The influence of open and closed mouth phases on the marine fish fauna of the Swartvlei estuary

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The Swartvlei estuary fish community was sampled during open and closed phases using seine and gill nets. Results showed a marked decline in the abundance of juvenile fish < 50 mm TL but not of larger size groups following mouth closure. Both the catch per unit effort and size composition of gill-net catches revealed no major changes between the open and closed phase, indicating that no substantial emigration of large juveniles and adults occurred prior to mouth closure. *Atherina breviceps*, which breeds both in the estuarine and marine environment, showed minimal fluctuations in abundance and size distribution when comparing the open and closed phase. Salinities in the Swartvlei estuary remain above 10 °/∞ during the closed phase thus reducing the possibility of fish kills which have been recorded in the Bot River estuarine system.
S. Afr. J. Zool. 1986, 21: 309 – 315

Die visgemeenskap van die Swartvlei-getyrivier is tydens oop en toe fases met trek- en stelnette gemonster. Resultate toon 'n merkwaardige afname na mondsluiting in die volopheid van jong visse < 50 mm TL maar nie van groter lengtegroepe nie. Beide die vangs per eenheidpoging en groottesamestelling van stelnetvangste het geen groot veranderings tussen die oop en toe fases vertoon nie, wat daarop dui dat daar geen aansienlike emigrasie van groot jong of volwasse visse voor mondsluiting plaasvind nie. *Atherina breviceps*, wat in beide die getyrivier- en seekuswateromgewing broei, toon minimale wisseling in volopheid en groottesamestelling wanneer die oop en toe fase met mekaar vergelyk word. Soutgehalte in die Swartvlei-getyrivier gedurende die toe fase bly bo 10 °/∞ en dit verminder die moontlikheid van vissterftes soos die wat in die Botriviermondsisteem aangeteken is.
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The majority of southern African estuaries have unstable mouths and are closed for long periods each year (Day 1951). Despite the environmental changes which occur following sand bar formation, very little information is available on the impact of mouth closure on estuarine plant and animal communities (Day & Grindley 1981).

The Swartvlei system is periodically cut off from the sea owing to sand bar formation, effectively preventing the movement of marine fish species between the estuary and sea. The aim of this study was to investigate the effect of mouth closure on the fish community of the Swartvlei estuary, thus contributing to an understanding of the ecology of an important component of the estuarine fauna.

Study area

The Swartvlei system (34°S/22°46'E) is situated on the Cape south coast and is fed by three rivers which arise in the Outeniqua mountains. There are two connected but distinct components of the Swartvlei system; the humic-stained upper reaches (Swartvlei) and the shallow sinuous lower reaches (Swartvlei estuary). Swartvlei is subject to fluctuations in salinity owing to seawater inflow and is therefore also estuarine. However, the region referred to in this paper as 'Swartvlei estuary' or 'the estuary' is the 7,2 km long channel extending from the rail bridge to the mouth (Figure 1).

The Swartvlei estuary is very shallow (maximum depth 4 m) with a narrow central channel bordered by intertidal sand flats of varying widths. The sediments of the entire estuary consist of recently deposited dune sand with the exception of the mouth area where dune rock borders the eastern shore. The estuary mouth frequently closes during the winter (Figure 2) owing to the heavy south-westerly wave conditions which are predominantly responsible for longshore sand transport along the Cape south coast (Whitfield, Allanson & Heinecken 1983).

Salinity decreases from the mouth to the rail bridge and from spring to neap tides (Liptrot 1978). Salinities above 30 °/∞ occur throughout the estuary immediately prior to and after mouth closure. These salinities then decline during the closed phase as lower salinity water from Swartvlei is displaced by the rivers into the estuary. Minimum salinities (< 5 °/∞) occur when the mouth is open and the rivers are flooding.

Temperature variations in the estuary follow a seasonal pattern ranging between 10°C (winter) and 29°C (summer) in shallow areas and 15°C to 27°C in the channel. Summer water temperatures in the lower estuary can decline to 13°C owing to the inflow of cold upwelled water from the sea (Schumann, Perrins & Hunter 1982).

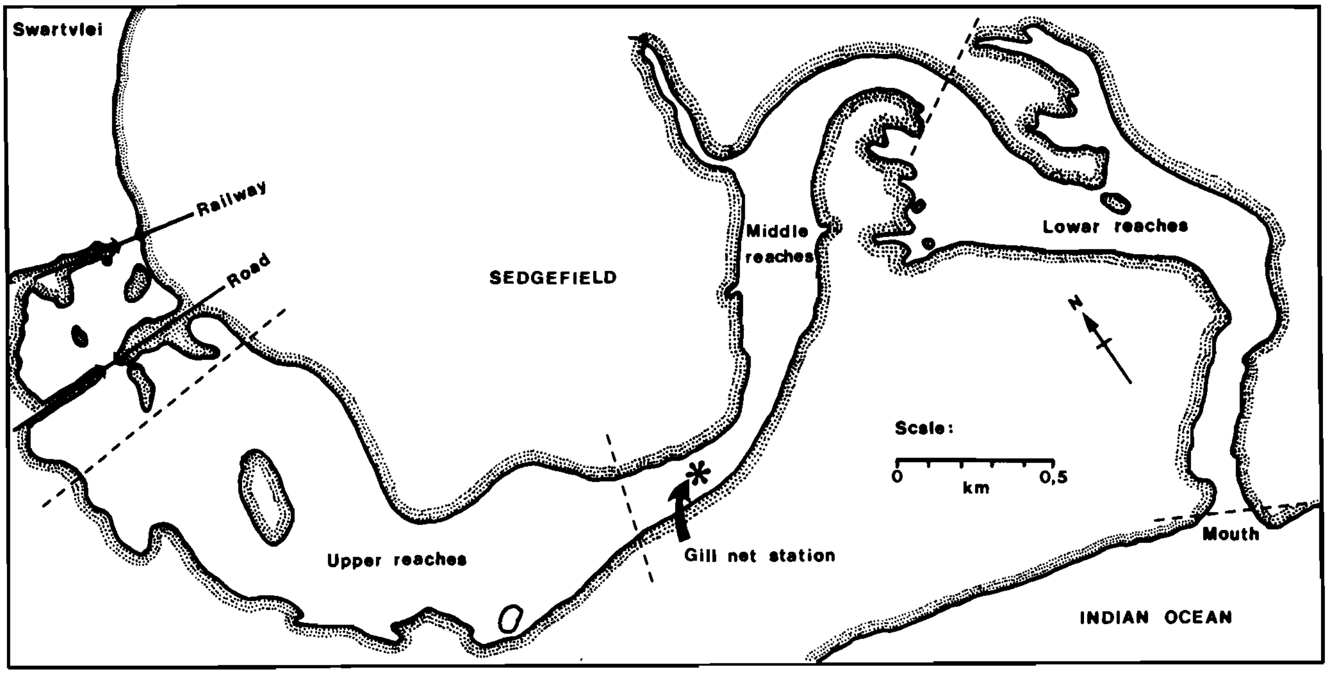

Figure 1 Swartvlei estuary showing the three major divisions for seine-net stations and the gill-net station.

Dissolved oxygen values vary mainly in response to biological activity. Horizontal variations depend on the distribution of aquatic plants within the estuary, higher oxygen values being associated with the presence of submerged plants. An analysis of values recorded in the estuary during the tidal and lagoon phases showed that closing of the mouth has no effect on the mean dissolved oxygen values in the channel areas (Liptrot 1978). However, deoxygenation does occur in localized areas towards the end of the lagoon phase. These areas are at the sides of the channel where large mats of the floating filamentous alga *Enteromorpha* decompose and in the deeper portions of the estuary (Liptrot 1978).

The most striking feature of the estuary is the presence of the two seagrasses, *Zostera capensis* and *Ruppia cirrhosa*, which occur in both mixed beds and pure stands. The area between high spring tide water level and low neap tide water level is a zone of tidal sand flats, with little or no submerged macrophyte vegetation. In slight depressions *Ruppia* is fairly dense but on the main sand flats the growth of this plant is very sparse, with only small individual leaves occurring above the sand surface. These develop rapidly when the estuary mouth is closed and the sand flats are continuously inundated for long periods (Howard-Williams & Liptrot 1980).

Methods

For the purposes of this study marine fishes are defined as those species which spawn at sea although some also breed in the estuarine environment (see Table 1).

Two types of gear were used to sample the fish community: seine and gill nets. A small seine net (3 m long, 1 m deep, 2 mm bar mesh) was used to capture fry in shallow water whereas the large seine net (30 m long, 2 m deep, 6 mm bar mesh in the purse) sampled juveniles in both deep and shallow areas. Netting was conducted monthly, during daylight hours, between July 1978 and December 1980. Large individuals in seine-net catches were identified and measured (mm total length) at the site of capture but small juveniles (< 50 mm TL) were preserved in 10% formalin for analysis in the laboratory. Catch per unit effort (CPUE) is expressed in terms of the average number of fish captured per 10 seine-net hauls. A total of 202 hauls were conducted during the open phase in the lower reaches, 47 in the middle reaches and 77 in the upper reaches. The corresponding number of hauls during the closed phase amounted to 42 in the lower reaches, 21 in the middle reaches and 45 in the upper reaches.

A set of six multifilament gill nets with bar mesh sizes of 20, 25, 32, 43, 55 and 73 mm were used monthly between January 1976 and December 1977 at a site midway up the estuary (Figure 1). The nets were set at 16h00 and lifted at 08h00 the following day. All fish were identified and measured (mm standard length) in the laboratory. CPUE data represents the average number of fish captured per sampling session.

Results

Figures 2 and 3 illustrate changes in salinity and temperature during the gill and seine netting programmes respectively. Water temperatures follow a typical seasonal pattern which is independent of estuary mouth condition. During March 1980 however, a temperature of 13°C was recorded in the lower reaches of the estuary caused by cold upwelled marine water which entered the system on the flood tide. Salinities within the estuary are closely linked to mouth condition. High salinities (20–35 °/oo) prevail prior to mouth closure but decline during the closed phase (Figures 2 and 3) owing to dilution caused by rivers entering the Swartvlei system. Low salinities during the open phase are the result of floodwaters entering the estuary from the lake following heavy rains in the catchment area.

The catch composition of marine fish species is given in Table 1. Mugilidae < 40 mm TL dominated catches in the small seine net during the open phase but declined in abundance during the closed phase (Table 2) owing to a cessation of 0+ juvenile recruitment. In comparison large seine-net catches showed greater similarity in composition and CPUE between the open and closed phase (Tables 1 and 2). The catch of both the small and large seine nets was dominated by Mugilidae, Sparidae and Atherinidae during the open and closed phase (Tables 1 and 2). Gill net fish catch composition

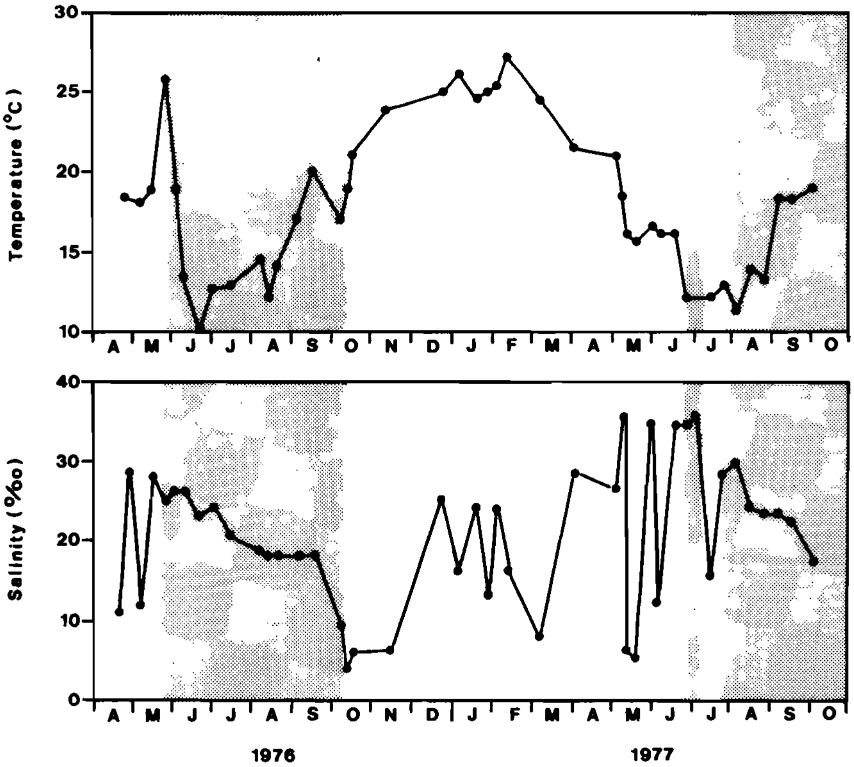

Figure 2 Surface temperature and salinity data from the middle reaches of the Swartvlei estuary during the gill-net programme (after Liptrot 1978). Shaded area indicates when the mouth was closed.

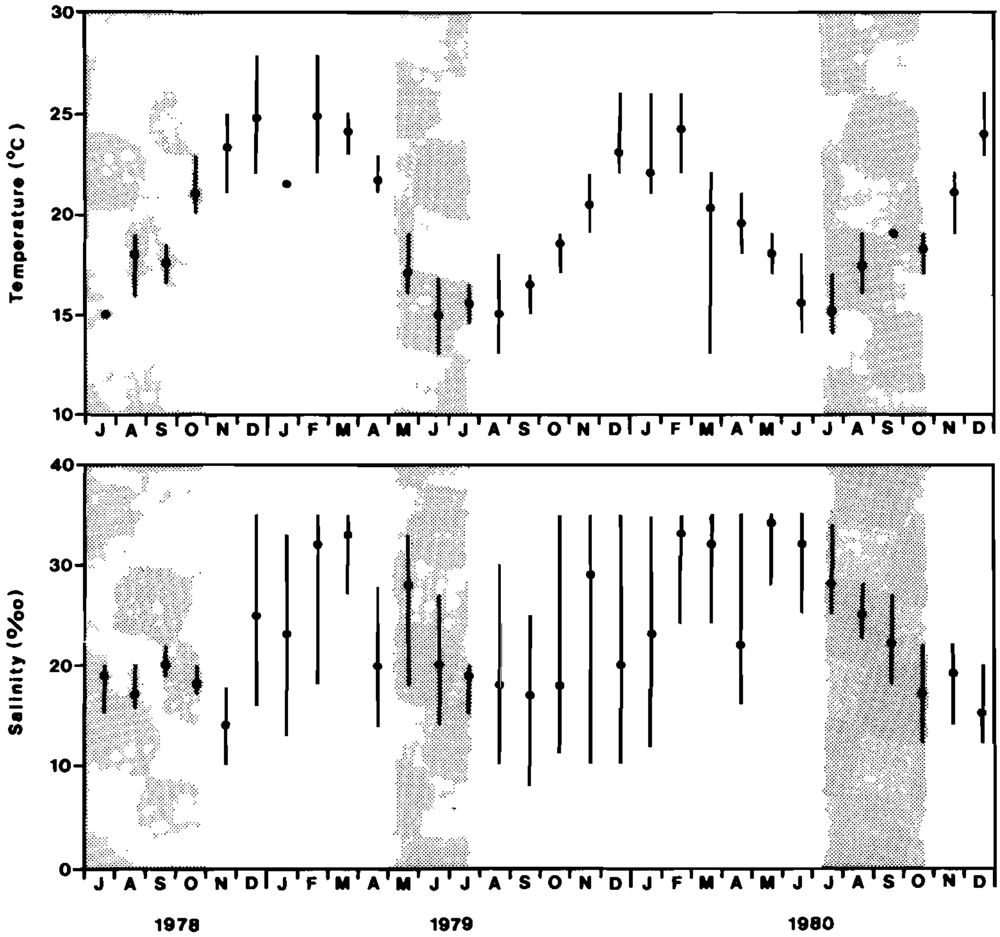

Figure 3 Surface temperature and salinity data (mean and range shown) during the seine-netting programme. Shaded area indicates when mouth was closed.

and CPUE showed no major changes between the open and closed phase (Tables 1 and 2) which indicates that there was no substantial emigration of large juveniles and adults prior to mouth closure.

Table 1 Catch composition of marine fish species captured by seine and gill netting in the Swartvlei estuary during the open and closed phase

Fish species	Family	Small seine		Large seine		Gill nets	
		Open	Closed	Open	Closed	Open	Closed
Argyrosomus hololepidotus	Sciaenidae	–	–	–	–	23	6
*Atherina breviceps**	Atherinidae	8048	636	3846	3507	–	–
Amblyrhynchotes honckenii	Tetraodontidae	–	–	1	–	–	–
Arothron hispidus	Tetraodontidae	–	–	2	–	–	–
Arothron immaculatus	Tetraodontidae	–	–	1	–	–	–
Boopsoidea inornata	Sparidae	–	–	1	–	–	–
*Clinus superciliosus**	Clinidae	7	–	24	26	–	–
Diplodus cervinus	Sparidae	–	–	25	2	–	–
Diplodus sargus	Sparidae	241	–	702	94	–	–
Elops machnata	Elopidae	–	–	–	–	2	–
Galeichthys feliceps	Ariidae	–	–	–	–	48	38
Hemirhamphus far	Hemirhamphidae	–	–	5	–	–	–
Heteromycteris capensis	Soleidae	7	1	13	7	–	–
Iso natalensis	Atherinidae	1	–	–	–	–	–
Lichia amia	Carangidae	1	–	7	9	63	16
Lithognathus lithognathus	Sparidae	99	–	1169	502	85	69
Lithognathus mormyrus	Sparidae	14	–	1	–	–	–
Liza dumerili	Mugilidae	1481	380	597	41	143	82
Liza macrolepis	Mugilidae	1	–	–	–	–	–
Liza richardsoni	Mugilidae	16922	688	1286	288	349	331
Liza tricuspidens	Mugilidae	2556	3	184	–	4	5
Monodactylus falciformis	Monodactylidae	2	–	526	623	116	76
Mugil cephalus	Mugilidae	56	–	17	6	80	68
Myliobatus aquila	Myliobatidae	–	–	–	1	–	–
Myxus capensis	Mugilidae	163	–	7	–	15	6
Pomadasys commersonni	Pomadasyidae	–	–	1	–	45	28
Pomadasys olivaceum	Pomadasyidae	–	–	3	–	–	–
Pomatomus saltatrix	Pomatomidae	–	–	–	–	2	–
Rhabdosargus globiceps	Sparidae	7	–	141	6	–	–
Rhabdosargus holubi	Sparidae	157	–	5985	4086	501	359
Rhabdosargus sarba	Sparidae	–	–	3	13	–	1
Sarpa salpa	Sparidae	271	1	1104	69	–	–
*Solea bleekeri**	Soleidae	1	–	3	28	–	–
Sparodon durbanensis	Sparidae	–	–	1	–	–	–
Spondyliosoma emarginatum	Sparidae	–	–	85	–	–	–
*Syngnathus acus**	Syngnathidae	1	–	40	44	–	–
Trachurus capensis	Carangidae	–	–	3	–	–	–
Valamugil buchanani	Mugilidae	1	12	–	–	–	–
Total number of fish		30037	1721	15783	9352	1476	1085
Number of seine hauls/gill-net periods		180	20	120	75	15	10
Catch per unit effort		1668	860	1315	1246	98	108

*Species which breed both in estuaries and the sea.

The length frequency distribution of the juveniles of five abundant fish species captured in the large seine net during the open and closed phase is shown in Figures 4 – 8. All the above species showed an increase in size (i.e. an increase in the proportion of larger individuals) during the closed phase owing to the absence of new 0+ recruits entering the population and growth of resident fishes. *Atherina breviceps*, which breeds both in estuaries and the sea (Day, Blaber & Wallace 1981; Beckley 1983), had a similar size composition during the open and closed phase (Figure 9). This information, together with CPUE data from the small and large seine net (Table 2), indicates that mouth condition has little impact on the abundance or length composition of *A. breviceps*.

An examination of the gill-net catch shows that most species undergo minor changes in size distribution between the open and closed phase (Figure 10). These data support the contention that there is no major exodus of large juveniles and adults prior to mouth closure.

Discussion

Most southern African estuaries are dominated by euryhaline marine fish species (Blaber 1980; Marais & Baird 1980; Day *et al.* 1981) which spawn at sea, often close inshore and in the vicinity of estuary mouths (Wallace, Kok & Beckley 1984). Egg and larval development also occurs in the marine environment but there is a mass migration of juveniles 10 – 60 mm SL into South African estuaries during spring and early summer (Wallace & van der Elst 1975). Clearly, immigration of these juveniles is dependent upon an estuary being in contact with the sea and the decline in CPUE of fishes from the small seine net (Table 2) during the closed phase is indicative of a breakdown in the recruitment process. Of particular importance is the timing and duration of the open phase (Wallace & van der Elst 1975; Whitfield 1980a). The Swartvlei mouth is normally closed in winter but open during summer (Whitfield *et al.* 1983) when most 0+ juveniles recruit into Cape estuaries. The closed phase is therefore unlikely to

Table 2 Changes in the catch per unit effort (CPUE) of the 10 most common marine fish species captured in seine and gill nets during the open (O) and closed (C) phase of the Swartvlei estuary

Fish species	Small seine CPUE	Fish species	Large seine CPUE	Fish species	Gill net CPUE
Liza richardsoni	940,1 (O)	*Rhabdosargus holubi*	498,8 (O)	*Rhabdosargus holubi*	33,4 (O)
	344,0 (C)		544,8 (C)		35,9 (C)
Atherina breviceps	447,1 (O)	*Atherina breviceps*	320,5 (O)	*Liza richardsoni*	23,3 (O)
	318,0 (C)		467,6 (C)		33,1 (C)
Liza tricuspidens	142,0 (O)	*Liza richardsoni*	107,2 (O)	*Liza dumerili*	9,5 (O)
	1,5 (C)		38,4 (C)		8,2 (C)
Liza dumerili	82,3 (O)	*Lithognathus lithognathus*	97,4 (O)	*Monodactylus falciformis*	7,7 (O)
	190,0 (C)		66,9 (C)		7,6 (C)
Sarpa salpa	15,1 (O)	*Sarpa salpa*	92,0 (O)	*Lithognathus lithognathus*	5,7 (O)
	0,5 (C)		9,2 (C)		6,9 (C)
Diplodus sargus	13,4 (O)	*Diplodus sargus*	58,5 (O)	*Mugil cephalus*	5,3 (O)
	0,0 (C)		12,5 (C)		6,8 (C)
Rhabdosargus holubi	8,7 (O)	*Monodactylus falciformis*	43,8 (O)	*Galeichthys feliceps*	3,2 (O)
	0,0 (C)		83,1 (C)		3,8 (C)
Lithognathus lithognathus	5,5 (O)	*Liza dumerili*	49,8 (O)	*Lichia amia*	4,2 (O)
	0,0 (C)		5,5 (C)		1,6 (C)
Mugil cephalus	3,1 (O)	*Liza tricuspidens*	15,3 (O)	*Pomadasys commersonni*	3,0 (O)
	0,0 (C)		0,0 (C)		2,8 (C)
Myxus capensis	9,1 (O)	*Rhabdosargus globiceps*	11,8 (O)	*Argyrosomus hololepidotus*	1,5 (O)
	0,0 (C)		0,8 (C)		0,6 (C)

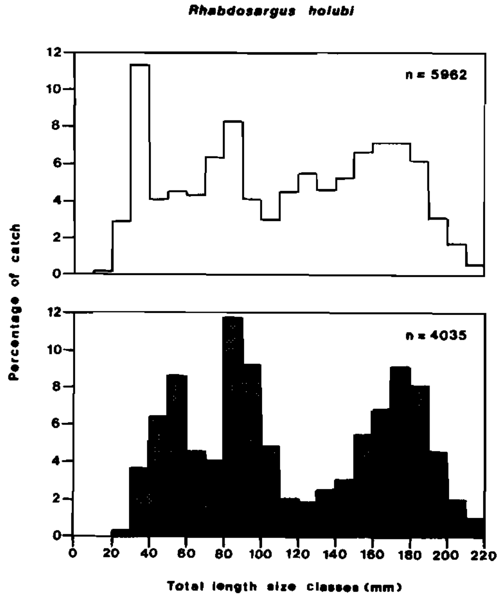

Figure 4 Length/frequency distribution of juvenile *Rhabdosargus holubi* captured in the large seine net during the open (open bars) and closed (stippled bars) phase of the Swartvlei estuary.

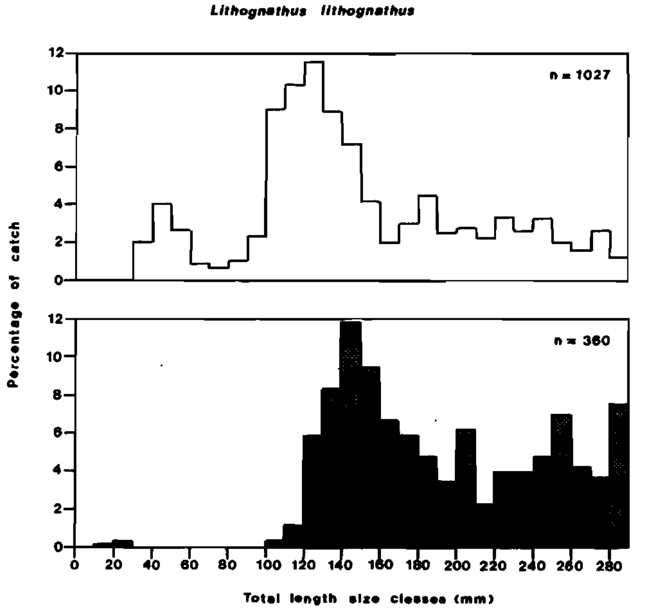

Figure 5 Length/frequency distribution of juvenile *Lithognathus lithognathus* captured in the large seine net during the open (open bars) and closed (stippled bars) phase of the Swartvlei estuary.

have a major impact on immigration into the Swartvlei system. In contrast the Bot River estuary (34°20'S / 19° 06'E) is breached at 2 – 4 year intervals (Bally 1985) and seine-net catches were dominated by *Atherina breviceps* (65%) and *Gilchristella aestuaria* (15%) both of which breed within the system (Bennett, Hamman, Branch & Thorne 1985). The low representation of juvenile marine species such as *Liza richardsoni, Lithognathus lithognathus, Lichia amia, Rhabdosargus holubi* and *Mugil cephalus* can be attributed to the infrequent opening of the Bot River mouth.

Gill-net catches in the Swartvlei estuary revealed minor changes in CPUE between the open and closed phase (Tables 1 and 2). Although the overall CPUE of marine fish species in the Bot system was also similar during the two phases, certain species (e.g. *L. lithognathus*) declined in abundance when the mouth opened. The most abundant marine species *L. richardsoni* showed minor fluctuations in abundance and average length following opening of the mouth (Bennett *et al.* 1985) which closely paralleled the situation in the Swartvlei estuary (Table 2; Figure 10). Evidence suggests that large marine fishes in the Bot system emigrate when the mouth opens, causing major declines in the average length of certain species e.g. *Pomatomus saltatrix* (Bennett *et al.* 1985). This pattern was not recorded in the Swartvlei estuary because the short closed phase (Figures 2 and 3) limited growth prior to opening of the mouth.

The foraging area available to fish species in the Swartvlei estuary increased considerably during the closed phase owing

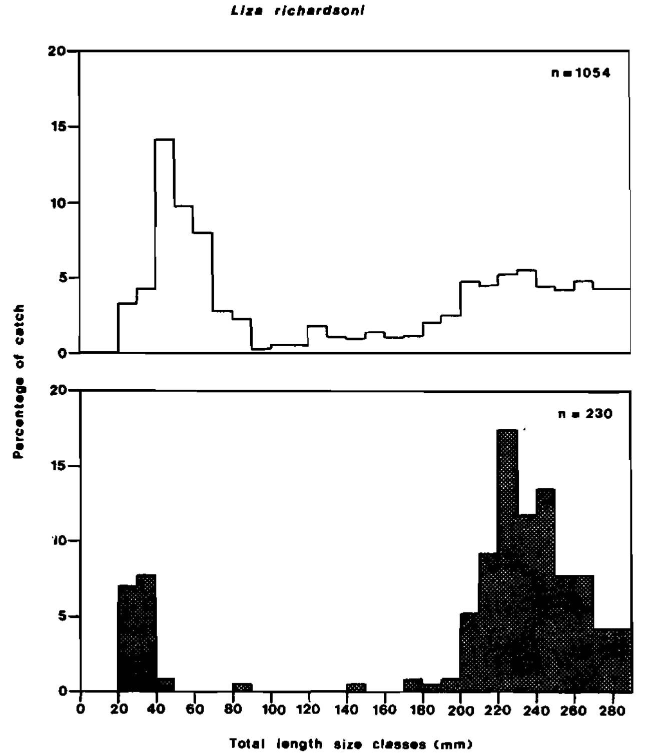

Figure 6 Length/frequency distribution of juvenile *Liza richardsoni* captured in the large seine net during the open (open bars) and closed (stippled bars) phase of the Swartvlei estuary.

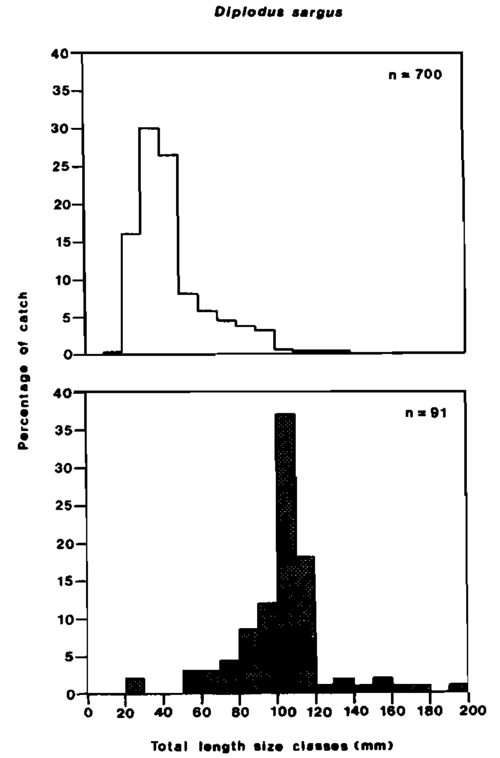

Figure 8 Length/frequency distribution of juvenile *Diplodus sargus* captured in the large seine net during the open (open bars) and closed (stippled bars) phase of the Swartvlei estuary.

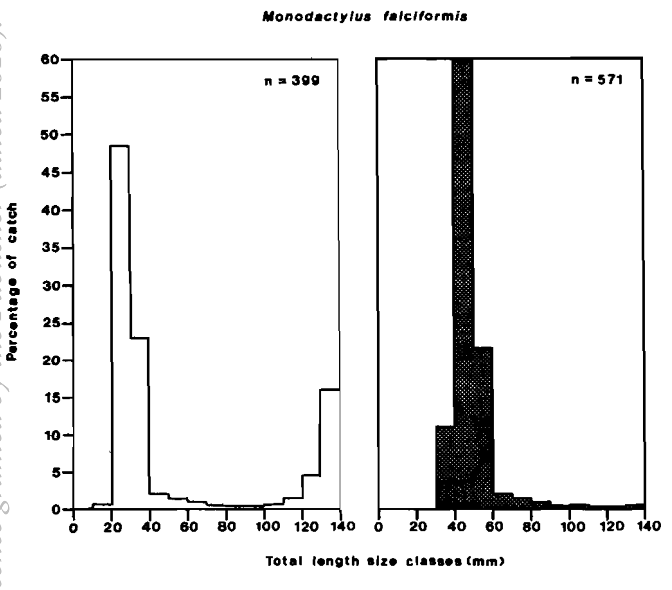

Figure 7 Length/frequency distribution of juvenile *Monodactylus falciformis* captured in the large seine net during the open (open bars) and closed (stippled bars) phase of the Swartvlei estuary.

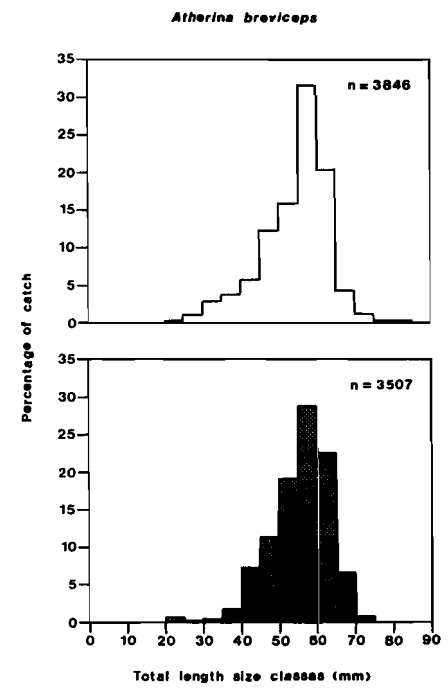

Figure 9 Length/frequency distribution of *Atherina breviceps* captured in the large seine net during the open (open bars) and closed (stippled bars) phase of the Swartvlei estuary.

to elevated water levels inundating intertidal and supratidal habitats. This situation was closely paralleled in the Mhlanga and Bot River estuaries where the water area increased by more than 50% during the closed phase. Breaching of these two systems resulted in a decline in the volume and area of the aquatic environment together with a slump in plant and invertebrate food resources (Whitfield 1980b; Branch, Bally, Bennett, de Decker, Fromme, Heÿl & Willis 1985). Indications are that the closed phase of certain South African estuaries provides an ideal nursery habitat for juvenile marine fishes in terms of nutrition. Day *et al.* (1981), using data from Blaber (1973), calculated that the biomass of *Rhabdosargus holubi* in the West Kleinemond estuary increased from 1,7 g m^{-2} at the time of mouth closure to 2,7 g m^{-2} when the mouth opened six months later.

Dilution of lagoonal waters from catchment areas during the closed phase of an estuary can cause osmoregulatory stress to resident marine fish species. The Bot River estuary remains closed for prolonged periods during which the salinities decline

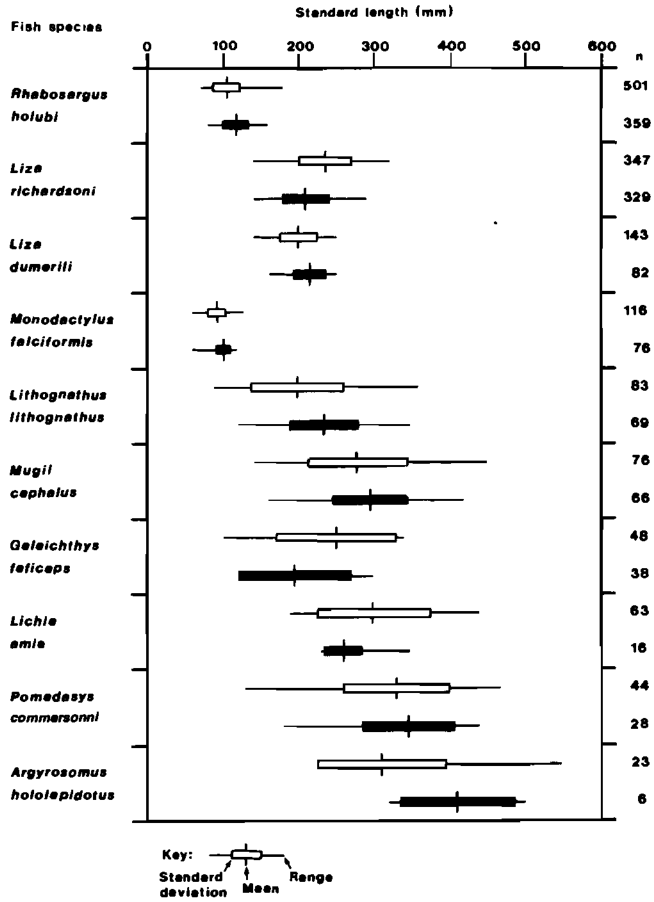

Figure 10 Sizes of the 10 most common fish species captured by gill netting in the Swartvlei estuary (open phase = open bar, closed phase = solid bar).

progressively (Fromme 1985). In October 1981, after four years of isolation from the sea, the maximum salinity in the estuary decreased to 3 °/oo resulting in a mass mortality of nine marine species (Bennett 1985) all of which have been recorded from the Swartvlei estuary during the closed phase. Salinities in the latter system decline from approximately 30 °/oo following mouth closure to 10 °/oo prior to breaching (Figures 2 and 3), thus avoiding salinities at which fish kills are likely to occur (Whitfield, Blaber & Cyrus 1981). Low salinities (3 – 5 °/oo) in the Swartvlei estuary have been measured when the estuary was open and rivers were flooding but no fish mortalities have been recorded.

Evidence from the Bot River estuary suggests that prolonged closed phases have a negative impact on marine fish species whereas the recent open/closed cycles in the Swartvlei estuary have no major effect on either the migration patterns or mortality rates of marine fishes utilizing this system. Both the above estuaries are mechanically breached at shorter intervals than would occur naturally (Fromme 1985; Whitfield *et al.* 1983). The more frequent opening of these systems benefits the marine fish component by permitting migration and increasing salinity of the estuary prior to mouth closure.

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