Fish utilization of surf-zones. Are they changing? A case study of the Sheltered, warm-temperate King's Beach

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Surf-zone fish communities and their shifts over time are generally poorly understood. The aim of this study was to compare the current surf-zone fish assemblage at King's Beach, South Africa, to a similar study conducted three decades ago, before the collapse of many exploited shore fishes in the region. Beach seine nets (mesh sizes of 10 and 50 mm) were used to target juvenile and adult fishes bimonthly from February to August 2011 over the high tide around sunset. A total of 14 species were recorded in both the 30 m and 100 m seine nets. The catch in these seine nets was dominated by *Pomadasys olivaceus* and *Liza richardsonii*, and this was significantly different to three decades ago, when *P. olivaceus*, *Sarpa salpa* and *Diplodus capensis* dominated the catch. Important linefish species belonging to the Sparidae and Sciaenidae families were significantly smaller and less abundant in this study. Two sparids, *S. salpa* and *Lithognathus mormyrus,* which made a large contribution to the surf-zone catch three decades ago were absent during this study. Reasons for the significant shifts in the surf-zone fish community, including overexploitation of the linefish and potential habitat modification, are discussed.

Key words: surf-zone, ichthyofauna, community shifts, overfishing, linefish.

INTRODUCTION

Many fish stocks globally have collapsed as a consequence of intensive overfishing (Jackson *et al.* 2001). An array of management decisions have been implemented to return these ecosystems to ecologically and economically sustainable states (Worm *et al.* 2009), a challenging task which is often hampered by the life-history of long-lived, late-maturing species (Hutchings 2000). Quantifying the effects of fishery collapse and identifying overfishing as an ultimate cause is sometimes diffused in complex systems by drivers such as climate change, habitat modification, or human disturbance (Finney *et al.* 2000; Jackson *et al.* 2001; Hutchings & Reynolds 2004).

In dynamic habitats such as sandy beach surf-zones, which are characteristically difficult to sample (Strydom 2007; Schlacher *et al.* 2008), effects of overfishing may be unclear. The extent to which fishes utilize surf-zones and the factors influencing community structure are generally poorly understood (Beyst *et al.* 2001; Vasconcellos *et al.* 2010). Surf-zones are important for many estuary-associated and economically important

fish species, especially in the early stages of their development (Whitfield 1989; Strydom 2003; Able 2005; Félix *et al.* 2007). Consequently, several studies have highlighted the value of surf-zones as nursery areas because of high densities of juvenile and/or larval fish (Whitfield 1989; Beyst *et al.* 2001; Ross & Lancaster 2002; Strydom & d'Hotman 2005; Able *et al.* 2010; Marin Jarrin & Shanks 2011).

In South Africa, many surf-zone fishes are exploited in linefishery (the hook and line fishery) and the populations of many of these species have collapsed (Attwood & Farquhar 1999; Griffiths 2000; Palmer *et al.* 2008). Unfortunately, few historical studies are available for comparison with the present day. Lasiak (1982), however, conducted a study of the fish assemblage in a sheltered surf-zone in Algoa Bay, South Africa. The study comprised a monthly assessment of the fish assemblage using a large (60 m long by 2 m high with 4 cm stretched mesh) and medium (30 m long by 2 m high with 1.7 cm stretched mesh) seine net, pulled in triplicate and duplicate, respectively, when sunset fell within two hours of high tide, over a period of two years from 1978 to 1980 (Lasiak 1982). With the subsequent collapse of the

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stocks of several linefish species in South Africa (Palmer *et al.* 2008), one would expect this to be reflected in the modern-day fish assemblage in the same habitat.

The objectives of this study were to evaluate changes in the surf-zone fish community, particularly the commercially important linefish species, over the last 30 years. This was achieved by conducting an assessment of the fish utilizing King's Beach and comparing this to the study by Lasiak (1982). The testable hypothesis for this study was that the current fish assemblage at King's Beach will be significantly different, in terms of the composition and abundance of species, from that observed by Lasiak (1982).

MATERIALS & METHODS

Study area

King's Beach (33°58'S, 25°19'E) is located in Port Elizabeth on the temperate coast of South Africa (Fig. 1). This 1.3 km long beach is the most sheltered surf-zone in Algoa Bay with an average wave height of 0.7 m and a surf-zone which usually extends 50 to 100 m offshore (McLachlan 1980). Tides are classed as microtidal (2.0 m fluctuation) and diurnal. The beach state is typically dissipative or intermediate (McLachlan 1980).

Field sampling

The sampling regimes and techniques described by Lasiak (1982) were followed where possible. Sampling was conducted at one location (midway along the beach), fortnightly over a six-month period from February to August 2011 whenever the high tide occurred within two hours of sunset. A total of 12 sampling trips were conducted, with triplicate collections (one hour before, at and one hour after sunset) from each gear type on every trip.

Two gear types were used. The first was a 100 m long by 2.0 m high bag-less monofilament net with 50 mm stretched mesh (which acted as a gillnet for some of the smaller fishes). The net was weighted near the centre with additional lead weights to ensure that this part of the net remained on the substrate during retrieval. The approximate volume of water sampled using this net was 6000 m^3. This net was deployed using a motorized rubber dinghy to take the net beyond the surf-zone breakers. A 110 m rope was attached to the bridle at each end of the net to facilitate onshore retrieval. The net was set parallel and approximately 100 m from the
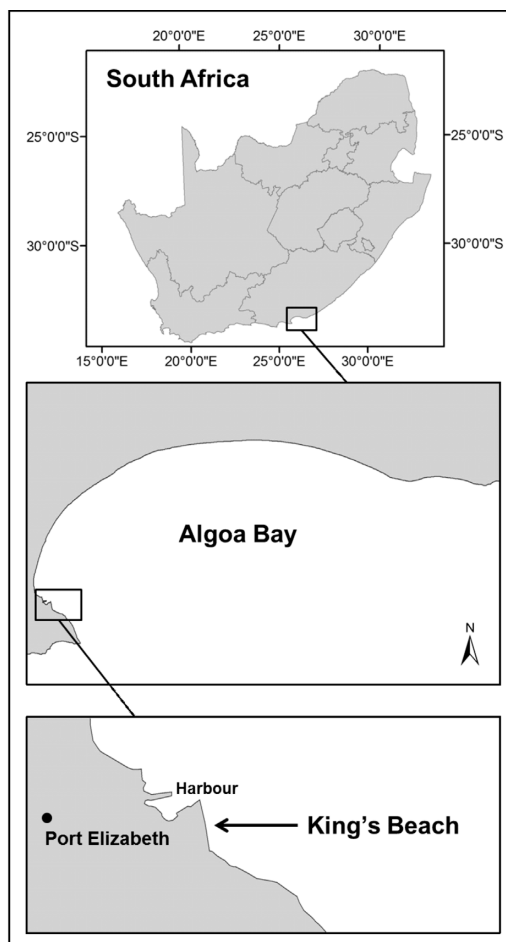

Fig. 1. Algoa Bay, South Africa, showing the location of the study area at King's Beach.

shore. Due to dangerous surf conditions and difficulty during boat launch, the 100 m seine was not used on one trip (18 June). A minimum of eight people were required to haul in the net.

A 30 m long by 1.5 m high seine net with 10 mm stretched mesh and a central bag was used to sample the shallower surf-zone. This net was hauled in an arc from the shore to approximately 1.5 m and at least four people were required to haul in the net. The approximate volume of water sampled using this net was 1000 m^3.

All fish that could be positively identified in the field were measured to fork-length (FL) and total-length (TL) and then released alive. The remainder were preserved in 10% formaldehyde and sea-water and then taken back to the laboratory for identification.

Temperature, salinity (parts per thousand; ‰),

pH and turbidity (measured as NTU) were recorded using a YSI 6600 multi-parameter meter, coinciding with the time of each replicate of the 100 m seine net. As several surf-zone studies have noted the possible link between floating seaweed in the surf-zone and fish densities (e.g. Crawley *et al.* 2006), a subjective scale was used to measure seaweed abundance in the water column. An ordinal scale, from 0 to 4, was used, ranging from no visible seaweed in the surf-zone (0), seaweed in the surf-zone but not washed ashore (1), sparse (2) and moderate (3) amounts of seaweed in both the surf-zone and washed ashore, to seaweed being highly visible and large amounts washed ashore (4).

Laboratory analysis

All fish were identified to the lowest taxonomic rank possible using reference guides for fish of the area (Smith & Heemstra 1995; Heemstra & Heemstra 2004). Mullet (Mugilidae) are particularly difficult to identify when they are young and therefore their teeth were analysed for identification (van der Elst & Wallace 1975). Fish were referred to as 'juveniles' and as 'adults' before and after reaching sexual maturity, respectively, as determined by known length–maturity relationships (Mann 2000; Heemstra & Heemstra 2004). All fish were measured according to fork length (FL) and total length (TL).

Data analysis

All biological and environmental data were tested for normality (Kolmogorov-Smirnov test) and for homogeneity of variances (Levene's test). The relationship between the gear type and species catch per unit effort (CPUE; number of fish per seine haul) data and the environmental data were tested using the statistical analysis software-package, PRIMER and the BIO-ENV routine (Clarke & Warwick 1994) or Spearman rank correlations.

For comparative purposes, the Lasiak (1982) monthly catch data from February to August were extracted for each species for the 30 m and 60 m seine net. As the species-specific length data were pooled in the Lasiak (1982) study, mean length data for selected species from the 60 m and 30 m seines from Lasiak (1982) and the 100 m and 30 m seines from the current study, respectively, were compared and no significant difference was seen in terms of mean net selectivity between the two studies ($P > 0.05$; d.f. = 5 and 9, respectively). Therefore direct comparisons between these two

net sizes were justified. A one-way paired Student's *t*-test or a Pearson chi-square analysis was conducted to compare the percent numerical contribution of each species in the two studies. Shannon-Wiener diversity (H') indices were calculated for each gear type where applicable:

$$H' = -\sum_{i=1}^{R} p_i \log p_i \, ,$$

where p_i is the proportion of individuals in the *i*th species and R is the total number of species.

Species were grouped by family and the numerical contribution of the dominant families was compared between the two studies using a Pearson chi-square analysis. Shifts in the community structure by family between the two studies were analysed using a multidimensional scaling (MDS) plot and the significance tested using an ANOSIM (Clarke & Warwick 1994). Abundance data were square-root transformed prior to analysis. Family CPUE, represented as the number of fish caught per sampling trip rather than per seine haul as these data were unavailable from Lasiak (1982), were compared between studies using non-parametric Mann-Whitney *U*-tests. For comparative purposes only catch data from the 30 m seine from before and after sunset were extracted as Lasiak (1982) did not sample with this net at sunset. Where applicable data are presented as mean ± S.D.

RESULTS

Environmental factors

Sea temperature in the surf-zone ranged from 13.5 to 20.3°C during the study period, with an overall decrease from February to the end of the study in August 2011 (Fig. 2). Salinity ranged from 32.0 to 36.2 ‰, with no obvious decrease after the nearby Baaken's River, which flows into the Port Elizabeth harbour adjacent to King's Beach, flooded in March (Fig. 2). The pH ranged from 7.66 to 8.79 throughout the study, with the lowest value recorded after heavy rainfall in March (Fig. 2). Turbidity ranged from 1.7 to 21.8 NTU (Fig. 2), with two clear peaks at the end of April and beginning of July 2011. These peaks in turbidity roughly coincided with two periods during the study when the surf-zone seaweed abundance was also high (Fig. 2) and followed stormy sea events.

There were no significant correlations between the CPUE data and environmental factors for any gear type, with the strongest correlations found between the suspended seaweed abundance and CPUE of the 30 m (0.198) seine and between
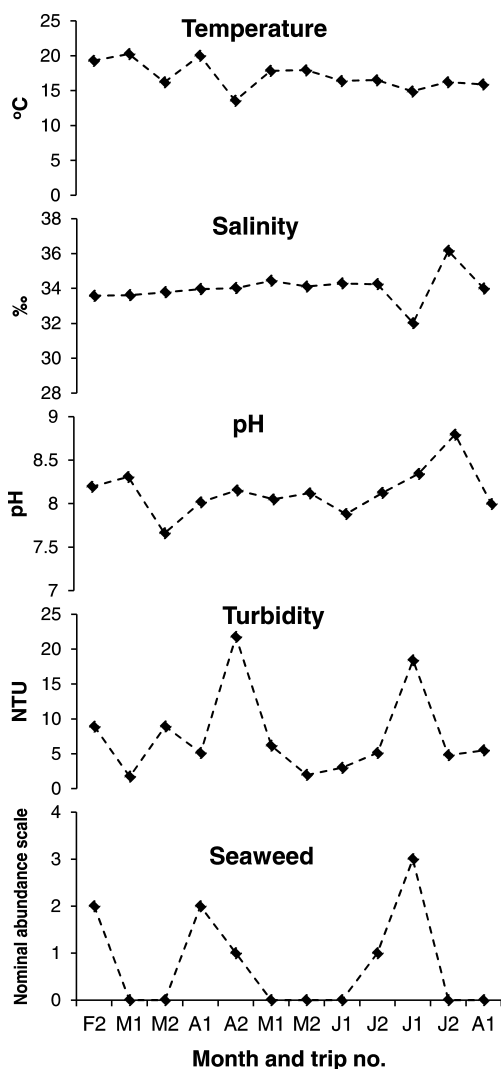
Fig. 2. Environmental variables measured in the surf-zone at King's Beach at two-weekly intervals over the sampling period (February to August 2011).

the pH and CPUE of the 100 m (–0.338) seine (Table 1). The CPUE was higher after sunset for both gear types but this was only significant for the 100 m seine (Table 1; Kruskall-Wallace test, $P < 0.05$). When analysed by species there was a strong negative correlation between turbidity and the CPUE of lesser guitarfish (*Rhinobatos annulatus*) (–0.899) in the 100 m seine and the estuarine roundherring (*Gilchristella aestuaria*) (–0.591) in the 30 m seine (Table 1). Sea temperature was negatively correlated with the CPUE of *Rhabdosargus globiceps* (–0.593) in the 30 m seine and *Pomatomus saltatrix* (–0.786) in the 100 m seine (Table 1).

The CPUE of the remaining species was either not significantly correlated to any of the measured environmental variables ($P > 0.05$) or the correlations were not considered meaningful because the CPUE of those species was low.

Fish composition in the 30 m seine net

In the current study, a total of 14 species belonging to eight families ($H' = 0.571$) were caught in the 30 m seine net (Table 2). Biweekly CPUE (34.1 ± 44.1 fish/trip) and catch composition were variable (Fig. 3). The catch was dominated by four species, *Pomadasys olivaceus, Liza richardsonii, Diplodus capensis* and *R. globiceps*, in terms of number, CPUE and consistency of occurrence (Table 2, Fig. 3). *D. capensis, L. richardsonii* and to a lesser extent, *R. globiceps* dominated the catch in the 30 m seine during the first few sampling months while *P. olivaceus* was by far the dominant species caught during middle sampling months (Fig. 3). With the exception of *G. aestuaria*, all of the other species caught in the 30 m seine contributed less than 1.0% to the total catch.

For comparable months (February to August), the species composition in the historical study (Lasiak 1982) was richer, but not more diverse, with 28 species belonging to 17 families ($H' = 0.527$; Table 3). *P. olivaceus* (70.1%), *L. richardsonii* (1.6%), *D. capensis* (5.6%) and *R. globiceps* (1.6%) were also a dominant component of the catch in the historical study. *Atherina breviceps* was by far the numerically dominant (49.0%) species (Lasiak 1982) when compared with this study (4.0%), but the bulk (97.9%) of *A. breviceps* caught by Lasiak (1982) were in the months outside of this study's sampling period (September to January). The sand steenbras *Lithognathus mormyrus*, strepie *Sarpa salpa* and maasbanker *Trachurus trachurus,* which were relatively important components (9.8%, 4.8% and 0.9%, respectively) in the 30 m seine net catch (Lasiak 1982), were absent during this study. Ten species were captured in over 50% of the sampling events during Lasiak's study compared with three species during the current study (Table 2).

Fish composition in the 100 m and 60 m seine net

In the present study, fourteen species belonging to nine families were caught in the 100 m seine net ($H' = 0.094$). The total catch of the 100 m seine was dominated by 1552 *L. richardsonii* which were captured in a single sample during the second fortnight in May (Table 4). Biweekly CPUE was

Table 1. Correlations between environmental variables and catch per unit effort (CPUE) for each gear type used in this study (BIOENV analysis). Furthermore, each gear is separated into CPUE of the four numerically dominant fish species (in addition to those which had strong significant correlations) caught by each gear type (Spearman rank order correlation analyses). The highest CPUE relative to sunset (before, at or after) is also indicated. The disproportionately large catch of *Liza richardsonii* in the 100 m seine net is not included in this table. Significant correlations ($P < 0.05$) are indicated with an asterisk.

Family	Species	CPUE	Sea temperature	Salinity	pH	Turbidity	Seaweed rank	Highest CPUE relative to sunset
30 m seine		11.4	-0.105	0.003	-0.192	-0.064	0.198	After
Haemulidae	*Pomadasys olivaceus*	6.9	-0.108	-0.452	-0.377	0.396	0.508	
Mugilidae	*Liza richardsonii*	1.6	-0.044	0.138	0.160	-0.377	-0.065	
Sparidae	*Diplodus capensis*	1.4	-0.421	-0.435	0.334	0.450	0.272	
Sparidae	*Rhabdosargus globiceps*	0.8	-0.593*	0.390	0.218	0.273	-0.026	
Clupeidae	*Gilchristella aestuaria*	0.2				-0.591*		
Mugilidae	*Myxus capensis*	0.1			0.591*			
Atherinidae	*Atherina breviceps*	0.1		0.640*			-0.677*	
100 m seine		2.9	0.010	-0.135	-0.338	0.066	-0.047	After*
Mugilidae	*Liza richardsonii*	1.3	-0.007	-0.103	0.050	0.043	-0.058	
Mugilidae	*Liza tricuspidens*	0.3	-0.029	-0.283	0.175	0.233	0.224	
Tetraodontidae	*Amblyrhynchotes honckenii*	0.3	0.480	-0.044	-0.131	-0.480	-0.196	
Sparidae	*Diplodus capensis*	0.2	0.125	0.042	-0.229	0.046	-0.394	
Rhinobatidae	*Rhinobatos annulatus*	0.2				-0.899*		
Pomatomidae	*Pomatomus saltatrix*	0.2	-0.786*					

Table 2. Species composition, total catch (number and %), consistency of species occurrence, percentage of juveniles, catch per unit effort (CPUE) and total length (TL) of all fishes caught in the 30 m seine net during fortnightly sampling trips at King's Beach. Months are indicated by their first letter, beginning in February and ending in August 2011.

Family	Species	Month							Total catch in catch		Consistency	Juveniles	CPUE		Total length (cm)	
		F	M	A	M	J	J	A	No.	%	%	%	Mean	Range	Mean	Range
Atherinidae	*Atherina breviceps*	X					X		2	<1	16.7	50	0.1	0–1	4.70	3.9–5.5
Clupeidae	*Gilchristella aestuaria*		X	X					7	2	16.7	0	0.2	0–5	5.19	4.5–6.0
Haemulidae	*Lithognathus lithognathus*			X		X	X		2	<1	16.7	100	0.1	0–1	29.85	25.8–33.9
	Pomadasys olivaceus		X	X	X	X	X		249	61	50.0	100	6.9	0–152	4.33	2.7–14.2
Kyphosidae	*Neoscorpis lithophilus*			X					1	<1	8.3	0	<0.1	0–1	36.00	–
Mugilidae	*Liza dumerii*			X	X				2	<1	16.7	100	0.1	0–1	12.75	11.3–14.2
	Liza richardsonii	X	X	X	X		X		59	14	58.3	93	1.6	0–34	7.51	2.8–28.6
	Liza tricuspidens			X					2	<1	8.3	100	0.1	0–2	5.85	5.7–6.0
	Mugil cephalus						X		1	<1	8.3	100	<0.1	0–1	4.40	–
	Myxus capensis		X					X	3	<1	16.7	100	0.1	0–2	5.90	5.1–7.0
Rhinobatidae	*Rhinobatos annulatus*		X		X		X		4	<1	16.7	50	0.1	0–3	47.75	22.4–63
Sparidae	*Diplodus capensis*	X	X	X	X	X	X		49	12	58.3	100	1.4	0–9	5.62	3.3–13.5
	Rhabdosargus globiceps	X	X	X	X				27	7	41.7	100	0.8	0–10	5.03	2.6–7.6
Tetraodontidae	*Amblyrhynchotes honckenii*		X						1	<1	8.3	100	<0.1	0–1	5.20	–
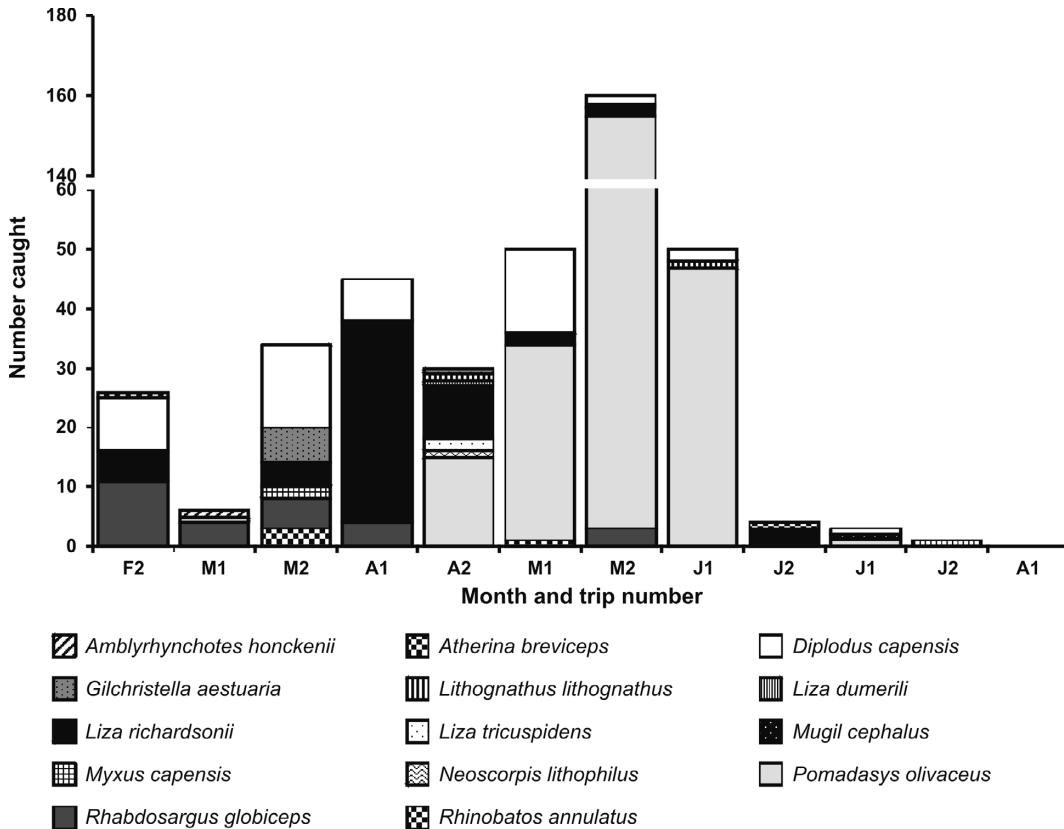
Fig. 3. Fish species contribution per sampling trip, as caught in the 30 m seine at King's Beach between February and August 2011. Months are indicated by their first letter and the fortnight within each month is indicated numerically.

consistently lower than for the 30 m seine when this *L. richardsonii* catch was excluded (8.7 ± 6.3 fish/trip). Although remaining the dominant species, its omission increased the H' to 0.237. The CPUE for other species was low (≤5.0 fish/haul) (Table 4). *L. richardsonii* was also the most consistently captured species and found in 72.7% of the seine net hauls (Table 4). The majority, 91.2% or 78.2% (excluding the disproportionately large *L. richardsonii* catch), of the fish caught were adults (Table 4).

In the historical study, a total of 42 species belonging to 24 families with an H' of 0.952 were captured during comparable months (February to August) using a 60 m seine net (Lasiak 1982) (Table 5). The most noticeable difference in the catch composition was *S. salpa* which dominated the catch (42.7% contribution) in the historical study, but was absent in the present study (Tables 4 & 5). Similarly, *L. mormyrus* was relatively abundant in the historical study (5.1%) but absent during the present study. However, all of the

remaining species which contributed more than 1.0% to the catch in the historical study were also present, but with a lower numerical contribution, in the catch of the current study (Tables 4 & 5). At least 12 species in the Lasiak (1982) study consistently occurred in well over 50% of the monthly samples (Table 5) while only two species in the current study were caught consistently in over 50% of the fortnightly samples (*L. richardsonii* and *R. annulatus*; Table 4).

Historical comparison: family differences

For the months of February to August, the Haemulidae dominated the total catch in the 30 m seine net in both the Lasiak (1982) and current study (Table 2 and Table 3; Fig. 4). Overall, the dominant families captured in the two studies were similar (Fig. 4). However, the Mugilidae contributed a higher proportion towards the total catch (16.4%) in the current study when compared with the historical study (Lasiak 1982) (1.6%; Fig. 4). Sciaenids and carangids, which were domi-

Table 3. Composition of the species captured in the 30 m seine net by Lasiak (1982) showing the total catch (number and %), the catch between the months February to August, the consistency of species occurrence during the monthly sampling trips and the mean and range of fish length measurements.

Family	Species	Total catch No.	%	February to August No.	%	Consistency in catch %	Total Length (cm) Mean	Range
Ambassidae	*Ambassis ambassis*	1	<1	1	<1	7.7	–	2.1–2.1
Atherinidae	*Atherina breviceps*	8338	49	177	4	69.2	7.9	3.4–11
Carangidae	*Caranx* sp.	3	<1	3	<1	23.1	–	4.2–7.1
	Lichia amia	5	<1	0	<1	7.7	–	4.1–5.9
	Trachinotus africanus	1	<1	0	<1	7.7	–	–
	Trachurus trachurus	375	2	44	<1	76.9	5.8	2.9–8.6
Clupeidae	*Etrumeus terres*	14	<1	12	<1	15.4	–	3.8–4.8
	Gilchristella aestuaria	16	<1	8	<1	53.8	–	–
Cynoglossidae	*Cynoglossus* sp.	3	<1	3	<1	15.4	–	–
Cyprinidae	*Gonorhynchus gonorhynchus*	3	<1	3	<1	7.7	–	3.8–4.3
Haemulidae	*Pomadasys commersonnii*	1	<1	1	<1	7.7	–	–
	Pomadasys olivaceus	5503	33	3516	70	100.0	4.3	2.1–16.8
Kyphosidae	*Neoscorpis lithophilus*	2	<1	0	<1	15.4	–	4.1–6.2
Monodactylidae	*Monodactylus falciformis*	8	<1	2	<1	46.2	22.5	21–23.3
Mugilidae	*Liza dumerili*	8	<1	3	<1	30.8	–	–
	Liza richardsonii	253	2	78	2	92.3	8.2	1.7–31.8
	Liza tricuspidens	1	<1	0	<1	7.7	–	–
Platycephalidae	*Platycephalus indicus*	1	<1	1	<1	7.7	–	4.9–5.2
Pomatomidae	*Pomatomus saltatrix*	6	<1	5	<1	23.1	19	7–50.8
Rhinobatidae	*Rhinobatos annulatus*	21	<1	16	<1	76.9	–	–
Sciaenidae	*Argyrosomus japonicus*	23	<1	18	<1	46.2	27.1	18–41.2
	Umbrina canariensis	17	<1	13	<1	53.8	27.3	3.5–55.8
Soleidae	*Austroglossis pectoralis*	1	<1	0	<1	7.7	–	–
	Heteromycteris capensis	7	<1	3	<1	30.8	–	–
Sparidae	*Diplodus cervinus*	3	<1	0	<1	15.4	–	–
	Diplodus capensis	374	2	279	6	100.0	7.2	2.2–36
	Lithognathus lithognathus	20	<1	2	<1	46.2	46.9	16.8–86.7
	Lithognathus mormyrus	698	4	489	10	100.0	5.5	2.1–29
	Pagellus natalensis	3	<1	3	<1	7.7	–	6.6–8.2
	Rhabdosargus globiceps	163	<1	81	2	76.9	5.5	2.8–10.1
	Rhabdosargus holubi	19	<1	2	<1	38.5	20.9	10.5–32.8
	Sarpa salpa	926	5	241	5	76.9	6.3	1.9–15.6
	Sparodon durbanensis	1	<1	0	<1	7.7	–	–
Sphyranidae	*Sphyraena acutipinnis*	15	<1	1	<1	38.5	–	5.1–10.2
Synathidae	*Sygnathus temminckii*	1	<1	0	<1	7.7	–	–
Tetraodontidae	*Amblyrhynchotes honckenii*	17	<1	10	<1	61.5	–	3.9–5.6
Triglidae	*Lepidotrigla* sp.	6	<1	0	<1	23.1	–	3.5–5.5

nant during the Lasiak (1982) study, were absent in the 30 m seine net catches in this study. Overall, there was a significant difference in the family composition between the two studies ($P < 0.05$; $\chi^2 = 146.5$).

Sparidae which dominated the catch of the large seine net in the historical study (Lasiak 1982) were replaced by the Mugilidae in this study (Fig. 5). The contribution of the top ten families (the remainder were summed for comparison as 'others') were significantly different between the two studies ($P < 0.05$; $\chi^2 = 1359.4$). Even when the exception-

Table 4. Species composition, total catch (number and %), consistency of species occurrence, percentage juvenile, catch per unit effort (CPUE) and total length (TL) of all fish caught in the 100 m seine net during in fortnightly sampling trips at King's Beach. Months are indicated by their first letter, beginning in February and ending in August 2011. The second June sample was not conducted.

Family	Species	Month							Total catch in catch		Consistency	Juveniles	CPUE		Total length (cm)	
		F	M	A	M	J	J	A	No.	%	%	%	Mean	Range	Mean	Range
Dichistiidae	*Dichistius multifasciatus*				X				1	<1	9.1	0	<0.1	0–1	27.80	–
Haemulidae	*Pomadasys olivaceus*		X	X					4	<1	36.4	25	0.1	0–1	15.13	13.3–16.1
Monodactylidae	*Monodactylus falciformis*						X		1	<1	9.1	100	<0.1	0–1	12.20	–
Mugilidae	*Liza richardsonii*	X	X	X	X	X	X		1595	97	72.7	8	48.3	0–1552	26.15	21.0–38.7
	Liza tricuspidens			X	X	X	X		10	<1	36.4	0	0.3	0–5	44.14	25.4–54.1
Pomatomidae	*Pomatomus saltatrix*	X	X	X	X				6	<1	36.4	67	0.2	0–3	24.78	23.3–26.9
Rhinobatidae	*Rhinobatos annulatus*	X	X	X	X	X		X	7	<1	54.5	57	0.2	0–2	62.64	34.2–104.5
Sciaenidae	*Argyrosomus japonicus*			X			X		4	<1	18.2	100	0.1	0–3	25.10	20.0–34.3
	Umbrina canariensis			X					1	<1	9.1	0	<0.1	0–1	49.80	–
Sparidae	*Diplodus capensis*			X		X	X		8	<1	36.4	13	0.2	0–4	25.21	15.4–32.7
	Diplodus cervinus				X				1	<1	9.1	0	<0.1	0–1	27.50	–
	Lithognathus lithognathus						X		1	<1	9.1	0	<0.1	0–1	69.20	–
	Rhabdosargus holubi				X				1	<1	9.1	0	<0.1	0–1	22.80	–
Tetraodontidae	*Amblyrhynchotes honckenii*			X					9	<1	9.1	11	0.3	0–4	13.87	11.7–17.0

Table 5. Species composition of the 100 m seine from Lasiak (1982) showing total catch (number and %), the catch between February and August, the consistency of occurrence and the mean and range of the length measurements.

Family	Species	Total catch		February to August		Consistency in catch	Total length (cm)	
		No.	%	No.	%	%	Mean	Range
Ariidae	*Galeichthys feliceps*	3	<1	3	<1	8	–	–
Atherinidae	*Atherina breviceps*	32	<1	12	<1	31	8.9	6.4–10.5
Carangidae	*Caranx* sp.	2	<1	0	<1	4	–	–
	Lichia amia	3	<1	0	<1	4	–	–
	Trachurus trachurus	6	<1	2	<1	12	6.4	5.3–8.0
Clupeidae	*Sardinops sagax*	1	<1	0	<1	4	–	–
Cynoglossidae	*Cynoglossus* sp.	1	<1	1	<1	4	–	–
	Cynoglossus capensis	6	<1	1	<1	8	–	–
Dasyatidae	*Dasyatis pastinaca*	37	<1	32	1	27	–	–
Dichistiidae	*Dichistius capensis*	3	<1	2	<1	12	–	–
	Dichistius multifasciatus	1	<1	1	<1	4	–	–
Gempylidae	*Trichiurus lepturus*	4	<1	4	<1	4	–	–
Haemulidae	*Pomadasys commersonnii*	21	<1	10	<1	54	–	–
	Pomadasys olivaceus	514	13	184	8	77	11.9	3.8–22.2
Kyphosidae	*Neoscorpis lithophilus*	1	<1	1	<1	4	–	–
Merlucciidae	*Merluccius capensis*	4	<1	4	<1	8	–	–
Monodactylidae	*Monodactylus falciformis*	409	10	200	9	81	21.8	17.0–25.4
Mugilidae	*Liza dumerili*	33	<1	10	<1	35	–	–
	Liza richardsonii	402	10	128	5	85	26.8	4.2–38.8
	Liza tricuspidens	22	<1	14	<1	27	–	–
	Mugil cephalus	2	<1	0	<1	4	–	–
Myliobatidae	*Myliobatis aquila*	14	<1	8	<1	38	–	–
	Pteromylaeus bovinus	5	<1	0	<1	8	–	–
Platycephalidae	*Platycephalus indicus*	1	<1	1	<1	4	–	–
Pomatomidae	*Pomatomus saltatrix*	62	2	26	1	65	28.4	11.1–50.3
Rajidae	*Raja miraletus*	1	<1	1	<1	4	–	–
	Leucoraja ocellata	1	<1	1	<1	4	–	–
Rhinobatidae	*Rhinobatos annulatus*	184	5	107	5	92	–	–
Sciaenidae	*Argyrosomus japonicus*	158	4	95	4	65	27.1	16.3–53.4
	Umbrina canariensis	67	2	45	2	73	37.0	9.7–83.7
Scombridae	*Scomber japonicus*	1	<1	0	<1	4	–	–
Scyliorhinidae	*Haploblepharus edwardsii*	1	<1	1	<1	4	–	–
	Halaelurus natalensis	5	<1	5	<1	12	–	–
Sillaginidae	*Sillago maculata*	6	<1	5	<1	8	–	–
Soleidae	*Austroglossis pectoralis*	4	<1	1	<1	12	–	–
	Heteromycteris capensis	9	<1	7	<1	31	–	–
	Synaptura marginata	1	<1	1	<1	4	–	–
Sparidae	*Cheimerius nufar*	4	<1	4	<1	12	–	–
	Diplodus cervinus	6	<1	1	<1	15	–	–

Table 5 (continued)

Family	Species	Total catch		February to August		Consistency in catch	Total length (cm)	
		No.	%	No.	%	%	Mean	Range
	Diplodus capensis	342	9	220	9	92	14.9	4.8–34.2
	Lithognathus lithognathus	64	2	17	<1	69	30.7	12.2–89.6
	Lithognathus mormyrus	129	3	120	5	54	14.8	5.0–29.1
	Pachymetopon blochii	1	<1	0	<1	4	–	–
	Pagellus natalensis	1	<1	1	<1	4	–	–
	Rhabdosargus globiceps	19	<1	11	<1	35	9.1	5.9–13.1
	Rhabdosargus holubi	54	1	18	<1	62	20.8	9.7–31.4
	Sarpa salpa	1257	32	999	43	65	13.1	5.3–25.8
Sphyranidae	*Sphyraena acutipinnis*	7	<1	0	<1	8	–	–
Tetraodontidae	*Amblyrhynchotes honckenii*	57	1	34	1	65	–	–
Triakidae	*Mustelus* sp.	3	<1	3	<1	12	–	–

ally large catch of *L. richardsonii* in the current study was omitted, the family composition between the two studies was significantly different ($P <$ 0.05; $\chi^2 = 474.2$), with Mugilidae now dominating the catch (54.6%).

When combining the catch in all gears the juvenile and adult contingents were dissimilar during the two studies (Fig. 6; ANOSIM, $P < 0.05$, Global $R = 0.731$ and 0.787 respectively). Juvenile fishes in the historical study in particular showed little variability between months compared with the large variability in the present study (Fig. 6).

For comparable species and months, the CPUE of Sparidae was far greater in the historical study than during this study for both the 30 m (52.0 ± 14.5 fish/trip *versus* 5.5 ± 7.0 fish/trip; Mann-Whitney, $P < 0.05$) and large seine (19.0 ± 15.9 fish/trip *versus* 0.8 ± 1.5 fish/trip; Mann-Whitney, $P < 0.05$) catches. Of the Sparidae caught, large individuals (greater than 30 cm TL) comprised a larger proportion in Lasiak's study (7.4%) than in this study (4.2%). The CPUE of Sciaenidae (*Argyrosomus japonicus* and *Umbrina canariensis*) in the historical study was also far greater than the current study for both the 30 m seine (4.4 ± 4.3 fish/trip *versus* 0 fish/trip) and large seine (10.0 ± 16.3 fish/trip *versus* 0.4 ± 0.9 fish/trip; Mann-Whitney, $P < 0.05$) catches.
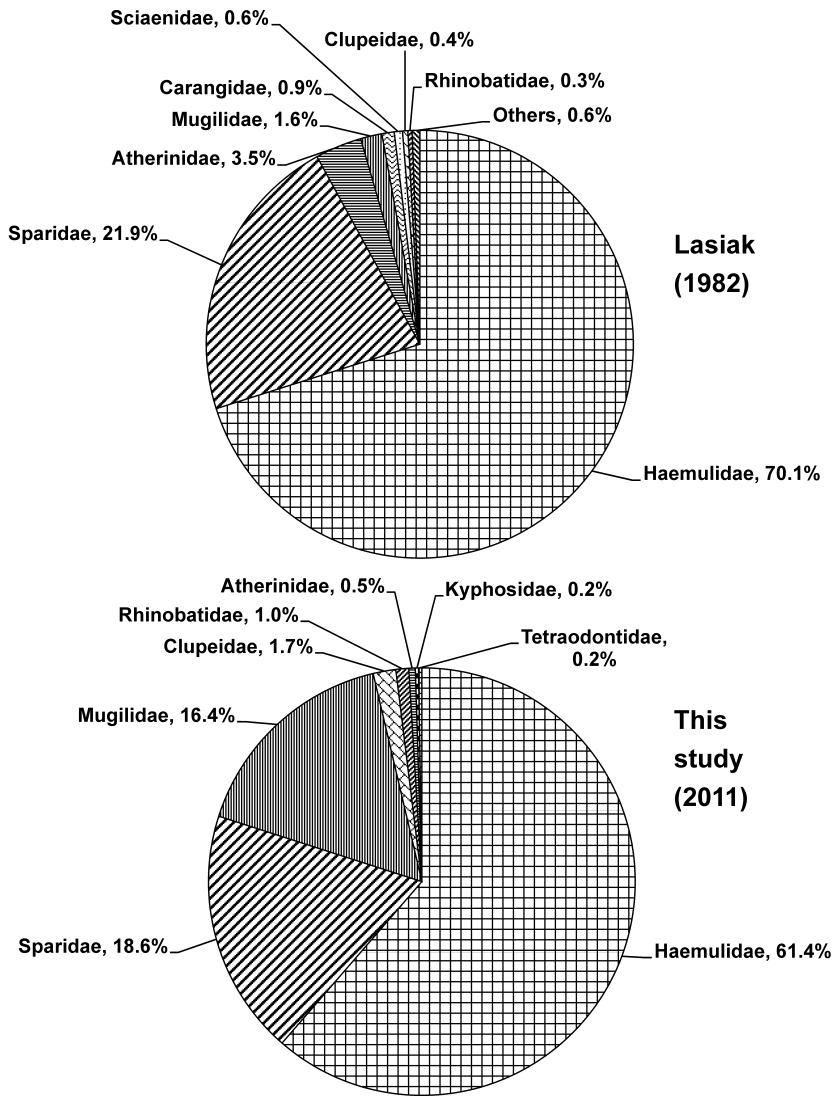
DISCUSSION

Environmental drivers

Environmental variables were not useful in explaining much of the overall CPUE variation between sampling trips in the present study; however, several species showed strong correlations with some of these variables (Table 1). The low salinity together with high pH and turbidity measured in the latter end of this study, possibly a reflection of local run-off and seepage into the surf-zone during winter storms, might explain the low CPUE during this period (Fig. 3). Turbidity may inhibit the feeding success of certain species (Clark 1997) and this might have played a part in the strong negative correlation observed between the CPUE of the benthic-feeding lesser guitarfish (*R. annulatus*) and turbidity (Table 1).

The density of suspended seaweed has been identified as a factor influencing the abundance of fishes in the surf-zone (Robertson & Lenanton 1984; Clark *et al.* 1996; Crawley *et al.* 2006). Van der Merwe & McLachlan (1987) found that detached macrophytes were not an important driver of juvenile fish abundance at King's Beach. The results of the present study suggest that overall CPUE was generally positively correlated to seaweed levels for juvenile fish caught in the 30 m seine (Table 1). However, for better resolution, an improved method for the quantification of seaweed density (e.g. Clark *et al.* 1996) may provide clearer relationships.

Lasiak (1984a) suggested that wind, more so than seasonality (Lasiak 1984b), was the dominant driver of variability in the surf-zone fish assemblage at King's Beach as it influenced the local temperature, turbidity and wave height. The current study provides some correlative evidence to confirm this observation (Table 1). However, it is most

Sciaenidae, 0.6%
Clupeidae, 0.4%
Carangidae, 0.9%
Rhinobatidae, 0.3%
Mugilidae, 1.6%
Others, 0.6%
Atherinidae, 3.5%

Sparidae, 21.9%

Lasiak
(1982)

Haemulidae, 70.1%

Atherinidae, 0.5%
Kyphosidae, 0.2%
Rhinobatidae, 1.0%
Tetraodontidae,
0.2%
Clupeidae, 1.7%

Mugilidae, 16.4%

This
study
(2011)

Sparidae, 18.6%

Haemulidae, 61.4%

Fig. 4. Percentage contribution of the fish families caught between February to August in the 30 m seine net by Lasiak (1982) (top) and this study in 2011 (bottom).

likely that a suite of interrelated variables drive the relative abundance of the fishes in the surf-zone at King's Beach, as is well-documented for surf-zones (e.g. Clark *et al.* 1996; Beyst *et al.* 2001).

Community shifts

The large net used by Lasiak (1982) was only 60 m in length and therefore a comparison with the 100 m net used in this study may have influenced the results. However, the differences in gear type were unlikely to have had an effect on the catch composition between the two studies as there was no significant difference in net selectiv-

ity (Figs 4 & 5). The relative abundance of the fish captured in the two studies may have been influenced by a difference in the deployment of the 30 m seine net, which was laid out just beyond the breakers, and therefore sampled more water, in the Lasiak (1982) study and by the larger-sized seine net in the present study. If a direct relationship is assumed between sampled volume and CPUE, then this sampling method and size difference for the 30 m and large seine net, respectively, would roughly equate to a reduction by 35% and an increase by 25% in the Lasiak (1982) catch by the two gears. However, when one considers the mag-
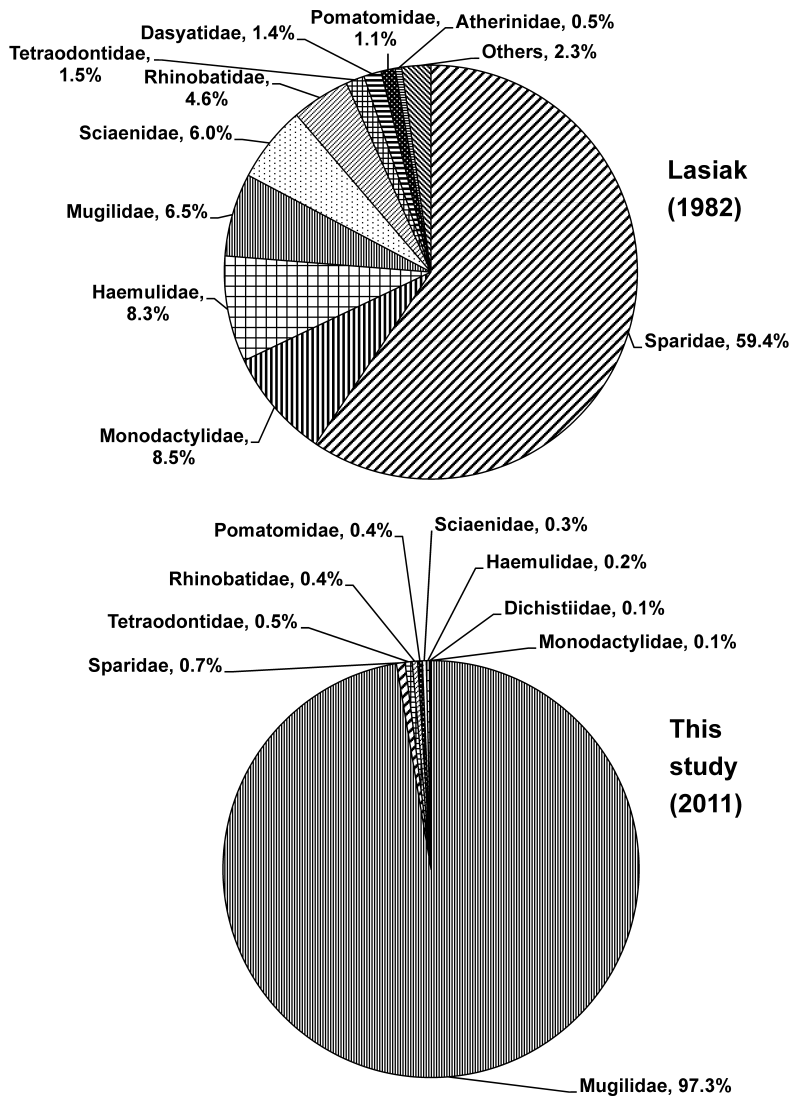
Fig. 5. Percentage contribution of the fish families caught between February to August in the 60 m seine net by Lasiak (1982) (top) and the 100 m seine net in this study in 2011 (bottom).

nitude of the difference in the catch of many of the species between this and the Lasiak (1982) study (Tables 2, 3, 4 & 5), these differences are not likely to influence the conclusions made in this study.

The comparison of the catch in the large seine net provides evidence for a shift in the composition, abundance and size frequency of the surf-zone fish community of King's Beach. This is perhaps best illustrated by two of the most important linefish families, the Sparidae and the Sciaenidae, which comprised a significant component of the catch in the Lasiak (1982) study, but were poorly represented in the present study.

Sparids were the most abundant family in the catch of the large seine net in the Lasiak (1982) study, while fishes belonging to the family Mugilidae dominated the catch in the present study (Fig. 5). An increase in the relative abundance of fish belonging to the family Mugilidae was also observed in the catch of the 30 m seine net (Fig. 4). However, the proportion of haemulids and sparids remained relatively stable (Fig. 4). One of the most likely explanations for the shift in the species composition would be the stock depletion of the linefish species. The majority of South Africa's linefish are considered to be overexploited
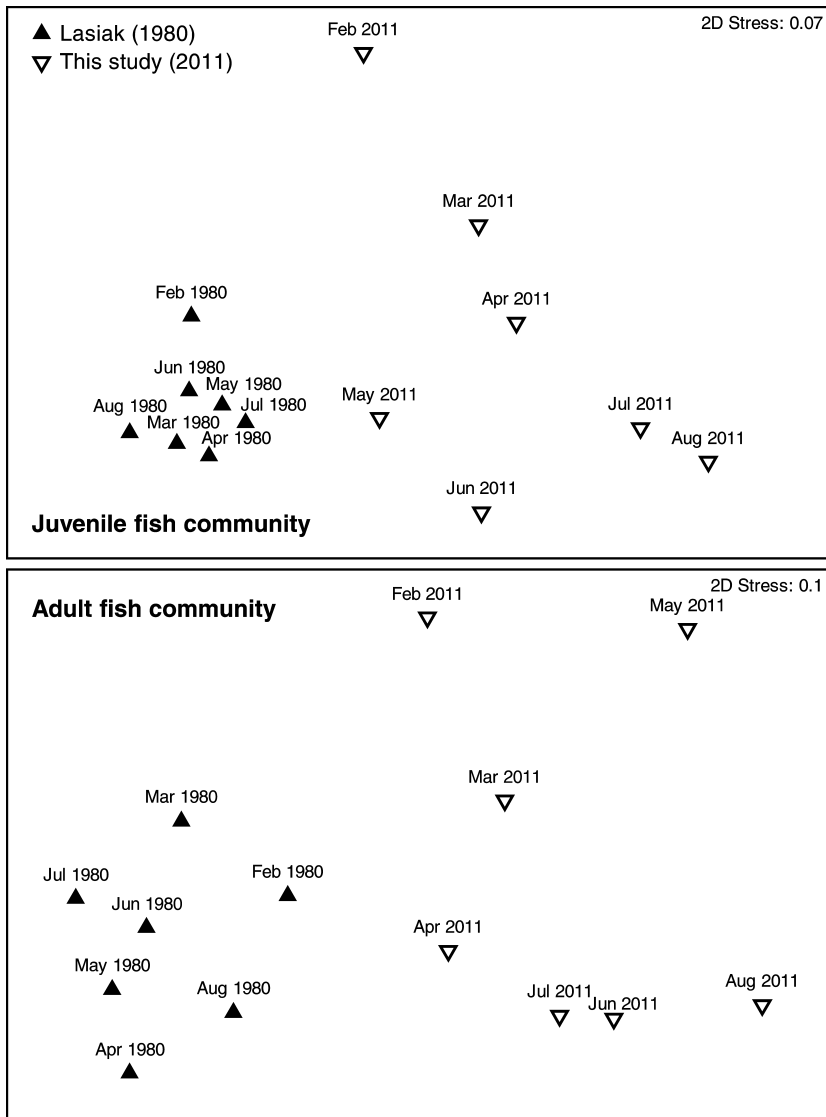
Fig. 6. Multi-dimensional scaling plots of the juvenile (30 m nets; upper plot) and adult (100 m and 60 m nets; lower plot) fish communities (by family) between February and August for 1979–80 (denoted as '1980') and 2011. Samples are grouped according to their respective months.

(Mann 2000) and in an annual week long shore-based linefish competition, the mean overall CPUE declined by more than half between the time periods 1978–1982 and 1999–2010 (Coetzee *et al.* 1989; Dicken *et al.* 2012). Although the relationship between reproductive output and recruitment success is far from clear (Dixon *et al.* 1999), egg production is considered to be a relatively good indicator of recruitment potential (Marshall *et al.* 1998). Thus, with large reductions in the relative abundance of adult fishes, the recruitment of larval linefish is expected to follow the same pattern, but this study did not aim to determine this. As specialist planktivores, the dominance of Mugilidae in this study is also indicative of the effects of exploitation, where fish from upper feeding guilds (such as Sparidae) are replaced with those belonging to lower feeding guilds (Jackson *et al.* 2001).

While overexploitation remains a plausible explanation, the absence of *S. salpa* or *L. mormyrus* (Sparidae) in the present study, which are not

heavily targeted in the linefishery (Table 2 & Table 4), suggests that other factors may also have played a role in the changes observed. The most obvious of these is that there may have been changes to the surf-zone habitat over the last three decades. Species noticeably absent or less abundant (from Sparidae and Sciaenidae families) in the current study mostly occur in sandy-bottom or rocky inshore habitats (Mann 2000; Heemstra & Heemstra 2004), which are similar at the study site to what they were three decades ago. Goschen & Schumann (2011) suggested that sand deposition had practically ceased by the 1980s following the construction of the harbour break-water wall in 1930. The 5 m depth contour, high water mark and sand input at King's Beach have also remained relatively stable since the 1980s (Goschen & Schumann 2011). While this study was dedicated to the nearshore zone, it is possible that an altered subtidal habitat may have contributed to the historical community shift observed. In particular, subtidal reef structures behind the surf-zone were more exposed during the 1980s and were covered by sand in the years prior this study (Goschen & Schumann 2011).

Regardless of the mechanism driving the shift in species composition in the surf-zone, the loss or drastic reduction of certain species, particularly those belonging to higher feeding guilds will likely have ecosystem effects due to the low functional redundancy in coastal marine assemblages (Micheli & Halpern 2005). For example, the simplification of the fish community in the Goukamma Marine Protected Area after the exploitation of a top predator, the red roman, *Chrysoblephus laticeps*, resulted in the increased abundance of a generalist feeder, the fransmadam, *Boopsoidea inornata* (Götz *et al.* 2009).

Diamond (1986) cautioned against a 'snap-shot' approach of analysis where conclusions are drawn from two isolated sampling events in the absence of continuous data. In this case, the two studies were conducted approximately three decades apart, and while Diamond's caution is valid, it should not deter one from conducting such an analysis, even if the reasons for any observed differences could be speculative. However, it is notable, firstly, that two key families have declined both in abundance and in length frequency distribution since the pre-exploitation assessment (Sparidae and Sciaenidae) and secondly, that at least two sparid species were completely absent from the current samples. These observations are robust in terms of the magnitude of difference between the two studies. While other factors such as possible undocumented increase in human disturbance at this popular beach (De Ruyck *et al.* 1998), sand deposition, altered habitat structure in adjacent areas, temporal local variability in Algoa Bay (Goschen & Schumann 2011), or even climate change could have contributed to the observed differences, the collapse of the linefish stock, particularly Sparidae and Sciaenidae, remains the most likely explanation for the shift in the surf-zone fish community.

CONCLUSION

The results of this study provide a well-defined picture of the community-level shifts and the possible effect of the recent collapse in southern African linefish on the juvenile surf-zone fish community at King's Beach. The universal signs of overfishing, such as a reduction in overall fish abundance, and a simplification of the fish community towards lower-level trophic feeders, were also evident in this study.

Surf-zones are inherently dynamic habitats and the fish communities inhabiting them are consequently highly variable (Lasiak 1984a; Vasconcellos *et al.* 2010; Marin Jarrin & Shanks 2011). Therefore, although the results of this study are clear, a broader long-term study would better differentiate between the effects of the linefish stock collapse and others such as habitat modification on southern African surf-zone fish communities. Additionally, the observed reduced adult fish abundance and the relationship between adult stock condition and recruitment (Marshall *et al.* 1998; Dixon *et al.* 1999) should prompt an investigation into the consequences for larval and juvenile fishes in nursery habitats such as surf-zones (Ross & Lancaster 2002; Strydom & d'Hotman 2005; Able *et al.* 2010). Ultimately it is vital that the entire life history of all important fish species is known if accurate conservation measures are to be enforced.

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