Report No: P WMA
19/G10/00/2413/3

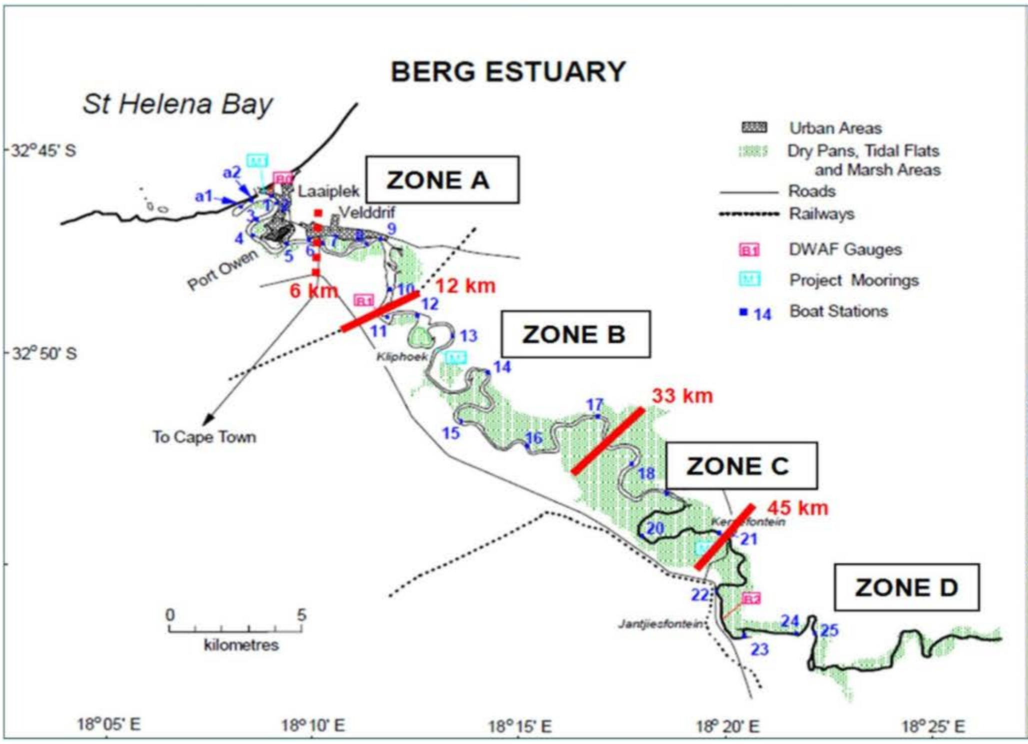
Department of Water Affairs
Directorate: Options Analysis

PRE-FEASIBILITY AND FEASIBILITY STUDIES FOR AUGMENTATION OF THE WESTERN CAPE WATER SUPPLY SYSTEM BY MEANS OF FURTHER SURFACE WATER DEVELOPMENTS

REPORT No.1 – VOLUME 3
Berg Estuary Environmental Water Requirements

APPENDIX No.G

Specialist Report - Fish




June 2012

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RECORD OF IMPLEMENTATION DECISIONS
PWMA19 G10/00/2413/7

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1 INTRODUCTION

The vast majority of coastal habitat in southern Africa is directly exposed to the open ocean, and as such is subject to intensive wave action throughout the year (Field & Griffiths 1991, Beckley 1984). Estuaries in southern Africa, however, offer a markedly different type of habitat in that they constitute the bulk of the sheltered, shallow water inshore habitat in the region. As such they represent an extremely important habitat for the region's fauna and flora that favour or requires access to sheltered marine habitats. Benefits provided by estuaries are not restricted to shelter from wave action and also include improved access to food resources associated with elevated nutrient concentrations, high primary productivity, elevated water temperatures that are conducive to rapid growth, and expansive areas of shallow and turbid water that offer some protection from predators (Wallace 1975, Claridge *et al*. 1986, Potter *et al*. 1990, Whitfield & Kok 1992). There are certain drawbacks associated with estuaries though, including the fact that they are highly variable in terms of their physico-chemical make-up (Whitfield 1983). Most importantly, the salinity of estuarine waters can vary from fresh (0 PSU) to hypersaline (40+ PSU) in a very short time, placing significant physiological strain on organisms living in these environments. Variations in temperature and dissolved oxygen concentration are similarly high and together with salinity severely limit the range of organisms that are able to make use of these habitats.

Marine fish species are a case in point, many having acquired the necessary adaptations to enable them to utilise estuaries for at least part of their life cycles. Indeed, Whitfield (1998) identified at least 100 species that show a clear association with estuaries in South Africa. Most of these are juveniles of marine species that enter estuaries as post-flexion larvae, where they remain for up to a year or more before returning to the marine environment as adults or sub-adults to spawn and hence complete their life cycles. Other fish species that use estuaries in southern Africa include some that are able to complete their entire life cycles in these systems, as well as a limited range of salt tolerant freshwater species, and a wider group of euryhaline marine species.

Estuaries in southern Africa take a range of different forms, distinguished mostly by their links to the open sea and freshwater inputs. Most authors recognise two major types of estuaries, namely permanently open systems (with a permanent connection to the sea) and temporally open-closed systems that are periodically cut off from the sea owing to the formation of a sand bar across their mouth. The Berg estuary is one of only three permanently open systems on the west coast of South Africa, and is rated as being one of the most important in the country from a conservation perspective (Turpie *et al*. 2002). Fish fauna inhabiting this system have been studied by a number of authors in the past (Day *et al*. 1981, Bennett 1993, Harrison 1997), all of whom have highlighted the importance of this system to the inshore marine fish fauna of the region. Some (e.g. Bennett 1993) have speculated on links between freshwater flow and the abundance of fish within the system but have not managed to significantly enhance understanding in this sphere owing to the limited temporal coverage of their sampling.

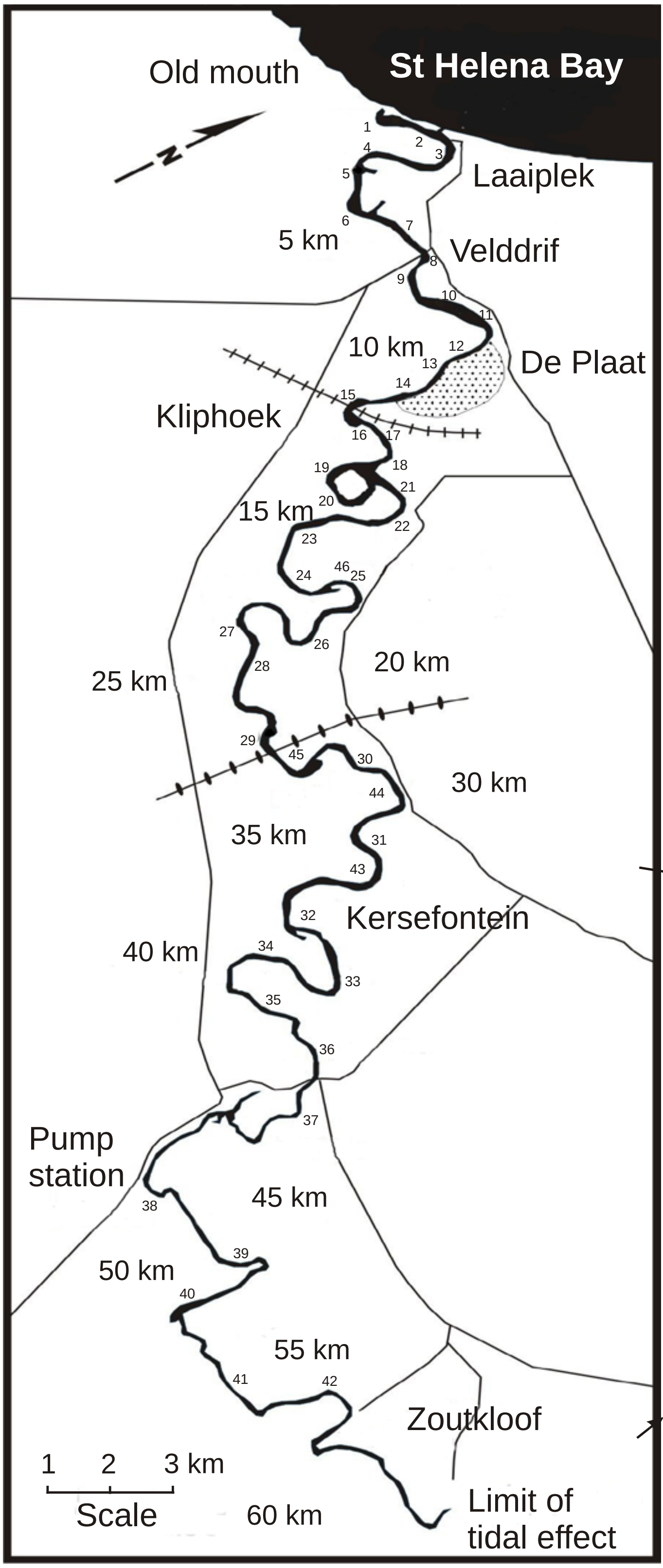

Figure 1.1 Fish sampling sites along Berg River estuary for the BRBMP. Sites 1-42 are all on the edge of the main channel , while 43-46 were located in pans on the floodplain.

Recent focus on the Berg estuary under the auspices of the Berg River Baseline Monitoring Programme (BRBMP) commissioned by the Department of Water Affairs and Forestry has now elevated the Berg estuary as one of the best studied large, permanently open estuarine systems in the country. Drawing on data from this monitoring programme and earlier surveys spanning a period of more than ten years, this report provides a detailed analysis of the variations in abundance, community structure and size composition of the fish fauna of the Berg estuary in relation to intra- and inter-annual changes in freshwater flow and other physico-chemical parameters.

2 METHODS

2.1 Study Area

The Berg River estuary is situated at 32°46'S, 18°09'E, approximately 120 km north of Cape Town near the towns of Laaiplek and Velddrif. The Berg River is the largest river in the Western Cape, a region that experiences long, dry summer seasons followed by elevated river flows driven by winter rainfall (Bennett 1993). The effects of the ocean tidal cycle can be measured up to 65 km from the mouth (Day 1981), making it one of the longest and largest estuaries in the country. The nature of the estuary channel changes from the mouth moving upstream. The lower reaches (last 15 km towards the mouth) have a moderately wide channel (up to 1.5 km in width) dominated with tidal mudflats, while the middle reaches flow through a broad channel in a seasonal flood plain of between 1.5 and 4 km wide. The channel in the upper 15 km of the estuary is much narrower (mostly less than 100 m wide) and is bounded by steep banks vegetated with riparian woodland.

Until 1966 the Berg River mouth was naturally located approximately 1 km to the south of its current position (Harrison 1997). In order for the estuary to be used as a fishing harbour, a new mouth was cut through the sand dunes in 1966 and the channel stabilized between three concrete breakwaters. The new channel is dredged to a minimum depth of 4 m, thus allowing the passage of purse-seine boats into the estuary (Bennett 1993). The original mouth rapidly silted up and created a lagoon running parallel to the coast (Figure 1.1).

2.2 Sampling methods

Fish populations in the Berg estuary were sampled on nine occasions for the Berg River Baseline Monitoring Programme:

- February 2003 (Summer)
- August 2003 (Winter)
- February 2004 (Summer)
- August 2004 (Winter)
- Feb 2005 (Summer)
- May 2005 (Autumn)
- August 2005 (Winter)
- November 2005 (Spring)
- Feb 2006 (Summer)

On each occasion, between 42 and 46 sites, covering a distance of 64 km, were sampled with a 30-m long, 12 mm stretched-mesh beach seine net (Figure 1.1). The net was laid from a small rowing boat, parallel to the shore and hauled shorewards by 5-8 persons. The distance at which the net was laid offshore, and hence the size of the sampling area, varied depending on the prevailing conditions at each site. All fish were removed from the net after it had been hauled to the shore, sorted into species, counted, weighed and measured (up to 100 individuals of each species). Large catches were sub-sampled on site to avoid unnecessary mortality of fish.

A fleet of gill nets was also deployed to sample fish fauna during the 2005 and 2006 field excursions. A total of 9 sites were surveyed on each occasion using a fleet of monofilament gill nets with 7 by 100m length mesh panels with mesh sizes of 44, 48, 51, 54, 75, 100, 145 mm stretched mesh. Nets were left to soak for a period of 1 hour at each site before being retrieved, cleaned of fish and other debris and reset.

Historical estuarine ichthyofaunal data from the Berg River were obtained from a number of discreet studies that examined the abundance, size frequency and distribution of fishes within the Berg River estuary. Some of these (a total of four studies) represented detailed surveys in which > 30 samples were collected, and the whole, or at least the greater part of the estuary was sampled. These provided data comparable with that collected during the baseline study and were analysed in conjunction with the baseline data. For simplicity and clarity in this paper the four historical studies are referred to as Winter 1992 and Summer 1993 (from Bennett 1993) and Summer 1994 and Summer 1996 (S. Lamberth & B. Clark unpublished data). Other published studies that provided less comprehensive data, including those by Day *et al*. (1981) and Harrison (1997), were also used in compiling a description of the Berg estuary ichthyofauna, but were not used for detailed comparisons.

Attempts were made to align the sampling methods employed for the current Berg River Baseline Monitoring Programme as closely as possible with that of the historical sampling procedures. The number of hauls taken (sites sampled) varied between the seasons (due to additional floodplain sampling during winters) and between the different studies. The exact location of sites sampled also varied between studies conducted by different researchers and for analysis and comparative purposes, data were analysed in relation to distance upstream. Details of the current and historical studies referred to in this report are presented in Table 3.1.

2.3 Classification of the fish fauna

The classification system developed by Whitfield (1994) was employed to subdivide the fish fauna of the Berg estuary into functional groups to enhance understanding of observed changes in community structure and abundance. Five major categories of estuary associated fish species and several subcategories are recognized under this system:

I. Estuarine species breeding in estuaries, further divided into:
   - Ia: Resident species not recorded spawning in marine or freshwater environment
   - Ib: Resident species also having marine and/or freshwater breeding populations

II. Euryhaline marine species usually breeding at sea with juveniles showing varying degrees of dependence on estuaries, further divided into:
   - IIa Juveniles dependent on estuaries as nursery areas
   - IIb Juveniles occurring mainly in estuaries, but also found at sea
   - IIc Juveniles occur mainly at sea, but also found in estuaries

III. Marine species that occur in estuaries in small numbers but are not dependent on estuaries

IV. Euryhaline freshwater species whose penetration into estuaries is determined primarily by salinity tolerance. Includes some species which may breed in both freshwater and estuaries

V. Catadromous species which use estuaries as transit routes between the marine and freshwater environments but may also occupy estuaries in certain regions, further 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 but use estuaries as nursery areas

Fish species in categories I, IIa and b, and V as defined by Whitfield (1994) are all wholly or largely dependent on estuaries for their survival and are hence the most important from an estuary conservation perspective. These species received most attention in this study.

2.4 Data Analysis

Analysis of all data for this study was undertaken using Microsoft Excel and the PRIMER (V5) software package. Data were root-root transformed for the Primer multivariate analyses, and similarity matrices constructed using the Bray-Curtis index and group average linkages as per recommendations from Clarke and Warwick (1994).

3 RESULTS

3.1 Physico-chemical characteristics of the estuary

Physico-chemical characteristics of the Berg estuary are reported on in detail by Beck & Basson (2007), Schumann (in press), Schumann & Brink (in press) and Clark & Taljaard (in press). Freshwater flows to the estuary are strongly seasonal, being lowest from December to March and peak between July and September (Figure 3.1). The salinity structure of the system responds strongly to the seasonal patterns in flow, with saltwater influences extending as far as 45 km upstream in summer but changing to a highly compressed system in winter with marine water influences extending not more than 10 km upstream (Figure 3.2). The timing of the sampling events in relation to the freshwater flow in the estuary is indicated in Figure 3.3. Winter sampling events generally corresponded with high flow periods, while the summer, autumn and spring sampling events corresponded with low flow periods.

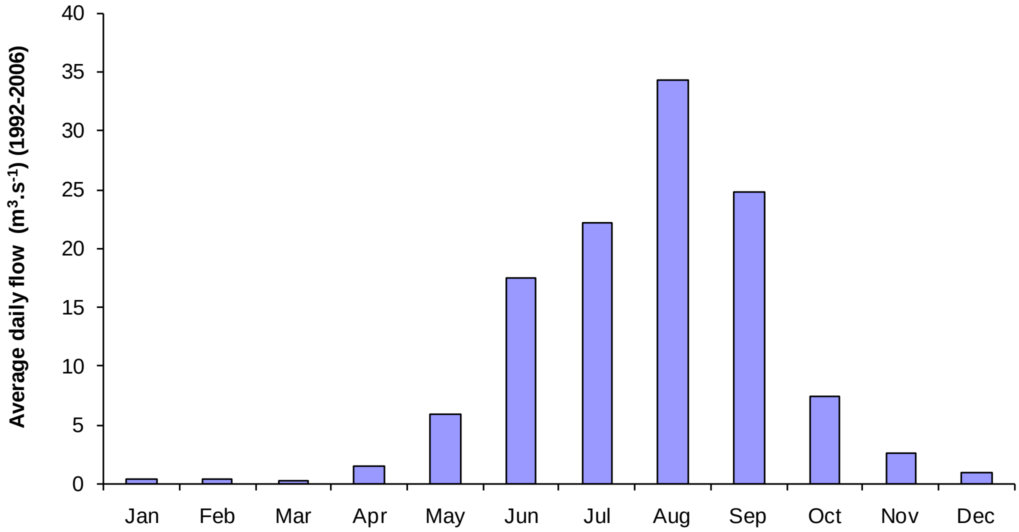

Figure 3.1 Variation in average daily freshwater discharge to the Berg River Estuary, 1992-2006, measured at Misverstand. (Data from Department of Water Affairs & Forestry)

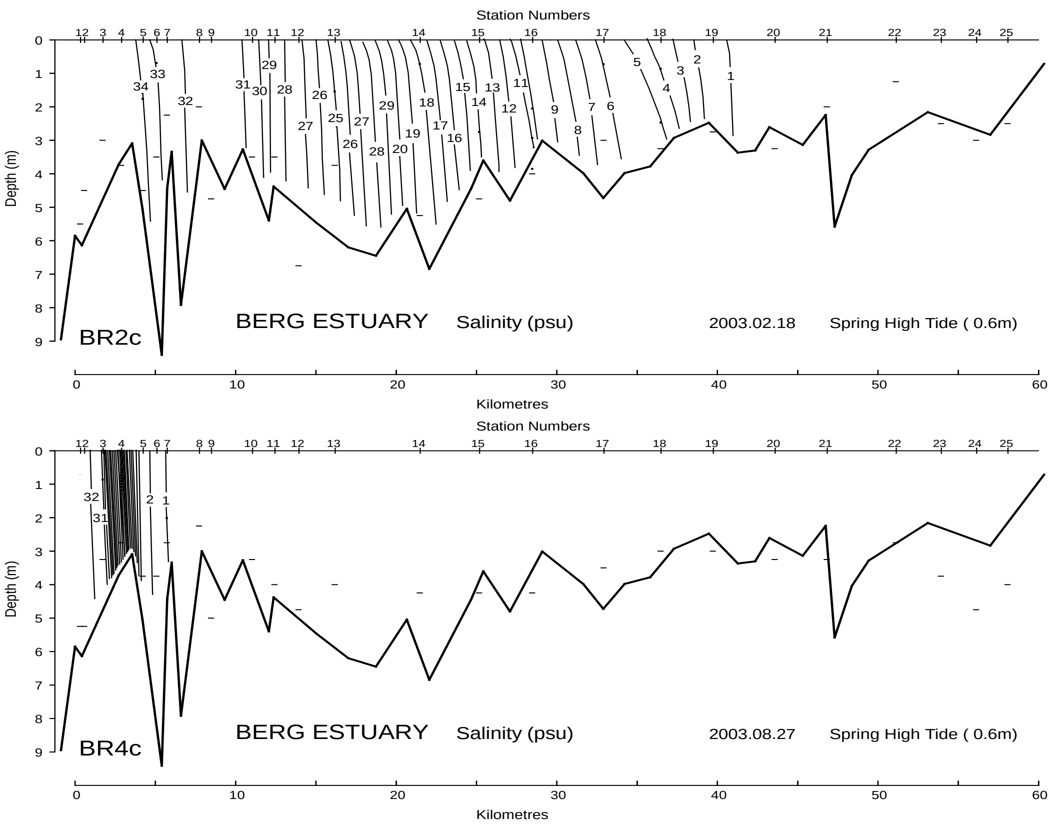

Figure 3.2. Typical salinity structure of the Berg River Estuary in Summer (top) and winter (bottom) (after Schuman 2007).

3.2 Species composition and abundance – seine net hauls

Available data on fish composition in the Berg River estuary includes seven summer (1993, 1994, 1996, 2003, 2004, 2005, 2006), four winter (1992, 2003, 2004, 2005), one spring (2005) and one autumn (2005) collection. The number of sites sampled on each occasion ranged from 55

(Summer 1993) to 32 (Summer 1994 and 1996) with the maximum distance of 64 km upstream being sampled during Summer 2003, Winter 2003, Winter 2005, Spring 2005 and Winter 2006, and a minimum distance of 37 km upstream being sampled during Summer 1994 and 1996. The total area sampled in each study also varied considerably from 7 325 to 15 975 m2 (Table 3.1). The total number of fish collected during each sampling event varied by more than 10-fold, from 20 402 (Summer 1996) to 243 226 (Summer 2006) (Table 3.2). Biomass of fish landed (only recorded from 2003 onwards) was similarly variable, ranging from 80-490 kg, while the number of species recorded ranged from 14-23 species (Table 3.3).

Table 3.1 Detailed historical and current ichthyofauna monitoring studies of the Berg River estuary. BRBMP = Berg River Baseline Monitoring Programme.

Researcher	Bennett (1993)	Bennett (1993)	Lamberth & Clark (unpubl.)	Lamberth & Clark (unpubl.)	BRBMP	BRBMP	BRBMP	BRBMP	BRBMP	BRBMP	BRBMP	BRBMP	BRBMP
Year	1992	1993	1994	1996	2003	2003	2004	2004	2005	2005	2005	2005	2006
Season	Winter	Summer	Summer	Summer	Summer	Winter	Summer	Winter	Summer	Autumn	Winter	Spring	Summer
Month	Sep	Jan	Mar	Feb	Feb	Aug	Feb	Aug	Feb	May	Aug	Nov	Feb
No. seine hauls	34	55	32	32	42	46	41	41	39	39	42	40	42
No gill net sets	-	-	-	-	-	-	-	-	9	9	9	9	9
Total area (m^2)	12 210	16 385	9 950	9 125	15 975	13 175	8 440	7600	8 588	7 325	7 950	9 750	9 225
No. species	16	18	14	16	18	15	22	16	20	17	15	22	17
Total fish*	32 234	49 431	52 297	20 402	47 310	27 227	50 599	45 622	50 241	36 396	58 351	105 040	243 226
Total biomass (g)	-	-	-	-	164 689	56 019	422 824	79 762	189 936	102 521	92 581	460 722	490 051
Distance upstream sampled (km)	64	59	37	37	64	64	62	54	62	62	64	64	64

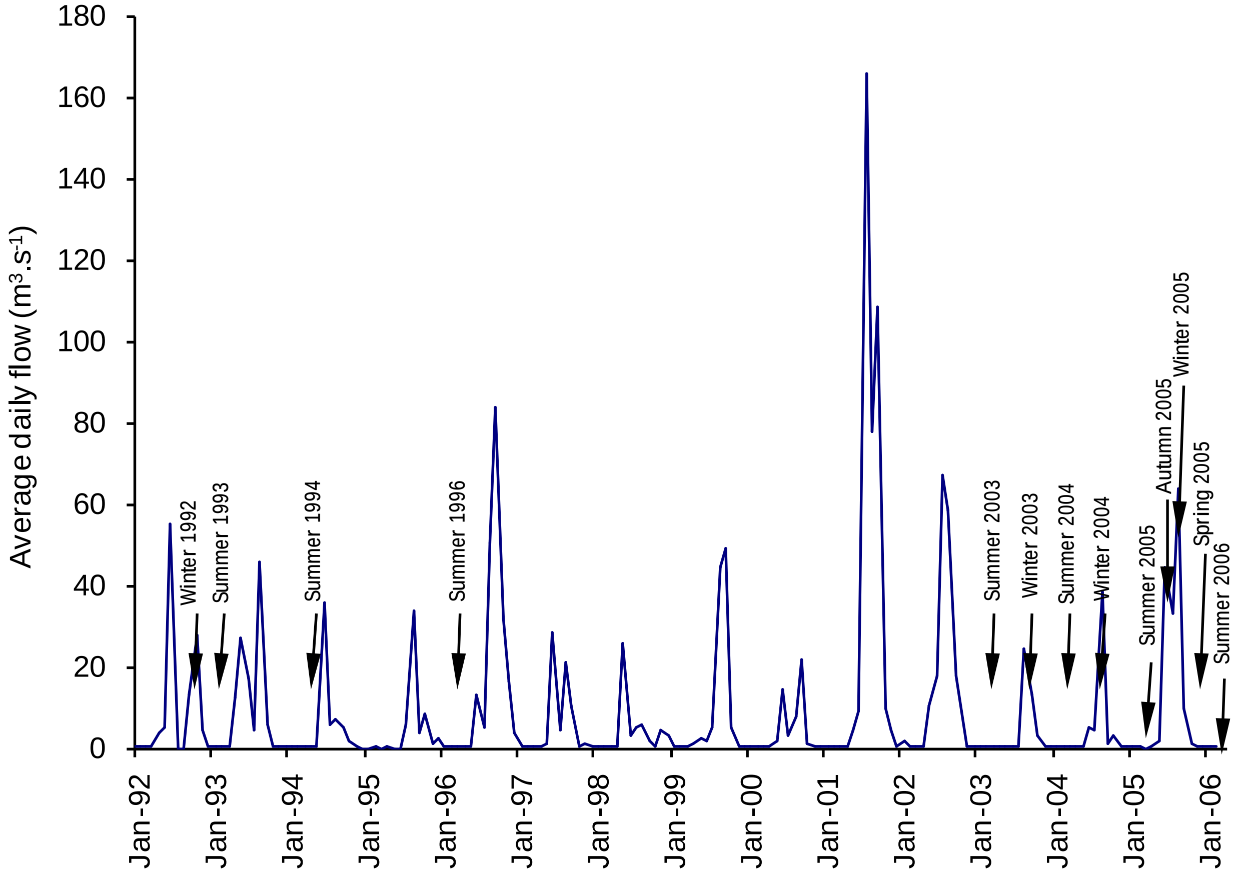

Figure 3.3 Timing of fish sampling events in relation to freshwater discharge into the estuary.

A number of interesting trends were evident in these three parameters (abundance, biomass and species richness) over the course of the study period (Figure 3.4). Firstly, abundance (measured as no. ind. m^{-2}) seems to have increased over the study period with an initial modest increase from 2004 onwards followed by a more marked increased from winter 2005 onwards. Species richness (measured as number of species recorded) exhibited a modest increase over the entire study period, from around 14-18 species between 1992 and 2003, rising to between 17 and 23 species from 2004 onwards. Some seasonal variability was also evident in the catches with typically fewer species and lower biomass recorded in the winter and autumn samples compared with summer and spring catches. No seasonal trend was evident in abundance, however.

Variation in abundance and species richness of the various categories of estuary associated fish species over the period 1992 to 2006 is shown in Figure 3.5. Abundance of Category 1a estuarine residents (breeding only in estuaries) were low through the study except in 1993 and 2004 when numbers were slightly elevated. Category 1b species (those able to breed in estuaries and the sea) showed a consistent increase in abundance with time while the Category 1a species in. By contrast, the marine migrant species (particularly the category IIc species – those whose juveniles are more abundant at sea than in estuaries) varied dramatically in abundance over the study period accounting for much of the variability observed in the overall abundance of fish in the estuary. Abundance of these species varied without any apparent link to season at modest levels (0.5-6.7 ind. m^{-2}) between 1992 and 2005 but rose dramatically in the last year of sampling (2006 – up to 85.2 ind. m^{-2}). Variation in species richness (number of species) of the various categories of estuary associated fish species is shown in Figure 3.6. The numbers of estuary associated marine species (notably categories IIb and III) increased slightly during the latter part of the sampling programme (2004-2007 vs. 1992-1996) whereas numbers of resident (category 1a and b) and freshwater species (category IV) remained relatively constant over this period.

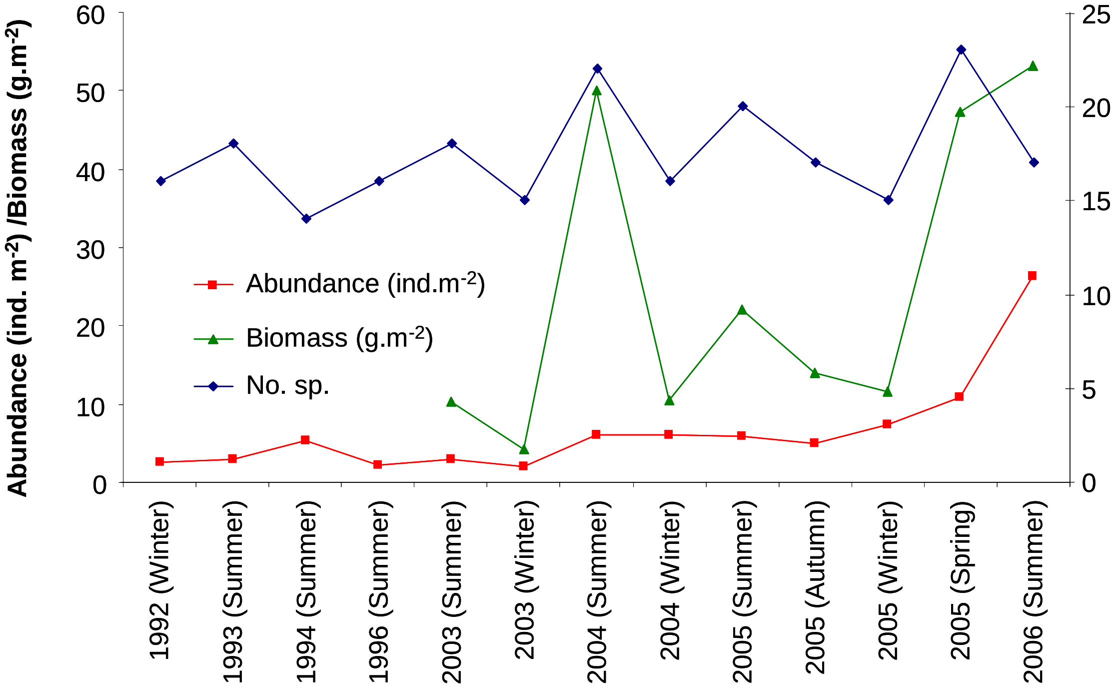

Figure 3.4 Variation in abundance, biomass and species richness recorded in seine net surveys of the Berg River Estuary between 1992 and 2006.

In terms of species composition, *Liza richardsonii* (southern mullet) was the most abundant species overall, making up 25-85% of the catches (overall average: 59%), followed by *Gilchristella aestuaria* (estuarine round herring) (3-58% of the catches, 22% overall), *Atherina breviceps* (silverside) (0-25%, 8% overall), *Psammogobius knysnaensis (*Knysna sand goby) (0-8%, 3% overall), *Caffrogobius nudiceps* (nude goby) (0-6%, 2% overall) and *Oreochromis mossambicus* Mozambique tilapia (0-14%, 2% overall) (Table 3.2, Figure 3.7). Together these six species accounted for 93-99% of the catches in each year (overall average: 97%). Contributions by the different species to total abundance varied from year to year and between seasons without any clearly discernable patterns (Figure 3.7). The relative contribution by numbers of fish in the various estuary dependence categories defined by Whitfield (1994) also exhibited no clearly discernable pattern from year to year, or between seasons (Figure 3.7). However, variations in the relative abundance of the various categories of estuarine associated fish species were clearly a function of variations in the abundance of the dominant fish species themselves rather than in the component species as a whole (Figure 3.7).

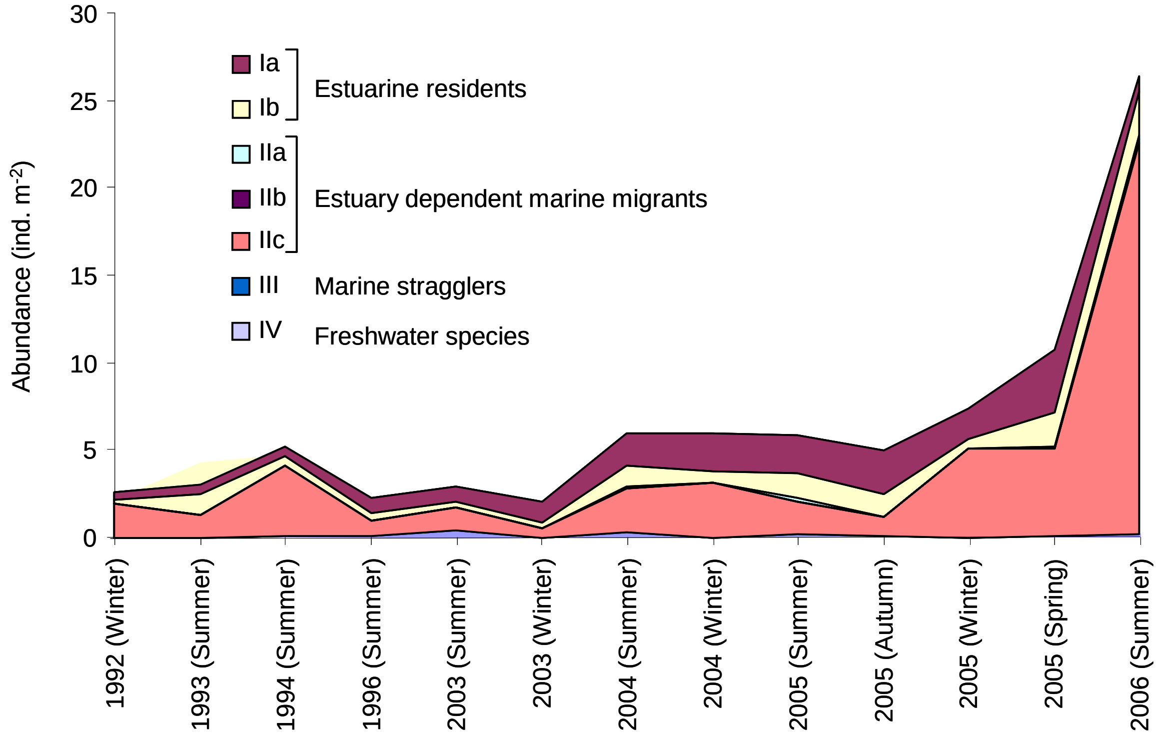

Figure 3.5 Contribution by various categories of estuary associated fish species (sensu Whitfield 1994) to total abundance in the Berg River estuary 1992-2006.

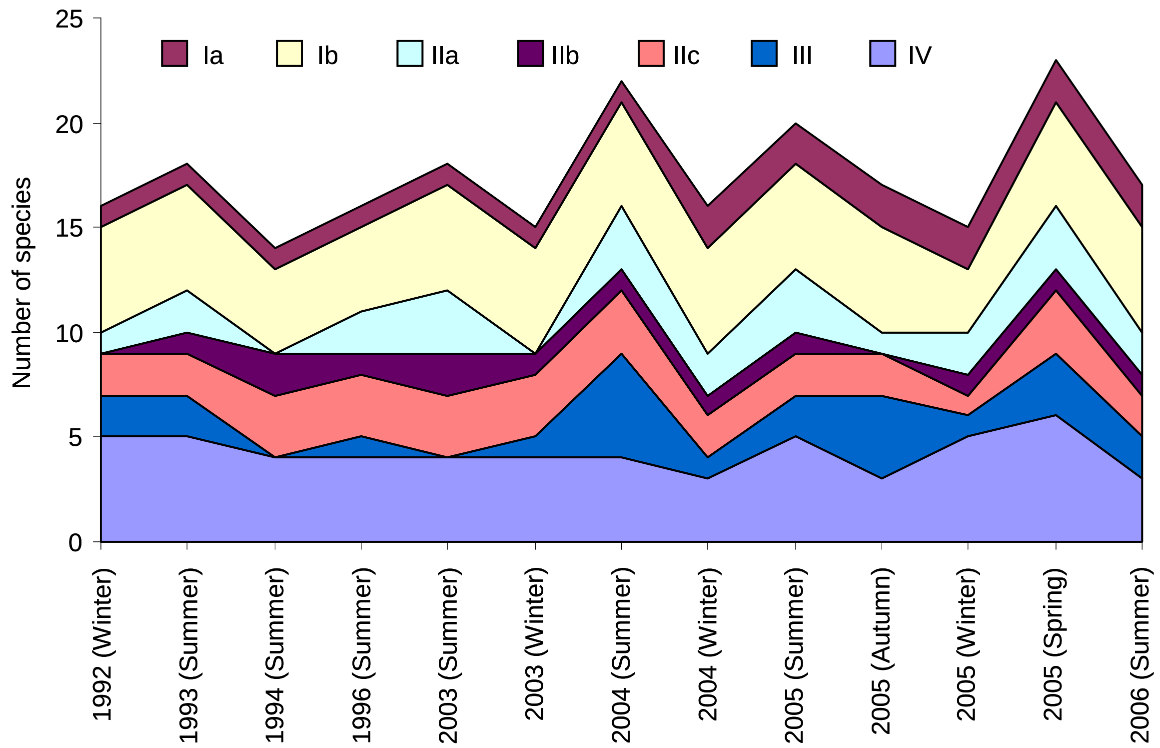

Figure 3.6 Variation in species richness (number of species) of the various categories of estuary associated fish species in the Berg River estuary 1992-2006.

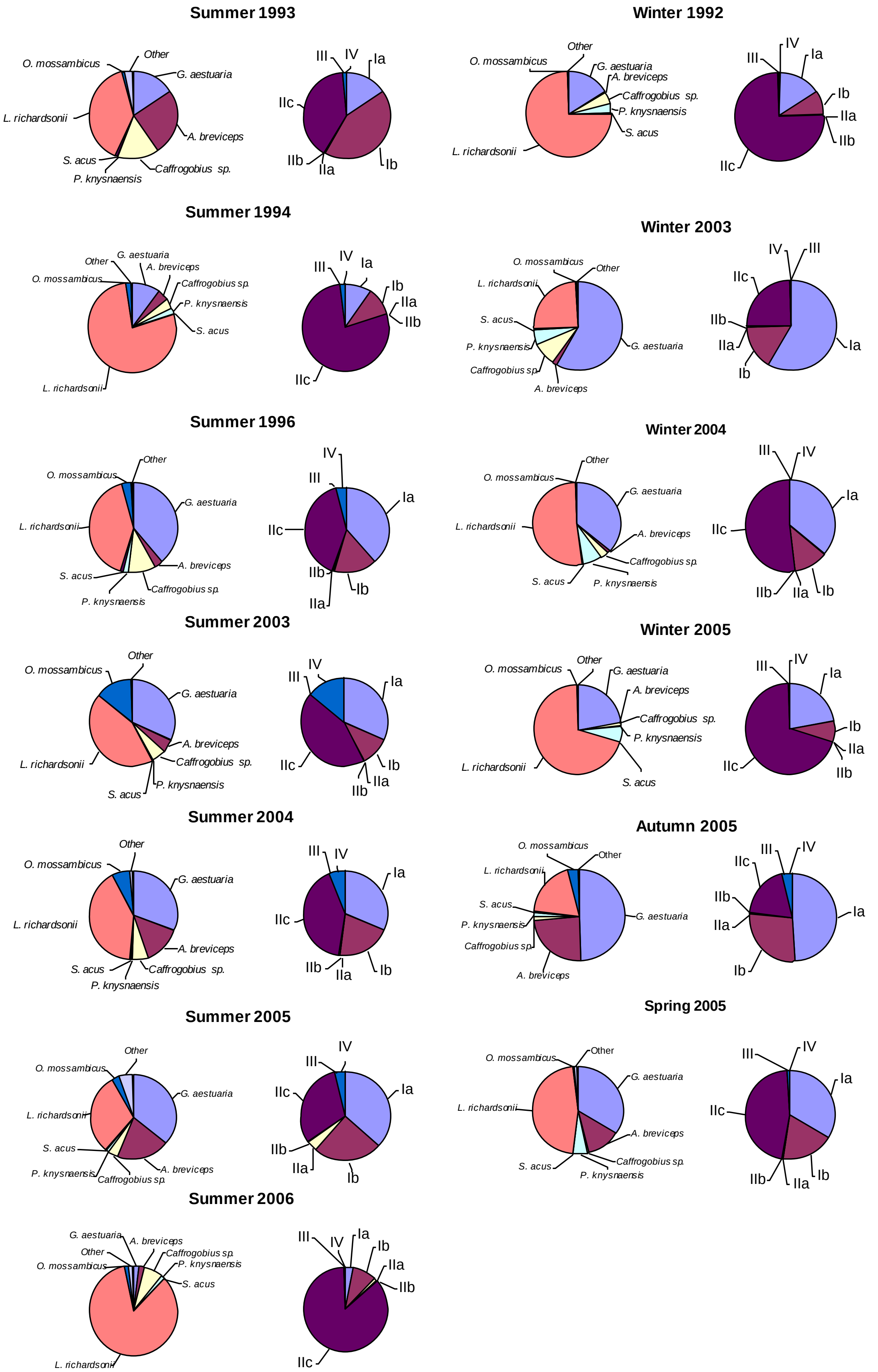

Figure 3.7 **Variation in fish community composition (abundance of the six most dominant species and in terms of estuary dependence categories sensu Whitfield 1994) in seine net hauls from the Berg River estuary from 1992-2006.**

Table 3.2 Summary of the species composition and abundance of fish in beach seine hauls from the Berg River estuary between 1992 and 2006.

Family	Species	Common name	Estuarine Dependence Category	Sep Winter 1992	Jan Summer 1993	Mar Summer 1994	Feb Summer 1996	Feb Summer 2003
Number								
Clupeidae	*Gilchristella aestuaria*	estuarine round herring	Ia	5216	7959	5337	7841	15011
Gobiidae	*Caffrogobius multifasciatus*	prison goby	Ia					
Atherinidae	*Atherina breviceps*	silverside	Ib	167	12199	2406	684	2139
Clinidae	*Clinus superciliosus*	super klipvis	Ib	6	453			35
Gobiidae	*Caffrogobius nudiceps*	nude goby	Ib					
Gobiidae	*Caffrogobius sp.*	nude goby	Ib	1451	7470	1738	2098	2589
Gobiidae	*Psammogobius knysnaensis*	Knysna sand gobi	Ib	960	334	1069	286	143
Syngnathidae	*Sygnathus temminicki*	pipefish	Ib	127	166	126	259	46
Carangidae	*Lichia amia*	Leervis, garrick	IIa		2		3	
Mugilidae	*Mugil cephalus*	flathead mullet	IIa	2	103			46
Sparidae	*Lithognathus lithognathus*	sea barbel	IIa				5	14
Sparidae	*Rhabdosargus holubi*	Cape stumpnose	IIa					2
Ariidae	*Galeichthyes feliceps*	white seacatfish	IIb			58		3
Soleidae	*Solea bleekeri*	blackhand sole	IIb		11	9	26	24
Mugilidae	*Liza richardsonii*	harder	IIc	23656	19926	40336	8395	20529
Pomatomidae	*Pomatomus saltatrix*	elf	IIc		20	35	68	56
Sparidae	*Rhabdosargus globiceps*	white stumpnose	IIc	1		1	7	18
Chaetodontidae	*Chaetodon marleyi*	butterfly fish	III				1	
Clupeidae	*Engraulis capensis*	anchovy	III					
Clupeidae	*Sardinops sagax*	sardine	III					
Dasyatidae	*Dasyatis marmorata*	blue stingray	III					
Myliobatidae	*Myliobatos aquila*	eagle ray	III					
Rhinobatidae	*Rhinobatos annulatus*	Sandshark	III	1	27			
Rhinobatidae	*Rhinobatos blockii*	bluntnose guitar fish	III					
Scyliorhinchidae	*Haploblepharus pictus*	dark shy shark	III					
Sparidae	*Sarpa salpa*	streepie	III					
Triglidae	*Cheilidonichtyes capensis*	gurnard	III		6			
Tetraodontidae	*Amblyrhynchotes honkenii*	Blassop	III	4				
Ariidae	*Clarias gariepinus*	sharptooth catfish	IV					
Centrarchidae	*Lepomis macrchirus*	Bluegill sunfish	IV	23	48			
Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	IV	1	564	1157	674	6543
Cyprinidae	*Cyprinus carpio*	carp	IV	3	32	7	30	92
Galaxiidae	*Galaxias zebratus*	Cape galaxias	IV	5				
Poeciliidae	*Gambusia affinis*	mosquito fish	IV		1	17	4	12
Salmonidae	*Micropterus dolomieu*	small-mouth bass	IV	7	110	1	21	8
		All species		31630	49431	52297	20402	47310
		No species		16	18	14	16	18
		No. hauls		36	55	32	32	42
		Area sampled		12210	16385	9950	9125	15975

Aug Winter 2003	Feb Summer 2004	Aug Winter 2004	Feb Summer 2005	May Autumn 2005	Aug Winter 2005	Nov Spring 2005	Feb Summer 2006	All Samples
15791	15689	16411	17965	17777	13138	35402	5984	179522
		88	440	28	121	135	1799	2610
466	6914	403	10233	8887		12408	5097	62004
181	64	93	36	79		14	200	1161
		1416	1370	465	390	1174	13983	18797
2324	2907							20577
1393	347	3444	392	615	3664	5214	3522	21383
125	156	84	249	90	94	309	107	1939
	6		37			8		56
	235	11	1960	19	2	13	2132	4524
	20	2	107		3	63	56	270
								2
								61
5	25	20	45		1	75	1608	1849
6871	20836	23594	15340	7244	40849	48486	206300	482362
4	243	1	333	9		708	821	2299
19	46					3		95
								1
1			2	4				7
							1	1
	25					3		28
	6							6
	8		2	1		1	10	50
				1				1
	7							7
	1							1
				1	11	3		21
		1						5
			2			5		7
					1			72
8	2961	12	1627	1140	54	393	1512	16645
35	80	18	89	8	17	490	92	993
			11		3	7		26
2	21	3		28	2	125		215
2	2		2			2	1	156
27227	50599	45622	50241	36396.4	58351	105040	243226	817772
15	22	16	20	17	15	23	17	227
46	41	41	39	39	43	41	40	527
13175	8440	7600	8588	7325	7950	9750	9225	135698

Table 3.3 Biomass (g) of fish in beach seine hauls from the Berg River estuary between 1992 and 2006.

Family	Species	Common name	Estuarine Dependence Category	Sep Winter 1992	Jan Summer 1993	Mar Summer 1994	Feb Summer 1996	Feb Summer 2003
Mass								
Clupeidae	*Gilchristella aestuaria*	estuarine round herring	Ia					12026.0
Gobiidae	*Caffrogobius multifasciatus*	prison goby	Ia					
Atherinidae	*Atherina breviceps*	silverside	Ib					1140.0
Clinidae	*Clinus superciliosus*	super klipvis	Ib					23.0
Gobiidae	*Caffrogobius nudiceps*	nude goby	Ib					
Gobiidae	*Caffrogobius sp.*	nude goby	Ib					5566.0
Gobiidae	*Psammogobius knysnaensis*	Knysna sand gobi	Ib					47.0
Syngnathidae	*Sygnathus temminicki*	pipefish	Ib					120.0
Carangidae	*Lichia amia*	Leervis, garrick	IIa					
Mugilidae	*Mugil cephalus*	flathead mullet	IIa					442.0
Sparidae	*Lithognathus lithognathus*	White steenbras	IIa					458.0
Sparidae	*Rhabdosargus holubi*	Cape stumpnose	IIa					48.0
Ariidae	*Galeichthyes feliceps*	white seacatfish	IIb					3.0
Soleidae	*Solea bleekeri*	blackhand sole	IIb					148.0
Mugilidae	*Liza richardsonii*	harder	IIc					112427.0
Pomatomidae	*Pomatomus saltatrix*	elf	IIc					4072.0
Sparidae	*Rhabdosargus globiceps*	white stumpnose	IIc					312.0
Chaetodontidae	*Chaetodon marleyi*	butterfly fish	III					
Clupeidae	*Engraulis capensis*	anchovy	III					
Clupeidae	*Sardinops sagax*	sardine	III					
Dasyatidae	*Dasyatis marmorata*	blue stingray	III					
Myliobatidae	*Myliobatos aquila*	eagle ray	III					
Rhinobatidae	*Rhinobatos annulatus*	Sandshark	III					
Rhinobatidae	*Rhinobatos blockii*	bluntnose guitar fish	III					
Scyliorhinchidae	*Haploblepharus pictus*	dark shy shark	III					
Sparidae	*Sarpa salpa*	streepie	III					
Tetraodontidae	*Amblyrhynchotes honkenii*	Blassop	III					
Triglidae	*Cheilidonichtyes capensis*	gurnard	III					
Ariidae	*Clarias gariepinus*	sharptooth catfish	IV					
Centrarchidae	*Lepomis macrchirus*	Bluegill sunfish	IV					
Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	IV					18347.0
Cyprinidae	*Cyprinus carpio*	carp	IV					8874.0
Galaxiidae	*Galaxias zebratus*	Cape galaxias	IV					
Poeciliidae	*Gambusia affinis*	mosquito fish	IV					4.0
Salmonidae	*Micropterus dolomieu*	small-mouth bass	IV					632.0
		All species						164689.0
		No species		16	18	14	16	18
		No. hauls		36	55	32	32	42
		Area sampled		12210	16385	9950	9125	15975

Not recorded

Aug Winter 2003	Feb Summer 2004	Aug Winter 2004	Feb Summer 2005	Nov Autumn 2005	Aug Winter 2005	May Spring 2005	Feb Summer 2006	All Samples
10030.4	16509.0	12154.1	11354.1	8747.3	6599.2	63104.8	3461.9	143986.8
		424.1	985.7	126.8	607.9	691.5	3928.7	6764.6
384.1	5675.0	390.5	9482.3	6582.4		34373.6	3175.0	61202.9
112.4	119.0	48.5	77.0	205.2		4.0	165.6	754.7
		1376.7	3784.3	1636.4	1723.4	3721.8	52999.8	65242.4
3115.3	3366.0							12047.3
1021.2	181.0	2407.2	183.7	932.6	2674.3	4953.9	798.7	13199.6
102.1	140.0	117.9	1830.2	154.4	139.8	614.2	66.0	3284.5
	13.0		2789.0			1000.0		3802.0
	6002.0	367.3	4760.9	734.0	127.3	1121.6	35646.4	49201.5
	3750.0	205.0	6566.7		485.0	1029.0	4535.0	17028.6
								48.0
								3.0
10.5	268.0	222.9	581.3		10.1	584.0	13630.8	15455.6
23615.7	287453.0	52755.1	94068.0	57303.5	48531.1	242153.4	333637.4	1251944.2
198.9	16929.0	220.0	12519.0	355.9		25517.5	18927.3	78739.6
67.0	131.0					200.1		710.1
								0.0
5.5			3.0	3.1				11.6
							78.8	78.8
	45500.0					675.0		46175.0
	4750.0							4750.0
	14500.0		5500.0	2200.0		325.0	3615.0	26140.0
				2800.0				2800.0
	12.0							12.0
	29.0							29.0
		10.0						10.0
		1.0		2.1	4.8	10.9		18.8
			169.0			952.4		1121.4
					43.7			43.7
565.9	5955.0	220.0	6733.0	2229.0	11137.9	14066.3	5076.5	64330.5
16729.3	11428.0	8845.0	28193.0	18500.0	20490.0	65390.6	13377.4	191827.3
					5.4	58.0		63.4
0.8	29.0	1.0	3.0	8.2	0.8	12.0		58.8
59.5	85.0		353.0			162.1	1201.0	2492.6
56018.6	422824.0	79762.3	189936.0	102520.8	92580.7	460721.9	490051.3	2059104.6
15	22	17	20	17	15	23	17	
46	41	41	39	39	43	41	40	
13175	8440	7600	8588	7325	7950	9750	9225	135697.5

In terms of biomass, a slightly different suite of species predominated compared with the abundance assessment, with *L. richardsonii* providing the greatest contribution (42-68%, 62% overall), followed by *Cyprinus carpio* (carp) (3-30%, 9% overall), *G. aestuaria* (1-18%, 7% overall), *Pomatomus saltatrix* (elf) (0-6%, 4% overall), *C. nudiceps* (0-11%, 3% overall), *O. mossambicus* (1-22%, 3% overall), *A. breviceps* (0-8, 3% overall). These seven species together made up 66-91% of the biomass in each survey (78% overall) (Table 3.3).

The floodplain surrounding the upper parts of the Berg estuary was sampled during four of the sampling excursions - Winter 1992, 2003, 2004, 2005, and Spring 2005 – being the only time when significant parts of the floodplain were covered with water. Number of species captured in these floodplain samples varied from 1-6 and included mostly freshwater species (*Lepomis macrochirus, O. mossambicus, C. carpio* and *Galaxias zebratus*) but also some estuarine residents (*P. knysnaensis* and *C. nudiceps*) and a marine migrant species (*L. richardsonii*). Densities of fish at the floodplain sites were all very low (generally <0.3 fish.m^{-2} except for two large catches of small *L. richardsonii. G. zebratus* is the only species considered to show a strong association with the floodplain areas, as it was not recorded in the main part of the estuary at all.

3.3 Species composition and abundance – gill net catches

A total of only 1 260 fish were captured in the gill net sets in the study period (Table 3.4). Each gill net set entailed setting a fleet of variable size gill nets (44, 48, 51, 54, 75, 100, 145 mm stretched mesh). This was done at 9 sites during each of the 2005 and 2006 field excursions. Catches were dominated by *L. richardsonii* (69% of the total), followed by *Mugil cephalus* (16%), *Pomatomus saltatrix* (8%) and *O. mossambicus* (1%). Other species present in the catches albeit in lower numbers included *Clarias gariepinus, Oreochromis mossambicus, Galeichthyes feliceps* and *Lichia amia*. These were all amongst the largest species recorded in the seine net catch, and were mostly marine migrants and freshwater species. Estuarine residents (which are mostly small species) were notably absent from the catches. No additional species not recorded in the seine net catches were found in the gill nets.

3.4 Species' distribution patterns

Some species displayed clear and consistent distribution patterns up the length of the estuary (Figure 3.8 - Figure 3.10). Some species (*G. aestuaria* and *M. cephalus*, Figure 3.8) showed no clear preference for any particular portion of the estuary. Some (*P. knsynaensis, Caffrogobius multifasciatus, P. saltatrix, Lichia amia, Lithoganthus lithoganthus* and *Solea bleekeri*, Figure 3.8) showed a clear preference for the middle reaches of the estuary. Some (*A. breviceps, L. richarsonii, Syngnathus temmincki, C. nudiceps, Clinus superciliosus, Rhabdosargus globiceps,* and *Rhinobatos annulatus* were more prevalent in the lower reaches Figure 3.9), while others (*O. mossambicus, C. carpio, Gambusia affinis,* and *Micropterus dolomieu*, Figure 3.10) showed a clear preference for the upper reaches of the estuary. All of those favouring the upper reaches of the estuary were freshwater species, while those favouring the whole or other portions of the estuary comprised a mixture of estuarine resident and marine migrant species.

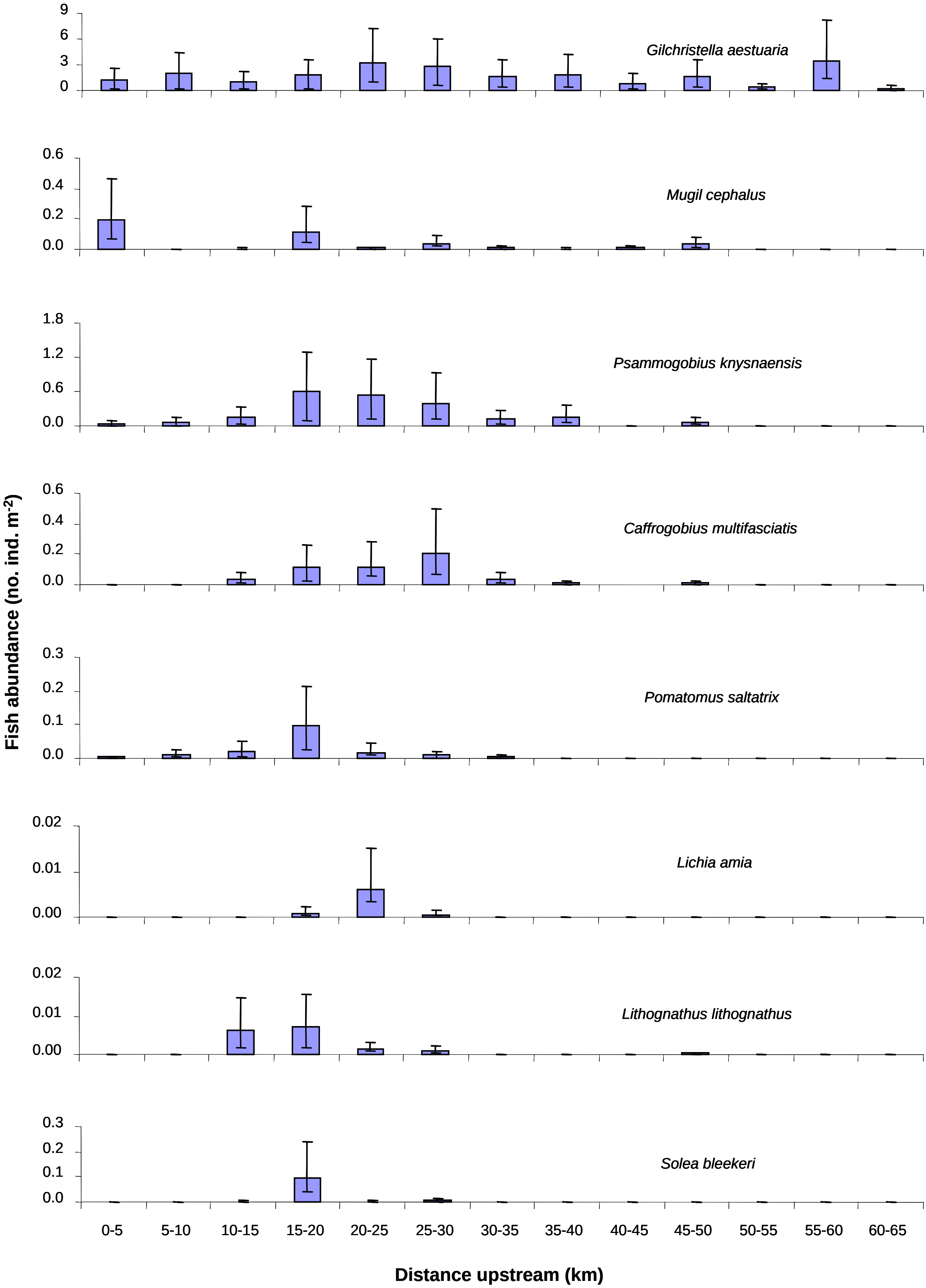

Figure 3.8 Variation in abundance of key fish species with distance upstream (I). Species distributed throughout the estuary and those favouring the middle reaches.

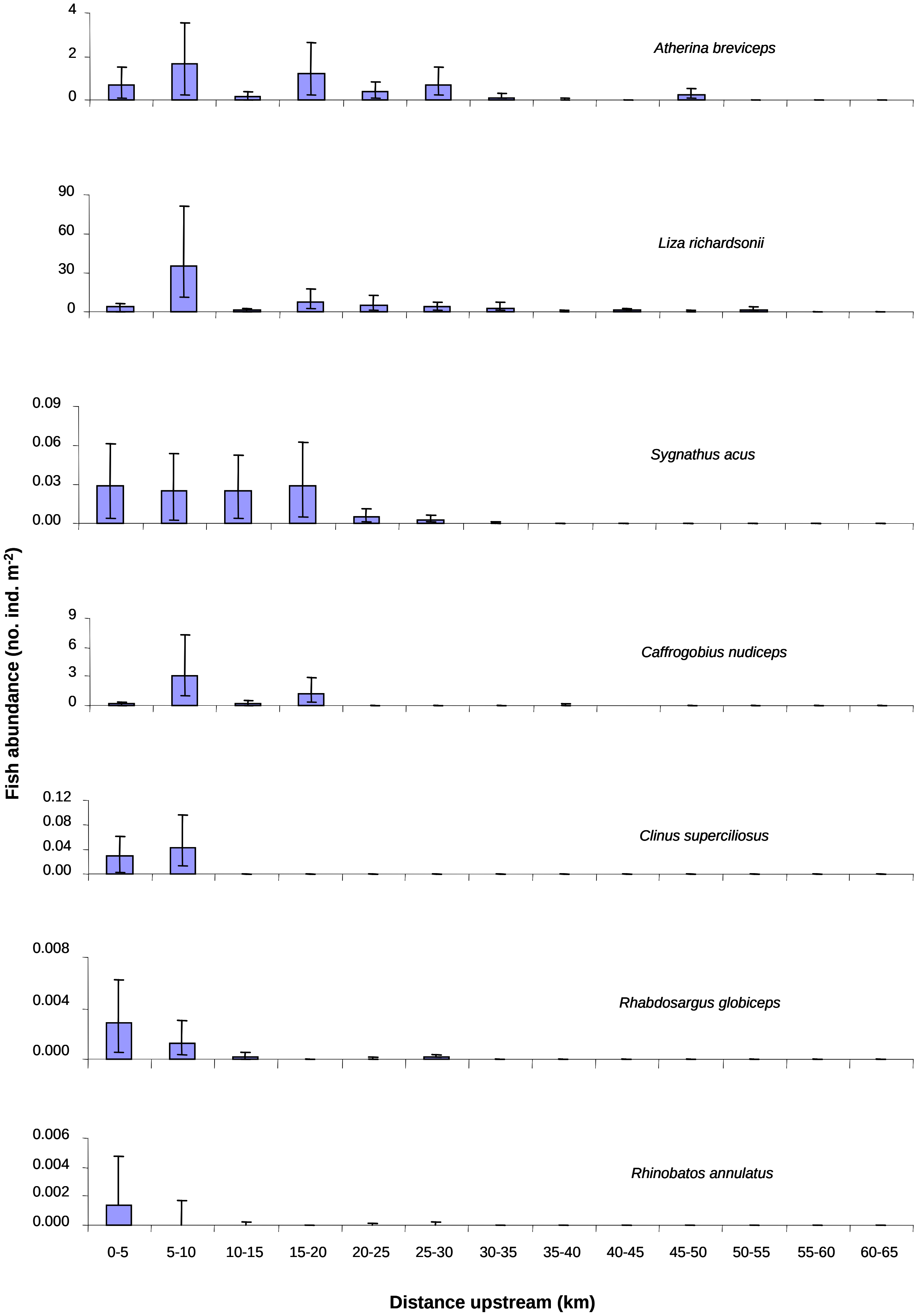

Figure 3.9 Variation in abundance of key fish species with distance upstream (II). Species favouring the lower reaches of the estuary.

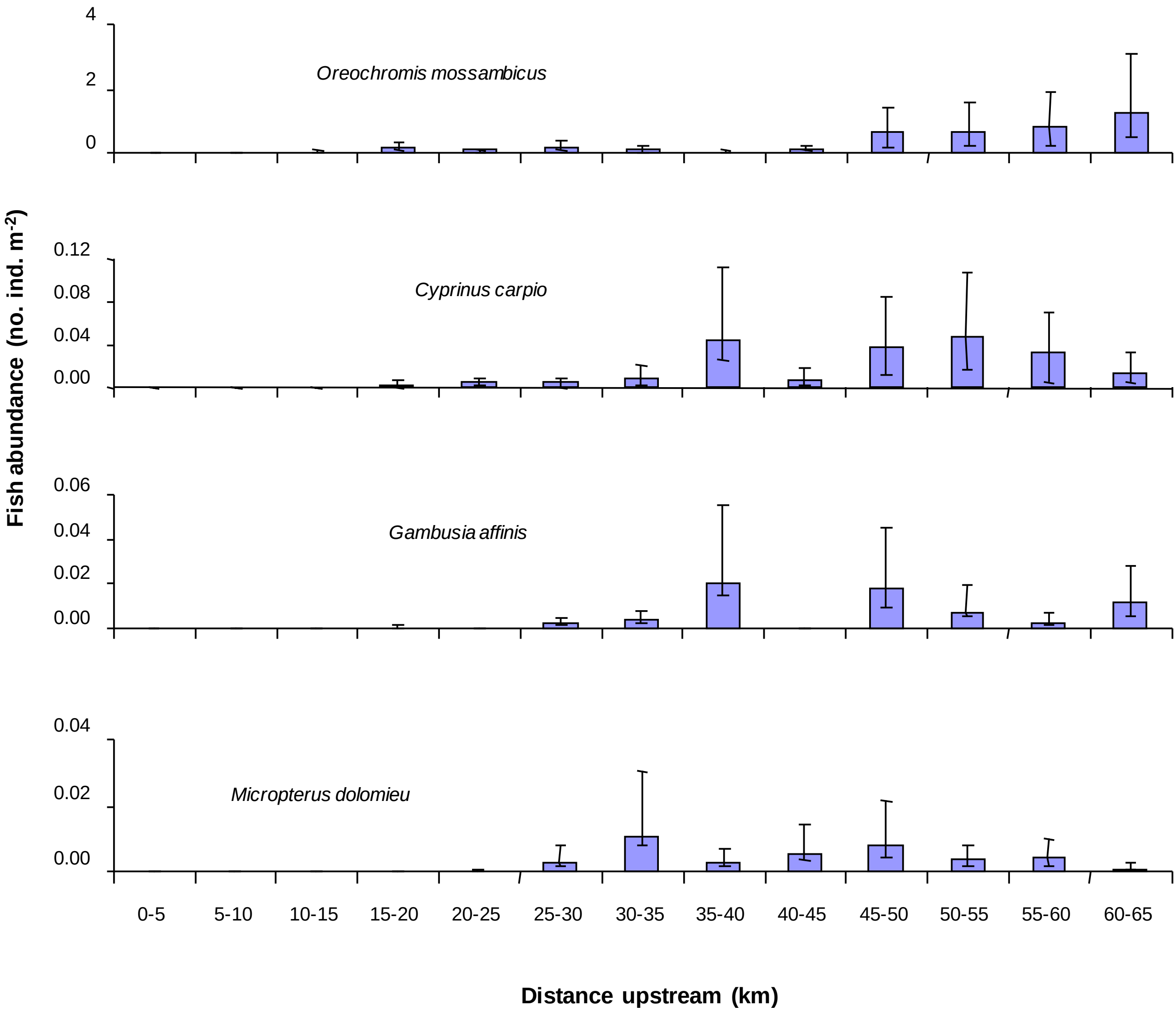

Figure 3.10 Variation in abundance of key fish species with distance upstream (III). Species favouring the upper reaches of the estuary.

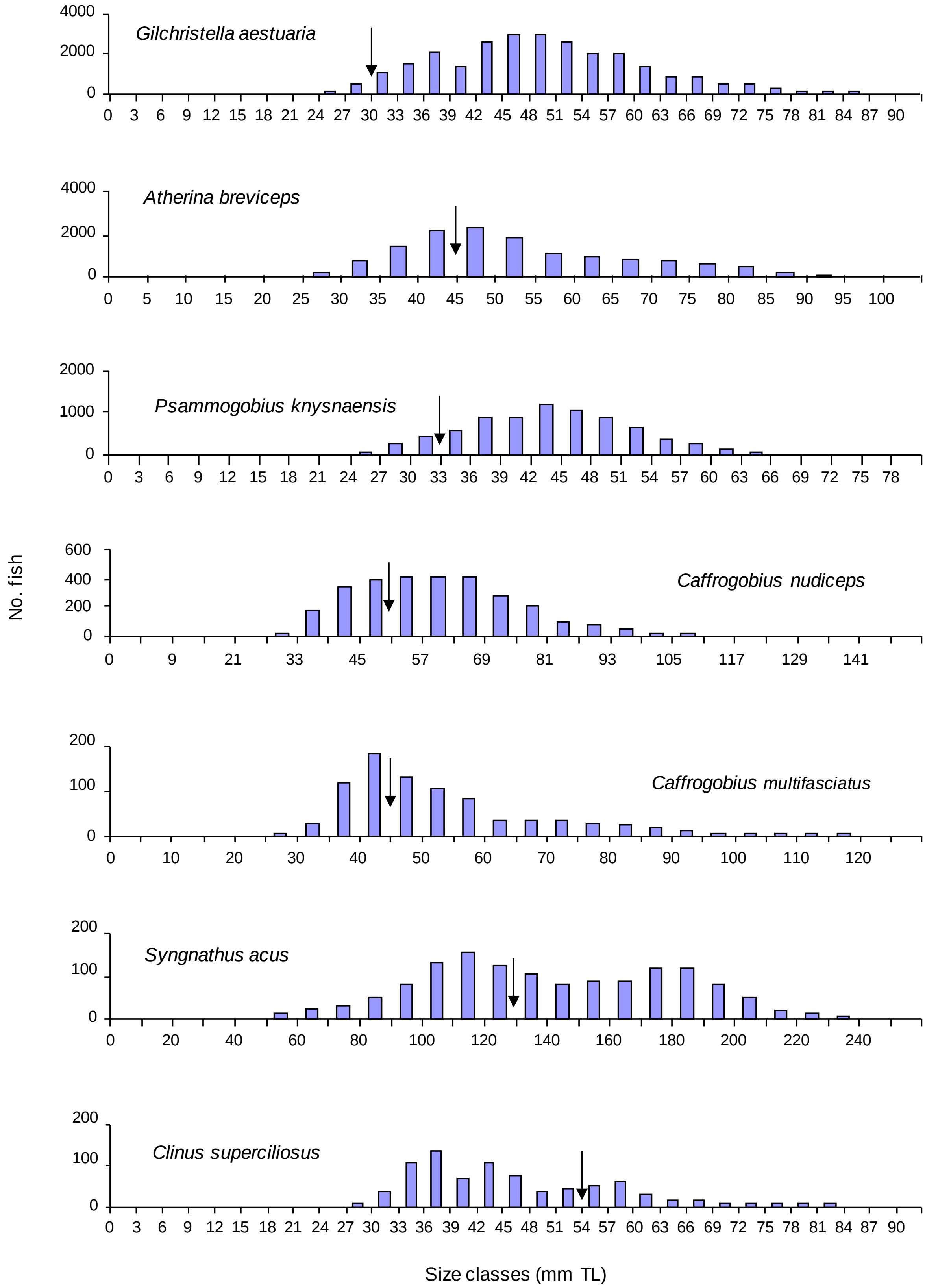

Figure 3.11 Length frequency distribution of dominant estuarine resident species in seine net catches from the Berg River Estuary, 1992-2006. Arrows indicate approximate size at 50% maturity (after Whitfield 1998). Note that the *G. aestuaria* length frequency distribution was truncated due to extremely low numbers of individuals in the large size classes. Maximum size achieved by this species was 126 mm TL.

Table 3.4 Species composition and abundance of fish caught in a fleet of variable size gill nets (44, 48, 51, 54, 75, 100, 145mm stretched mesh) in 2005/2006

			Month	Feb	May	Aug	Nov	Feb	
			Season	Summer	Autumn	Winter	Spring	Summer	All
Family	Species	Common name	Year	2005	2005	2005	2005	2006	Samples
Clinidae	*Clinus superciliosus*	super klipvis	Ib					1	1
Carangidae	*Lichia amia*	Leervis, garrick	IIa	1	1			7	9
Mugilidae	*Mugil cephalus*	flathead mullet	IIa	20	38	3	103	39	203
Ariidae	*Galeichthyes feliceps*	barbel		1	1		3		5
Mugilidae	*Liza richardsonii*	harder	IIc	232	181	83	190	170	856
Pomatomidae	*Pomatomus saltatrix*	elf	IIc	35	21		15	25	96
Ariidae	*Clarias garipinus*	sharptooth catfish	IV	4				3	7
Cichlidae	*Oreochromis mossambicu*	Mozambique tilapia	IV	2	3	1	10	2	18
Cyprinidae	*Cyprinus carpio*	carp	IV	41	5	1	16	2	65
		All species		336	250	88	337	249	1260

3.5 Length frequency distributions of dominant species

Size frequency distributions of the dominant species in catches from the Berg estuary are presented in Figure 3.11 (estuarine resident species), Figure 3.12 (marine migrant species), and Figure 3.13 (freshwater species). The estuarine round herring *G. aestuaria* (Figure 3.11) was comprised predominantly of adult fish up to 126 mm TL. Juveniles were more abundant in catches in the winter than summer. The silverside *A. breviceps* was represented by high numbers of both adults and juveniles, with adult individuals predominating (Figure 3.11) – mesh. The maximum size of this species sampled was 108 mm TL but the majority of individuals were < 90 mm TL. Juveniles < 30 mm TL were most abundant during the summer sampling excursions. Knysna sand goby *P. knysnaensis* from the Berg estuary ranged in size from 15 to 81 mm TL, juveniles (30 mm TL) being more abundant in summer than winter (Figure 3.11). Similar size frequency distributions were recorded for *C. nudiceps* (nude goby) and *C. multifasciatus* with both adults and juveniles being abundant in the estuary through all sampling events (Figure 3.11). Juvenile *C. nudiceps* (<50 mm TL) made up a greater portion of the catches in winter and spring than summer or autumn, while the reverse was true for *C. multifaciatus*, with juveniles being more abundant in catches during summer and autumn than in winter or spring. The largest *C. nudiceps* and *C. multifaciatus* captured measured 142 and 291 mm TL, respectively. Pipefish *Sygnathus temmincki* ranged in size from 30-250 mm TL (Figure 3.11). Juveniles (<130 mm TL) were present through all sampling events but made up a greater portion of the winter catches relative to the summer catches. Super klipfish *Clinus superciliosus* was comprised of a mix of adults and juveniles, with juveniles being more abundant than the adults.

Dominant marine migrant species for which frequency histograms were prepared included *L. richardsonii* (southern mullet), *P. saltatrix* (elf), flathead mullet (*Mugil cephalus*), *Lithognathus lithognathus* (White steenbras), and *Solea bleekeri* (blackhand sole). Most of the species were represented by juveniles only. *L. richardsonii* were present in the catches throughout the year and include only a small number of adult individuals (>200 mm TL, Figure 3.12). The largest individual of this species, measuring 337 cm, was captured in the gill nets. *P. saltatrix* was represented almost exclusively by juveniles (Figure 3.12) with a few larger, adult fish recorded in the gill net catches (up to 409 mm TL). Smallest fish (to 30 mm TL) were all recorded during the summer field excursions. *M. cephalus* was represented almost exclusively by juveniles (<770 mm TL, Figure 3.12) with a small number of adult fish (up to 337 mm TL) appearing in the gill nets catches. *L. lithognathus* was recorded in the seine net catches only and included only juveniles in the range 30-220 mm TL (Figure 3.12). The smallest individuals (<120 mm TL) were recorded in summer. *S. bleekeri* appeared in the catches at sizes from 45-120 mm TL, and as such included both juvenile and adult individuals. Smallest individuals (<60 mm TL) appeared sporadically in the catches and showed no clear seasonality.

Dominant freshwater species for which length frequency histograms were prepared included Mozambique tilapia *O. mossambicus*, carp *C. carpio*, mosquito fish *Gambusia affinis* and small mouth bass *Micropterus salmoides* (Figure 3.13). Tilapia, carp and bass were all mostly represented by juveniles accompanied by a few adult individuals. These three species all seem to breed in spring/summer with juveniles predominating in the catches taken at these times. Mosquito fish comprised a range of adult and juvenile individuals. No clear seasonal pattern was evident in the catches of either adults or juveniles of this species.

3.6 Multivariate analysis of current and historic sampling

Multi-Dimensional Scaling (MDS) ordination plots, representing the similarity between sites based on the composition and abundance of fish contained therein, show a gradient of decreasing similarity between sites sampled in the upper reaches of the estuary with those nearer the mouth (Figure 4.1). On many of the ordination plots sites are arranged in the form of an arch which, rather than reflecting the true distribution of sites relative to one another, simply reflects the fact that the forces repelling dissimilar sites (and those causing similar sites to cluster together) in the algorithm used to draw up the plots decay exponentially with increasing dissimilarity and thus allow the ordination plot to collapse into this formation rather than forcing it to maintain a linear trajectory (Clarke 1993). This gradient of similarity between sites is indicative of the changing physico-chemical characteristics occurring in the estuary relating to the portion of the estuary in which different fish species choose to occupy. During the winter months the gradient appears more severe than the summer months with the lower sites clustering more closely and the upper sites being more dispersed (Figure 4.1).

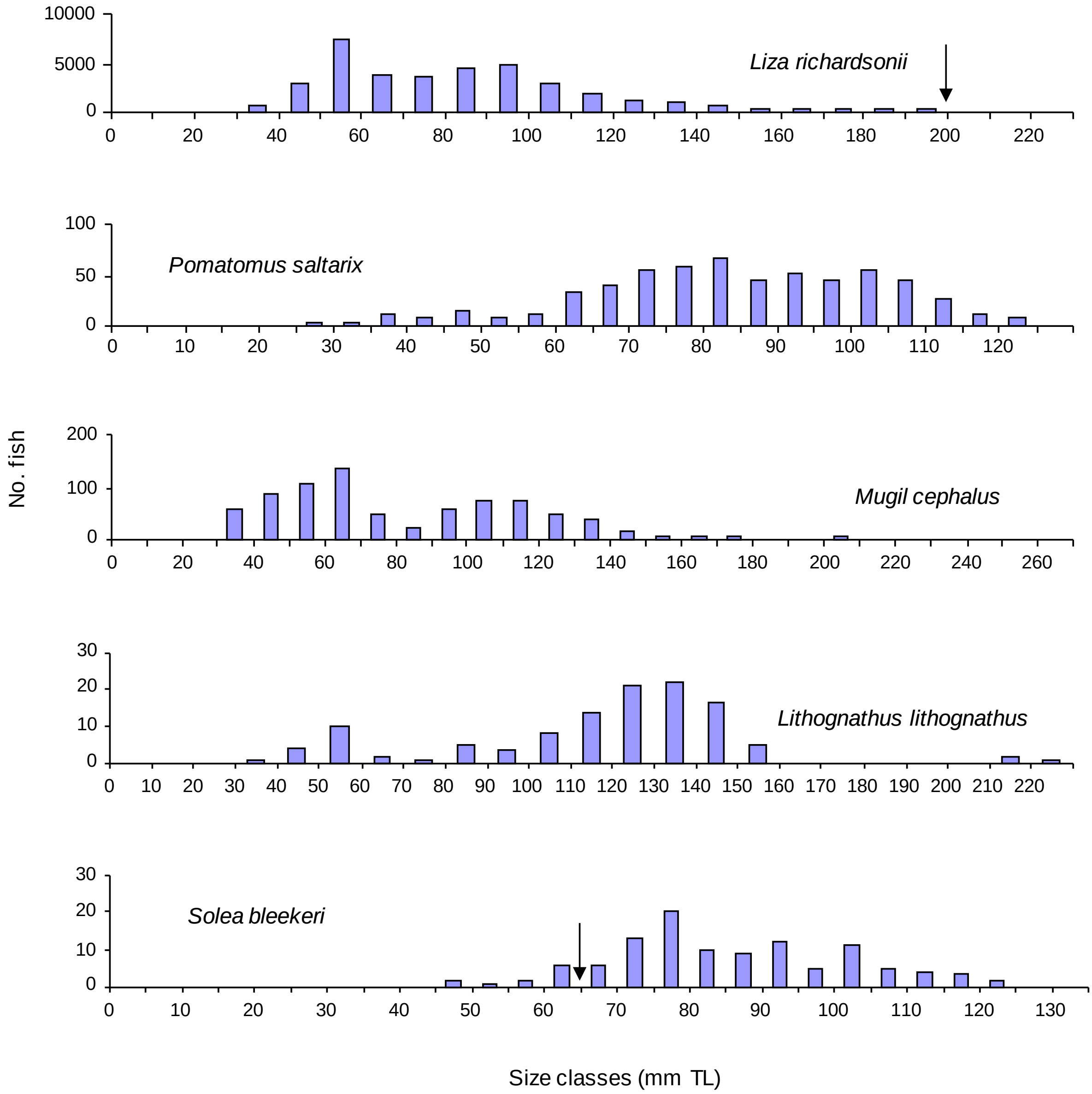

Figure 3.12 Length frequency distribution of dominant marine migrant species in seine net catches from the Berg River Estuary, 1992-2006. Arrows indicate approximate size at 50% maturity (after Whitfield 1998).

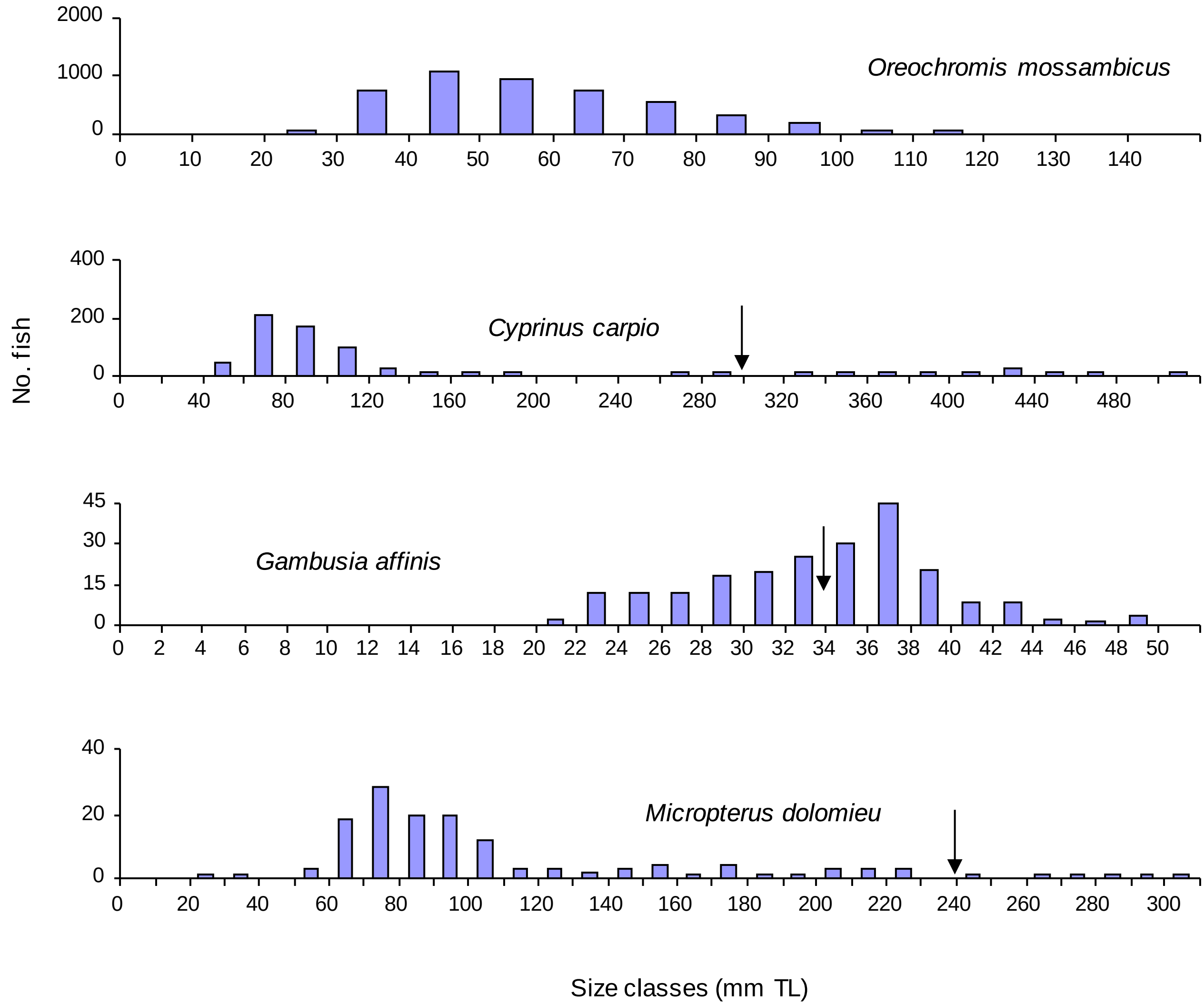

Figure 3.13 Length frequency distribution of dominant freshwater species in seine net catches from the Berg River Estuary, 1992-2006. Arrows indicate approximate size at 50% maturity (after Whitfield 1998).

4 DISCUSSION

4.1 Importance of the Berg River estuary to estuarine fish communities

Compared to marine coastal waters, estuaries are considered to be highly productive, with calm, shallow, warm waters, and lowered salinities (Bennett 1993). These attributes promote rapid growth and/or reduced mortality for fish species, hence making them ideal environments for colonisation by juveniles of marine species. For these reasons, many species of fish occupy estuaries for either their entire life cycle, or part of it, becoming entirely dependent on estuaries for breeding success. Fish species that are classified as estuarine residents, only breeding in estuaries, (e.g. *Gilchristella aestuaria*) and species that are predominantly marine when adult, but are dependant, either partially or entirely, on estuaries as juveniles, (e.g. *Mugil cephalus*) are often the species of greatest concern when changes occur within an estuary. However, it is important not to lose sight of the fact that fish, irrespective of the group to which they belong, occupy an important position in the food chain within an estuary, and that changes in their composition or abundance will affect other groups, both higher up and lower down in the system. Species of greatest interest, therefore, include those of high abundance: *L. richardsonii*, *G. aestuaria, A. breviceps, C. nudiceps, P. knysnaensis* and *O. mossambicus* (some of which are partially dependent on estuaries) and those that are less abundant, but remain important due to their being largely or wholly dependent on estuaries for their continued existence (*C. superciliosus, C. multifasciatus, S. bleekeri, P. saltatrix*, *M. cephalus, S. bleekeri, Galeichthyes feliceps*, *Lichia amia,* and *Lithognathus lithognathus*). Many of the latter species are also endemic to southern Africa and some are considered threatened (Mann 2000).

On the West Coast of South Africa, only three river systems, namely, Orange, Olifants and Berg Rivers, have large enough catchments and sufficient flow to maintain a permanent connection with the sea (Harrison 1997). These systems are considered to be comparatively poor in fish species richness when compared to estuaries on the south-east and east coasts of South Africa (Harrison 1997). Only 25 species of fish are commonly associated with west coast estuaries as compared to 100 species from the south-eastern coast and 242 from the east coast (Bennett 1993). This trend reflects the well-established eastward increase in species diversity observed for fish, and a number of other taxa, with a change from temperate to subtropical and tropical conditions (Bennett 1993). However, although the numbers of species present in west coast estuaries is low, they do represent a relatively high proportion (79%) of the total west coast inshore fish community (Bennett 1993, Lamberth *et al*. 2008).

The composition of the fish fauna in west coast estuaries is also strongly skewed towards resident rather than marine migrant species. The contribution by marine migrants in the Berg, both in terms of the number of species (39%) and individuals (51%) present is low relative to most other permanently open estuaries in South Africa. Estuaries of this type are typically more heavily dominated by marine migrant species, owing to the fact that they are open to the sea all year round (Bennett 1989, Whitfield 1998). Marine migrants normally account for 60-65 % of species and an even greater proportion of individuals in permanently open estuaries, while seasonally closed estuaries have a lower proportion of marine species (ca. 50-60 %) and normally closed estuaries the lowest. Most (if not all) species found in west coast estuaries also occur in estuaries further east. This implies that estuaries on the west coast are regionally important from a conservation perspective, certainly more so than some of the nationwide estuary importance ranking systems (e.g. Turpie 1995), which do not take account of this fact, suggest. Indeed, if one looks at the importance scores allocated to estuaries around the country based on botanical importance (Colloty *et al*. 2002), birds (Turpie 1995) and fish (Maree *et al*. 2003), one can see that the Berg and Olifants estuaries are rated highly in respect of the former components (Botanical: Berg = 4, Olifants =6, and Avifauna: Berg = 3, Olifants = 7) but lower, and we believe erroneously so, in respect of their fish fauna. (ranked 29 and 28, respectively).

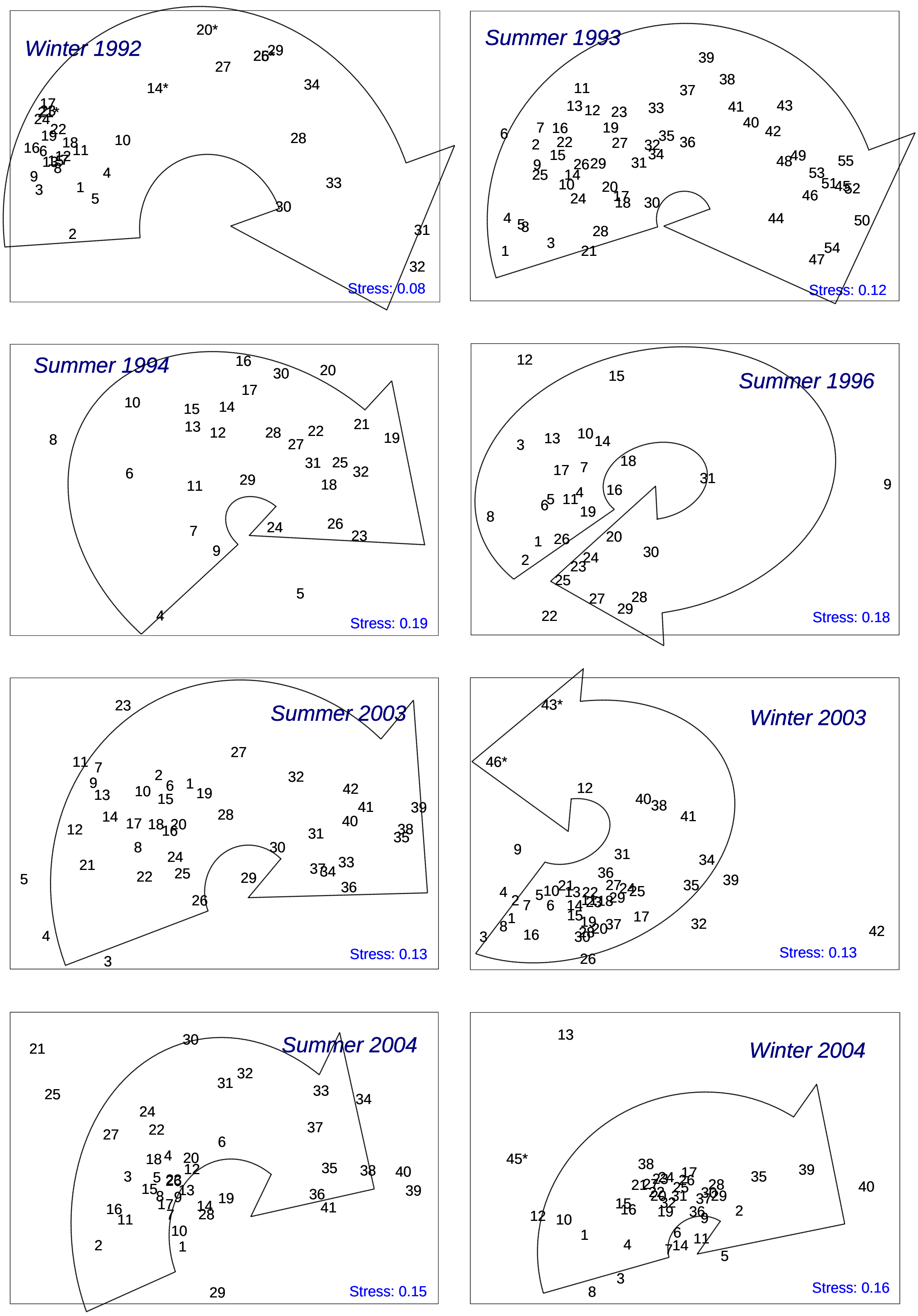

Figure 4.1 Ordination plots of seine net fish samples taken from the Berg River estuary between 1992 and 2006. Arrows indicate the manner in which sites from each sampling excursion (numbered in order from the mouth upstream) are typically arranged in an arched formation. An explanation of this effect is provided in the text.

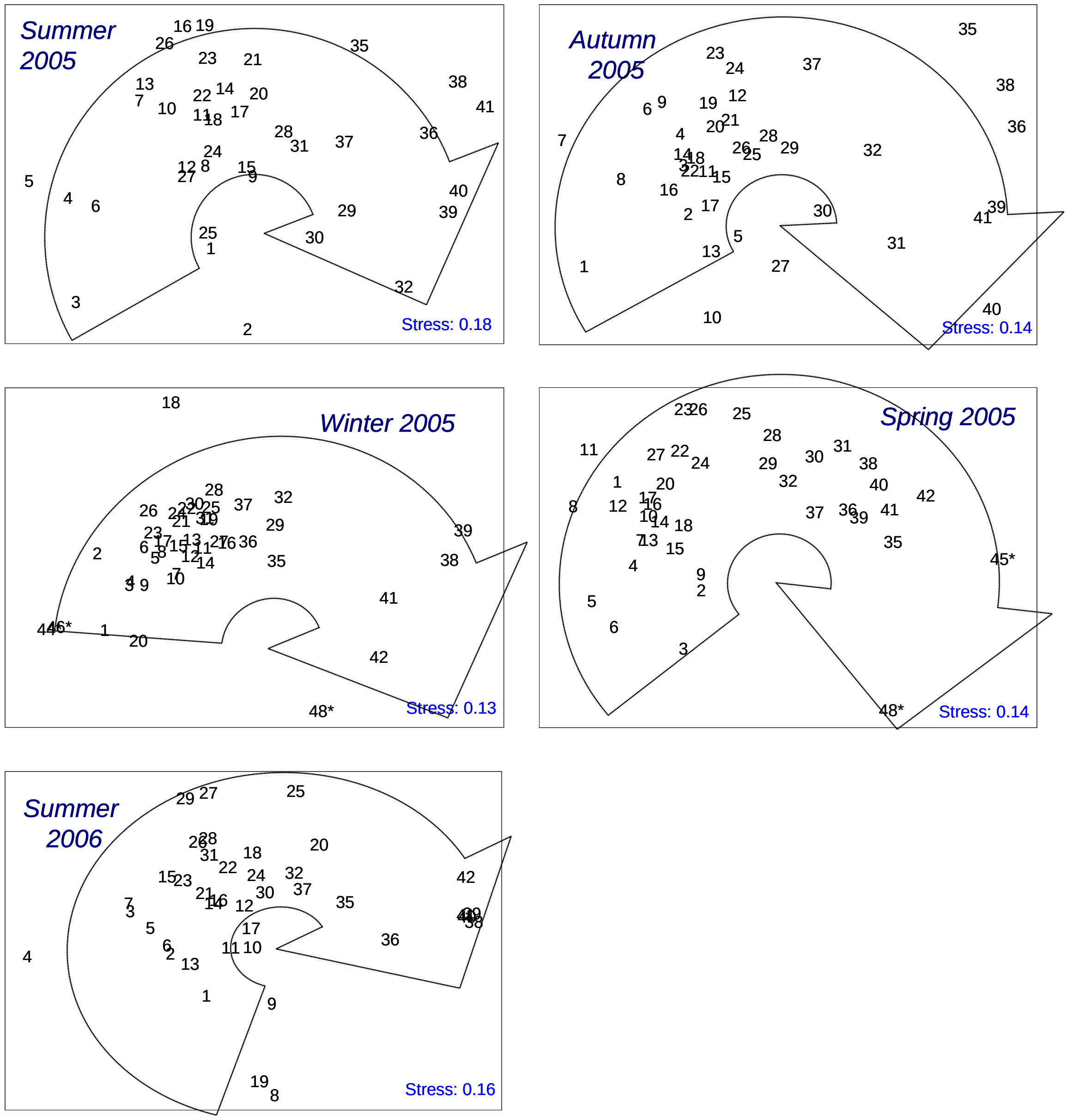

Figure 4.1 **Continued. Ordination plots of seine net fish samples taken from the Berg River estuary between 1992 and 2006. Arrows indicate the manner in which sites from each sampling excursion (numbered in order from the mouth upstream) are typically arranged in an arched formation. An explanation of this effect is provided in the text.**

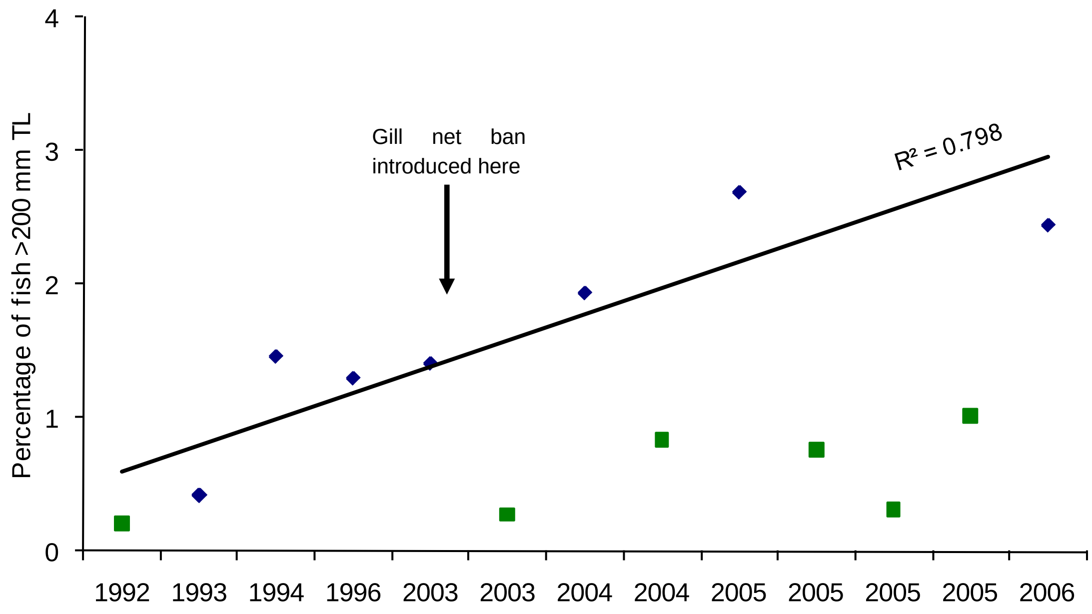

Figure 4.2 Proportion (%) of *L. richardsonii* >200 mm TL in seine net catches from the Berg River estuary taken in summer (blue diamonds) and other seasons (green squares). The regression line was prepared using the summer catches only (i.e. the blue diamonds).

4.2 Variations in the composition and abundance of fish in the Berg River estuary

The composition and abundance of fish in the Berg River estuary has clearly varied considerably over the last 14 years with some clear long-term changes apparent. Total number of species and abundance have both increased over this period, with changes in abundance being more marked than species richness. Seasonal variations in species richness and biomass were also evident, with summer and spring catches being higher than those taken in autumn or winter. Hutchings *et al*. (2007) noticed a similar increase in catch-per-unit-effort by shore and boat anglers in the Berg River estuary over the latter portion of the survey period (2003-2005) which he attributed to a ban imposed on gill net fishing in the estuary imposed at the end of 2003. Considering that *L. richardsonii* were the primary target of this fishery it is quite likely that the increase in fish abundance evident in data collected in this study (mostly a function of an increase in abundance of this species) is also a function of the ban imposed on the gill net fishery.

Marked variations were also evident in the species composition of the catches between sampling events, both within (i.e. from one season to another) and between sampling years. These changes were mostly a function of variations in the abundance of the 5-6 dominant species in the estuary, which in turn affected the contribution by the different categories of estuary associated fish species. No clear seasonal or longer term patterns were evident in these variations.

An issue of potential relevance to variations observed in both the abundance and composition of fish in the Berg River estuary is the somewhat anomalous 'black tide' event which occurred in the adjacent St Helena Bay during the summer of 1994, and even penetrated the lower reaches of the estuary (up to 2 km from the mouth). Pitcher and Calder (2000) report that a dense accumulation of phytoplankton developed within St. Helena Bay at this time, and the gradual decay of this matter used up available oxygen in the water, while emitting hydrogen sulphide (Pitcher and Calder 2000). This resulted in the water in the bay and lower estuary becoming highly anoxic (low oxygen), causing a large-scale mortality of many marine species including fish. It has been proposed (Lamberth *et al.* 2008) that large numbers of marine fish may have moved into the estuary from the sea in an attempt to escape from the noxious 'black tide' waters. This may explain the higher than expected abundance of larger fish in the estuary at this time (note that abundance of large *L. richardsonii* in 1994 is elevated somewhat relative to 1993 and 1996 on Figure 4.2) and the disproportionately large contribution by this species to overall fish numbers at this time (Figure 3.7).

Estuarine resident species, able to breed in both estuarine and marine waters, displayed size frequency distributions typical of species in this category. Juveniles of most of these species are very small (<50 mm TL) and were probably not effectively sampled by the meshes of net used during this study (mesh size = 12 mm stretched). This effect was most marked for the smallest of these species, *G. aestuaria* and *P. knysnaensis*, where catches appeared to be strongly skewed toward adult individuals, but less severe for the larger species (e.g. *Caffrogobius* spp. and *Syngnathus temmincki*). *G. aestuaria* is reported to spawn during spring and summer (Melville-Smith & Baird 1980, Whitfield 1989), and is only likely to start recruiting into the catches in winter or even the following summer when it reaches a large enough size not to pass through the meshes of the net. Something of particular interest was the fact that individuals of the species up to 126 mm TL were recorded in the samples, which is considerably larger than the maximum size of 80 mm TL recorded for populations in other estuaries around the country (Whitfield 1998). Recruitment by the remaining resident species (*A. breviceps, C. nudiceps, P. knysnaensis* and *S. temmincki)* was noted to be strongest during the summer sampling events, which correspond to the peak recruitment times recorded elsewhere (Whitfield 1989, 1998). Some of these species (e.g. *C. nudiceps, P. knysnaensis*) are thought to deliberately spawn near the mouth of estuaries thus allowing the tide to disperse the larvae into the marine environment (Whitfield 1998). Juveniles then recruit back into estuaries some months later (normally in late summer), which would correlate with the peaks in recruitment observed in this study.

Marine migrant species in the Berg estuary were represented mostly by juveniles, with peak recruitment also occurring during the summer sampling events. These species mostly grow to a large size (>300 mm TL) and although individuals larger than this were probably not common in the estuary, they would not necessarily have been adequately sampled by the gear used in this study. Larger individuals of some of these species (e.g. *L. richardsonii, M. cephalus, P. saltatrix,* and *L. amia*) were indeed recorded in gill net surveys completed in 2005/2006. It is also likely that individuals of this size and larger would have been caught in large numbers by the commercial gill net fishers that, until 2003, were permitted to operate in the estuary. Mesh sizes used by these fishermen are mostly in the range of 44-64 mm, and while they ostensibly target mullet (*L. richardsonii* and *M. cephalus*) other bycatch species (particularly *P. saltatrix*) make an important contribution to their catches (Hutchings & Lamberth 2002a & b). Indeed, Hutchings *et al.* (2007) noted a significant increase in the size range of fish targeted by shore and boat anglers in the estuary following the imposition of the ban on the gill net fishery. A corresponding statistically significant (r^2 = 0.76, P >0.05) increase was observed in the proportion of *L. richardsonii* larger than 200 mm TL in the catches taken during summer in this study, but not in the other seasons or for any of the other species. The lack of a corresponding increase in other species was not particularly surprising considering their low abundance in the catches and the fact that the net used in this study does not sample fish larger than 200 mm TL very effectively due to its small size (30 m in length).

Some illegal fishing still takes place in the estuary (pers. obs.) and may still be sufficient to eliminate many of the larger fish in the estuary. The body depth to total length ratio of many of the other marine migrant species frequenting the Berg estuary is much higher than that for *L. richardsonii* which would make them susceptible to capture by gill nets at a much smaller size than for mullet. The low numbers of individuals >100 mm TL of these species (particularly *P. saltartix, L. lithognathus, L. amia*) in the Berg, which are common in estuaries on the south coast where gill netting is banned, may well be a reflection of high levels of historic gill net fishing effort. A number of freshwater species were present in modest numbers in catches in the estuary, represented mostly by juveniles. These were all euryhaline freshwater species that occur throughout the main stem of the Berg River (Clark et al. *In press*).

The distribution of different estuary associated fish species in the estuary was also interesting. Most of the estuary dependent marine migrants (Whitfield's 1994 Category IIa and IIb species – e.g. *L. amia, L. lithognathus, S. bleekeri*) displayed a preference for the middle reaches of the system, while the facultative marine migrants (Category IIc species – e.g. *L. richardsonii* and *Rhabdosargus globiceps*) and marine vagrants (e.g. *Rhinobatos annulatus*) were more abundant near the mouth. Some estuarine residents were widely distributed throughout the estuary (e.g. G. *aestuaria*), some were most abundant in the middle reaches of the system (e.g. *C. multifasciatus, P. knysnaensis*) while others were most abundant near the mouth (*C. nudiceps, C. superciliosus,* and *S. temmincki*). Freshwater species (e.g. *O. mossambicus, C. carpio, M. dolomieu,* and *G. affinis*) were all concentrated in the upper reaches of the estuary. Differences in the longitudinal habitat preferences displayed by these species contributed to clear gradients in species composition up the length of the estuary as was evident in the results of multivariate analyses of community structure.

4.3 Importance of the lower Berg River floodplain for estuarine fish species

The floodplain surrounding the upper parts of the Berg estuary was sampled during four of the sampling excursions - Winter 1992, 2003, 2004, 2005, and Spring 2005 – being the only times when significant parts of the floodplain were covered with water. Number of species captured in these floodplain samples was low (1-6 per survey) and included mostly freshwater species (*Lepomis macrochirus, O. mossambicus, C. carpio* and *Galaxias zebratus*) but also some estuarine residents (*P. knysnaensis* and *C. nudiceps*) and a marine migrant species (*L. richardsonii*). Densities of fish at the floodplain sites were also very low (generally <0.3 fish.m^{-2} except for two large catches of small *L. richardsonii.* All of the pans on the floodplain are known to dry out completely in summer and are located high up in the estuary (mostly >30 km from the mouth). For these reasons, they are probably of little direct value as a habitat for estuarine species, particularly as they are seldom connected to the main part of the estuary for more than a few days at a time (pers. obs.). *G. zebratus* is the only species considered to show a strong association with the floodplain areas, as it was not recorded in the main part of the estuary. *G. zebratus* is an indigenous species of freshwater fish that used to be abundant in the Berg River but has largely been eliminated from the system due to the introduction of alien fish species and other anthropogenic influences (Clark *et al*. In press). It is considered to be an extremely hardy species and is known to tolerate a wide range of water and temperature conditions (Skelton 1993). It is unlikely, however, that this species is able to survive when the floodplain dries out in summer or is able to complete its life cycle in the short period during which the floodplain pans contain water, considering that it only matures at 38-40 mm TL and reaches an age of at least 10 years (Barnard 1943). It is more likely that the specimens recorded in 1992 had recently arrived in this habitat, after having been carried downstream with the floodwater during the recent floods. For these reasons the floodplain surrounding the estuary is considered of little direct importance to estuarine fish. (It should be noted that the only other species found exclusively on the floodplain, *L. macrochirus*, is an alien and as such its presence on the floodplain is of little consequence).

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