that the Berg River estuary is the larger of only two permanently open estuaries in the Namaqua marine biogeographical province.

The likely effects of dams

Dams in the catchment are likely to result in reduced volumes of water entering the estuary and a reduction in the frequency and magnitude of flooding. There are no data on the effects that these dams will have on the Berg River estuary, but work elsewhere (Whitfield & Bruton 1989) suggests that they potentially have marked negative effects on the estuary, and on their fish communities.

Reduced river flows are likely to result in a reduction in nutrients entering the estuary, and reduced flooding will lower the productivity of the floodplain and lessen the detrital input to the estuary. Reduced scouring of the estuary basin will result in the consolidation of sediments in the middle and upper reaches which will allow encroachment by marginal vegetation and eventually cause an overall reduction in the shallow marginal habitat favoured by many species. Marine sediments may accumulate in the lower reaches.

Reduced flushing of the system by fresh water will allow increased upstream penetration by sea-water and general increases in the salinity of the middle and lower reaches. This will cause an upstream shift in the polyhaline or 'true estuarine' zone and a reduction in its size. The occurrence of warm, turbid, low salinity plumes from the estuary into the adjacent sea will also be reduced, causing a reduction in the cues followed by migrant fish entering the estuary.

The accumulation of marine sediments will cause areas in the lower reaches to become shallower than areas further upstream. If strong vertical stratification occurs these deeper areas will fill with hypersaline water which may become stagnant and unsuitable for occupation by most species. Prolonged periods of minimal freshwater flow could result in the occurrence of hypersaline conditions throughout the middle and upper portions of the estuary. These conditions will result in mass mortalities among species unable to avoid them.

The relationship between the magnitude of freshwater reduction and its likely negative effects on the estuarine habitat, and consequently on the fish community, are unknown. There is no doubt that the estuary is already 'degraded' to some extent as the Berg River is already supplying the water needs of all the towns and agriculture in its catchment and is exporting water to supply Cape Town and Saldanha. Current annual freshwater inflows are 30% less than historical flows (Berg 1993). There are at least two artificial obstructions in the channel and three road and rail embankments across the floodplain. There have also been substantial changes in the lower reaches. The position of the mouth has been moved and stabilized, the channel is frequently dredged, and saltworks cover large areas of the floodplain. These changes have already manifested themselves in increased upstream penetration of salt water (Fisheries Development Corporation 1973), a loss of diversity and a changed species composition among benthic invertebrates (Hockey 1993) and have decreased commercial gill-net catches in the estuary (Schrauwen 1993).

There are no baseline data with which to compare the species composition, distributions and abundance observed during the course of this study, but it is likely that the ecological interactions leading to the current community composition are different to those prevailing a few decades ago. There is no doubt that general reductions in the stocks of estuarine-associated angling species have occurred around southern Africa since the mid-1960s (Van der Elst 1989; Bennett 1991), a fact attributable to estuarine degradation (Wallace *et al.* 1984; Bennett 1993). Thus, when one considers that the Berg is probably the most important estuary to fish on the west coast, no further disturbance of this habitat should be considered. In fact, it could be argued that money should be spent on its rehabilitation.

While maintaining the view that no further reduction in freshwater supply to the estuary is desirable, it is realized that, in financial terms, the value of the Berg River's water to Cape Town will considerably outweigh the value of the catch of fish that utilize the estuary. It is inevitable, therefore, that unless a cheaper scource of water is located, or unless the population can be persuaded to pay more for water obtained from other sources, the Berg River will be damned. Given that dams will be built, the minimum freshwater requirements to maintain the estuarine habitat in a condition that will not result in a significant alteration of the fish community are approximately as follows:

1. A series of 'small' floods between mid-June and mid-August of sufficient volume and duration to result in inundation of the floodplain to 'average' levels, and sufficient frequency to ensure water in at least the low-lying pools throughout this period.
2. A single 'major' flood in mid-August (preferably every year, but at least every five years) of sufficient intensity and duration to ensure no abnormal accumulations of sediment in any part of the estuary.
3. Continual flows throughout the year of sufficient volume to ensure that surface salinities of 34 ppt do not occur more than 15 km from the mouth, and bottom salinities of 5 ppt do not occur above 45 km. These flows should also ensure that salinities of more than 45 ppt never occur in any part of the estuary and that surface salinities of less than 30 ppt occur at the mouth during outgoing tides between September and December, and at least during the last hour of outgoing spring tides for the remainder of the dry season.

The actual flows necessary to meet these requirements are only likely to be quantified once the dams are in place and correlations between salinity, sedimentation and freshwater flows can be established. It is extremely important, therefore, that the developers commit themselves to maintaining the requirements of the estuarine communities before the dams are constructed. They must also be aware that, in some years, the estuary will require the entire river flow as this represents the minimum requirements to which the estuarine communities are adapted.

Acknowledgements

I would like to thank all those who helped during the netting surveys, with the processing of the data and with the preparation of the manuscript. This work was funded by the Department of Water Affairs and Forestry.

References

BECKLEY, L.E. 1983. The ichthyofauna associated with *Zostera capensis* Setchell in the Swartkops estuary, South Africa. *S. Afr. J. Zool.* 18: 15–24.

BECKLEY, L.E. 1984. The ichthyofauna of the Sundays estuary, South Africa, with particular reference to the juvenile marine component. *Estuaries* 7: 248–250.

BEGG, J.W. 1976. Some notes on the Sandvlei fish fauna, Muizenberg Cape. *Piscator* 96: 4–14.

BENNETT, B.A. 1985. A mass mortality of fish associated with low salinity conditions in the Bot River estuary. *Trans. Roy. Soc. S. Afr.* 45: 437–448.

BENNETT, B.A. 1987. The rock-pool fish community of Koppie Alleen and an assessment of the importance of Cape rock-pools as nurseries for juvenile fish. *S. Afr. J. Zool.* 22: 25–32.

BENNETT, B.A. 1989. A comparison of the fish communities in the nearby permanently open, seasonally open and normally closed estuaries in the south-western Cape, South Africa. *S. Afr. J. Mar. Sci.* 8: 43–55.

BENNETT, B.A. 1991. Long-term trends in the catches by shore anglers in False Bay. *Trans. Roy. Soc. S. Afr.* 47: 683–692.

BENNETT, B.A. 1993. Aspects of the biology and life history of white steenbras *Lithognathus lithognathus* in southern Africa. *S. Afr. J. Mar. Sci.* 13: 83–96.

BENNETT, B.A., HAMMAN, K.C.D., BRANCH, G.M. & THORNE, S.C. 1985. Changes in the fish fauna of the Bot River estuary in relation to the opening and closure of the estuary mouth. *Trans. Roy. Soc. S. Afr.* 45: 449–464.

BERG, R.R. 1993. Hydrology of the Berg River estuary. Unpub. report to the Dept. of Water Affairs and Forestry, 14 pp.

BRIGGS, J.C. 1974. Marine zoogeography. McGraw-Hill, New York, 475 pp.

DAY, J.H. 1981. Summaries of current knowledge of 43 estuaries in southern Africa. In: Estuarine ecology with particular reference to southern Africa, (ed.) J.H. Day, pp. 251– 329. A.A. Balkema, Rotterdam.

DAY, J.H., BLABER, S.J.M. & WALLACE, J.H. 1981. Estuarine fishes. In: Estuarine ecology with particular reference to southern Africa, (ed.) J.H. Day, pp. 197–222. A.A. Balkema, Rotterdam.

FIELD, J.G., CLARKE, K.R. & WARWICK, R.M. 1982. A practical strategy for analysing multi-species distribution patterns. *Mar. Ecol. Prog. Ser.* 8: 37–52.

FISHERIES DEVELOPMENT CORPORATION 1973. Berg River salinity. *Fish. Develop. Corp. S. Afr.* 22-1: 1–34.

GAUCH, H.G. 1982. Multivariate analyses in community ecology. Cambridge University Press, Cambridge.

HOCKEY, P.A.R. 1993. Benthic aquatic invertebrates of the lower Berg River: current status and implications of altered flow regimes. Unpub. report to the Dept. Water Affairs and Forestry, 10 pp.

MARAIS, J.F.K. 1981. Seasonal abundance, distribution and catch per unit effort using gill-nets, of fishes in the Sunday's estuary. *S. Afr. J. Zool.* 16: 71–72.

MARAIS, J.F.K. 1983a. Seasonal abundance, distribution and catch per unit effort of fishes in the Krom estuary, South Africa. *S. Afr. J. Zool.* 18: 31–36.

MARAIS, J.F.K. 1983b. Fish abundance and distribution in the Gamtoos estuary with notes on the effects of floods. *S. Afr. J. Zool.* 18: 103–109.

MILLARD, N.A.H. & SCOTT, K.M.F. 1954. The ecology of South African estuaries. Part 5: Richards Bay. *Trans. Roy. Soc. S. Afr.* 34: 279–324.

POTTER, I.C., BECKLEY, L.E., WHITFIELD, A.K. & LENANTON, R.C.J. 1990. Comparisons between the roles played by estuaries in the life cycles of fishes in temperate Western Australia and southern Africa. *Env. Biol. Fish.* 28: 143–178.

SCHRAUWEN, Y. 1993. Socio-economics for the Berg River estuary directly associated with the natural environment. Unpub. report to the Dept. Water Affairs and Forestry, 6 pp.

SMITH, J.L.B. 1949. The sea fishes of southern Africa. Central News Agency, Cape Town, 550 pp.

STEPHENSON, T.A. & STEPHENSON, A. 1972. Life between tide marks on rocky shores. W.H. Freeman, San Francisco, 425 pp.

TALBOT, F.H. 1955. Notes on the biology of the white stumpnose, *Rhabdosargus globiceps* (Cuvier), and on the fish fauna of the Klein River estuary. *Trans. Roy. Soc. S. Afr.* 34: 387–407.

VAN DER ELST, R.P. 1989. Marine recreational angling in South Africa. In: Oceans of life off southern Africa, (eds) A.I.L. Payne, R.J.M. Crawford, pp. 164–176. Vlaeberg Publishers, Cape Town.

WALLACE, J.H. 1975. The estuarine fishes of the east coast of South Africa. Part 1: Species composition and length distribution in the estuarine and marine environments. Part 2: Seasonal abundance and migrations. *Investl. Rep. oceanogr. Res. Inst.* 40: 1–72.

WALLACE, J.H., KOK, H.M., BECKLEY, L.E., BENNETT, B.A., BLABER, S.J.M. & WHITFIELD, A.K. 1984. South African estuaries and their importance to fishes. *S. Afr. J. Sci.* 80: 203–207.

WHITFIELD, A.K. & BRUTON, M.N. 1989. Some biological implications of reduced freshwater inflow into eastern Cape estuaries: a preliminary assessment. *S. Afr. J. Sci.* 85: 691–695.

WHITFIELD, A.K. 1991. A bibliography of South African estuarine research (1950–1990). *Investl. Rep. J.L.B. Smith Inst. Ichthyol.* 36: 1–75.

WHITFIELD, A.K., BECKLEY, L.E., BENNETT, B.A., BRANCH, G.M., KOK, H.M., POTTER, I.C. & VAN DER ELST, R.P. 1989. Composition, species richness and the similarity of ichthyofaunas in eelgrass *Zostera capensis* beds of southern Africa. *S.Afr. J. Mar. Sci.* 8: 251–259.

WINTER, P.E.D. 1979. Studies on the distribution, seasonal abundance and diversity of the Swartkops estuary ichthyofauna. M.Sc. thesis, University of Port Elizabeth, South Africa.