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COASTAL ZONE UTILIZATION BY JUVENILE FISH
IN THE EASTERN CAPE, SOUTH AFRICA

by

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ABSTRACT

Many coastal fish exhibit age-specific differential distribution and shallow inshore regions provide nursery habitats for juveniles of some species. In this study the occurrence of juvenile fish along the Eastern Cape coast was examined with the objective of assessing the importance of coastal habitats as nursery areas for the common coastal teleosts.

The thesis comprises ten separate research papers and an overview of coastal zone utilization by juvenile teleosts in the Eastern Cape. Research was concentrated in Algoa Bay and covered the nearshore ichthyoplankton, tidal exchange of fish eggs, larvae and juveniles across the mouth of the Swartkops estuary, the ichthyofauna of the Swartkops and Sundays estuaries, the juvenile fish associated with subtidal soft substrata and rocky reefs and the ichthyofauna occurring in tidal pools on rocky shores.

The ichthyoplankton of the nearshore region of Algoa Bay was investigated to establish the availability of larvae to recruit into coastal nursery habitats. Larvae of pelagic species (Engraulidae and Clupeidae) and coastal species with benthic eggs (Gobiidae and Blenniidae) dominated the nearshore ichthyoplankton, whilst coastal species with pelagic eggs such as Sparidae and Mugilidae were poorly represented. During 24-hour ichthyoplankton studies over spring and neap tides in the mouth of the Swartkops estuary, early juveniles (10-20 mm in length) of coastal species with pelagic eggs were, however, found to enter the estuary on the flood tide. Larvae of resident estuarine species were flushed out on the ebb tide.

Juveniles of 39 teleost species were captured by seine netting in the

macrophyte beds of the Swartkops estuary, whilst juveniles of 44 species were caught in the Sundays estuary. The juveniles were those of resident species, such as Gilchristella aestuarius and Caffrogobius multifasciatus, and those of marine species utilizing the estuary as a nursery habitat, such as Rhabdosargus holubi, Diplodus sargus and Lithognathus lithognathus. Monthly size-frequency histograms were used to determine recruitment patterns and growth increments of the marine species.

An inshore small-mesh trawling survey along the Cape south coast showed shallow soft substratum regions to be an important nursery habitat for species such as Argyrosomus hololepidotus and Pomatomus saltatrix. Juveniles abundant in estuaries were not, however, located during this survey. Shallow-water beam trawling in the nearshore area immediately outside the Swartkops estuary mouth also failed to capture estuarine-associated juveniles. SCUBA diving observations over subtidal reefs revealed Sparidae and Cheilodactylidae to be the most abundant fish and juveniles of 22 species were identified.

Forty-four species of teleosts were found during regular rotenone collections in tidal pools around Cape Recife and these were classified as residents or transients. Clinidae, Gobiidae and Blenniidae were the major families of residents whilst juveniles of Sparidae, Cheilodactylidae, Mugilidae and tropical vagrants contributed to the transient component. After sampling, rapid recolonization of tidal pools occurred with higher densities of recolonizers in summer than in winter. Repopulation was not, however, exclusively by juvenile recruits.

From the work outlined above and other published research, a tabular synopsis of relative abundance and distribution of juveniles of 67 teleost

species in major coastal habitats was developed. Juveniles of 63% of these species were restricted to a single habitat (estuaries, tidal pools, subtidal reefs or subtidal soft substrata) whilst the remaining 37% showed distribution overlaps between various habitats. Of the juveniles restricted to a single habitat, 20 were small species (e.g. Gobiidae and Clinidae) which were resident in well defined habitats such as estuaries or tidal pools, and showed direct recruitment to the adult population. Both estuarine and non-estuarine habitats were concluded to be important nursery areas for juveniles of coastal teleosts in the Eastern Cape.

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INTRODUCTION

Nektonic organisms are able to select habitats which are optimal for different stages in their life histories (Barnes & Hughes 1982). Teleosts, in particular, show age-specific habitat separations with juveniles often using distinct nursery areas where they grow and develop before recruiting to the adult populations (Cushing 1975; Helfmann 1978; Keast 1978).

The coastal zone presents juvenile fish with a diverse array of possible nursery habitats. Estuaries have been recognized as important nurseries for marine fish by numerous workers including Gunter (1967), McHugh (1967), Clark (1974), Wallace & van der Elst (1975), Haedrich & Hall (1976), Cain & Dean (1976), Lenanton (1977), Shenker & Dean (1979), Weinstein (1979), Blaber (1980), Whitfield (1980), Nakamura, Taylor & Workman (1980), Day, Blaber & Wallace (1981), Potter, Loneragan, Lenanton, Chrystal & Grant (1983) and Currin, Reed & Miller (1984). The nursery functions of other coastal habitats, including shallow inshore areas (Pillay 1967; Zijlstra 1972; Rauck & Zijlstra 1978; Toole 1980; Roper & Jillett 1981), mangrove swamps (Austin 1971; Beumer 1978; Bell, Pollard, Burchmore, Pease & Middleton 1984), surf zones adjacent to sandy beaches (McFarland 1963; Modde 1980; Lasiak 1981; Robertson & Lenanton 1984), tidal pools (Randall 1955) and marine macrophyte beds (Heck & Orth 1980; Lenanton 1982) have also been documented.

The major reasons why shallow coastal habitats serve as nursery areas are:
 (i) the presence of abundant food and
 (ii) the reduction of predation (Zijlstra 1972; Joseph 1973; Clark 1974; Olla, Bejda & Martin, 1974; Cushing 1975; Wallace & van der Elst 1975; Haedrich & Hall 1976; Miller & Dunn 1980; Blaber 1980; Blaber & Blaber 1980; Heck & Orth 1980; Weinstein, Weiss & Walters 1980; Whitfield 1980, 1983; Lasiak 1981; Lenanton 1982; Thormann 1983; Robertson & Lenanton 1984;

Miller, Reed & Pietrafesa 1984). Estuaries, in particular, have been considered as food rich areas but Nixon (1980) has critically examined the viewpoint that salt marshes and wetlands associated with estuaries are important in sustaining juvenile fish. He stated that "perhaps estuarine dependent juvenile fish simply do well in shallow protected waters, the same environment that usually favours salt marsh development". Boesch & Turner (1984) have reviewed evidence relating to the role of food and refuge in estuaries. They support the refuge hypothesis though they found that salt marsh detritus may not be as important in supporting fish species as was once thought.

Toole (1980), from work on intertidal nursery areas, has proposed that in addition to the advantages of food and refuge in nursery areas, segregation of different sized fish may reduce competition. Competition can only occur where a shared resource, such as food or living space, is in short supply (Sale 1979). When competition is intense it may force individuals to occupy marginal parts of the habitat and this may lead to an expansion of range (Branch 1984). Occupation of nursery areas by juveniles could be interpreted as such range expansion.

Juvenile marine fish are abundant in the estuaries of southern Africa (Day 1951; Talbot 1955; Blaber 1973; Wallace & van der Elst 1975; Winter 1979; Whitfield 1980; Day, Blaber & Wallace 1981) but, as pointed out by Heydorn (1979), no studies have shown if the juveniles are actually dependent on estuarine nursery areas. It can only be concluded that fish are dependent on estuarine nursery areas if juveniles are found to be absent or scarce in the sea (Clark, Smith, Kendall & Fahay 1969). In order to investigate estuarine dependency, a research programme was initiated in the Eastern Cape in 1980 by the Port Elizabeth Museum and the University of Port

Elizabeth. This thesis was developed from the above mentioned research programme, and the objectives were: (i) to investigate the occurrence of juvenile teleosts in the Eastern Cape coastal zone, and (ii) to assess the importance of the various shallow coastal habitats as nursery areas.

FEATURES OF THE STUDY AREA

The Eastern Cape coast, which extends from Knysna to Port Alfred, is characterised by three conspicuous embayments, namely, Plettenberg Bay, St Francis Bay and Algoa Bay (Fig. 1). Research for this thesis was concentrated in Algoa Bay and its immediate environs because of the variety of coastal habitats in the area and the proximity of laboratory facilities. Long sandy beaches dominate the western and northern shores of Algoa Bay, whilst rocky shores with tidal pools extend around the Cape Recife headland. The subtidal region of Algoa Bay is characterized by soft substrata interspersed with rocky reefs. Two permanently open estuaries, the Swartkops and the Sundays, enter Algoa Bay.

The waters of Algoa Bay are warm temperate with a mean sea-surface temperature of 17.5°C (Beckley 1983). The strong Agulhas boundary current flows in a south-westerly direction along the edge of the continental shelf outside Algoa Bay, whilst the inshore circulation within the bay is chiefly cyclonic (Harris 1978). Tides are semi-diurnal with a mean tidal range of 1.6 m at springs and 0.5 m at neaps (Beckley & McLachlan 1979). Waves along the Eastern Cape coast are a mixture of those generated by local winds and those generated by storms moving from west to east in the depression belt south of the African continent (Darbyshire & Darbyshire 1964). Deep-sea waves in the area are generally south or south west in direction, but on entering Algoa Bay they are deflected to the south east due to

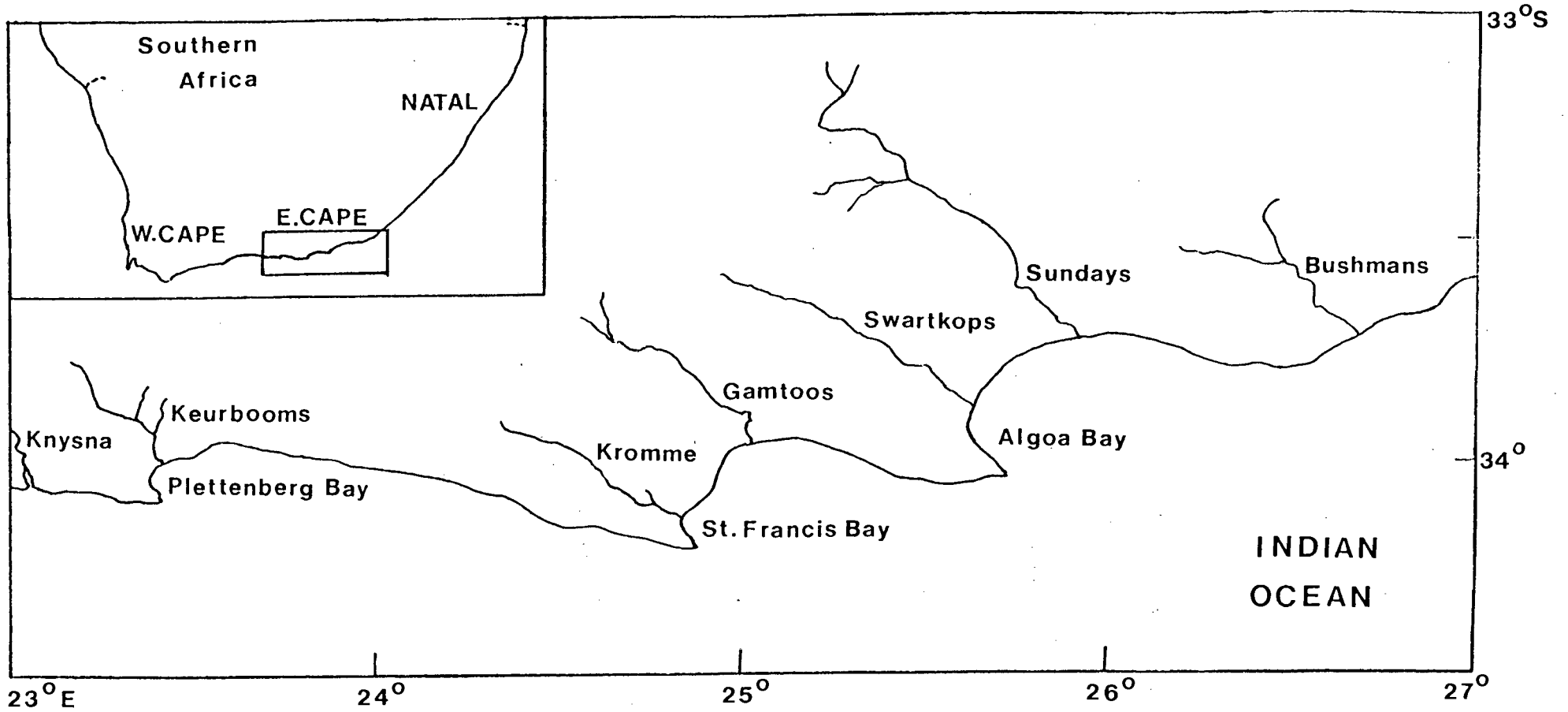


Fig. 1 Map of the Eastern Cape coast showing the large bays and rivers

refraction by Cape Recife and the shallow Rijk Bank (Beckley & McLachlan 1979). South westerly winds predominate throughout the year with an increased easterly component in the summer months (Beckley 1983). Localised upwelling is induced at Cape Recife and Cape Padrone by winds with an easterly component (Schumann, Perrins & Hunter 1982; Beckley 1983).

Approximately 1500 species of fish have been recorded from the waters of southern Africa and, of these, nearly 25% are endemic (van der Elst 1981). The diversity of fish decreases from the warm waters of Natal to the cooler waters of the Western Cape, mainly due to the southern distribution limits of the tropical Indo-Pacific component (Smith 1965). Some 300 teleost species have been recorded from Eastern Cape coastal waters (Smith 1965), though many are found only infrequently as they are deep-water, pelagic or tropical species. General information on coastal teleosts can be found in Barnard (1925, 1927), Smith (1965), Smith & Smith (1966) and van der Elst (1981). Recent research on teleosts in the Eastern Cape includes that of Hecht (1976) on the major trawled species, Coetzee & Baird (1981) on the angling fish, Lasiak (1982) on the surf zone ichthyofauna, Smale (1983) on the top predatory species, and Buxton & Smale (1984) on the reef fish of the Tsitsikamma coastal park. Fish occurring in estuaries have also received attention and recent work includes that of Winter (1979), Marais & Baird (1980a,b) and Marais (1981, 1982, 1983a,b).

RESEARCH SUMMARY

For the purposes of this thesis, the Eastern Cape coastal zone was divided into five major habitats: estuaries, tidal pools, subtidal reefs, subtidal

soft substrata and surf zones of sandy beaches. The occurrence of juvenile fish in each of these major habitats was determined with the ichthyofauna of the Sundays estuary, the Swartkops estuary macrophyte beds, the tidal pools around Cape Recife and the shallow subtidal areas of Algoa Bay receiving particular attention. The main channel of the Swartkops estuary and the sandy beach surf zones of Algoa Bay were not investigated as these areas were studied by Winter (1979) and Lasiak (1982), respectively. In addition, to ascertain the availability of fish larvae for recruitment into the various coastal habitats, the ichthyoplankton of the nearshore region of Algoa Bay was studied. Tidal exchange of larvae and early juveniles across the mouth of the Swartkops estuary was also examined.

These investigations are presented as ten research papers in Part 2 of this thesis and are briefly outlined below:

1. The ichthyoplankton assemblage of the Algoa Bay nearshore region in relation to coastal zone utilization by juvenile fish (submitted for publication)

The results of a two-year ichthyoplankton survey of sampling stations located off sandy beaches, estuary mouths and a rocky shore in Algoa Bay are given. Larvae of coastal and pelagic species were found and the species composition, temporal patterns in abundance and size frequency distribution of the larvae are presented. Larvae of the families Gobiidae, Engraulidae and Clupeidae numerically dominated the ichthyoplankton whilst larvae of families such as Sparidae, Mugilidae and Pomadasysidae, which are extremely abundant in coastal habitats as juveniles, were poorly represented. This is the first study of marine ichthyoplankton in the Eastern Cape.

2. Tidal exchange of ichthyoplankton in the Swartkops estuary mouth, South Africa (S. Afr. J. Zool. 20 : 15-20)

Tidal transport of fish eggs, larvae and early juveniles in the mouth of the Swartkops estuary was examined by plankton and fine-mesh seine netting during 24-hour sampling sessions at spring and neap tides. Small larvae of resident estuarine species were found to be swept out of the estuary on the ebb tide, whilst early juveniles of marine species using the estuary as a nursery were found to enter on the flood tide. Catches of these early juveniles near the bank on the ebb tide suggests active migration towards the bank to prevent being swept back to sea.

3. The ichthyofauna associated with Zostera capensis (Setchell) in the Swartkops estuary, South Africa (S. Afr. J. Zool. 18 : 15-24)

The teleosts occurring in the macrophyte beds of the lower reaches of the Swartkops estuary were sampled over 15 months. Species composition and size-frequency distributions of the catches are presented, and the recruitment patterns of juveniles are correlated with previously documented breeding cycles of adults. The small shoaling species Atherina breviceps and Gilchristella aestuarius numerically dominated the catches. Recruitment of juveniles of various species of mullet took place throughout the year, but marked spring and summer recruitment was evident for juvenile sparids such as Rhabdosargus holubi and Diplodus sargus.

4. The ichthyofauna of the Sundays estuary, South Africa, with particular reference to the juvenile marine component (Estuaries 7 : 248-258)

The ichthyofauna of the Sundays estuary was investigated by monthly seine netting at six stations throughout the estuary over a period of a year. Forty-seven species of fish were captured and both estuarine residents and marine species utilizing the estuary as a nursery were identified. Recruitment periods for juveniles of marine species and cohort growth of Rhabdosargus holubi and Lithognathus lithognathus were followed. Estuarine dependency of marine juveniles is discussed.

5. South African estuaries and their importance to fishes (S. Afr. J. Sci. 80 : 203-207)

This co-authored paper is the result of a workshop on estuarine-associated fish. Fish occurring in South Africa estuaries are allocated to six categories, according to the extent of their dependence on estuaries. Eight species which spend their entire life cycles in estuaries are distinguished and 22 species are shown to be dependent on estuaries for the juvenile phase of their life cycle.

6. Inshore small-mesh trawling survey of the Cape south coast. Part 2. Occurrence of estuarine-associated fishes (S. Afr. J. Zool. 19 : 165-169)

An inshore small-mesh trawling survey, extending from St Sebastian Bay to Algoa Bay, resulted in a series of five papers. This co-authored paper examines the catch data of various estuarine-associated fish. Extensive

shallow inshore nursery areas were revealed for Argyrosomus hololepidotus, Pomatomus saltatrix and Galeichthys sp., whilst only a few adults of species such Rhabdosargus holubi and Pomadasys commersonii were caught. Three ecologically distinct groupings of inshore fish are revealed, including a specialised group dependent on estuarine nursery areas.

7. Shallow-water trawling off the Swartkops estuary, Algoa Bay (S. Afr. J. Zool. 19 : 248-250)

Juvenile fish occurring in Algoa Bay off the mouth of the Swartkops estuary were collected using a small 3 m beam trawl. The catch composition is presented and, despite the proximity of the estuary, the trawls failed to capture species which are known to be abundant as juveniles in the estuary. It was concluded that the estuary had little influence on the species composition of the ichthyofauna outside the mouth.

8. Underwater observations of reef fish from Algoa Bay and the adjacent coast (to be submitted for publication)

This short paper reports on SCUBA diving observations of fish occurring over shallow reefs in and around Algoa Bay and serves to complement the inshore trawling survey which was confined to soft substrata. A checklist of species recorded, frequency of occurrence, relative abundance and presence of juveniles is given. Juveniles of 22 species were recorded of which 55% belonged to the family Sparidae.

9. The fish community of East Cape tidal pools and an assessment of the nursery function of this habitat (S. Afr. J. Zool. 20 : 21-27)

The role of tidal pools as a nursery habitat for juvenile marine fish is examined in this paper. A two-year study, using both visual census and ichthyocide collection methods, was made of the fish occurring in tidal pools around Cape Recife. Species were identified as residents or transients on the basis of whether both adults and juveniles or only juveniles were found. Gobiidae and Clinidae were the most abundant residents. The importance of tidal pools as nursery areas for juvenile Sparidae and Cheilodactylidae is shown.

10. Tide-pool fishes : recolonization after experimental elimination (J. Exp. Mar. Biol. Ecol. 85 : 287-295)

Repopulation of tidal pools after periodic rotenone poisoning is reported in this paper. Summer recruitment patterns of juveniles settling for the first time strongly influenced recolonization papers although older juveniles and, in the case of resident species, even adults, recolonized the pools.

The above papers, with the exceptions of the two co-authored papers, are entirely the original work of the candidate. The co-authored paper on the importance of South African estuaries to fish resulted from a workshop to which the candidate contributed. The candidate assisted in editing the information from the workshop and drafting the manuscript. The candidate participated in the research cruises leading to the co-authored paper on small-mesh trawling on the south coast and, although the raw data was

processed by staff of the Port Elizabeth Museum, the manuscript was largely written by the candidate.

OVERVIEW OF COASTAL ZONE UTILIZATION BY JUVENILE FISH IN THE EASTERN CAPE

The objective of this section of my thesis is to present a tabular synopsis of the distribution and relative abundance of juvenile fish in Algoa Bay and discuss the importance of different habitats as nursery areas for the common coastal teleost species in the Eastern Cape. The ten research papers presented in Part 2 of the thesis, the other papers in the inshore small-mesh trawling survey of the Cape south coast series (Wallace, Kok, Buxton & Bennett 1984; Smale 1984; Buxton, Smale, Wallace & Cockcroft 1984) and the theses of Winter (1979) and Lasiak (1982) are the sources of information unless otherwise indicated.

In the study area, five major coastal habitats (estuaries, tidal pools, shallow subtidal reefs, shallow subtidal soft substrata and sandy beach surf zones) were distinguished. Juveniles of 67 coastal teleost species were found to occur in sufficient numbers to be included in a comparison of these habitats as nursery areas. The relative abundance of juveniles of these species in the five major habitats is given in Table 1. Because of the variety of techniques required to investigate the ichthyofauna of the five habitats (seine netting, trawling, poisoning and visual census) actual numbers are not given, but a relative scale of present, common and abundant is used. Although such a scale does have limitations, the table clearly indicates which habitats are predominantly utilised by the juveniles of the various species.

SPECIES NAME	< 25m Soft Substrata	Surf Zone	Estuaries	Tidal Pools	< 25m Reefs
<u>Cynoglossus capensis</u>	**				
<u>Merluccius capensis</u>	*				
<u>Caffrogobius agulhensis</u>	*				
<u>Umbrina capensis</u> †	*	*			
<u>Trachurus capensis</u>	**	**			
<u>Pagellus natelensis</u>	**	*			
<u>Argyrosomus hololepidotus</u> †	***	*	*		
<u>Pomatomus saltatrix</u> †	***	*	*		
<u>Pomadasys olivaceum</u>	***	***	*		
<u>Lithognathus mormyrus</u>	*	***	*		
<u>Rhabdosargus globiceps</u> †	*	**	*		
<u>Galeichthys feliceps</u>	***		*	*	
<u>Lichia amia</u>		*	*		
<u>Atherina breviceps</u>		*	***	*	
<u>Liza richardsoni</u>		**	***	*	
<u>Gilchristella aestuarius</u>			***		
<u>Solea bleekeri</u>			***		
<u>Caffrogobius multifasciatus</u>			***		
<u>Glossogobius tenuiformis</u>			**		
<u>Psammogobius knysnaensis</u>			***		
<u>Syngnathus acus</u>			**		
<u>Omobranchus woodi</u>			*		
<u>Elops machnata</u> †			*		
<u>Valamugil buehanani</u>			*		
<u>Myxus capensis</u>			*		
<u>Liza tricuspidens</u>			**		
<u>Liza dumerili</u>			***		
<u>Mugil cephalus</u>			***		
<u>Lithognathus lithognathus</u> †			***		
<u>Pomadasys commersonni</u> †			***		
<u>Platycephalus indicus</u>			*		
<u>Heteromycteris capensis</u>			***		
<u>Monodactylus falciformis</u>			***		
<u>Rhabdosargus holubi</u> †			***	*	
<u>Clinus superciliosus</u>			*	***	
<u>Caffrogobius saldanha</u>				***	
<u>Caffrogobius caffer</u>				***	
<u>Chorisochismus dentex</u>				**	
<u>Halidesmus scapularis</u>				**	
<u>Clinus dorsalis</u>				*	
<u>Clinus navalis</u>				*	
<u>Pavoclinus graminis</u>				*	
<u>Blennioclinus brachycephalus</u>				*	
<u>Blennioclinus stella</u>				*	
<u>Clinus capensis</u>				*	
<u>Parablennius cornutus</u>				*	

continued/...

SPECIES NAME	< 25m Soft Substrata	Surf Zone	Estuaries	Tidal Pools	< 25m Reefs
<u>Epinephalus guaza</u> †				*	*
<u>Diplodus cervinus</u>			*	**	*
<u>Chaetodon marleyi</u>				*	*
<u>Chirodactylus brachydactylus</u>				**	*
<u>Cheilodactylus fasciatus</u>				**	*
<u>Sparodon durbanensis</u> †				**	*
<u>Acanthistius sebastoides</u>				*	**
<u>Gymnocrotophus curvidens</u> †					**
<u>Chrysoblephus laticeps</u> †					**
<u>Chrysoblephus cristiceps</u> †					**
<u>Cheilodactylus pixi</u>					**
<u>Boopsoidea inornata</u>					***
<u>Pachymetopon aeneum</u>					***
<u>Petrus rupestris</u> †					*
<u>Oplegnathus conwayi</u>					*
<u>Spondyliosoma emarginatum</u>	*		*		***
<u>Cheimerius nufart</u>	*				**
<u>Diplodus sargus</u> †	*	***	***	***	***
<u>Sarpa salpa</u>	*	***	*	**	***
<u>Amblyrhincotes honckenii</u>	*	*	*	*	

TABLE 1 Distribution and relative abundance of juvenile fish as determined by seining, trawling, visual census and ichthyocide methods in five coastal habitats in and around Algoa Bay

(*** abundant, ** common, * present, † angling species)

Of the 67 species listed in Table 1, 24% occurred over subtidal soft substrata, 21% in sandy beach surf zones, 50% in estuaries, 40% in tidal pools and 26% over subtidal reefs. In each habitat specific juveniles were particularly abundant. Over shallow subtidal soft substrata Galeichthys feliceps, Argyrosomus holodepidotus, Pomatomus saltatrix and Pomadasys olivaceum were most abundant, whilst in the surf zone P. olivaceum, Lithognathus mormyrus, Diplodus sargus and Sarpa salpa occurred in high numbers. Many species were abundant in estuaries, including Rhabdosargus holubi, Lithognathus lithognathus, Monodactylus falciformis, Mugil cephalus, Liza dumerili and Liza richardsoni, but Gilchristella aestuarius was numerically dominant. In tidal pools Clinus superciliosus, Chirodactylus brachydactylus and Diplodus sargus were most abundant, whilst over shallow subtidal reefs shoals of Boopsoidea inornata, Diplodus sargus, Spondylisoma emarginatum, Pachymetopon aeneum and Sarpa salpa were numerically dominant.

On examining Table 1 it is immediately obvious that, in addition to some species being more abundant than others, there are large groups of species which occur solely in one habitat, whilst other species show distributional overlaps between two or more habitats. The various groupings evident in Table 1 are discussed below.

The juvenile fish occurring over shallow subtidal soft substrata and in the surf zones of sandy beaches show considerable overlap. As the seaward boundary of sandy beach surf zones is not well defined (McLachlan 1983) it is to be expected that a continuum of fish distribution between the two habitats exists. Juveniles of a small group of three species were, however, restricted to subtidal soft substrata. These were the tongue fish Cynoglossus capensis, a small goby Caffrogobius agulhensis, and the

commercially important hake species Merluccius capensis. Both C. capensis and C. agulhensis are benthic forms and surf zone seine netting was probably not an adequate sampling method for these species. Little is known of the biology of these inshore species but larvae of C. capensis were regularly found in the nearshore ichthyoplankton of Algoa Bay, whilst larvae of the multispecies genus Caffrogobius numerically dominated the nearshore ichthyoplankton. M. capensis adults are trawled in deep water around the coast of southern Africa and the inshore small mesh trawling survey showed that most juveniles occurred in water deeper than 30 m.

Juveniles of the sciaenid Umbrina capensis, the sparid Pagellus natalensis and the horse mackerel Trachurus capensis comprise a small group of species which were found to occur in both subtidal soft substratum regions and the surf zone. During the trawling survey, most juvenile P. natalensis and T. capensis were caught at depths <20 m. In the surf zone T. capensis juveniles were common in the summer months. Adult U. capensis are caught by anglers in the Eastern Cape, but though juveniles occurred in both beach seine and inshore trawl catches, and larvae were collected during the nearshore ichthyoplankton survey, little is known of the breeding biology of this species.

A group of five species Argyrosomus hololepidotus, Pomatomus saltatrix, Pomadasys olivaceum, Lithognathus mormyrus and Rhabdosargus holubi were recorded over soft substrata, in surf zones and in estuaries. The kob, A. hololepidotus, is an important line fish and juveniles were particularly abundant at depths <20 m. Algoa Bay was found to represent a major nursery area for this species. The reproductive cycle of A. hololepidotus has recently been described by Smale (1985) and larvae were also found in the nearshore ichthyoplankton of Algoa Bay. P. saltatrix is another important

line fish and juveniles were found to be abundant over soft substrata in embayments along the Cape south coast. This species undergoes lengthy coastal migrations to Natal to spawn and the larvae drift southwards in the Agulhas current to juvenile nursery areas in the Cape (van der Elst 1981). P. olivaceum is a small species found to be particularly common in both surf zones and shallow subtidal areas. Large numbers of P. olivaceum <5 cm were caught at King's Beach whilst, at depths <20 m, larger juveniles of 5 to 10 cm constituted much of the trawled catch. At depths >20 m the P. olivaceum catch consisted of fish of 10 to 20 cm in length. L. mormyrus, another small species, was particularly abundant in the surf zone in Algoa Bay, but although numerous juveniles <10 cm were trawled in depths of 5 to 9 m in Plettenberg Bay, they were infrequent in inshore trawls in Algoa Bay. The L. mormyrus caught in the surf zone at King's Beach were <10 cm in length, whilst with the exception of the Plettenberg Bay catch, those trawled in the Eastern Cape were mostly between 10 and 20 cm. Although near the eastern limit of its distribution range, R. globiceps juveniles were common in summer in the surf zone at King's Beach, whilst a few specimens were captured in the lower reaches of the Swartkops and Sundays estuaries and in the trawling survey.

Juveniles of four species which show various distributional overlaps between coastal habitats comprise the next grouping. Juveniles of the sea barbel Galeichthys feliceps were trawled in large numbers in the shallow soft substratum regions of Algoa Bay (<9 m) and juveniles were also recorded in low numbers in estuaries and tidal pools. Marais (1983a) states that spawning occurs in estuary mouths in the Eastern Cape and mouth brooding adult males have been captured in both estuaries and over subtidal soft substrata. Small Lichia amia (leervis) juveniles were caught in low numbers in Eastern Cape estuaries and occasionally in the surf zone of

sandy beaches. Sexual maturity is attained at 60 cm and numerous subadults were caught in gill nets in the Swartkops and Sundays estuaries (Marais & Baird 1980b; Marais 1981). Atherina breviceps (silverside) juveniles were particularly abundant in the lower reaches of the Swartkops estuary, whilst adults ($x = 7.6$ cm) were the most abundant species caught in the surf zone at King's Beach. Some juveniles were also recorded from the surf zone and tidal pools, whilst larvae were found in the nearshore ichthyoplankton of Algoa Bay. Juveniles of the mullet Liza richardsoni were also very abundant in Eastern Cape estuaries, though small juveniles and sexually mature adults were common in the surf zone in Algoa Bay. Juveniles were also recorded in tidal pools west of Cape Recife.

The largest group of species relying solely on one habitat was the group utilizing estuaries as nursery areas. Eighteen species were recorded exclusively in estuaries and comprised both juveniles of estuarine residents and marine species. The estuarine residents occurring in the Swartkops and Sundays estuaries were all small species, namely, Gilchristella aestuarius, Solea bleekeri, Caffrogobius multifasciatus, Glossogobius tenuiformis, Psammogobius knysnaensis, Syngnathus acus and Omobranchus woodi. These fish breed in estuaries and larvae of some of these species were recorded during tidal exchange studies in the mouth of the Swartkops estuary. Of the species spawning in the sea and entering the estuary as juveniles, mugilids were particularly common. Mugil cephalus and Liza dumerili were abundant, Liza tricuspidens common, and Myxus capensis and Valamugil buchanani present. The white steenbras Lithognathus lithognathus, an important angling species, showed a marked influx of juveniles into Eastern Cape estuaries in spring and were found to return to the sea in their second year. Juveniles of the spotted grunter Pomadasys commersonii (another important angling species) and Monodactylus

falciformis which favoured the upper vegetated regions of the Sundays estuary, entered the estuaries during the summer months. In contrast to S. bleekeri, only juveniles of Heteromycteris capensis, the other sole species in Eastern Cape estuaries, were found. Juveniles of Platycephalus indicus and Elops machnata, two widely distributed tropical species, occurred in low numbers in Eastern Cape estuaries. Whilst larvae of marine species such as sparids and mugilids occurring in the estuary as juveniles were not abundant in the nearshore ichthyoplankton of Algoa Bay, early juveniles showed a marked influx into the Swartkops estuary on the flood tide.

The species Rhabdosargus holubi and Clinus superciliosus form a small group of species occurring in both estuaries and tidal pools. R. holubi was the second most abundant species occurring in Eastern Cape estuaries. Juveniles recruited to the estuaries mainly in spring at length of <2 cm and grew to about 10 cm in their first year before returning to the sea where subadults and adults were found to occur chiefly over subtidal reefs. Some R. holubi juveniles >5 cm in length were found in tidal pools west of Cape Recife. Clinus superciliosus juveniles were particularly abundant in tidal pools, the habitat of the live bearing adults. By modal progression juveniles were found to grow rapidly and attained lengths of up to 10 cm in a year. A few specimens were found in the lower reaches of the Swartkops estuary.

The thirteen species of juveniles which were found to be exclusive to tidal pools were all cryptic species and consisted of the suckerfish Chorisochismus dentex, two gobies Caffrogobius caffer and C. saldanha, the crevice dwelling congrogadid Halidesmus scapularis, the rock cod Epinephalus guaza, the blenny Parablennius cornutus and six species of

Clinidae. It is suspected that juveniles of several of these species may also occur in shallow subtidal rocky areas adjacent to tidal pools, where no ichthyocide sampling would be carried out because of wave action and excessive water movement. Buxton & Smale (1984) only recorded two of the above species when they used an ichthyocide on subtidal reefs in the depth range of 10 to 30 m along the Tsitsikamma coast. With the exception of E. guaza all the above species occur as adults in tidal pools. Tidal pool fish exhibit reproductive specializations to prevent loss of eggs from the nearshore region and gobies, blennies and gobiesocids produce benthic eggs whilst the South African clinids are viviparous. Larvae of these four families were found in the Algoa Bay ichthyoplankton with gobiid larvae constituting 48% of the total ichthyoplankton.

Juveniles of six species, namely, Diplodus cervinus, Chaetodon marleyi, Chirodactylus brachydactylus, Cheilodactylus fasciatus, Sparodon durbanensis and Acanthistius sebastoides constituted a group which occurred in tidal pools but were also found to occur subtidally over shallow subtidal reefs. With the exception of A. sebastoides these juveniles found subtidally were larger than those found intertidally. Juveniles of D. cervinus were also recorded in low numbers in the lower reaches of the Swartkops estuary. From the tidal pool recolonization study, C. brachydactylus and C. fasciatus were found to recruit to tidal pools during winter and spring, whilst S. durbanensis juveniles recruited during the summer months.

Of the eight species of juvenile teleosts comprising the group found to occur exclusively over shallow subtidal reefs, all, with the exception of Oplegnathus conwayi and Cheilodactylus pixi, belong to the family Sparidae. Boopsoidea inornata and Pachymetopon aeneum occur in shoals over the

reefs whilst the juveniles of the other species usually occur singly. Chrysoblephus laticeps (red roman) and Chrysoblephus cristiceps (dageraad) are important line fish and juveniles were frequently observed during diving surveys. Juveniles of another important fish Petrus rupestris were, however, infrequently observed over shallow reefs in and around Algoa Bay but in the Tsitsikamma area Buxton & Smale (1984) recorded them to be more abundant over deeper reefs. Small juveniles of G. curvidens were particularly common in shallow areas near the shore.

Two species Spondyliosoma emarginatum and Cheimarius nufar form a small group which frequent reefs, but also occur in other habitats. S. emarginatum, a small sparid, occurred in shoals over reefs but juveniles were also recorded from the lower reaches of the Eastern Cape estuaries and from the trawls over soft substrata. Juveniles of C. nufar, an important line fish, were frequently observed over reefs in Algoa Bay and though some juveniles were trawled over soft substrata, their stomach contents suggested that they had been feeding around reefs.

Two sparid species which occur over reefs as adults, Diplodus sargus and Sarpa salpa, were found as juveniles in all the habitats investigated in the Eastern Cape coastal zone. In estuaries, these two species frequented the lower reaches whilst only low numbers were caught over subtidal soft substrata. Shoals of juveniles of the species were particularly common over shallow subtidal reefs, with S. salpa juveniles extending deeper than those of D. sargus. Though juveniles of D. sargus were particularly abundant in tidal pools, S. salpa were never sampled by rotenone poisoning in tidal pools closed off from the sea at low tide. During visual census of rocky shore ichthyofauna shoals of S. salpa were, however, observed in pools open to the sea. The presence of abundant D. sargus and S. salpa at

King's Beach can probably be related to the subtidal reefs and intertidal rocky areas in the vicinity. Amblyrhyncotes honckenii juveniles also showed a wide distribution, being found in low numbers in all habitats except over subtidal reefs. Larvae of this species were recorded from the nearshore ichthyoplankton, but larvae of the sparids common over reefs were poorly represented in the ichthyoplankton in relation to their abundance as juveniles.

Surprisingly, juveniles of two common rocky shore angling species Pachymetopon grande (hottentot) and Coracinus capensis (galjoen) and two sought after line fish species Cymatoceps nasutus (poenskop) and Chrysoblephus gibbiceps (red stumpnose) were not encountered in any of the five coastal habitats in Algoa Bay during the study period. Buxton & Smale (1984) also failed to locate any P. grande or C. capensis juveniles in the Tsitsikamma area, but did record a few juveniles of C. nasutus and C. gibbiceps.

Analysis of the various groupings of the 67 species discussed above indicates that 4% showed distributional overlaps between four or five habitats, 15% between three habitats and 18% between two habitats, whilst 27% were recorded only from estuaries, 19% only in tidal pools, 12% only over subtidal reefs, 5% only over subtidal soft substrata and none only in sandy beach surf zones. The juveniles showing distributional overlaps thus comprised 37% of the species whilst the juveniles specific to only one habitat comprised 63%.

In order to keep the large component of juveniles specific to single habitats in perspective it is, however, necessary to consider the phenomenon of direct recruitment. Direct recruitment of juveniles to adult

populations is characteristic of small coral reef fish (Helfmann 1978; Johannes 1978; Sale 1978; Williams & Sale 1981) and in this study was clearly evident for species with resident populations of breeding adults in well defined habitats such as tidal pools and estuaries. Juveniles of 20 of the species occurring in the two habitats showed direct recruitment and include the gobies, clinids, blennies, G. aestuarius, S. bleekeri, S. acus, C. dentex and H. scapularis.

The distributional overlaps between habitats shown by juveniles of various species, and particularly those of species associated with subtidal soft substrata, surf zones and estuaries, are interesting in view of recent comparable research in Australia. Blaber & Blaber (1980) investigated four estuarine and shallow soft substratum habitats around Moreton Bay on the east coast and found distributional overlaps between juveniles in the four habitats. They also investigated a number of factors influencing the differential distribution of juvenile fish and adult fish and concluded that the relative importance of each factor differed according to species with the only common denominator being the preference of juveniles for shallow water. Lenanton (1982) investigated nursery habitats of commercially and recreationally important fish species in south western Australia and found 13 of 16 species previously shown to be abundant in estuaries to occur in the inshore marine environment as well.

In comparison with the Western Cape, the Eastern Cape does not have a major commercial fishery although some 2000 tons of fish are caught annually by demersal trawling and commercial line fishing (Smale & Buxton 1985). There is, however, a considerable recreational fishery and, with the exception of the seasonal run of pelagic species such as Katsuwonus pelamis and Thunnus albacores, this relies on coastal species particularly A. hololepidotus,

P. saltatrix, L. amia, P. commersonii, L. lithognathus, C. nufar,
D. sargus, C. laticeps, C. cristiceps, P. grande and S. durbanensis (Marais
& Baird 1980a; Coetzee & Baird 1981; Smale & Buxton 1985). Nursery
habitats for most of these species were identified during this study.

In conclusion, this overview comparing the juvenile teleosts found in five
inshore habitats in the Eastern Cape coastal zone, has clearly shown the
importance of both estuarine and non-estuarine areas as nursery habitats.
With a total estuarine area of only 600 km² along a coastline length of
about 4000 km, it is appropriate that the coastal ichthyofauna of southern
Africa utilizes an array of nursery habitats.

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THE ICHTHYOPLANKTON ASSEMBLAGE OF THE ALGOA BAY NEARSHORE REGION IN
RELATION TO COASTAL ZONE UTILIZATION BY JUVENILE FISH

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A B S T R A C T

The nearshore ichthyoplankton of Algoa Bay was sampled at six stations over two years using a 1.5 m diameter plankton net towed from a ski-boat. Larvae of 26 families of teleosts were identified with Gobiidae constituting 48.0%, Engraulidae 26.7% and Clupeidae 12.1% of all larvae sampled. Caffrogobius spp., Engraulis capensis and Etrumeus teres were the dominant species whilst representatives of families such as Sparidae and Mugilidae which numerically dominate juvenile nursery areas in Algoa Bay were not abundant in the nearshore ichthyoplankton. The various taxa occurring in the ichthyoplankton are discussed in terms of distribution of adults and juveniles, breeding biology and available information on early life history. The paucity of larvae of coastal species with pelagic eggs is highlighted and, with reference to the findings of other workers and local oceanographic conditions, a possible spawning strategy is suggested.

INTRODUCTION

Fish species utilizing coastal nursery areas such as estuaries generally spawn in the sea and, on completion of larval development, the early juveniles migrate into the nursery areas (Gunter 1967; Clark 1974). Clark, Smith, Kendall & Fahay (1969) have reported on an extensive grid of offshore stations along the east coast of the United States which was regularly sampled to locate larvae of species abundant as juveniles in the estuaries of the Middle Atlantic Bight. Numerous publications, including Kendall (1972), Richards & Kendall (1973), Fahay (1974), Kendall & Reintjies (1975) and Kendall & Walford (1979) have resulted from this survey, and spawning times and seasons were identified for many species. Along the coast of southern Africa, juvenile fish are also abundant in coastal nursery areas such as estuaries and surf zones (Wallace & van der Elst 1975; Day, Blaber & Wallace 1981; Lasiak 1981) and the present study of the ichthyoplankton of Algoa Bay was aimed at investigating the availability of larvae to recruit into coastal nursery areas from the nearshore region.

Marine ichthyoplankton research in southern Africa dates from Gilchrist (1903, 1904) but, in general, has been concentrated on the early life histories of commercially important species on the west and south west coasts (see Shannon & Field (in press) for a review). Ichthyoplankton research along the east coast has been neglected except for a few cruises to try and locate eggs and larvae of pilchard Sardinops ocellata and anchovy Engraulis capensis (Anders 1975; Shelton & Kriel 1980). The present study is the first of a marine ichthyoplankton assemblage in the East Cape, although the fish larvae occurring in the Swartkops, Sundays and Kromme estuaries have been investigated (Melville-Smith 1978, 1981;

Melville-Smith & Baird 1980; Melville-Smith, Baird & Wooldridge 1981; Wooldridge & Bailey 1983; Beckley 1985a).

MATERIALS AND METHODS

Six stations were selected for the ichthyoplankton study in Algoa Bay. These stations were located in water of 5-7 m depth, just behind the breaker line off, respectively, Sundays Beach, Sundays estuary mouth, Coega Beach, Swartkops estuary mouth, King's Beach and Bird Rock (Fig. 1). Over a two year period from January 1980 to January 1982, eleven series of samples were taken at each of the six stations at intervals of approximately two months. Sampling commenced at Sundays Beach just after dark and the series was usually completed at either King's Beach or Bird Rock before 23h00.

A large conical net with a diameter of 1.5 m, length of 6.5 m and a mesh aperture of 500 μm was used. A rope between the net and a large inflatable buoy allowed for the maximum sampling depth to be regulated. The gear was towed at about 2 knots behind a 6 m ski-boat. The net sampled the water column from about 1 m above the bottom to the surface. A Kahlisco 005WA130 flowmeter was used to quantify the volume of water sampled. Sampling time at each station varied from 3-7 minutes and during each tow an average of 330 m^3 of water was sampled. Sea-surface temperature was measured at each station with a thermometer accurate to 0.1°C.

The zooplankton samples were transferred from the net to plastic containers and immediately preserved with formaldehyde in seawater (5% v/v). In the laboratory, fish larvae in the samples were separated from the rest of the zooplankton (chiefly mysids, copepods and chaetognaths) with the aid of a

stereomicroscope. The fish larvae were identified and the standard length of each larva measured using a stereomicroscope and a micrometer accurate to 0.1 mm. Miss A.E. Louw of the South African Museum assisted with identification of larvae, and the collection of laboratory-reared larvae assembled by Brownell (1979) was used as an aid in identifying some specimens.

RESULTS

Mean sea-surface temperatures for the six stations during the study period varied between 14.7°C and 22.9°C with maxima in summer. These are shown with the monthly means of temperatures measured daily at Humewood Beach in Algoa Bay in Fig. 2. Spatial and temporal variation in density of ichthyoplankton during the two year survey is shown in Table 1. Densities varied from 1 to 562 larvae per 100 m³. The station off the Swartkops estuary mouth characteristically had a higher density of ichthyoplankton (\bar{x} = 207 larvae per 100 m³) than the other stations which had mean densities of 39 to 93 larvae per 100 m³. In general, ichthyoplankton densities were greater in summer than winter (Fig. 2) with the exception of the unusually high densities of larvae which occurred at the Swartkops estuary mouth station in winter of 1981.

Twenty-six families of teleosts were identified from the ichthyoplankton samples and Fig. 3 indicates that numerically the family Gobiidae dominated the nearshore ichthyoplankton of Algoa Bay, constituting 48.0% of the total number of larvae captured. Engraulidae constituted 26.7%, Clupeidae 12.1%, Blenniidae 4.0%, Sciaenidae 2.4%, Sparidae 1.5%, Soleidae 1.5%, and the other 15 families 2.3%. Only 0.8% of all the larvae sampled were

unidentifiable.

The numbers of each species captured, size range and mean length are given in Table 2. Thirty species were identified but within the families Sparidae, Mugilidae, Clinidae and the genus Caffrogobius the absence of adequate descriptions of larvae and the diversity of species in Algoa Bay precluded identification to species level. Size-frequency histograms for the most abundant taxa are given in Fig. 4. The majority of larvae had mean standard lengths <10 mm. The clupeid larvae, however, were much larger with mean lengths of 21.5 mm and 23.9 mm for Etrumeus teres and Sardinops ocellata, respectively.

The densities of the various taxa of larvae at each sampling date were calculated from total number of each species captured in a particular sampling series, divided by the total volume of water sampled in a series, and are given in Table 3. Of the numerically dominant taxa, Caffrogobius spp. larvae occurred throughout the year but, proportionally, they contributed a greater percentage to the ichthyoplankton density during winter (Fig. 5). Engraulis capensis showed distinct density maxima in summer when this species contributed 41-59% of the ichthyoplankton (see January 1980, February 1981 and January 1982 in Fig. 5). Densities of Etrumeus teres and Sardinops ocellata larvae were also greatest during summer and were particularly high during summer 1981. No definite seasonal trends in larval density were evident in the case of Sparidae, Argyrosomus hololepidotus, Parablennius cornutus, Heteromycteris capensis or Cynoglossus capensis. Solea bleekeri larvae were more abundant in summer than winter.

DISCUSSION

The dominant taxa of ichthyoplankton occurring in the nearshore region of Algoa Bay are discussed below in terms of distribution of adults and juveniles, breeding biology and available information on early life history. An overview relating the findings of this study to those of other workers and local oceanographic conditions concludes the discussion.

Gobiidae

The gobiid genus Caffrogobius is ubiquitous in the East Cape where four species are known to be abundant. Caffrogobius multifasciatus occurs predominantly in estuaries (Beckley 1983a, 1984a), Caffrogobius caffer and Caffrogobius saldanha in tidal pools (Beckley 1985b; 1985c) and Caffrogobius agulhensis subtidally (Beckley 1984b). Another two species, Caffrogobius natalensis and Caffrogobius nudiceps are also known from the East Cape but the former is rare and the latter is more common in the West Cape (Smith 1960).

Gobies produce demersal eggs with adhesive threads or pedestals (Breder & Rosen 1966) and Gilchrist (1916) has described the demersal eggs of Caffrogobius nudiceps. Beckley (1985a) found that extremely high numbers (up to 15 per m³) of very small, 2-3 mm SL, Caffrogobius multifasciatus larvae were flushed out of the Swartkops estuary at ebb tide and this may account for the high densities of goby larvae found off the Swartkops estuary mouth during the present survey. It must be stressed, however, that the Caffrogobius multifasciatus larvae were identified by inference (Caffrogobius agulhensis, Caffrogobius caffer and Caffrogobius saldanha have not been recorded in the Swartkops estuary) and distinguishing

features between the larvae of the various Caffrogobius species are unknown. It is interesting to note that O'Toole (1974) found the pelagic goby Sufflogobius bibartus to dominate the offshore ichthyoplankton of South West Africa, contributing 67% of the total fish larvae captured.

Engraulidae

The larvae of the commercially exploited Engraulis capensis showed clear summer peaks of abundance in the nearshore plankton of Algoa Bay. Though Anders (1975) recorded anchovy eggs and larvae on the east coast of South Africa, research effort on anchovy larvae has been concentrated in South West Africa (O'Toole 1977; Badenhorst & Boyd 1980) and in the south western Cape (Shelton & Kriel 1980; Shelton & Hutchings 1981, 1982; Shelton 1984). In the latter area, Shelton & Hutchings (1982) delineated the spawning time of anchovy as between October and January, with spawning maxima restricted to a 200 km inshore zone between Cape Point (34° 50'S 18° 32'E) and Cape Infanta (34° 27'S 20° 51'E).

In laboratory rearing experiments on anchovy, King, Robertson & Shelton (1978) found time of hatching to decrease from 108 hr to 21 hr as temperature was raised from 12° to 23°C. They found size at hatching to range from 2.4 mm to 3.2 mm though Badenhorst & Boyd (1980) have recorded anchovy larvae of under 2 mm in formaldehyde preserved samples. Although no eggs were recorded in the present survey, the occurrence of newly hatched larvae (from 2.0 mm SL) in the nearshore plankton of Algoa Bay and the rapid rate of development of eggs in water >20°C - comparable to the temperatures which occur in Algoa Bay in summer (Fig. 2) - suggest spawning of Engraulis capensis in Algoa Bay.

Because of increasing evidence of anchovy abundance east of Cape Agulhas (34° 50'S 20° 00'E) from ichthyoplankton data (Beckley 1983b) and studies of the diets of predatory fish and seabirds (Hecht 1976; Smale 1983; Randall 1983; Batchelor & Ross 1984) the Sea Fisheries Research Institute extended anchovy surveys as far east as East London (33°01'S 27° 55'E) in 1983 and 1984. During these surveys, Algoa Bay was the only area east of Cape Agulhas where anchovy eggs were found near the coast (P.A. Shelton pers. comm.). Investigation into chlorophyll distribution in southern African waters (Shannon, Hutchings, Bailey & Shelton 1984) has established the presence of a plume of high chlorophyll extending southwards from East London into Algoa Bay, and they have proposed this as a possible food supply for anchovy in the region.

Clupeidae

Larvae of the clupeid Etrumeus teres occurred throughout the sampling period but showed greatest densities in spring and early summer. Davies, Newman & Shelton (1982) from work in the south western Cape, found Etrumeus teres to have protracted spawning which was most intense from August to October. They found highest densities of eggs in offshore waters. The prevalence of large larvae (Fig. 3) with a mean length of 21.5 mm in the Algoa Bay nearshore region implies either offshore spawning in the East Cape as well, or, immigration of larvae spawned to the west.

Sardinops ocellata larvae, the most thoroughly described fish larvae from the coast of southern Africa (Brownell 1979), were abundant in the ichthyoplankton of Algoa Bay during the summer of 1980, but only occurred in low numbers in 1981. The majority of larvae were large ($x = 23.9$ mm) corres-

ponding to an age of nearly two months (Boyd & Badenhorst 1981) and, therefore, were probably not spawned in Algoa Bay. Davies, Newman & Shelton (1982) indicated that during 1977/1978 the highest densities of Sardinops ocellata eggs were found south of Cape Agulhas from October to February, whereas earlier studies in the 1960s, before overfishing of pilchard had occurred, recorded greatest densities off St Helena Bay (32° 45'S 18° 05'E) on the west coast (Crawford 1981). Anders (1975) located a pilchard spawning area on the east coast though the seasonal occurrence of Sardinops ocellata along the Natal coast ("the sardine run") is not considered a spawning migration (Baird 1971). The recent (1983/1984) Sea Fisheries Institute surveys from the south western Cape to East London failed to capture any significant concentrations of pilchard eggs or larvae (P.A. Shelton pers. comm.). It appears that with the collapse of the pilchard stock, the occurrence and distribution of Sardinops ocellata eggs and larvae along the coast of southern Africa is highly variable.

Blenniidae

Two species of Blenniidae contributed 4.0% to the total nearshore ichthyoplankton sampled in Algoa Bay. Parablennius cornutus occurs both intertidally and subtidally on rocky shores from Doring Bay (31° 50'S 18° 17'E) to Durban (29° 51'S 31° 01'E) (Penrith & Penrith 1982). Eyberg (1984) determined that the spawning period of Parablennius cornutus in Natal was from May to November and noted that larvae on hatching from benthic eggs had a mean length of 3,5 mm. In the present study, larvae of this species were recorded on all sampling dates except December 1980 and February 1981, suggesting a similar long breeding season in the East Cape. Large larvae of this species were also very abundant in the ichthyoplankton in the mouth of the Swartkops estuary in October 1980 (Beckley 1985a). The

second species of blenniid, Omobranchus woodi, is mainly estuarine in occurrence and is distributed from Knysna (34° 03'S 23° 03'E) to Kosi Bay (26° 53'S 32° 58'E) (Penrith & Penrith 1982). The distinct seasonal occurrence of the larvae in the present study coincides well with the summer peaks of abundance (up to 15 per m³) recorded by Melville-Smith (1978) in the Swartkops estuary. Omobranchus woodi larvae were found at all six stations in Algoa Bay and were also found on the ebb tide in the ichthyoplankton in the mouth of the Swartkops estuary (Beckley 1985a).

Sciaenidae

Sciaenid larvae of the species Argyrosomus hololepidotus and Umbrina capensis constituted 2.4% of the total number of fish larvae captured in the nearshore region of Algoa Bay. The Argyrosomus hololepidotus larvae were small ($x = 3.9$ mm) and were most abundant in summer and autumn. Smale (1983) regards Algoa Bay as a major breeding area for Argyrosomus hololepidotus and suggests that this species migrates from other areas of the coast to the East Cape to spawn. Smale (1984) has identified the shallow (0-9 m) soft substratum areas of Algoa Bay as a major nursery area for this species and Beckley (1984b) has captured small juveniles (from 13 mm TL) in shallow-water trawling off the Swartkops estuary mouth. The few Umbrina capensis larvae captured were also small ($x = 4.3$ mm) and, although Lasiak (1982) has recorded juveniles and ripe adults from the surf zone of Algoa Bay, little is known of the biology of this species.

Sparidae

The family Sparidae in southern Africa is represented by 42 species (Smith 1975) of which 50% are endemic. Twenty-five sparid species are regularly

captured in the East Cape and though the larvae of a few have been described (Gilchrist 1903, 1916; Ranzi 1933; Brownell 1979) most South African species are undescribed. Coastal nursery habitats are extensively utilized by sparids in the East Cape with juveniles of Rhabdosargus holubi, Lithognathus lithognathus and Diplodus sargus abundant in estuaries (Beckley 1983a, 1984a), juveniles of Lithognathus mormyrus, Diplodus sargus, Sarpa salpa and Rhabdosargus globiceps abundant in sandy beach surf zones (Lasiak 1981, 1982), juveniles of Sparodon durbanensis, Diplodus sargus and Diplodus cervinus abundant in tidal pools (Beckley 1985b, 1985c) and juveniles of Chrysoblephus laticeps, Chrysoblephus cristiceps, Boopsoidea inornata, Sarpa salpa, Spondyliosoma emarginatum and Pachymetopon aeneum abundant on shallow subtidal reefs (Beckley in prep.). The paucity of sparid larvae (only 1.5% of total nearshore ichthyoplankton) in relation to the abundance of juveniles is difficult to account for as ripe adults of numerous species have been recorded in the East Cape (see van der Elst (1981) for summaries of available information on breeding biology of common South African sparids). Sparids produce pelagic eggs (Breder & Rosen 1966) though Spondyliosoma emarginatum has benthic eggs (van Bruggen 1965). Spawning and development of larvae away from the nearshore region are offered as possible explanations for the low numbers of larvae in the present survey. On the other hand, more sparid species may be discovered to undergo breeding migrations to Natal waters, similar to that described for Sarpa salpa by Joubert (1981).

Pleuronectiformes

The larvae of three families of flatfishes, namely Bothidae, Soleidae and Cynoglossidae were captured in the nearshore ichthyoplankton of Algoa Bay

with the latter two families more abundant and together constituting 2.1% of the total number of larvae sampled. Solea bleekeri spawns in both estuaries and the sea (Day, Blaker & Wallace 1981) and in the present survey larvae of this species were more abundant in summer than winter. This corresponds with the January/February peak of larval abundance recorded by Melville-Smith (1978) in the Swartkops estuary. Heteromycteris capensis, although also occurring in estuaries, breeds in the sea (Melville-Smith 1978; Brownell 1979) and Lasiak (1982) has recorded ripe specimens throughout the year in the surf zone. Cynoglossus capensis occurs subtidally over soft substrata in Algoa Bay (Wallace, Kok, Buxton & Bennett 1984; Beckley 1984b) but very little is known of the biology of this species.

Other taxa

The Gobiesocid larvae captured in the nearshore plankton are believed to be those of Chorisoichismus dentex for although Gilchrist's (1916) description of larvae of this species (based on larvae hatched from eggs dredged in False Bay) is poor, the pigmentation pattern described fits that of the Algoa Bay larvae. Chorisoichismus dentex is common in tidal pools and subtidally in the East Cape (Beckley 1985b). The family Clinidae is represented by at least 15 species along East Cape rocky shores. Clinus superciliosus, the most common species, is viviparous and prepartum embryos attain a length of 20 mm (Veith 1979) so it is concluded that the small clinid larvae captured in the present survey are probably those of a smaller species such as Blennioclinus stella.

The remainder of the larvae captured in the nearshore ichthyoplankton of Algoa Bay only occurred in very low numbers. Of these, Atherina breviceps,

Pomadasys olivaceum and mullet are associated with coastal nursery areas, in particular, sandy beach surf zones and estuaries (Lasiak 1982; Beckley 1983a, 1984a). Melville-Smith (1978) recorded peak numbers of Atherina breviceps larvae entering the Swartkops estuary during January, whilst Beckley (1983a) found juveniles to be extremely abundant in the lower reaches of the estuary in late summer. Lasiak (1982) recorded ripe Atherina breviceps in the surf zone from August to December. B.A. Bennett (in prep.) has found the eggs to be demersal, with long sticky threads, but the spawning location of this species in Algoa Bay has yet to be identified.

Juveniles of Pomadasys olivaceum are one of the dominant species occurring off sandy beaches in Algoa Bay (Lasiak 1982) and van der Elst (1981) states that this species spawns year round in deep water. Juvenile mullet, in particular Liza dumerili and Liza richardsoni, are extremely abundant in East Cape estuaries (Beckley 1983a, 1984a) and van der Horst & Erasmus (1981) and Lasiak (1983) have concluded that these two species spawn in the inshore marine environment. The extremely low numbers of Pomadasys olivaceum and mullet larvae captured in the nearshore region indicates that the larvae probably develop away from the coast and only migrate inshore to nursery habitats as post-larvae capable of swimming.

Concluding Overview

The ichthyoplankton of the nearshore region of Algoa Bay can be divided into three categories based on distribution of the adults and types of eggs they produce. The first category comprises larvae of pelagic species with pelagic eggs and includes the families Engraulidae and Clupeidae. The second category comprises larvae of coastal species with benthic eggs and

includes the families Gobiidae, Blenniidae, Gobiesocidae and Atherinidae. The family Clinidae, with its many viviparous species, can, in effect, be included in this category as well. The third category comprises larvae of coastal species with pelagic eggs and includes the families Sparidae, Sciaenidae, Pomadasyidae, Mugilidae and Soleidae. Species belonging to these families are abundant as juveniles in coastal habitats but were found in relatively low numbers in the nearshore ichthyoplankton survey.

Ruple (1984) investigating the occurrence of larval fish off the Mississippi coast, used sampling stations in the outer surf zone which correspond directly with the Algoa Bay study in terms of depth and distance from the shore. Eighteen of the 28 families of larvae he recorded were common to the Algoa Bay inshore ichthyoplankton. As was the case in Algoa Bay, Ruple (1984) found low numbers of larvae of the species utilizing the surf zone as juveniles. Similarly, Miller (1974) and Leis & Miller (1976) found that families which dominated the reef ichthyoplankton of Hawaii were virtually absent in the inshore ichthyoplankton around the islands.

Johannes (1978) reviewed reproductive strategies of coastal fish in tropical areas and indicated that many coastal species migrate offshore to spawn in order to avoid predation on the eggs and larvae by filter feeding benthos and zooplankton eating reef fish. Leis & Miller (1976) investigating offshore distribution patterns of fish larvae at stations ranging from 0,5 to 12 km off the islands of Hawaii, found that larvae of reef species with demersal eggs decreased in abundance with distance offshore, but larvae of reef fish with pelagic eggs increased in abundance with distance offshore. They describe how some families, e.g. Chaetodontidae, have developed prolonged and elaborate pelagic larval stages which result in large post larvae capable of swimming long distances back to the coast. In

Algoa Bay, however, recruitment of early juveniles of sparids, sciaenids, pomadasyids and mugilids to various coastal habitats occurs at lengths of 10-20 mm (Lasiak 1982; Beckley 1983a, 1984a, 1985a,b) indicating relatively short larval phases. Johannes (1978) and Sale (1980) in their reviews covering the early life history of coastal reef fish suggest, as did Leis & Miller (1976), that for most larvae without lengthy larval phases, current eddies and gyres must prevent larvae from being lost to the coastal populations.

Along the east coast of southern Africa, the strong Agulhas current flows in a south westerly direction along the edge of the continental shelf (Harris 1978) but movement of inshore shelf surface water is largely longshore under the influence of local winds (J. Lutjeharms, pers. comm.) In Algoa Bay, however, there is evidence for cyclonic within-bay circulation (Harris 1978) whilst the long sandy beaches which dominate the shoreline are characterised by surf circulation cells in the nearshore region (McLachlan & Bate 1985). Coastal species with pelagic eggs could spawn in deeper water, possibly at the seaward edge of subtidal reefs as found in tropical waters (Johannes 1978), so that eggs and larvae become entrained in the within-bay circulation. In this way, the eggs and larvae would avoid retention in the surf circulation cells and the numerous nearshore filter feeders and zooplankton predators but yet not have to actively swim vast distances to recruit to coastal habitats on completion of larval development.

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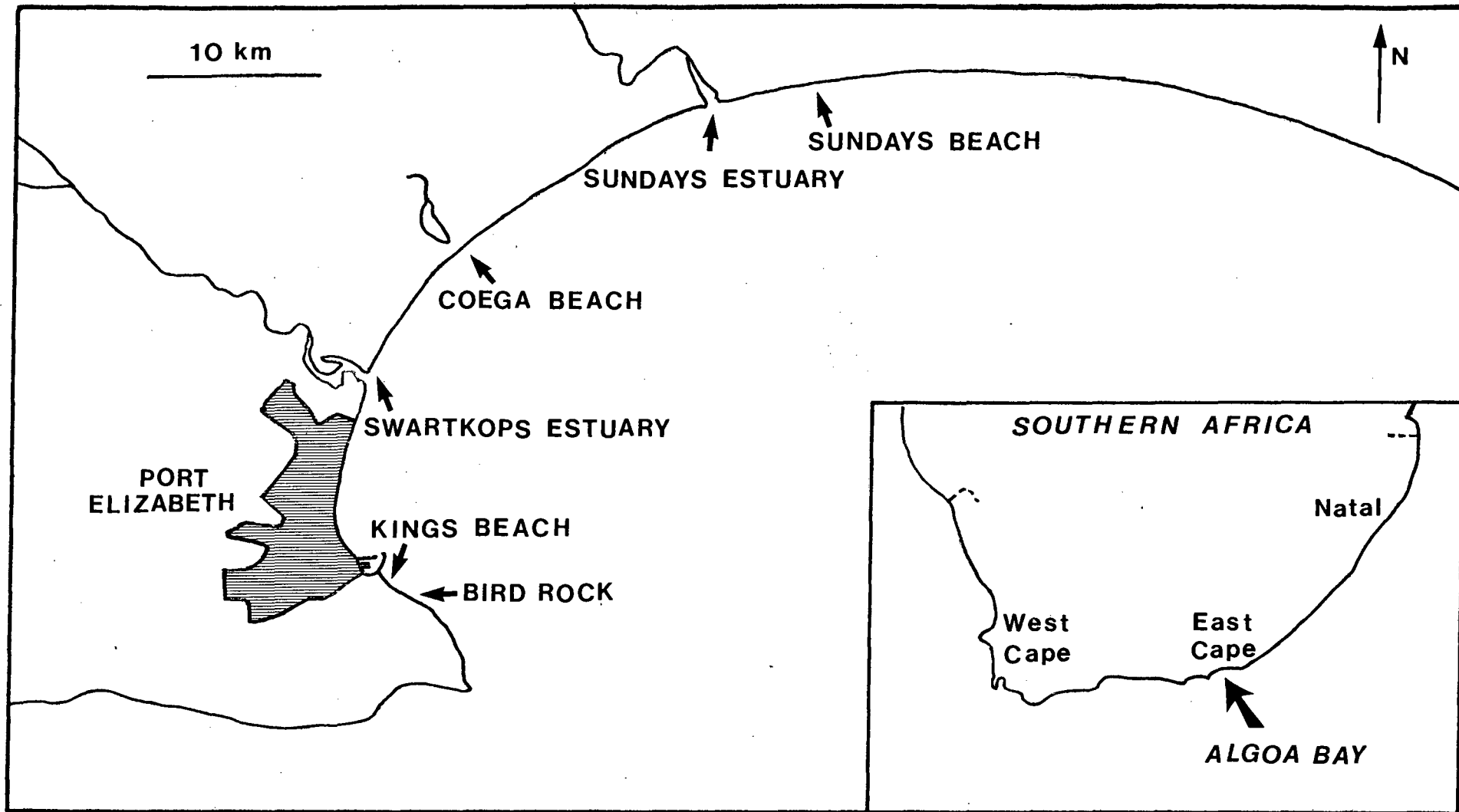


Figure 1. A map of Algoa Bay showing the six sampling stations in the nearshore ichthyoplankton survey.

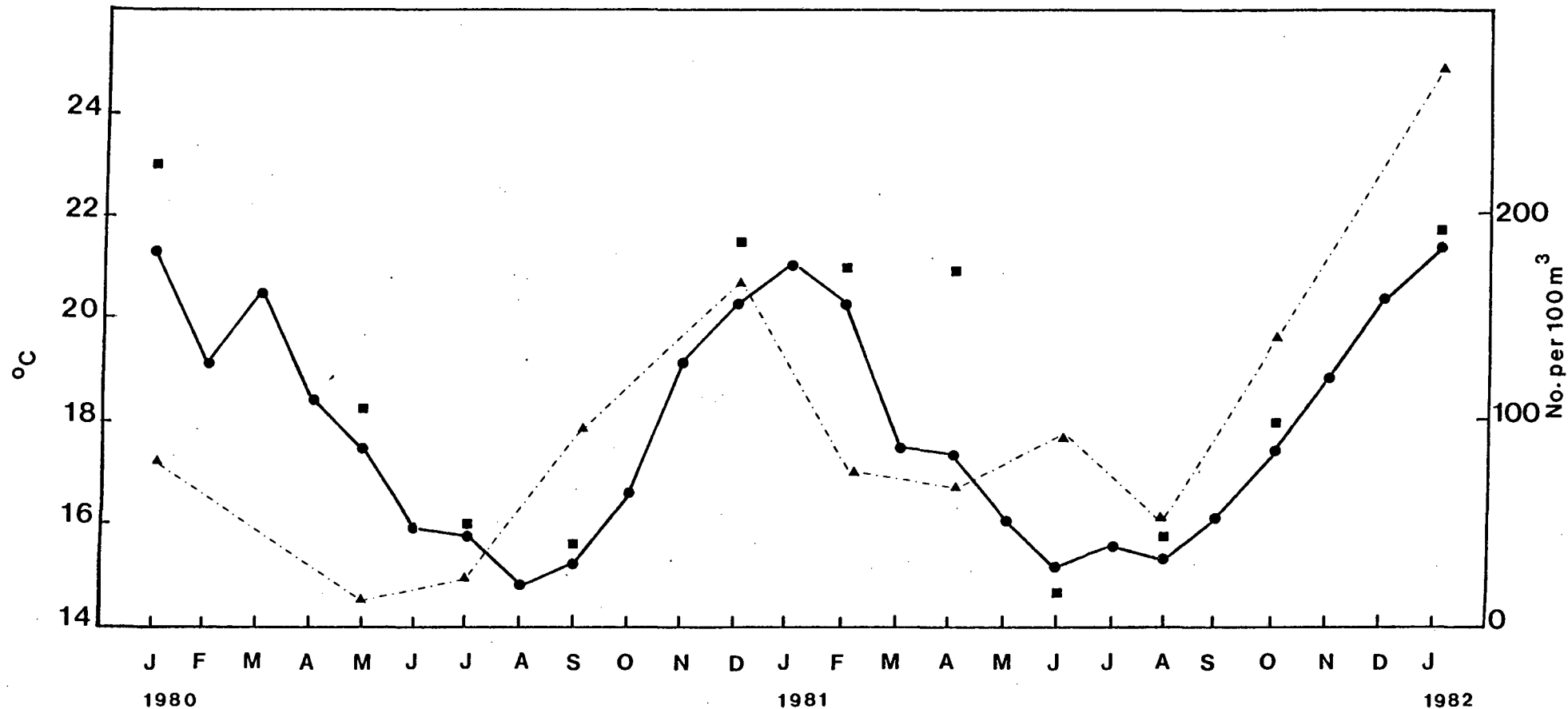


Figure 2. Mean monthly sea-surface temperature in Algoa Bay during the sampling period (●—●) with mean temperatures recorded during each sampling series superimposed (■). Ichthyoplankton density for each sampling series is given as the mean for the six stations (▲—▲).

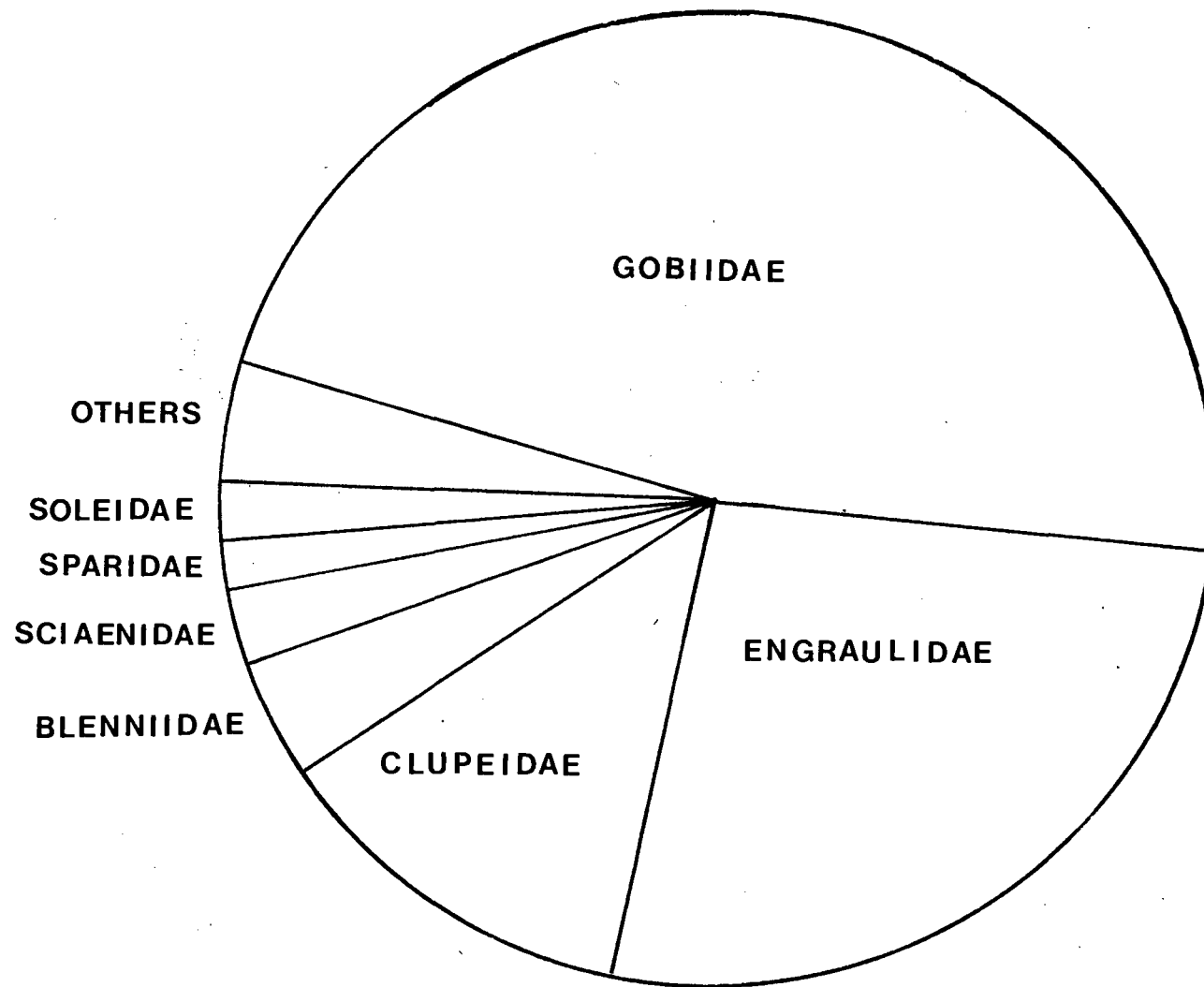


Figure 3. Pie-diagram showing the proportions which various fish families contributed to the total catch of larvae.

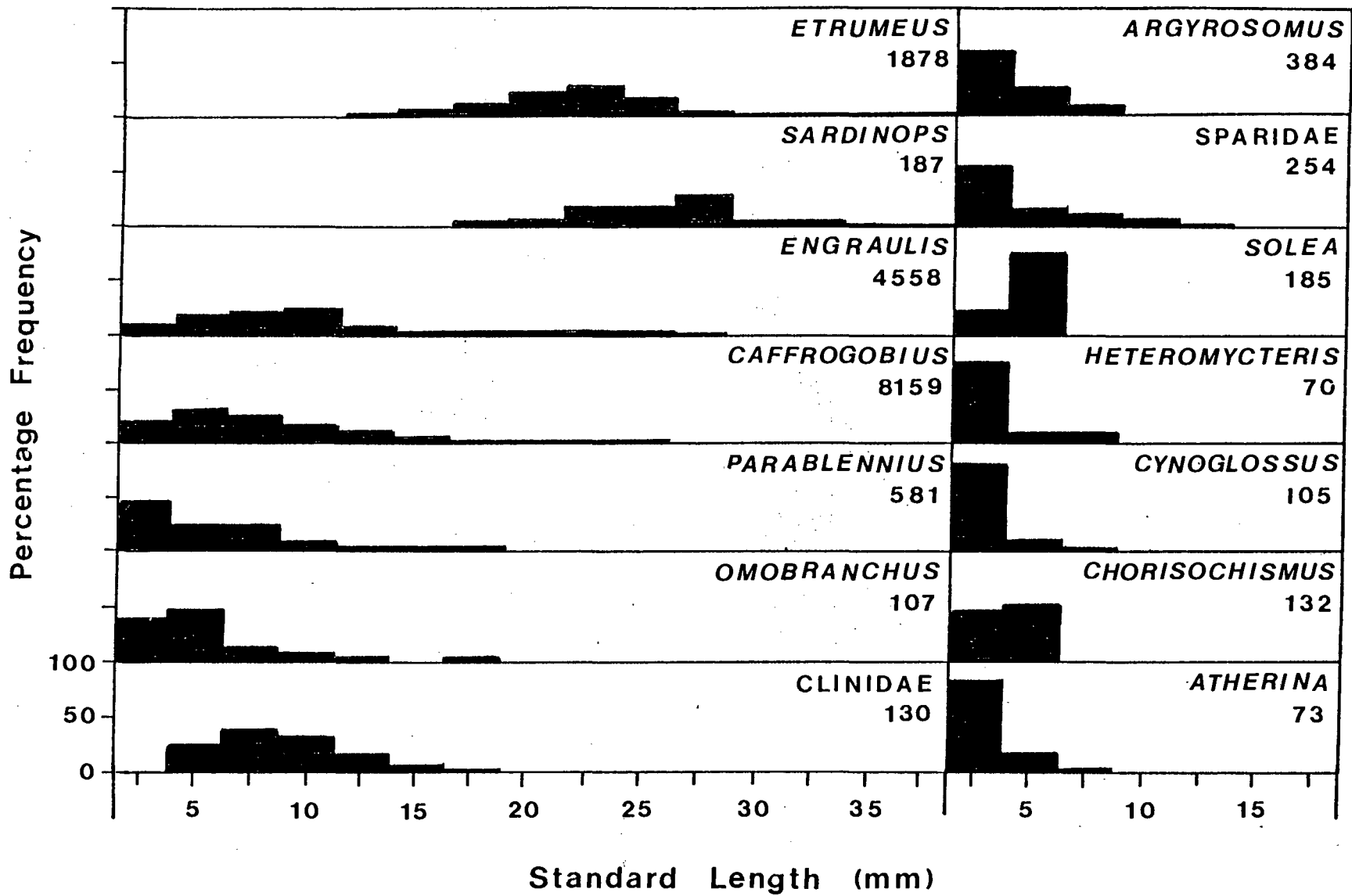


Figure 4. Size-frequency histograms for the dominant taxa of larvae occurring in the Algoa Bay ichthyoplankton.

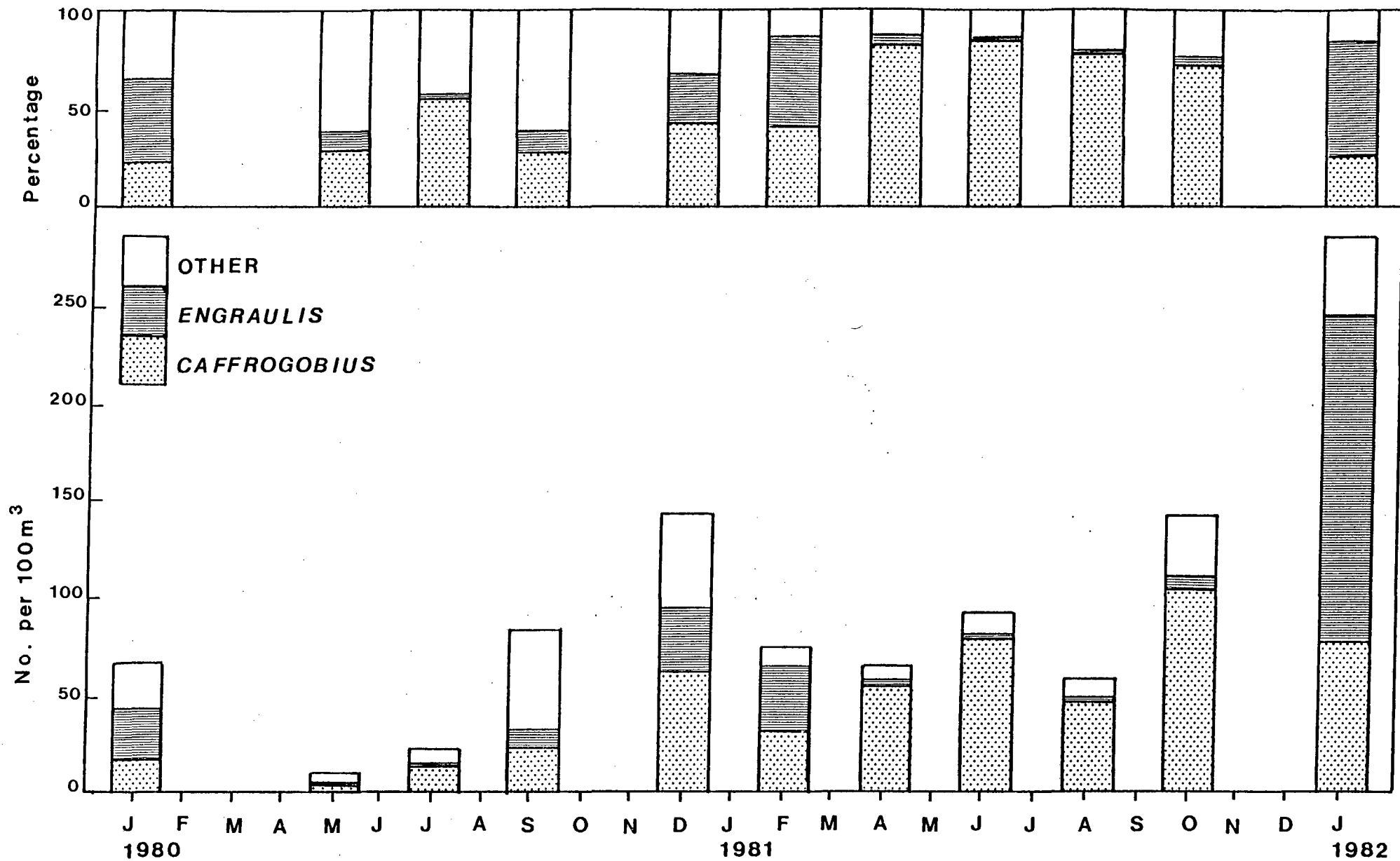


Figure 5. Numerical and percentage contributions of *Caffrogobius* spp. and *Engraulis capensis* to the ichthyoplankton assemblage of the nearshore region of Algoa Bay.

Series	Sundays Beach	Sundays Estuary	Coega Beach	Swartkops Estuary	Kings Beach	Bird Rock	Series Mean
22 Jan 1980	n.s.	n.s.	28	62	35	191	79
10 May 1980	8	20	16	1	8	20	12
28 July 1980	6	11	26	15	65	21	24
30 Sept 1980	46	82	163	8	109	170	96
3 Dec 1980	2	299	199	1.n.	1.n.	1.n.	167
10 Feb 1981	25	6	29	170	105	112	75
15 April 1981	27	46	48	261	8	4	66
17 June 1981	6	66	38	416	7	30	94
25 Aug 1981	124	20	21	29	12	85	49
27 Oct 1981	72	21	73	542	87	44	140
5 Jan 1982	71	81	380	562	341	196	272
Station Mean	39	65	93	207	78	87	

TABLE 1. Spatial and temporal variation in density of fish larvae per 100 m³ at the six stations in the Algoa Bay nearshore region for the 11 sampling series in the study period (n.s. = no sample; 1.n. = lost net).

FAMILY	S P E C I E S	TOTAL CATCH	SIZE RANGE (mm)	MEAN (mm)	SD (mm)
ELOPIDAE	<u>Elops machnata</u>	2	31.9 - 37.4	34.7	3.9
CLUPEIDAE	<u>Etrumeus teres</u>	1 878	2.3 - 37.0	21.5	4.3
	<u>Sardinops ocellata</u>	187	3.4 - 36.4	23.9	6.4
ENGRAULIDAE	<u>Engraulis capensis</u>	4 558	2.4 - 45.4	10.0	5.9
	? <u>Stolephorus sp.</u>	21	13.2 - 31.9	22.5	4.8
SYNODONTIDAE	? <u>Synodus indicus</u>	1	7.4	7.4	-
EXOCOETIDAE	<u>Hemirhampus far</u>	1	8.8	8.8	-
GADIDAE	<u>Gaidropsaurus capensis</u>	6	1.8 - 2.7	2.2	0.4
OPHIDIIDAE	<u>Xiphiurus capensis</u>	7	2.8 - 4.1	3.5	0.4
BOTHIDAE	<u>Arnoglossus capensis</u>	5	2.8 - 5.0	3.9	0.8
SOLEIDAE	<u>Austroglossus pectoralis</u>	3	2.2 - 2.7	2.4	0.3
	<u>Heteromycteris capensis</u>	70	1.4 - 8.8	3.4	1.7
	<u>Solea bleekeri</u>	185	1.7 - 5.3	4.1	0.8
	<u>Synaptura marginata</u>	4	2.6 - 3.2	3.0	0.3
CYNOGLOSSIDAE	<u>Cynoglossus capensis</u>	105	1.5 - 9.6	3.2	1.3
SYNGNATHIDAE	<u>Syngnathus acus</u>	4	8.4 - 14.7	11.3	3.4
CARANGIDAE	<u>Trachurus capensis</u>	11	2.0 - 25.5	5.2	6.8
POMATOMIDAE	<u>Pomatomus saltatrix</u>	2	24.4 - 39.8	32.1	10.9
SCIAENIDAE	<u>Argyrosomus hololepidotus</u>	384	2.0 - 10.0	3.9	1.8
	<u>Umbrina capensis</u>	18	2.3 - 7.6	4.3	2.0
POMADASYIDAE	<u>Pomadasyus olivaceum</u>	8	8.8 - 64.9	24.0	20.3
SPARIDAE	Unidentified spp.	254	1.8 - 11.3	4.6	2.5
	<u>Sarpa salpa</u>	7	15.8 - 36.5	19.1	7.7
MUGILIDAE	Unidentified spp.	9	2.0 - 19.4	8.0	6.7
ATHERINIDAE	<u>Atherina breviceps</u>	73	4.7 - 9.8	5.8	0.8
GOBIIDAE	<u>Psammogobius knysnaensis</u>	58	2.1 - 7.0	3.9	1.5
	<u>Caffrogobius spp.</u>	8 159	1.7 - 25.2	7.3	3.5
BLENNIIDAE	<u>Omobranchus woodi</u>	107	2.7 - 17.1	5.1	2.5
	<u>Parablennius cornutus</u>	581	2.0 - 17.5	5.4	2.8
CLINIDAE	Unidentified spp.	130	4.3 - 17.0	8.5	2.6
SCORPAENIDAE	<u>Coccotropsis gymoderma</u>	2	2.4 - 4.7	3.6	1.6
CONGIPODIDAE	<u>Congiopodus spinifer</u>	2	3.5 - 4.1	3.8	0.4
TRIGLIDAE	<u>Trigla capensis</u>	5	2.6 - 3.9	3.4	0.5
GOBIESOCIDAE	? <u>Chorisochismus dentex</u>	132	1.5 - 6.1	4.1	1.1
TETRADONTIDAE	<u>Amblyrhyncotes honckenii</u>	16	2.1 - 92.3	9.8	22.1
UNIDENTIFIED LARVAE		139	1.5 - 5.2	2.5	0.8
TOTAL		17 134	1.5 - 92.3		

TABLE 2 Species composition, total catch, size range and mean size of fish larvae captured in the Algoa Bay nearshore region during the study period.

	01/80	05/80	07/80	09/80	12/80	02/81	04/81	06/81	08/81	10/81	01/82
<u>Elops machnata</u>								+	+		
<u>Etrumeus teres</u>	0.5	0.9	0.3	44.1	34.8	1.4	1.1	5.8	6.2	12.4	1.6
<u>Sardinops ocellata</u>	+	+	+	1.8	10.3			+	0.1	+	0.1
<u>Engraulis capensis</u>	26.9	1.1	0.3	8.5	34.7	34.0	4.0	0.5	0.6	6.6	169.0
? <u>Stolephorus</u> sp.	0.5			0.6							
? <u>Synodus indicus</u>								+			
<u>Hemiramphus far</u>											+
<u>Gaidropsaurus capensis</u>			0.1	+					0.1		
<u>Xiphiurus capensis</u>		+		0.2							
<u>Arnoglossus capensis</u>											0.3
<u>Austroglossus pectoralis</u>									0.2		
<u>Heteromycteris capensis</u>	0.2	0.4	0.2	+		0.5	0.6	0.7	0.3	0.2	0.8
<u>Solea bleekeri</u>	5.6	+	+		0.1	1.3	0.3	+	+	+	3.2
<u>Synaptura marginata</u>	+					0.2					+
<u>Cynoglossus capensis</u>	0.7	1.4	+			0.4	0.1	+	0.1	0.2	1.9
<u>Syngnathus acus</u>									0.2		+
<u>Trachurus capensis</u>	+	+	+	0.1		0.3		0.1			
<u>Pomatomus saltatrix</u>					0.1						
<u>Argyrosomus hololepidotus</u>	2.4	2.5	0.2	0.1		0.5	4.0		0.2	0.7	9.7
<u>Umbrina capensis</u>	0.2			+		0.5		+		+	0.4
<u>Pomadasys olivaceum</u>	+			+	0.2			0.2			
Sparidae spp.	1.4	0.2	0.3	1.3	+	0.9	0.2	0.6	0.3	1.8	8.0
<u>Sarpa salpa</u>		+		+					0.3		
Mugilidae spp.	0.1	+									0.3
<u>Atherina breviceps</u>	3.8					0.2	+				
<u>Psammogobius knysnaensis</u>	0.6	+	0.5	0.2	0.4	0.3			0.2	0.3	0.7
<u>Caffrogobius</u> spp.	15.1	2.9	11.7	22.4	60.3	30.8	53.8	78.6	46.9	104.2	78.1
<u>Omobranchus woodi</u>	3.4				0.2	0.5				0.4	1.8
<u>Parablennius cornutus</u>	1.4	0.5	6.9	1.3			1.5	4.4	1.3	11.8	2.5
Clinidae spp.	0.6	+	0.4	1.9	1.4	1.1	+	0.3	0.3	0.1	1.6
<u>Coccotropsis gymnoforma</u>											0.1
<u>Congiopodus spinifer</u>				0.1		0.3					
<u>Trigla capensis</u>			0.1						0.3		+
? <u>Chorisochismus dentex</u>	0.6					0.2		0.3	0.3	3.6	2.8
<u>Amblyrhynchotes honckenii</u>	+				0.2				+	+	0.2
Unidentified larvae	1.8	0.3	0.2	0.3		2.1	0.1	0.1	1.2		2.3
TOTAL	65.9	10.6	21.4	83.1	142.7	75.3	64.7	91.9	59.3	142.6	285.6

TABLE 3. Density (larvae per 100 m³) for each species in the nearshore ichthyoplankton for each sampling series (+ indicates < 0.1 larva per 100 m³).

Tidal exchange of ichthyoplankton in the Swartkops estuary mouth, South Africa

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Tidal exchange of fish eggs, larvae and juveniles in the mouth of the Swartkops estuary was examined by plankton and seine-netting during two 24-h sampling sessions. Small larvae of resident estuarine species such as *Caffrogobius multifasciatus*, *Psammogobius knysnaensis* and *Omobranchus woodi* appear to be passively swept out of the estuary on the ebb-tide. Early juveniles of marine species which utilize the estuary as a nursery ground, such as *Rhabdosargus holubi*, *Liza richardsoni* and *Heteromycteris capensis*, enter the estuary on the flood-tide. Catches of these species near the bank during ebb-tide suggest that they actively migrate towards the banks to prevent being swept back out to sea. *S. Afr. J. Zool.* 1985, 20: 15–20

Die gety-uitruiling van eiers, larwes en kleinvisies in die Swartkopsriviermond is deur middel van planktonmonsters en treknetvangste tydens twee 24 h-periodes ondersoek. Dit wil voorkom asof larwes van spesies wat getyrieviere bewoon soos *Caffrogobius multifasciatus*, *Psammogobius knysnaensis* en *Omobranchus woodi* passief uit die riviermond met die ebgety uitgespoel word. Kleinvisies van mariene spesies wat die getyrievier as 'n grootwordgebied gebruik soos *Rhabdosargus holubi*, *Liza richardsoni* en *Heteromycteris capensis* dring die getyrievier binne tydens die vloedgety. Vangste van hierdie spesies langs die wal gedurende die ebgety impliseer dat die kleinvisies moontlik aktief na die kante toe swem om uitspoeling terug see toe te verminder.

S.Afr. Tydskr. Dierk. 1985, 20: 15–20

Most marine fish species spawn at sea but the larvae and early juveniles of some of these species leave the marine environment to enter sheltered, food-rich estuarine nursery areas (Gunter 1967; Clark, Smith, Kendall & Fahay 1969; Wallace 1975; Wallace & van der Elst 1975; Day, Blaber & Wallace 1981). The factors influencing the recruitment of the early life stages of these fishes into estuaries are multiple (Blaber & Blaber 1980; Whitfield 1980, 1983) and the actual process of transport into the estuary may be by active swimming or passive drift with tidal currents (Creutzberg 1958; Gunter 1967; Pacheco & Grant 1973).

To investigate this process of recruitment into estuaries, two 24-h sampling sessions were conducted in the mouth of the Swartkops estuary (33°52'S/25°38'E) in South Africa. This estuary was selected because its ichthyofauna is well known (Winter 1979; Marais & Baird 1980; Melville-Smith & Baird 1980; Beckley 1983a), the ichthyoplankton in the adjacent coastal waters of Algoa Bay has also been studied (Beckley 1983b) and other workers were concurrently investigating crustacean movements into the estuary (Emmerson 1983; Wooldridge 1983). By sampling continuously over 24-h periods, it was possible to monitor the time of day and phase of tide during which fish larvae and early juveniles entered the estuary and hence obtain an indication of the extent of passive drift and active swimming during this process.

Materials and Methods

Sampling in the mouth of the Swartkops estuary was conducted in early spring when recruitment into the estuary was evident from catches of small juveniles in the macrophyte beds in the estuary (Beckley 1983a). The first sampling session was after spring-tides, from 12h00 on 28 October 1980 through to 12h00 the following day (Session 1) and the second was after neap-tides from 12h00 on 8 October 1981 through to 12h00 the next day (Session 2).

A station was established in mid-channel in the mouth of the Swartkops estuary (Figure 1) by securing a mooring buoy to a heavy anchor. At 90-min intervals, measurements of surface and bottom (1 m above substratum) water temperature, salinity and current velocity were taken from a small boat secured to the mooring. A weighted water-sampling bottle, a thermometer accurate to 0.1°C, an AO refractometer accurate to 1‰ and a calibrated OGAWA SEIKI Model OSK861 current meter were used for these measurements. Data on tidal height were obtained from an Ott gauge installed at the Port Elizabeth harbour located 10 km south of the estuary.

Biological samples were also taken every 90 min. Surface

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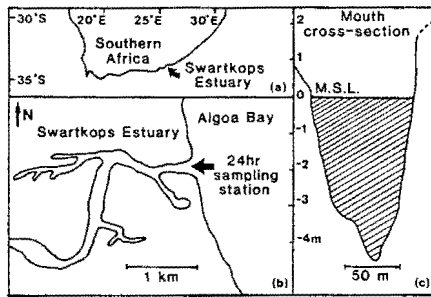


Figure 1 (a) Location of the Swartkops estuary; (b) sampling station locality; (c) cross-section of the mouth region (after Reddering & Esterhuysen 1980).

and bottom plankton samples were collected using two 57 cm diameter WP2 nets, each fitted with a calibrated KAHLSCO Model 005-WA130 flowmeter and 190 μm St Martins nylon mesh netting. The nets were connected to booms installed on either side of the bow of the boat, with one net positioned just below the water surface and the other held about 1 m above the substrate by means of a long steel rod. Plankton tows were carried out in midstream against the current and were restricted to about a minute in duration in order to prevent accumulation of suspended sand in the nets.

Seine-netting was also undertaken at 90-min intervals using a 15 m \times 2,5 m (2 mm stretched mesh) net. The net was laid from the boat parallel to the north bank and then hauled onto the shore. Efficiency of the seine-net was, however, extremely variable because of the strong tidal currents and catch per unit effort (CPUE) cannot be used with any confidence for quantitatively comparing exchange of juvenile fish over the tidal cycle.

All biological samples were preserved in 10% formalin. In the laboratory, the plankton samples were sorted using a dissecting microscope to separate fish eggs, larvae and juveniles from the rest of the plankton. The larvae and juveniles were identified (using Ranzi 1933; Smith 1965; Haigh 1972; van der Elst & Wallace 1976; Louw & O'Toole 1977; Akatsu, Ogasawara & Yasuda 1977; Melville-Smith 1978; Brownell 1979) and standard lengths measured to the nearest 0,1 mm. Fish in the seine-net catches were also identified and total lengths measured to the nearest 1 mm.

Terminology used follows that of Jones, Martin & Hardy (1978) with a yolk-sac larva being the stage between hatching and absorption of yolk, a larva being the stage between absorption of yolk and acquisition of the minimum adult fin ray complement and a juvenile being the stage between acquisition of the minimum adult fin ray complement and sexual maturity.

Results

Session 1

The October 1980 24-h sampling session coincided with post spring-tide conditions (five days after full moon) and darkness lasting about 10 h. During this sampling session, predicted times for low tide in Algoa Bay were 12h17 and 00h45 and high tide 18h39 and 07h07. Tidal height had a range of 1,1 m and tidal current velocity in the estuary mouth reached 1,2 m s^{-1} (Figure 2). Surface and bottom current velocities followed the same pattern, as did surface and bottom temperatures and salinities (Figure 2). Water temperature increased on the ebb-tide with the outflow of warm estuarine water and decreased on the flood-tide with the inflow of cooler sea water.

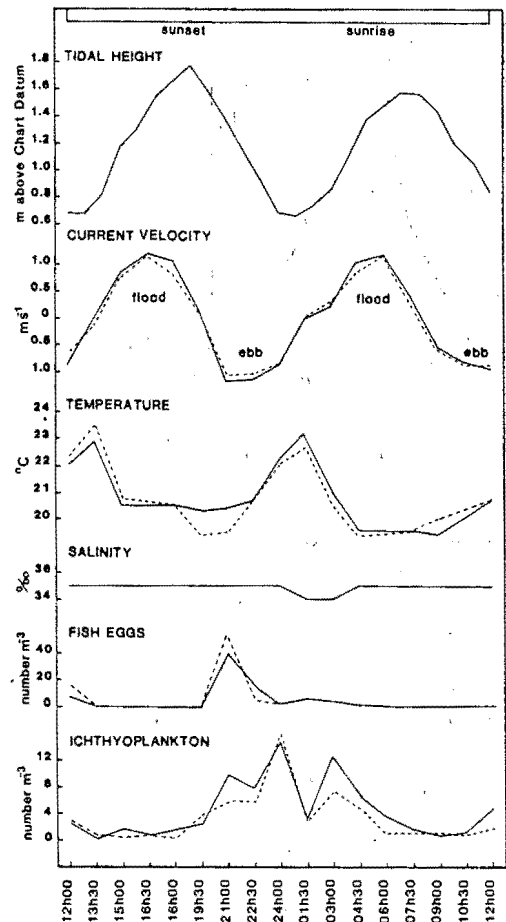


Figure 2 Physical and biological data from Session 1 (— surface, - - - bottom if it differs from the surface value).

The density of fish eggs in the plankton ranged from 0–53,8 eggs m^{-3} with a mean of 4,9 eggs m^{-3} (Figure 2). There was a marked efflux of small unidentified eggs (0,7–0,8 mm diameter with a single oil globule) from the estuary on the evening ebb-tide. The density of fish larvae and juveniles in the plankton tows ranged from 0,2–15,9 m^{-3} with a mean of 3,9 m^{-3} . Densities of fish larvae and juveniles in the surface and bottom samples followed the same pattern although they were slightly but significantly higher in the surface samples (Wilcoxon paired sample test $p < 0,05$).

The larvae and juveniles captured in the plankton tows comprised 17 species and some unidentified larvae (probably more than one species). *Caffrogobius multifasciatus* was the dominant species of larval fish and occurred in 91% of the samples. *Psammogobius knysnaensis* and *Parablennius cornutus* occurred in 76% and 74% of the samples, respectively. Numerically (based on density values), *Caffrogobius multifasciatus* constituted 53% of all larvae and juveniles captured in the plankton tows, *Parablennius cornutus* 9%, *Rhabdosargus holubi* 8%, *Sardinops ocellata* 8%, *Heteromycteris capensis* 5% and the rest collectively 17%.

Figure 3 gives the density m^{-3} of larvae and juveniles (surface and bottom samples averaged) for each species captured in Session 1. *Caffrogobius multifasciatus* larvae were particularly abundant during the evening ebb-tide and 99% of these larvae were 2–3 mm in length. *Rhabdosargus holubi* (10–13 mm), *Heteromycteris capensis* (7–10 mm) and to a lesser extent, *Spondylisoma emarginatum* (8–12 mm) showed an influx on the flood-tides whilst, surprisingly, there

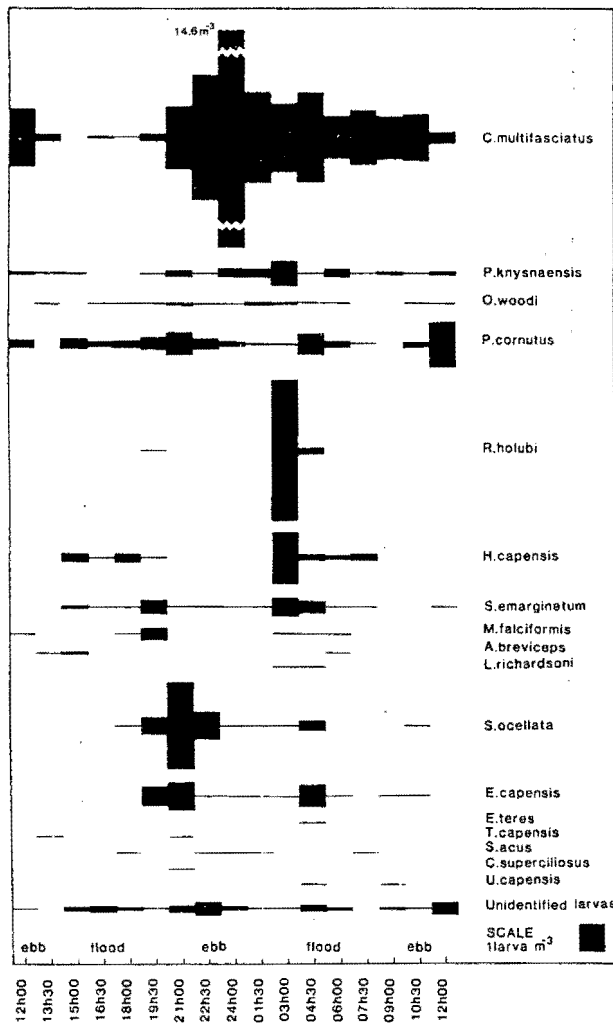


Figure 3 Density of fish larvae and juveniles in the plankton samples of Session 1 (surface and bottom samples averaged).

was an efflux of the pelagic species *Sardinops ocellata* (11–21 mm) and *Engraulis capensis* (7–21 mm) on the evening ebb-tide. Mean number of species per sample was significantly higher during the night ($\bar{x} = 8,8$) than during the day ($\bar{x} = 4,9$) (t test for independent sample means $p < 0,005$). Mean density of larvae and juveniles was also significantly higher at night ($\bar{x} = 7,4 \text{ m}^{-3}$) than during the day ($\bar{x} = 1,5 \text{ m}^{-3}$) (t test for independent sample means $p < 0,005$).

In the seine-net catches of Session 1, a total of 1 775 fish of 23 species was captured (Table 1). Juvenile sparids, specifically *Rhabdosargus holubi*, *Spondylisoma emarginatum* and *Diplodus sargus*, were captured most frequently and were present in 82%, 94% and 88% of the hauls respectively. Juvenile *Liza richardsoni*, *Sarpa salpa*, *Heteromycteris capensis*, *Parablennius cornutus* and the shoaling pelagic species *Etrumeus teres*, *Sardinops ocellata* and *Engraulis capensis* also occurred.

Session 2

The October 1981 24-h sampling session coincided with post neap-tide conditions (2 days after first quarter) and darkness lasting about 11 h. During the sampling session, predicted times for high tide in Algoa Bay were 12h00 and 00h15 and low tide 18h12 and 06h45. Tidal height had a range of 0,9 m and tidal current velocity in the estuary mouth reached $0,8 \text{ m s}^{-1}$ (Figure 4). Surface and bottom current velocity,

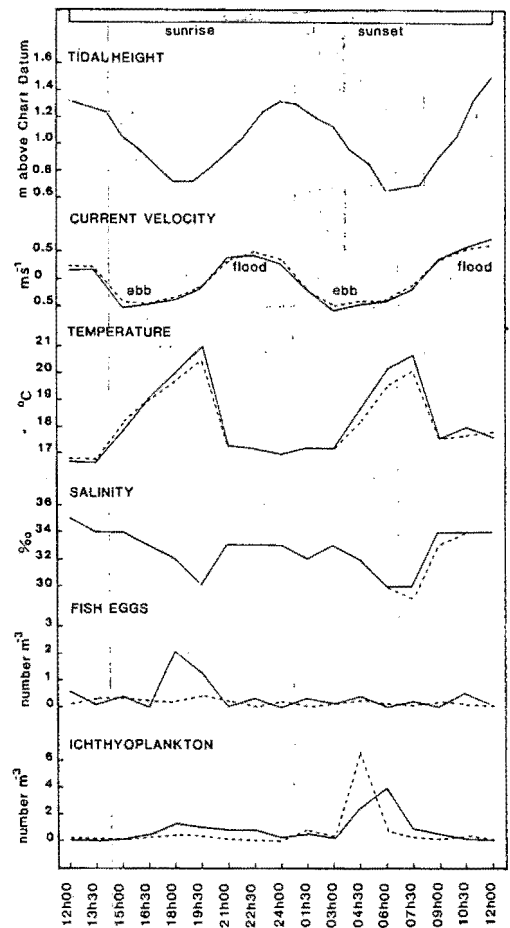


Figure 4 Physical and biological data from Session 2 (— surface, - - - bottom if it differs from the surface value).

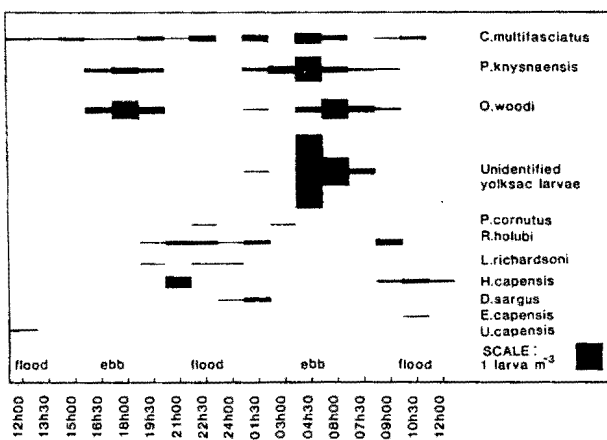
temperature and salinity measurements were all lower than those measured during Session 1. Temperature decreased on the flood-tide and salinity increased whilst on the ebb-tide temperatures increased and salinity decreased (Figure 4).

Egg density in the plankton tows was extremely low, ranging from 0–2,1 eggs m^{-3} with a mean of 0,3 eggs m^{-3} (Figure 4). There was an efflux of unidentified eggs at sunset on the ebb-tide. Larval and juvenile densities ranged from 0–6,6 m^{-3} with a mean of 0,7 m^{-3} (Figure 4). Densities of larvae and juveniles in the plankton tows in the surface and bottom water followed the same pattern and were not found to be significantly different (Wilcoxon paired sample test $p > 0,05$).

The larvae and juveniles in the plankton tows comprised 11 species, one of which remained unidentified as the larvae were still in the yolk-sac stage. In terms of frequency of occurrence, *Caffrogobius multifasciatus* larvae were found in 56% of all samples. Numerically (based on density values), the unidentified yolk-sac larvae (1–2 mm) constituted 37% of the total, *Omobranchus woodi* (2–4 mm) 20%, *Psammogobius knysnaensis* (2–3 mm) 17%, *Caffrogobius multifasciatus* (2–18 mm) 13% and the other seven species, collectively, 13%. Figure 5 shows *Psammogobius knysnaensis* and *Omobranchus woodi* to be abundant on the ebb-tide whilst *Rhabdosargus holubi* (9–12 mm), *Liza richardsoni* (12–14 mm), *Heteromycteris capensis* (7–8 mm) and *Diplodus sargus* (9–10 mm) were most abundant on the night flood-tide. Mean number of species per sample was significantly higher during the night ($\bar{x} = 2,8$) than during the day

Table 1 Abundance, frequency and size of fish captured by siene-netting during two 24-h sampling sessions in the mouth of the Swartkops estuary (^acommon names taken from Smith 1975)

Name	Common name ^a	October 1980			October 1981		
		Number	Frequency (%)	Length range (TL mm)	Number	Frequency (%)	Length range (TL mm)
<i>Rhabdosargus holubi</i>	Cape stumpnose	233	82	11-140	2826	82	10-16
<i>Liza richardsoni</i>	southern mullet	50	59	10-342	797	71	12-285
<i>Spondylisoma emarginatum</i>	steentjie	309	94	9-14	1	6	13
<i>Diplodus sargus</i>	blacktail	223	88	7-32	200	71	10-140
<i>Sarpa salpa</i>	strepie	53	29	15-60	230	47	18-52
<i>Heteromycteris capensis</i>	Cape sole	40	35	7-55	403	71	8-50
<i>Etrumeus teres</i>	redeye round-herring	352	35	22-44	151	12	17-34
<i>Engraulis capensis</i>	Cape anchovy	139	53	9-34	34	12	16-30
<i>Sardinops ocellata</i>	South African pilchard	194	65	14-31	-	-	-
<i>Atherina breviceps</i>	Cape silverside	44	29	51-83	77	65	42-89
<i>Gilchristella aestuarii</i>	estuarine round-herring	45	12	37-66	1	6	56
<i>Psammogobius knysnaensis</i>	Knysna sandgoby	15	53	7-52	20	65	7-59
<i>Caffrogobius multifasciatus</i>	prison goby	1	6	41	22	29	11-25
<i>Parablennius cornutus</i>	horned blenny	71	59	4-23	1	6	19
<i>Trachurus capensis</i>	maasbanker	5	18	11-25	1	6	15
<i>Syngnathus acus</i>	longnose pipefish	2	12	57	2	6	59-74
<i>Monodactylus falciformis</i>	Cape moony	2	12	6	12	29	7-10
<i>Lithognathus mormyrus</i>	sand steenbras	1	6	76	-	-	-
<i>Clinus superciliosus</i>	super klipfish	1	6	24	25	29	16-27
<i>Rhabdosargus globiceps</i>	white stumpnose	1	6	21	-	-	-
<i>Lithognathus lithognathus</i>	white steenbras	1	6	19	3	12	11-14
<i>Argyrosomus hololepidotus</i>	kob	1	6	7	-	-	-
<i>Diplodus cervinus</i>	zebra	1	6	7	-	-	-
<i>Amblyrhynchotes honckenii</i>	evileyed blaasop	-	-	-	4	18	50-76
<i>Mugil cephalus</i>	flathead mullet	-	-	-	2	6	27-28
<i>Chorisochismus dentex</i>	rocksucker	-	-	-	1	6	10
<i>Pomadasys olivaceum</i>	piggy	-	-	-	10	29	12-49
<i>Valamugil buehanani</i>	bluetail mullet	-	-	-	2	12	20-21
<i>Pomatomus saltatrix</i>	elf	-	-	-	1	6	201
<i>Myxus capensis</i>	freshwater mullet	-	-	-	1	6	41
<i>Liza dumerili</i>	groovy mullet	-	-	-	5	18	202-260
<i>Coracinus multifasciatus</i>	banded gaijoen	-	-	-	1	6	20
<i>Elops machnata</i>	tenpounder	-	-	-	1	6	39
<i>Chaetodon marleyi</i>	double butterflyfish	-	-	-	1	6	21
<i>Myliobatis aquila</i>	eagleray	-	-	-	1	6	400

**Figure 5** Density of fish larvae and juveniles in the plankton samples of Session 2 (surface and bottom samples averaged).

($\bar{x} = 1,9$) (t test for independent sample means $p < 0,05$) but mean densities at night ($\bar{x} = 1,0 \text{ m}^{-3}$) were not significantly higher than during the day ($\bar{x} = 0,5 \text{ m}^{-3}$) (t -test for indepen-

dent samples means $p > 0,05$). In the seine-net catches, a total of 4 848 fish of 30 species was captured (Table 1). *Rhabdosargus holubi* occurred in 82% of the hauls, *Liza richardsoni*, *Heteromycteris capensis* and *Diplodus sargus* each in 70% and *Sarpa salpa* in 47%. Juveniles of the pelagic species *Engraulis capensis* and *Etrumeus teres* were also captured.

Discussion

Fish occurring in South African estuaries have been divided into categories by Wallace, Kok, Beckley, Bennett, Blaber & Whitfield (1984) on the basis of the extent to which their juveniles are dependent on estuaries. In the present context, these categories can be condensed into three groups, namely resident estuarine species, marine species utilizing estuaries as nursery areas and incidental marine species. The influx and efflux of larvae and juveniles of these groups to and from estuaries are likely to differ as follows:

- (i) Resident estuarine species spawn in the estuary and their larvae should occur regularly in the plankton but may be lost from the estuary on the ebb-tide as estuarine water flows seaward;

- (ii) In the case of marine species spawning at sea but utilizing the estuary as a nursery area, larvae and juveniles should enter on the flood-tide;
- (iii) Incidental marine species are likely to have an irregular influx and efflux of larvae.

Examination of the tidal distribution of ichthyoplankton in the mouth of the Swartkops estuary during the sampling sessions, reveals that three such patterns can be distinguished.

Species falling into the first group include *Caffrogobius multifasciatus*, *Psammogobius knysnaensis* (Gobiidae) and *Omobranchus woodi* (Blenniidae), all small species with demersal eggs (Gilchrist & Hunter 1919; Breder & Rosen 1966) which are known to spawn in the Swartkops estuary (Melville-Smith & Baird 1980). Larvae of these species, together with those of *Gilchristella aestuarius* from the upper reaches, dominate the ichthyoplankton of the Swartkops estuary (Melville-Smith & Baird 1980). The larvae of *Caffrogobius multifasciatus*, *Psammogobius knysnaensis* and *Omobranchus woodi* captured in the plankton tows during the present study, were all very small (95% < 5 mm) and occurred frequently in the samples. Larvae of *Caffrogobius multifasciatus* were particularly abundant during Session 1 with a large efflux on the ebb-tide. Although reduced, their density was also relatively high on the early morning flood-tide, probably as a result of transport back into the estuary of some of these larvae. *Psammogobius knysnaensis* and *Omobranchus woodi* showed marked effluxes of larvae on the ebb-tide in Session 2.

Melville-Smith, Baird & Wooldridge (1981), when investigating tidal movements of larvae of the estuarine species *Gilchristella aestuarius* in the middle reaches of the Sundays estuary, also found that densities increased on the ebb-tide and decreased on the flood-tide. In the middle reaches of the Sundays estuary, current velocity was stratified and *Gilchristella aestuarius* larvae and some estuarine copepods (Wooldridge & Erasmus 1980) were found to concentrate in the slower-moving bottom water to prevent themselves from being carried seawards. However, in the mouth of the Swartkops estuary, current velocities are not significantly different between surface and bottom (1 m above substratum) waters (paired sample *t* test $p > 0,05$) and such a mechanism for avoiding being swept out to sea on the ebb-tide would be to no avail.

In the second group of fish, flood-tide immigration of larval and juvenile *Rhabdosargus holubi*, *Heteromycteris capensis*, *Spondyliosoma emarginatum* and in lower densities *Liza richardsoni*, *Monodactylus falciformis*, *Diplodus sargus* and *Atherina breviceps* was significantly greater than the ebb-tide efflux (Spearman's rank correlation $p < 0,05$). All these marine species occur as juveniles in the Swartkops estuary (Winter 1979; Beckley 1983a) although the extent to which they depend on the estuary as a nursery area differs (Wallace *et al.* 1984). The sparids, mullet and soles had definitive fin elements and their size (7–14 mm) corresponds with that of one- to two-month-old specimens reared at 15°C by Brownell (1979).

The seine-net catches, which were concentrated on the bank near the mouth, also contained similar sized juvenile sparids, mullet and soles during flood-tides. Despite the absence of these juveniles from plankton samples during the ebb-tides, they were captured in more than 70% of ebb-tide seine-net samples. There is thus a possibility that juveniles migrate to the banks during the ebb-tide to avoid being swept back to sea. Wooldridge & Erasmus (1980) found that two mysid spe-

cies maintained position in the estuary in this way and Emerson (1983) suggested that zoea 6 *Palaemon pacificus* also use this mechanism whilst immigrating into the Swartkops estuary. Quantitative cross-channel measurements of current velocities and juvenile fish densities would, however, be necessary to confirm that juvenile marine fish use this mechanism as well.

The larvae of several marine species which occur incidentally in estuaries were also captured. *Sardinops ocellata*, *Engraulis capensis* and *Etrumeus teres* are pelagic shoaling species and the occurrence of their larvae in the ichthyoplankton and seine-net catches in the mouth of the Swartkops estuary was unexpected. Larvae and juveniles of these species are, however, abundant in the inshore ichthyoplankton of Algoa Bay and collectively comprised 47% of the total catch in a two-year survey (Beckley 1983b). Their presence in the estuary, particularly the night ebb-tide in Session 1, may possibly be accounted for by them having been swept into the estuary on the preceding spring flood-tide and becoming temporarily trapped in a plug of tidal water. The presence of *Trachurus capensis* and *Umbrina capensis* is also regarded as incidental.

Clinus superciliosus, *Syngnathus acus* and *Parablennius cornutus* do not fit easily into any of the three groupings outlined above. *Clinus superciliosus* and *Syngnathus acus* are complicated cases as these species exhibit reproductive specializations (viviparity and possession of a male brood pouch, respectively) and breed in both estuaries and the sea (Day, Blaber & Wallace 1981). *Parablennius cornutus* is unknown from the Swartkops estuary, except for three larval specimens (Melville-Smith 1978). However, there has not been an investigation of the cryptic fish occupying the rocky areas of the north bank near the mouth, where this blenny could occur. On the other hand, larvae of this species are also abundant in the inshore plankton (Beckley 1983b) and the larvae in the mouth of the estuary during Session 1 could thus also be due to an influx on the spring-tide, similar to that suggested for clupeid and engraulid larvae.

Finally, the movement of fish larvae and juveniles in the mouth of the Swartkops estuary is concluded to be largely by passive drift, though active swimming may be utilized by some marine migrants. The larvae of the estuarine resident species, because of their small size and absence of fin elements, appear to be entirely at the mercy of tidal currents and many are lost from the estuary on the ebb-tide. Conversely, marine species are swept into the estuary on the flood-tide and it is suggested that these juveniles, because of their larger size and definitive fin elements, can actively prevent themselves from being flushed back out to sea by migrating to the banks to avoid the mainstream ebb current.

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The ichthyofauna associated with *Zostera capensis* Setchell in the Swartkops estuary, South Africa

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The ichthyofauna associated with *Zostera* beds in the lower reaches of the Swartkops estuary was examined by means of haul seine netting over 15 months. Thirty-nine fish species were caught in the *Zostera* beds and the small shoaling species, *Hepsetia breviceps* and *Gilchristella aestuarius*, constituted 55% of the total catch in terms of numbers. Juveniles of six mullet species occurred in the *Zostera* and recruitment took place throughout the year. Sparids such as *Rhabdosargus holubi* and *Diplodus sargus* showed marked spring and summer recruitment. The recruitment patterns of juveniles to the *Zostera* beds is correlated with documented breeding cycles of adults, particularly those breeding in the shallow inshore marine environment. The Swartkops *Zostera* beds were found to form an integral and important part of the nursery function of the estuary.

S. Afr. J. Zool. 1983, 18: 15–24

Die visgemeenskap in die *Zostera*-beddens van die Swartkops-riviermond is deur middel van treknetvangste oor 15 maande bestudeer. Nege-en-dertig spesies is gevang en 55% van die aantal vis wat gevang is, het uit die twee spesies *Hepsetia breviceps* en *Gilchristella aestuarius* bestaan. Kleintjies van ses Mugilidae-spesies het in die *Zostera* voorgekom en rekrutering het gedurende die hele jaar plaasgevind. Sparidae soos *Rhabdosargus holubi* en *Diplodus sargus* het rekrutering gedurende lente en somer vertoon. Die rekruteringspatroon van klein vissies tot die *Zostera*-beddens is gekorreleer met gedokumenteerde teelsiklusse van volwasse, in besonder, die spesies wat in die vlak kuswaters voortplant. Die studie het bewys dat die Swartkops *Zostera*-beddens 'n integrale en belangrike deel van die kweekfunksie van die getyrvier uitmaak.

S.-Afr. Tydskr. Dierk. 1983, 18: 15–24

Studies on the ichthyofauna of the Swartkops estuary near Port Elizabeth (33°58'S/25°37'E) have recently been undertaken to follow up the pioneer surveys by Gilchrist (1918). Work by Winter (1979), Marais & Baird (1980a, b) and Melville-Smith & Baird (1980) has provided information on the species composition, seasonal abundance and size frequency distribution of the adult, juvenile and larval fish occurring in the main channel of the estuary.

Two relatively large creeks, Modderspruit and Tippers Creek, are located in the lower reaches of the 16-km long Swartkops estuary (Figure 1). The creeks support about 9 ha (B. Talbot, pers. comm.) of the seagrass *Zostera capensis*. The importance of seagrasses such as *Zostera*, *Posidonia* and *Thalassia* as nursery areas for juvenile fish is well documented (Adams 1976; Weinstein & Heck 1979; Young 1981) and is emphasized by Kikuchi (1980) in his review of faunal relationships in temperate seagrass beds.

The present study was aimed at determining the significance of *Zostera* beds in the Swartkops estuary as nursery areas for juvenile fish and thereby supplementing the results of earlier workers who did not effectively sample the vegetated creeks of the lower reaches. The study forms part of a comparative programme on juvenile marine fish in estuaries and the nearshore coastal region. Concurrent with the present study were investigations of the invertebrates associated with *Zostera* beds in the Swartkops estuary (Nusch 1981; Emmerson, Watling & Watling 1982) and the Kromme estuary (Hanekom 1982).

Methods

Fish were collected monthly from January 1980 through March 1981 by means of a small haul-seine net (10,5 m × 2,5 m) with a stretched mesh size of 2 mm. At low tide a haul covering about 60 m² was made through the *Zostera* at each of two stations in Tippers Creek and at one station in Modderspruit (Figure 1). A further haul was made in an area with no subtidal *Zostera* along the bank of the main channel of the estuary between the two creeks. Surface-water temperature and salinity were measured in the creeks on each sampling occasion.

Catches were kept frozen until sorted, identified and counted, and total lengths of specimens measured in mm. As the small shoaling species *Hepsetia breviceps* (Cuvier) and *Gilchristella aestuarius* (Gilchrist) were the subject of

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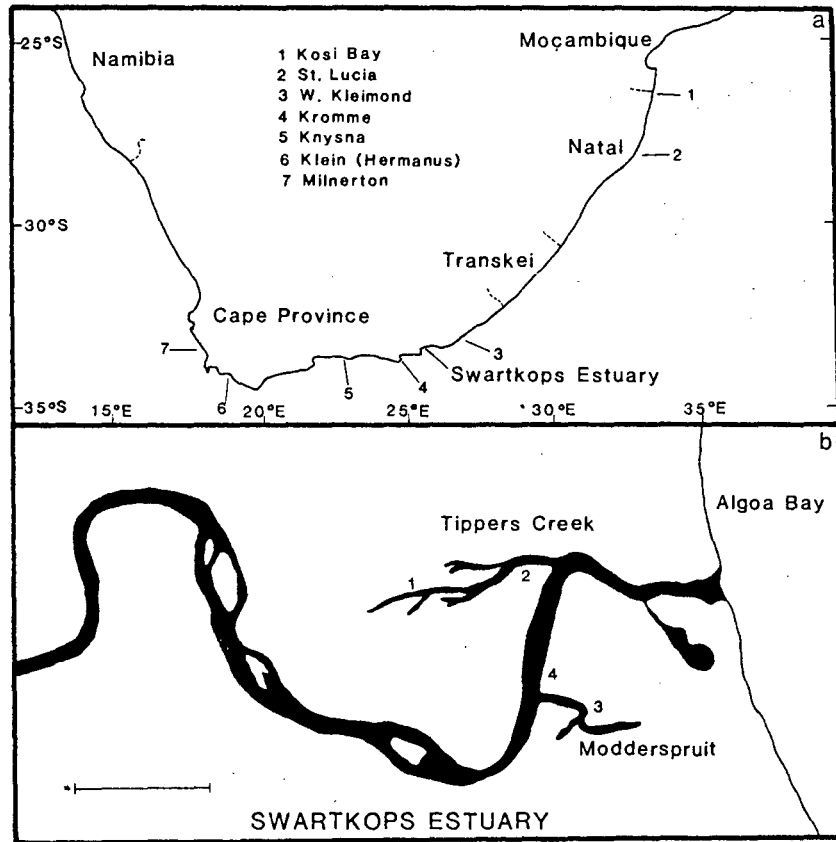


Figure 1 (a) Map of Southern Africa showing the geographical position of the Swartkops estuary and other areas mentioned in the text. (b) The middle and lower reaches of the Swartkops estuary showing the sampling stations in the creeks (1-3) and channel (4).

a separate study by Talbot (1982) only a subsample of 100 specimens of these two species was measured from each station each month. Juvenile mullet were identified from dentition characteristics (van der Elst & Wallace 1976) but as it often proved difficult to identify mullet of less than 30 mm with confidence all mullet of this size class were grouped together.

Results

Modderspruit and Tippers Creek in the lower reaches of the Swartkops estuary experience semidiurnal tides with a mean spring range of 1,6 m (Beckley & McLachlan 1979) and a time lag of about 1 h after predicted times for Algoa Bay. Salinity varies from 30-35‰ except after heavy rains. As the creeks are shallow (< 2 m depth) water temperature is variable and often differs considerably from that of the main channel of the estuary and the adjacent sea (Figure 2).

Haul seining proved to be an effective sampling technique for juvenile fish as during the 15-month study period, 62 020 fish were caught at the three *Zostera* stations and 4 371 at the channel station. Mean catch per haul was 1 328 (SE ± 296) fish for the *Zostera* stations and only 291 (SE ± 43) fish at the channel station. Total combined catch per month for the three *Zostera* stations varied greatly, ranging from 481 to 11 437 fish depending largely on the catch of the small shoaling species *H. breviceps* (Figure 3).

Thirty-nine species were recorded from the creek stations and 30 species from the channel station (Table 1). Four species recorded in the channel area were not captured in

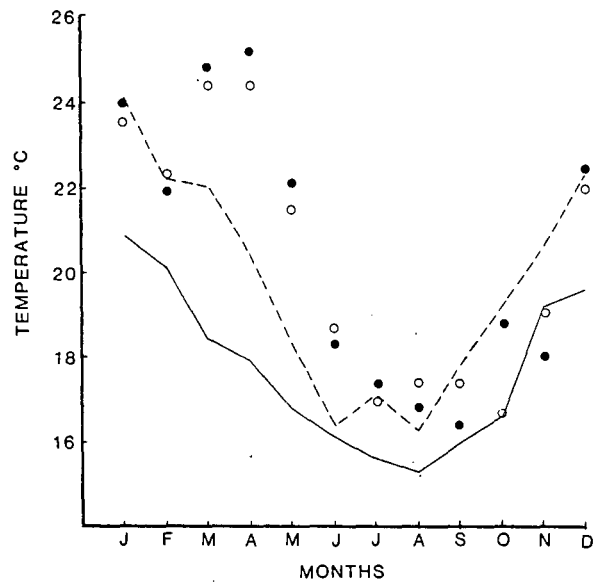


Figure 2 Water temperatures measured in Modderspruit (●) and Tippers Creek (○) during the study period compared with mean monthly water temperature for the lower reaches of the estuary (..... after Marais & Baird 1980b) and Algoa Bay (— after Beckley & McLachlan 1979).

the *Zostera*, giving a total of 43 species caught during the study period. The number of species captured in the *Zostera* each month varied between 12 and 28 with more species being caught in the summer months (Figure 3).

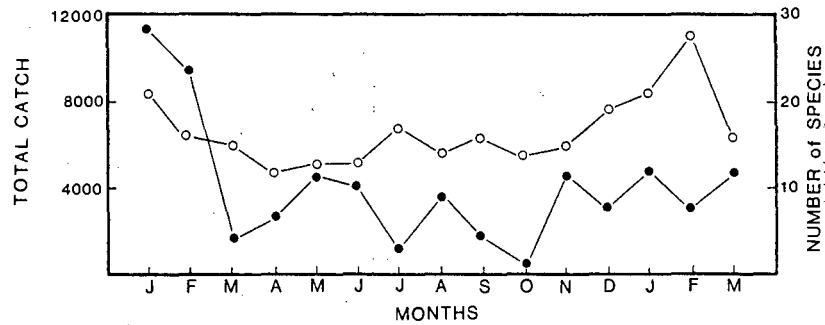


Figure 3 Total monthly catch by seine netting at the three Swartkops creek *Zostera* stations (●—●) and total number of species captured in the *Zostera* each month (○—○).

Table 1 List of fish species captured by haul seine netting during 1980/81 in the lower reaches of the Swartkops estuary. Lengths given in mm, Z indicates occurrence in *Zostera* beds and C indicates occurrence at the channel station.

Species	Length range	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
<i>Ambassis natalensis</i> Gilchrist & Thompson	17				Z											
	22								C							
<i>Amblyrhynchotes honckenii</i> (Bloch)	21-32	Z												Z	Z	
	23-77			C										C	C	
<i>Arothron hispidus</i> (Lacépède)	34-54							Z							Z	
<i>Arothron immaculatus</i> (Bloch-Schneider)	15-25	Z														
<i>Caffrogobius multifasciatus</i> (Smith)	12-102	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
	13-61	C	C	C	C	C		C	C	C	C	C	C	C	C	C
<i>Clinus superciliosus</i> (Linnaeus)	26-81	Z								Z		Z	Z			
	38-98											C	C		C	
<i>Diplodus cervinus</i> (Valenciennes)	9-80	Z	Z							Z	Z	Z	Z	Z	Z	Z
	9-41											C	C	C	C	
<i>Diplodus sargus</i> Linnaeus	10-134	Z	Z		Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
	10-93				C	C				C		C	C	C	C	C
<i>Engraulis capensis</i> Gilchrist	36		C													
<i>Epinephelus guaza</i> (Linnaeus)	57														Z	
<i>Etrumeus teres</i> (Dekay)	31-36											C				
<i>Gilchristella aestuarius</i> (Gilchrist)	17-50	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
	27-52	C	C			C		C		C	C			C	C	
<i>Hepsetia breviceps</i> (Cuvier)	12-68	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
	12-75	C	C		C	C		C	C	C	C			C	C	C
<i>Heteromycteris capensis</i> Kaup	7-44	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
	8-56	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
<i>Lichia amia</i> (Linnaeus)	46-98	Z												Z		
<i>Lithognathus mormyrus</i> (Linnaeus)	68											C				
<i>Liza dumerili</i> (Steindachner)	13-221		Z	Z	Z	Z	Z	Z	Z	Z	Z		Z	Z	Z	Z
	11-237				C	C	C		C		C		C			C
<i>Liza richardsoni</i> (Smith)	11-160		Z	Z	Z	Z		Z	Z		Z	Z	Z	Z	Z	Z
	28-180							C						C		C
<i>Liza tricuspidens</i> (Smith)	17-116	Z	Z	Z	Z		Z	Z	Z		Z		Z	Z	Z	Z
	29-126	C	C			C							C	C	C	C
<i>Lophodiodon calori</i> (Bianconi)	11													Z		
<i>Lutjanus fulviflamma</i> (Forsskål)	17-21														Z	Z
<i>Monodactylus falciformes</i> (Lacépède)	7-28	Z											Z	Z	Z	
	11-17	C														
<i>Mugil cephalus</i> Linnaeus	7-153	Z	Z	Z	Z	Z	Z	Z	Z	Z			Z	Z	Z	
	8-172	C	C	C	C	C	C	C	C	C						
<i>Myxus capensis</i> (Valenciennes)	24-29			Z											Z	
<i>Omobranchus woodi</i> (Gilchrist & Thompson)	19-20	Z												Z		
	18-19													C	C	
<i>Pelates quadrilineatus</i> (Bloch)	22													Z		

Table 1 (continued)

Species	Length range	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
<i>Platycephalus indicus</i> (Linnaeus)	224-300 206			Z							C	Z				
<i>Pomadasys commersonni</i> (Lacépède)	36-323 15-17			Z												Z
<i>Pomadasys olivaceum</i> Day	21-96 30-58	Z	Z			Z			Z					Z	Z	Z
<i>Psammogobius knysnaensis</i> Smith	8-47 10-53	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
<i>Pseudupeneus pleurotaenia</i> (Playfair)	45															Z
<i>Rhabdosargus globiceps</i> (Cuvier)	12-68 10-56	Z	Z									Z	Z	Z		
<i>Rhabdosargus holubi</i> (Steindachner)	10-200 10-173	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
<i>Sarpa salpa</i> (Linnaeus)	13-80				C	C			C	C		C	C	C	C	C
<i>Solea bleekeri</i> Boulenger	11-80 21-73	Z	Z	Z		Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
<i>Sparodon durbanensis</i> (Castelnau)	18				C	C			C	C		C	C			Z
<i>Spondylisoma emarginatum</i> (Cuvier)	10-71 11-35	Z	Z								Z	Z	Z	Z	Z	Z
<i>Stephanolepis auratus</i> (Castelnau)	21-97 38															Z
<i>Stolephorus commersonii</i> (Lacépède)	39 18-55					Z										C
<i>Stolephorus holodon</i> (Boulenger)	39															C
<i>Syngnathus acus</i> Linnaeus	53-224 52-177	Z	Z	Z		Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
<i>Trachurus capensis</i> Castelnau	37															Z
<i>Valamugil buchanani</i> (Bleeker)	17-20							Z		Z						

Figure 4 illustrates by means of a pie diagram the composition of the fish community caught in the *Zostera* beds over the sampling period. *H. breviceps* dominated the catches and constituted 46,1% of the total catch.

The size range of *H. breviceps* was 12-68 mm with the smaller size classes particularly abundant in the late summer months. *G. aestuarius*, another small shoaling species,

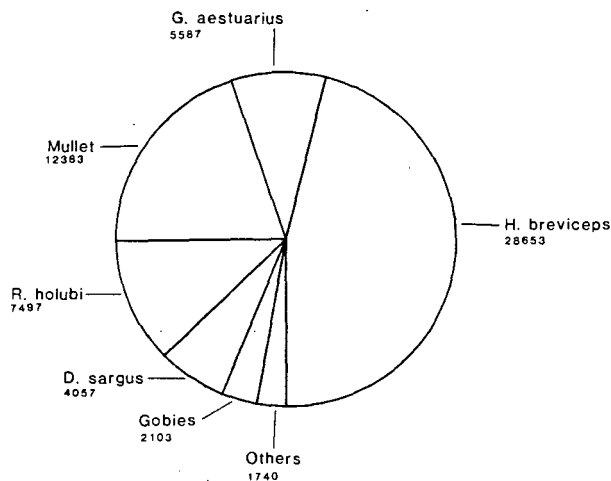


Figure 4 Pie diagram of fish catch composition in the Swartkops creek *Zostera* beds.

constituted 9,0% of the catch and ranged in size from 17-50 mm.

Six species of mullet were recorded from the *Zostera* areas. Of these, *Myxus capensis* Valenciennes and *Valamugil buchanani* (Bleeker) were only recorded on two occasions in very low numbers (totals of five and two specimens respectively). About half the mullet captured (Figure 5) were unidentified specimens < 30 mm whilst those > 30 mm were identified as *Mugil cephalus* Linnaeus, *Liza dumerili*

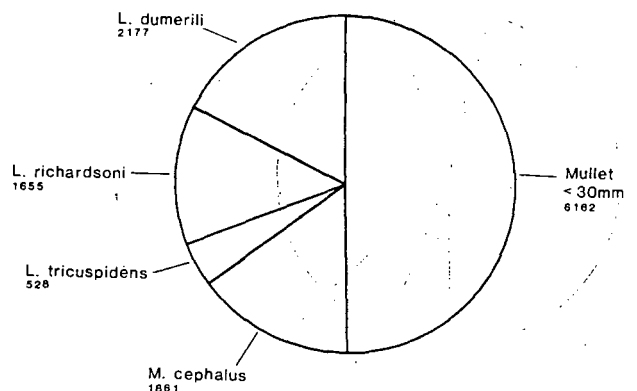


Figure 5 Composition of total mullet catch in the Swartkops creek *Zostera* beds.

(Steindachner), *Liza richardsoni* (Smith) and *Liza tricuspidens* (Smith). The predominance of small mullet is clearly illustrated in the size frequency histogram for total catch of mullet in the *Zostera* (Figure 6); the peaks in abundance of small mullet occurring in June and November 1980 (Figure 7).

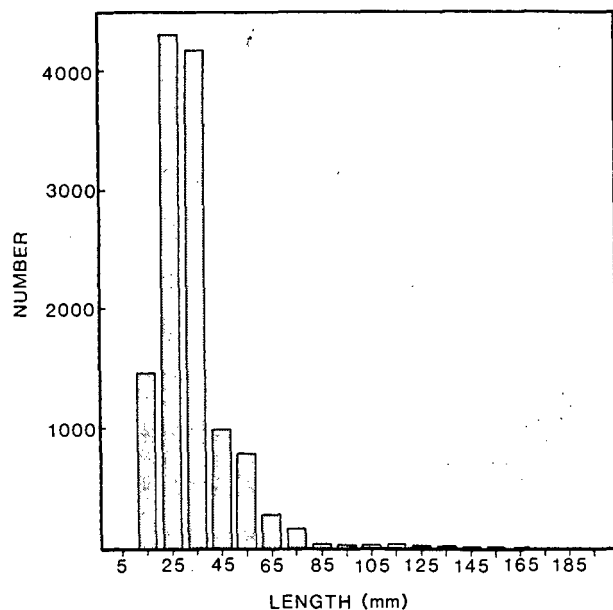


Figure 6 Size frequency histogram for total mullet catch in the Swartkops creek *Zostera* beds ($n = 12383$).

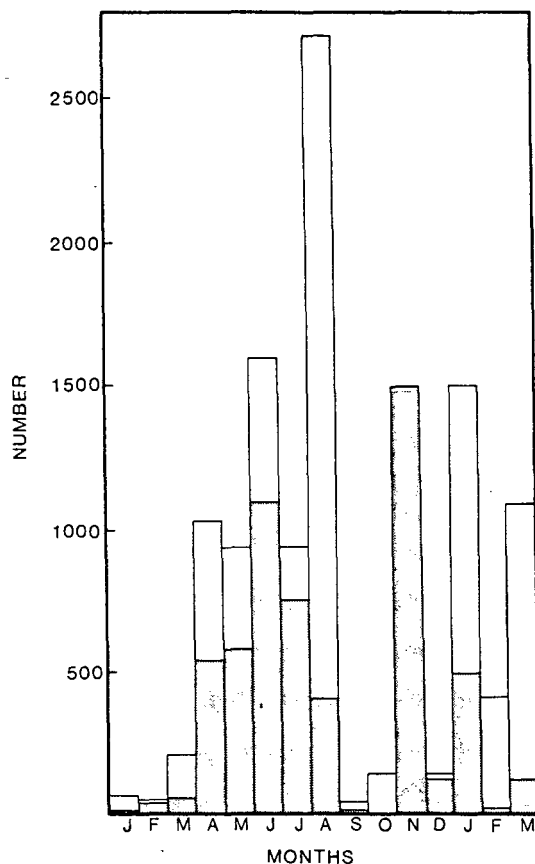


Figure 7 Monthly mullet catches in the Swartkops creek *Zostera* beds. Shaded sections indicate mullet of < 30 mm total length ($n = 12383$).

Rhabdosargus holubi (Steindachner) constituted 12% of the total catch in the creek *Zostera* beds with small juveniles dominating the catch. Figure 8 shows monthly size frequency histograms and a marked spring and summer influx of juveniles is clear. Similarly, *Diplodus sargus* (Valenciennes) which constituted 6,5% of the *Zostera* bed catch, showed a distinct spring and summer influx of juveniles (Figure 9).

Of the two species of Gobiidae (3,3% of the *Zostera* catch), *Caffrogobius multifasciatus* (Smith) was usually more abundant than *Psammogobius knysnaensis* (Smith). Figure 10 shows combined size frequency histograms for the two species over the study period. Recruitment of juvenile gobies occurred throughout the year with a definite peak for *P. knysnaensis* between March and May.

The remaining 2,8% of the catch in the creek *Zostera* consisted of 27 species. Twenty of these species occurred in very low numbers with total catch per species being less than 25 specimens during the study period. The remaining seven species consisted of *Pomadasys olivaceum* Day, three sparids, two soles and a pipefish.

P. olivaceum and the three sparids, *Spondyliosoma emarginatum* (Cuvier), *Rhabdosargus globiceps* (Cuvier) and *Diplodus cervinus* (Valenciennes) showed the same marked spring and summer recruitment pattern as *R. holubi* and *D. sargus*. The two small soles *Heteromycteris capensis* Kaup and *Solea bleekeri* Boulenger occurred throughout the year in the creeks as did the pipefish *Syngnathus acus* Linnaeus. Adult male pipefish carrying larvae were found intermittently throughout the year.

Discussion

The results illustrate that the creek *Zostera* beds in the lower reaches of the Swartkops estuary provide an important habitat for juvenile fish. These findings support the statement by Wallace & van der Elst (1975) that the nursery function of estuaries is most important during the first year of life and is intimately related to aquatic plant communities.

A crude estimate of total standing stock of fish in the creek *Zostera* of the lower reaches of the Swartkops estuary can be obtained by extrapolation of the mean catch per seine-net haul. This yields a total of two million fishes for the 9 ha of creek *Zostera* and amounts to 22 fish m^{-2} as opposed to only 5 fish m^{-2} for the channel station.

Ten species of fish caught during the study period may be described as tropical strays and the capture of *Ambassis natalensis* Gilchrist & Thompson, *Arothron hispidus* (Lacépède), *Lutjanus fulviflamma* (Forskål) and *Pelates quadrilineatus* (Bloch) in the Swartkops creek *Zostera* extends the southern distribution limit for these species (Smith 1965; Day, Blaber & Wallace 1981; van der Elst 1981). Local species not usually associated with estuaries but caught during the present sampling included the rocky shore residents, *Epinephalus guaza* (Linnaeus) and *Sparodon durbanensis* (Castelnau) and the pelagic species *Trachurus capensis* (Castelnau), *Engraulis capensis* Gilchrist and *Etrumeus teres* (Dekay).

Noticeably absent from the *Zostera* areas were juveniles of the kob, *Argyrosomus hololepidotus* (Lacépède) and the white steenbras, *Lithognathus lithognathus* (Cuvier) which are popular angling species in the estuary (Marais & Baird

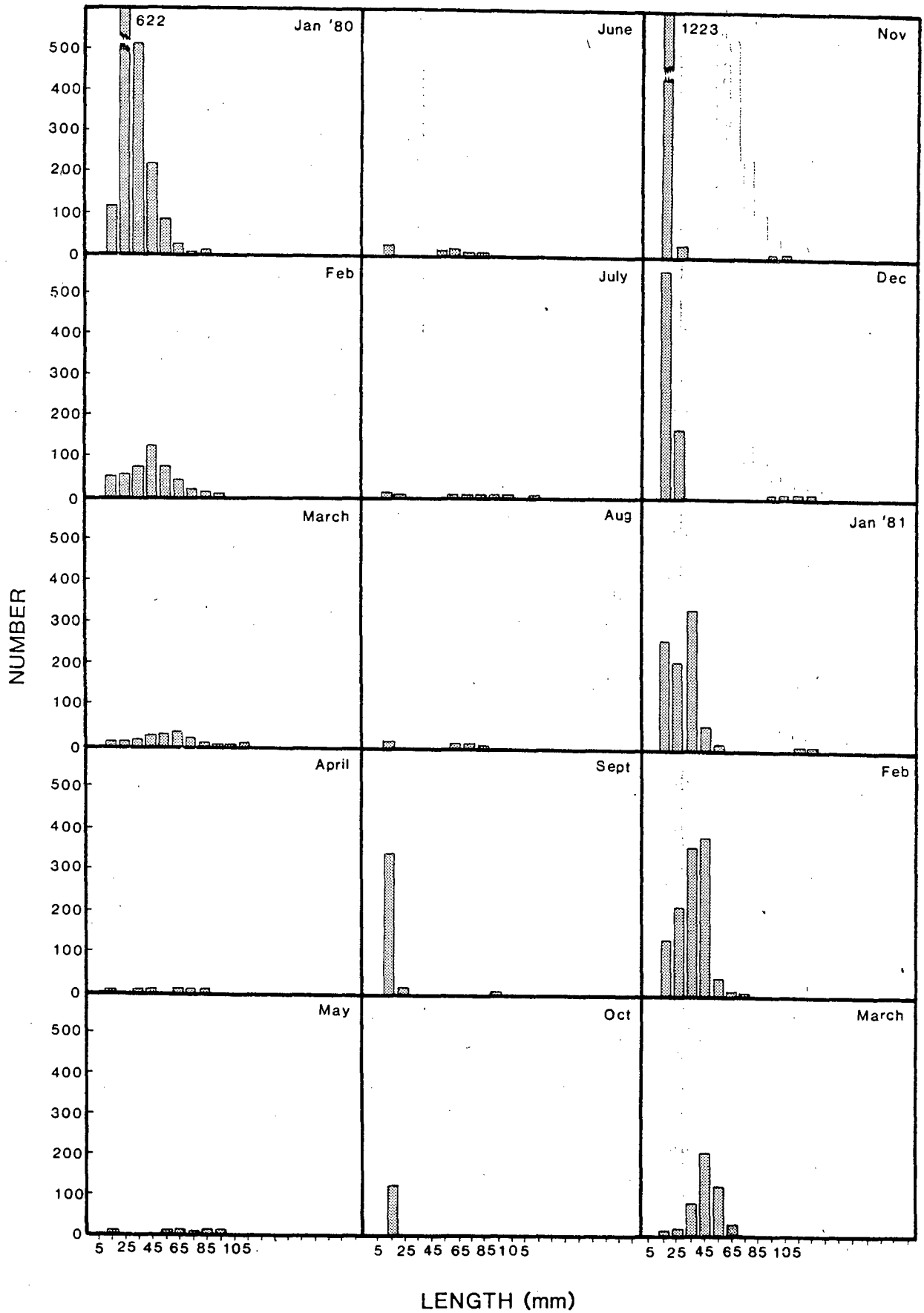


Figure 8 Monthly size frequency histograms for *Rhabdosargus holubi* in the Swartkops creek *Zostera* beds ($n = 7497$).

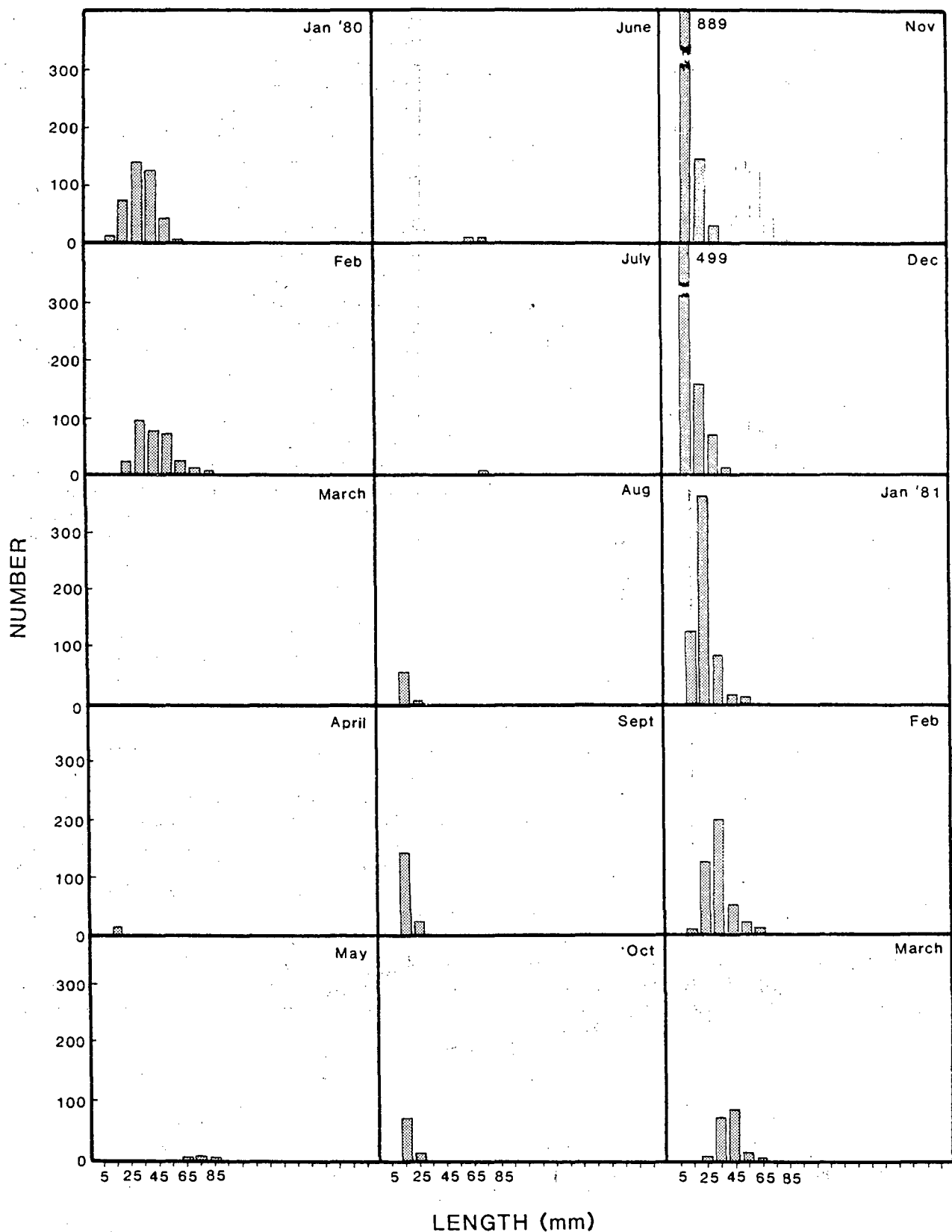


Figure 9 Monthly size frequency histograms for *Diplodus sargus* in the Swartkops creek *Zostera* beds ($n = 4057$).

1980a). Melville-Smith & Baird (1980) have recorded *A. hololepidotus* larvae ranging in length from 2–16 mm in the Swartkops ichthyoplankton, and whilst Winter (1979) did catch juveniles of 120–280 mm (standard length),

Wallace & van der Elst (1975) report that this species prefers deeper parts of estuaries. Winter (1979) has also recorded *L. lithognathus* of 20–200 mm (standard length) from the main channel of the Swartkops estuary.

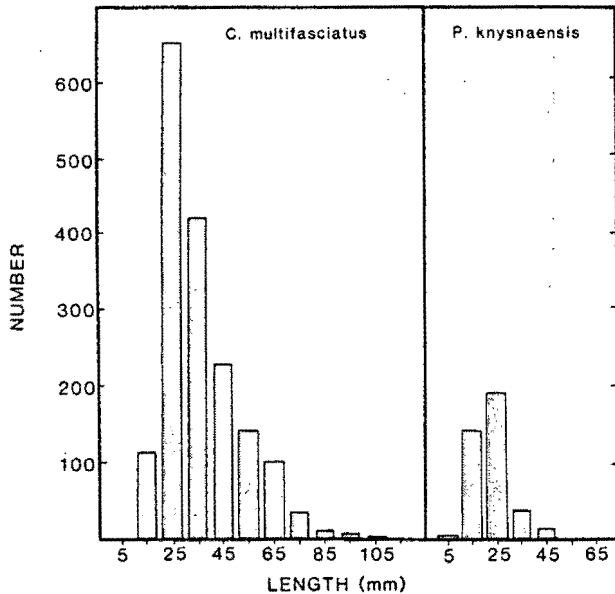


Figure 10 Size frequency histograms for the total catch of the two gobies *Caffrogobius multifasciatus* and *Psammogobius knysnaensis* in the Swartkops creek *Zostera* beds ($n = 2103$).

During the present study few juveniles of another two popular estuarine angling fish, the leervis, *Lichia amia* (Linnaeus) and the spotted grunter *Pomadasys commersonni* (Lacépède) were caught in the creek *Zostera* although Wallace & van der Elst (1975) have reported large numbers of the latter in St. Lucia *Zostera* beds. In total, only three juvenile *L. amia* (46, 56 and 98 mm), two juvenile *P. commersonni* (36 and 46 mm) and two larger *P. commersonni* (310 and 323 mm) were captured. Winter (1979) recorded *L. amia* juveniles from 45 mm (standard length) in the estuary and distinguished two size groups of *P. commersonni*. The two groups consisted of juveniles of 50–170 mm (standard length) and adults of over 300 mm (standard length).

Hepsetia breviceps is abundant in bays and estuaries along the Cape coast where it is preyed upon by birds and larger fish (Day *et al.* 1981). The numerical abundance of this species is clearly illustrated by the present study as well as those of Els (1979) and Winter (1979). Lasiak (1982) reported that at Kings Beach, a sheltered sandy beach in Algoa Bay about 15 km south of the Swartkops estuary mouth, *H. breviceps* constituted 49,5% of surf-zone catches with a seine net of the same dimensions and mesh size as that used by Winter (1979). Although *H. breviceps* is recorded breeding in estuaries in summer (Day *et al.* 1981), Melville-Smith & Baird (1980) do not include it in a list of species which spawn in the Swartkops estuary. Furthermore, Lasiak (1982) has reported adults in a sexually ripe condition in the Kings Beach surf zone from August to December. As the size range of specimens caught in the *Zostera* beds was 12–68 mm and those at Kings Beach, 34–110 mm with adult fish of 70–100 mm predominating (Lasiak 1982), it appears that in Algoa Bay *H. breviceps* spawns in the shallow inshore marine environment and larvae, juveniles and some adults enter and frequent the mouth and lower reaches of estuaries.

Gilchristella aestuarius, an estuarine fish, undergoes its

complete life cycle in the estuary and consequently is represented in estuaries through its entire length range (Wallace 1975a; Blaber 1979; Talbot 1982). In the Swartkops estuary this small filter-feeding species numerically dominates catches in the middle and upper reaches (Winter 1979; Talbot 1982) while Melville-Smith & Baird (1980) found that *G. aestuarius* larvae constituted 31% of the Swartkops ichthyoplankton. This species spawns in the upper reaches from October through January and as the larvae grow their distribution extends towards the mouth and into the *Zostera* beds of the lower reaches (Melville-Smith & Baird 1980; Talbot 1982).

In the Swartkops creek *Zostera*, the combination of shoals of *Hepsetia* and *Gilchristella*, with respective origins in the nearshore marine environment and the upper reaches of the estuary, constitutes 55% of the total creek fish community.

The four mullet species abundant as juveniles in the *Zostera* are also numerous as larger specimens in the main channel of the estuary (Marais 1976; Winter 1979; Marais & Baird 1980b). These species do not occur in the estuary as larvae (Melville-Smith & Baird 1980). Recruitment of juvenile mullet < 30 mm occurred throughout the year in the creek *Zostera*, implying that, collectively, the four species probably spawn throughout the year. The work of van der Horst & Erasmus (1981) has shown that *Liza dumerili* spawns from December through February near the mouth of the Swartkops river whilst Lasiak (1982) has similarly shown that *Liza richardsoni* spawns from September through March in Algoa Bay. Wallace (1975b) reports the spawning period for *Mugil cephalus* to be from May to September in Natal waters and as Brownell (1979) has recorded eggs of this species off the Cape peninsula from July through October it would appear that spawning time is similar in East Cape waters. *Liza tricuspidens* spawns from August through November in Natal (Wallace 1975b) but this spawning period has not been confirmed in Cape waters.

Rhabdosargus holubi was the second most abundant species in the Swartkops *Zostera* beds and Winter (1979) also found this from seine netting throughout the estuary. *R. holubi* juveniles have been shown to feed on plant material such as *Ruppia spiralis* Linnaeus and *Zostera capensis* but only the epiphytic diatoms and algae and epifauna of those macrophytes are digested (Blaber 1974a; Whitfield 1980).

Day *et al.* (1981) record the presence of *R. holubi* juveniles in estuaries from Kosi Bay to Milnerton lagoon. Both the present study and that of Melville-Smith & Baird (1980) recorded specimens < 20 mm throughout the year with a marked influx of juveniles in early summer. In the Swartkops creek *Zostera*, growth is rapid to about 80 mm when numbers become too low to follow the cohort in the creeks. *R. holubi* larger than this are still abundant in the main channel of the estuary until they reach about 150 mm and return to the sea (Winter 1979). The majority captured by Lasiak (1982) in the surf zone were 170–230 mm in length. Growth studies by Wallace & van der Elst (1975) in Natal estuaries and Winter (1979) in the Swartkops estuary indicate growth of about 100 mm in the first year for this species. Blaber (1974b), however, found growth of only 60 mm in the first year for the closed West Kleinmond estuary north of Algoa

Bay.

The blacktail, *Diplodus sargus*, is primarily an inshore species favouring rocky shores (van der Elst 1981). It has a long breeding season with peak spawning activity from July through September, and though tidal pools and inshore reefs serve as nursery areas for these species (Joubert 1981; van der Elst 1981; Lasiak 1982), juveniles have been recorded in estuaries from Kosi Bay to Hermanus lagoon (Day *et al.* 1981). The influx of juveniles recorded in the Swartkops *Zostera* in spring and early summer corresponds to the breeding season described above. Winter (1979) has noted the juvenile *D. sargus* are usually associated with *Zostera* in the lower reaches of the Swartkops estuary and recorded that after floods small *D. sargus* were absent from the estuary until *Zostera* became re-established some three to four months after the floods.

Only two of the three species of goby common in the Swartkops estuary were captured in the present study, but as Malan (1979) found *Glossogobius giuris* (Hamilton-Buchanan) to be confined to the upper reaches, the absence of this species in the creek *Zostera* of the lower reaches was to be expected. Melville-Smith & Baird (1980) report that goby larvae constitute 59.4% of the Swartkops estuary ichthyoplankton and occur throughout the year. Juvenile gobies of less than 20 mm were captured each month in the creek *Zostera* and the peak of small *Psammogobius knysnaensis* from March to May coincides with the period of maximum recruitment recorded in the main channel by Malan (1979). *P. knysnaensis* breeds in estuaries (Day *et al.* 1981).

The three sparids, *Spondylisoma emarginatum*, *Diplodus cervinus* and *Rhabdosargus globiceps* were only recorded from September through March in the *Zostera* beds and adults are known to breed in spring and summer (Talbot 1955; Brownell 1979; van der Elst 1981). *S. emarginatum* is a common reef fish along the Cape east and south coasts (van der Elst 1981). Winter (1979) did not record any *S. emarginatum* in the main channel of the Swartkops estuary but Hanekom (1982) has found this species in *Zostera* beds in the Kromme estuary. *D. cervinus* is also a common reef fish in the eastern Cape and was also recorded seasonally in summer in the Swartkops estuary by Winter (1979). *R. globiceps* is abundant in the southern Cape and Talbot (1955) has investigated the biology of this species in the Klein estuary. Juveniles were abundant in *Zostera* and *Ruppia* beds and stayed in the estuary for two years before returning to the sea (Talbot 1955). Lasiak (1982) only caught juveniles in the surf zone in Algoa Bay and whilst Winter (1979) did not capture *R. globiceps* in the Swartkops estuary, Marais & Baird (1980a) record the occurrence of a few large specimens in anglers' catches in this estuary. Another juvenile sparid recorded in low numbers from the Swartkops estuary *Zostera* was *Sarpa salpa* (Linnaeus). Joubert (1981) has proposed that adult *S. salpa* migrate to Natal to breed in deep water off the coast and the fry drift southwards with the Agulhas current to the Cape where they occur in tidal pools and estuaries, in particular, the Knysna estuary. Lasiak (1982) captured numerous juveniles of 20–30 mm and only one ripe male specimen in 24 months of surf zone netting.

The pomadasid, *Pomadasys olivaceum*, also showed a

summer influx of juveniles into the Swartkops *Zostera* but occasional specimens were caught throughout the year. Winter (1979) recorded the same trend in the main channel of the estuary and Joubert (1981) has found that in Natal waters this species has a long breeding season. Lasiak (1982) has found Kings Beach to be an important nursery area for juveniles of this species which spawns in inshore waters.

The sole, *Solea bleekeri*, is known to breed in estuaries (Wallace 1975a; Melville-Smith & Baird 1980; Whitfield 1980) as well as in the sea (Day *et al.* 1981). *Heteromycteris capensis* breeds at sea (Melville-Smith 1978; Brownell 1979) and Lasiak (1982) has found ripe specimens throughout the year in the surf. The pipefish *Syngnathus acus* also breeds in estuaries and the sea (Day *et al.* 1981) and Melville-Smith (1978) collected metamorphosed larvae of 10–14 mm in the Swartkops ichthyoplankton. *S. acus* was most abundant during the summer months in the creek *Zostera*.

The spring/summer influx of juveniles of numerous fish species in the Swartkops estuary coincides with an increase in standing crop of *Zostera* itself. Emmerson *et al.* (1982), in an investigation of Swartkops *Zostera* beds, found that the high summer standing crop of 160 g (dry mass) m⁻² dropped off to 40 g (dry mass) m⁻² in winter. This is owing to the die-off of aerial shoots after flowering whilst the rhizomes are persistent, remaining buried in the substrate (Edgcumbe 1980). Nienhuis & Bree (1980) have recorded a similar summer increase for *Zostera marina* (Linnaeus) standing crop in Holland.

In conclusion, it appears that the creek *Zostera* beds in the lower reaches of the Swartkops estuary form an important and integral part of the nursery function of the estuary by providing a sheltered, food-rich habitat. Consequently, it is essential that the vegetated marginal areas of estuaries be included in estuarine management programmes. Though numerous species occurred in the *Zostera*, juveniles of *H. breviceps*, *R. holubi*, *L. dumerili*, *L. richardsoni*, *M. cephalus* and *D. sargus* were numerically dominant. Other workers have recorded spawning of these species in the shallow marine environment. In the present study extremely small fish (< 20 mm) were also captured at the main channel station but juveniles of all species, except those which can be termed the true estuarine complement of *G. aestuarius*, gobies and soles, were more abundant in the *Zostera* than the main channel. Finally, it is apparent that the use of a small mesh seine net for sampling facilitated the capture of extremely small juveniles (< 20 mm) not previously recorded from the estuary.

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The Ichthyofauna of the Sundays Estuary, South Africa, with Particular Reference to the Juvenile Marine Component

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ABSTRACT: The ichthyofauna of the Sundays Estuary was investigated by monthly seine netting over a period of a year. Forty-seven species were captured though 23 of these were represented by a total catch of less than 25 specimens each. The small clupeid *Gilchristella aestuarius* was numerically dominant and constituted 80% of the catch. The study confirms that in addition to this species, two species of goby, *Caffrogobius multifasciatus* and *Psammogobius knysnaensis* and the sole *Solea bleekeri* complete their life cycles in the estuary. Many other species such as mullet, utilize the estuary as a juvenile nursery area. First year juveniles of *Rhabdosargus holubi*, *Lithognathus lithognathus*, *Pomadasy's commersonni* and *Monodactylus falciformis*, by virtue of their abundance in the Sundays Estuary and other South African estuaries, and their absence from other coastal environments, appear to be dependent on estuaries as juvenile nursery areas.

Introduction

The South African coastline is characterized by heavy wave action, strong ocean currents and, with the exception of the Agulhas Bank, steep bathymetry. In marked contrast, South African estuaries though limited in area are calm and shallow with some even subject to seasonal closure from the sea. The ichthyofauna of many of these estuaries has been investigated and it has been suggested that juveniles of species important to recreational and commercial fisheries may be dependent on estuaries as nursery areas (Wallace and van der Elst 1975; Blaber and Blaber 1980; Blaber 1981; Day et al. 1981).

Juvenile fish may, however, only be concluded to be dependent on estuaries if they are found to be absent or scarce in the open sea (Clark et al. 1969). Therefore, to assess estuarine dependence amongst juvenile ma-

rine fish along the South African coast, a program of concurrent studies on species composition, size frequency distribution and seasonality of juveniles in south coast estuaries, tidal pools and the inshore sublittoral was undertaken. The present study of the ichthyofauna of the Sundays Estuary forms part of this assessment.

The Sundays River rises in the Karoo region of South Africa and flows in a south westerly direction towards the Indian Ocean where it enters Algoa Bay (33°43'S, 25°51'E) via a 21 km channel-like estuary (Fig. 1). The mouth is permanently open and bordered by an extensive coastal dune field, while the estuary is characterized by steep banks and an absence of salt marshes or large mud flats. The estuary is shallow (<6 m at LWST) and is subject to semidiurnal tides with a spring tide range of 1.5 m near the mouth. A horizontal salinity gradient occurs from mouth to head and water temperatures vary seasonally from 14 °C to 26 °C (Wooldridge and Bailey 1982). Forbes and Allanson (1970) have investigated the chemical features of the Sundays Estuary.

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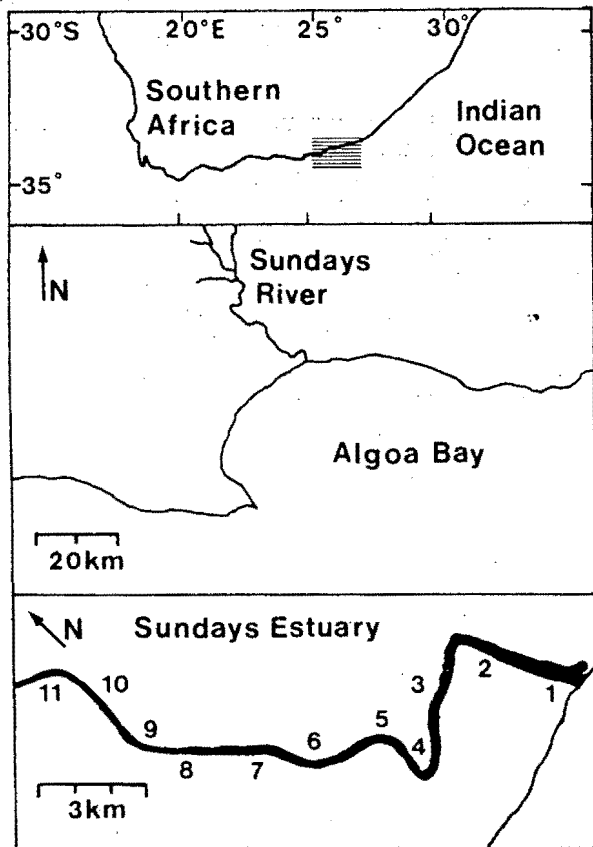


Fig. 1. Location of the Sundays Estuary and sampling stations.

Marginal vegetation in the estuary is limited to *Potamogeton crispus* at the head, *Phragmites australis* in the upper reaches, a xanthophyte *Vaucheria* sp. in the middle reaches and a small bed of *Zostera capensis* near the mouth. Phytoplankton blooms often occur in the lower reaches during summer and Archibald (1981) has investigated the diatoms of the Sundays Estuary. Day (1981) includes notes on the benthos of the estuary, while Wooldridge and Melville-Smith (1979), Wooldridge and Erasmus (1980), Melville-Smith et al. (1981) and Wooldridge and Bailey (1982) have completed detailed studies on the zooplankton community. Marais (1981, 1982) has monitored gill-net catches of the larger fishes occurring in the estuary.

Materials and Methods

During the period April 1980 through to March 1981, regular monthly trips were made to the Sundays Estuary to sample fish. Seine netting took place during low tide at six stations, representative with regard to

salinity of the lower, middle and upper reaches of the estuary. Station numbers and positions correspond to those used by Wooldridge and Bailey (1982) and are indicated in Fig. 1. A large seine net (50 m × 2 m with 12 mm stretched mesh) was used at stations 2, 4 and 11, while a small seine net (10 m × 2 m with 2 mm stretched mesh) was used at stations 1, 5 and 9. Logistical reasons precluded seining at all six stations over a single low tide period so sampling at stations 1, 5 and 9 was always done between 1800 h and 2300 h in the course of evening plankton sampling, while the three other stations were sampled the next morning.

The catch was preserved in 10% formalin and brought back to the laboratory for sorting and identification. Total length was measured to the nearest millimeter. Juvenile mullet were identified from the dentition characteristics given by van der Elst and Wallace (1976). Monthly length frequency distributions of *Rhabdosargus holubi* and *Lithognathus lithognathus*, two sparids which showed a marked influx of juveniles into the estuary, were analyzed using probability paper (Cassie 1954).

Results

During the study, 47 species of fish were captured by seine netting in the Sundays Estuary (Table 1). Thirty-four species were caught in the lower reaches, 33 in the middle reaches, 28 in the upper reaches and 19 species occurred throughout the estuary. A total of 129,883 fish was netted during the study. The small shoaling clupeid species *Gilchristella aestuarius* numerically dominated the catch and made up 80% of the total. *Rhabdosargus holubi* was the second most abundant species making up 3.6% of the catch. Seven mugilid species collectively comprised 6.4% while four species of Gobiidae contributed 2.8%. *Monodactylus fal-ciformis* contributed 2.3%, two species of Soleidae made up 2.2% and the other 31 species constituted the remaining 2.6% of the total catch. Some 23 species were represented by a total catch of less than 25 specimens each during the study period. Ten species were caught on every sampling trip to the estuary, while seven species were only captured on a single occasion.

Gilchristella aestuarius is an estuarine

TABLE 1. Seine net catch composition from the Sundays estuary (April 1980 to March 1981).

Species	Total Catch	Size Range mm	Distribution*	Frequency (Months)
CHONDRICHTHYES				
Myliobatidae				
<i>Myliobatis aquila</i> (Linnaeus, 1758)	3	477-675	L	2
Torpedinidae				
<i>Torpedo fuscomaculata</i> Peters, 1855	1	271	L	1
OSTEICHTHYES				
Clupeidae				
<i>Etrumeus teres</i> (Dekay, 1824)	1	40	L	1
<i>Gilchristella aestuarius</i> (Gilchrist, 1914)	103,813	9-65	L; M; U	12
<i>Sardinella gibbosa</i> (Bleeker, 1849)	1	50	L	1
Engraulidae				
<i>Stolephorus holodon</i> (Boulenger, 1900)	4	17-91	L; M	3
Elopidae				
<i>Elops machnata</i> (Forsskal, 1775)	42	22-97	M; U	5
Ophichthidae				
<i>Ophisurus serpens</i> (Linnaeus, 1766)	1	137	L	1
Cyprinidae				
<i>Cyprinus carpio</i> Linnaeus, 1758	24	370-635	U	6
Ariidae				
<i>Galeichthys feliceps</i> (Valenciennes in C & V, 1840)	36	50-181	L; M	7
Hemiramphidae				
<i>Hyporhamphus capensis</i> (Thomiot, 1886)	2	34-57	M; U	2
Atherinidae				
<i>Atherina breviceps</i> (Cuvier in C & V, 1835)	851	10-69	L; M	11
Syngnathidae				
<i>Syngnathus acus</i> Linnaeus, 1758	16	77-312	L; M; U	6
Platycephalidae				
<i>Platycephalus indicus</i> (Linnaeus, 1758)	4	105-235	M	3
Ambassidae				
<i>Ambassis gymnocephalus</i> (Lacépède, 1802)	104	15-45	M; U	5
Teraponidae				
<i>Terapon jarbua</i> (Forsskal, 1775)	10	26-43	M; U	3
Carangidae				
<i>Caranx sexfasciatus</i> (Quoy & Gaimard, 1824)	4	66-81	M	1
<i>Lichia amia</i> (Linnaeus, 1758)	11	49-315	L; M; U	6
Pomadasyidae				
<i>Pomadasy commersonni</i> (Lacépède, 1802)	691	8-362	L; M; U	10
<i>Pomadasy olivaceum</i> (Day, 1875)	421	15-124	L; M; U	12
Sparidae				
<i>Acanthopagrus berda</i> (Forsskal, 1775)	16	15-169	M; U	5
<i>Diplodus sargus</i> (Linnaeus, 1758)	197	11-107	L	11
<i>Lithognathus lithognathus</i> (Cuvier in C & V, 1830)	793	14-267	L; M; U	12
<i>Lithognathus mormyrus</i> (Linnaeus, 1758)	22	18-44	L	4
<i>Rhabdosargus globiceps</i> (Cuvier in C & V, 1830)	23	24-111	L	9
<i>Rhabdosargus holubi</i> (Steindachner, 1881)	4,751	7-282	L; M; U	12
<i>Sarpa salpa</i> (Linnaeus, 1766)	1	20	L	1
<i>Spondylisoma emarginatum</i> (Cuvier in C & V, 1830)	21	21-34	L	2
Sciaenidae				
<i>Argyrosomus hololepidotus</i> (Lacépède, 1802)	90	27-232	L; M; U	10
Monodactylidae				
<i>Monodactylus falciformis</i> (Lacépède, 1801)	3,022	6-189	L; M; U	9
Cichlidae				
<i>Oreochromis mossambica</i> (Peters, 1852)	12	82-198	L; M; U	5
Mugilidae				
<i>Liza dumerili</i> (Steindachner, 1869)	4,474	10-307	L; M; U	12
<i>Liza richardsoni</i> (Smith, 1846)	1,342	10-382	L; M; U	12

TABLE 1. Continued.

Species	Total Catch	Size Range mm	Distribution ^a	Frequency (Months)
<i>Liza tricuspidens</i> (Smith, 1935)	207	20-437	L; M; U	11
<i>Mugil cephalus</i> Linnaeus, 1758	2,100	8-300	L; M; U	11
<i>Myxus capensis</i> (Valenciennes in C & V, 1836)	94	21-172	M; U	6
<i>Valamugil buchanani</i> (Bleeker, 1853)	106	18-59	L; M; U	6
<i>Valamugil cunnesius</i> (Valenciennes in C & V, 1836)	1	136	U	1
Blenniidae				
<i>Omobranchus woodi</i> (Gilchrist & Thompson, 1908)	9	17-45	L; M	3
Gobiidae				
<i>Caffrogobius multifasciatus</i> (Smith, 1959)	1,162	12-122	L; M; U	12
<i>Glossogobius tenuiformis</i> (Fowler, 1934)	152	6-101	U	11
<i>Oligolepsis keiensis</i> (Smith, 1938)	18	21-62	M	7
<i>Psammogobius knysnaensis</i> Smith, 1936	2,351	7-74	L; M; U	12
Soleidae				
<i>Heteromycteris capensis</i> Kaup, 1858	1,387	10-85	L; M; U	12
<i>Solea bleekeri</i> (Boulenger, 1898)	1,489	11-133	L; M; U	12
Tetraodontidae				
<i>Amblyrhyncotes honckenii</i> (Bloch, 1795)	2	98-185	L	2
<i>Gastrophysus scleratus</i> (Forster, 1788)	1	40	M	1

^a (L = lower reaches, M = middle reaches, U = upper reaches).

species which spends its entire life cycle in estuaries and the size range of the fish captured represents all sizes of development from larvae to adults (Fig. 2). Large numbers of juveniles occurred in the late summer months and a maximum density of 125 per m² was calculated from catches in the middle reaches.

Of the seven species of mullet, *Liza dumerili* was the most abundant (54% of the mullet catch) and occurred throughout the year. *Mugil cephalus* and *Liza richardsoni* were also caught throughout the year and constituted 25% and 16% of the total mullet catch respectively. *Liza tricuspidens*, *Valamugil buchanani* and *Myxus capensis* occurred in lower numbers and only one specimen of *Valamugil cunnesius* was caught. Length frequency histograms (Fig. 3) show that juveniles of less than 50 mm dominated the catch. These small mullet were found throughout the year and on average made up 63% of the mullet catch each month.

Four species of Gobiidae were caught in the Sundays Estuary with *Psammogobius knysnaensis* and *Caffrogobius multifasciatus* being the most abundant and occurring throughout the estuary. *Glossogobius tenuiformis* was restricted to the upper reaches and *Oligolepsis keiensis* to the middle reaches. Length frequency distributions for

P. knysnaensis and *C. multifasciatus* are given in Fig. 2 and peak periods of recruitment were found during the summer months.

Solea bleekeri and *Heteromycteris capensis* were the only species of Soleidae caught, and they occurred throughout the estuary. Their length frequency distributions are given in Fig. 2. From the bimodal distribution found for the small sole *S. bleekeri*, it appears that both adults and juveniles occur in the estuary and peak recruitment of juveniles occurred in late summer. Only juvenile *H. capensis* were found in the estuary and a recruitment peak was recorded in November.

Nine species of Sparidae were encountered in the Sundays Estuary. *Rhabdosargus holubi* and *Lithognathus lithognathus* were the only species that were abundant throughout the estuary over the study period (Fig. 4). Juveniles of *Diplodus sargus*, *Rhabdosargus globiceps*, *Spondyliosoma emarginatum*, *Lithognathus mormyrus* and *Sarpa salpa* were only found in low numbers in the lower reaches, while *Acanthopagrus berda* was only caught in the middle and upper reaches. Figure 5 illustrates that though very small *R. holubi* (<20 mm) occurred in catches throughout the year, there was an influx of juveniles in late winter and in spring. Analysis of length frequency dis-

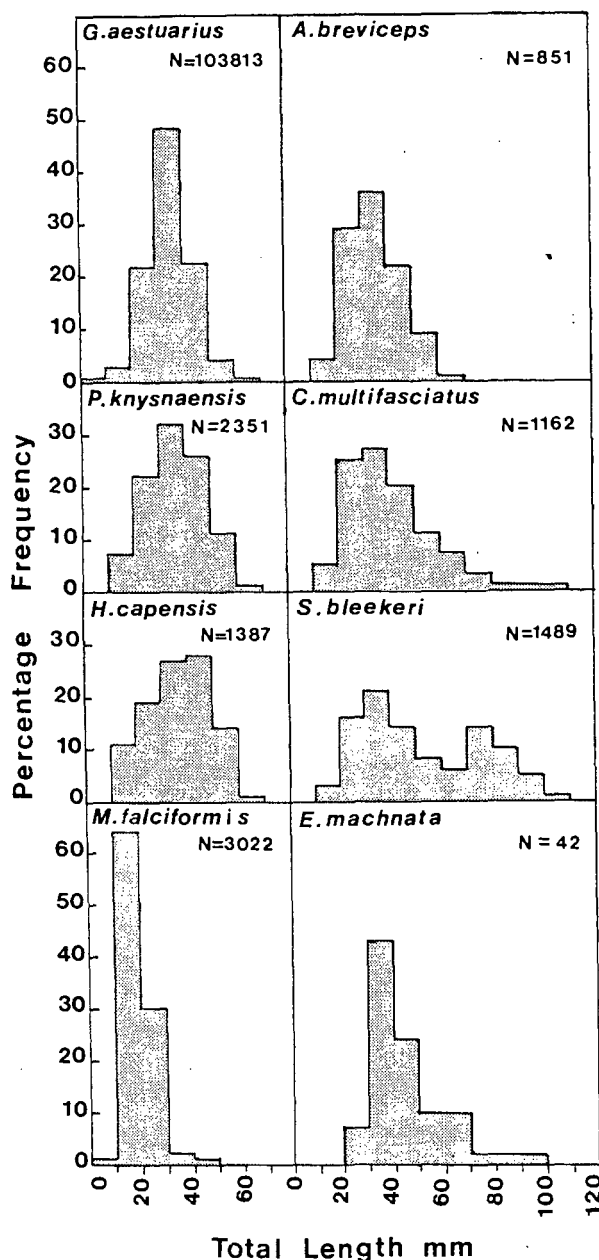


Fig. 2. Length frequency distributions for total catches of *Gilchristella aestuarius*, *Atherina breviceps*, *Psammogobius knysnaensis*, *Caffrogobius multifasciatus*, *Heteromycteris capensis*, *Solea bleekeri*, *Monodactylus falciformis* and *Elops machnata*.

tributions indicates growth to between 90 and 100 mm during their first year in the estuary. *L. lithognathus* also showed a marked spring influx of juveniles and from Fig. 6 it appears that juveniles grow to about 140 mm during their first year in the estuary.

During the late summer months, small juveniles of *Monodactylus falciformis* were particularly abundant in the upper reaches of the Sundays Estuary where they sheltered

amongst submerged *Potamogeton* plants. The majority of those captured were in the 10–30 mm size range (Fig. 2). Juveniles of two pomadasids were also captured with those of *Pomadasys commersonni* more abundant in the middle and upper reaches and those of *Pomadasys olivaceum* occurring chiefly in the lower reaches (Fig. 4). *Atherina breviceps* juveniles (Fig. 2) were found mainly in the lower reaches, while juvenile *Argyrosomus hololepidotus* occurred predominantly in the middle reaches with the majority larger than 150 mm (Fig. 4). Low numbers of *Elops machnata*, *Galeichthys feliceps* and *Lichia amia* juveniles were also captured.

Discussion

Seventeen of the 47 fish species recorded in the present study were also captured by Marais (1981) who used gill nets in the Sundays Estuary. Marais (1981) recorded an additional four marine species (*Pomatomus saltatrix*, *Diplodus cervinus*, *Thryssa vitrirostris* and *Rhinobatus annulatus*) and two other freshwater species (*Labeo umbratus* and *Micropterus cyprinoides*) to bring the total number of species recorded in the Sundays Estuary to 53. Of these 53 species, 9 were captured only as adults, 26 as both adults and juveniles and 18 only as juveniles. In addition, the capture of *Sardinella gibbosa*, *Oligolepsis keiensis* and *Valamugil cunnesius* in the Sundays Estuary extends the known southern distribution limit of these species (Smith 1965; Hoese and Winterbottom 1979; Day et al. 1981).

Gilchristella aestuarius was found to be particularly abundant in the Sundays Estuary and Wooldridge and Bailey (1982) have recorded extremely high numbers of eggs (3,500 per m³) and larvae (2,250 per m³) of this species in the plankton of the upper and middle reaches during the summer months. This species is an important prey item for piscivorous birds and for large predatory fish such as *Argyrosomus hololepidotus* and *Elops machnata* (Day et al. 1981) and as a zooplankton feeder, *G. aestuarius* constitutes an important link in the Sundays Estuary foodweb.

The two goby species, *Psammogobius knysnaensis* and *Caffrogobius multifasciatus*, and the small sole *Solea bleekeri* also

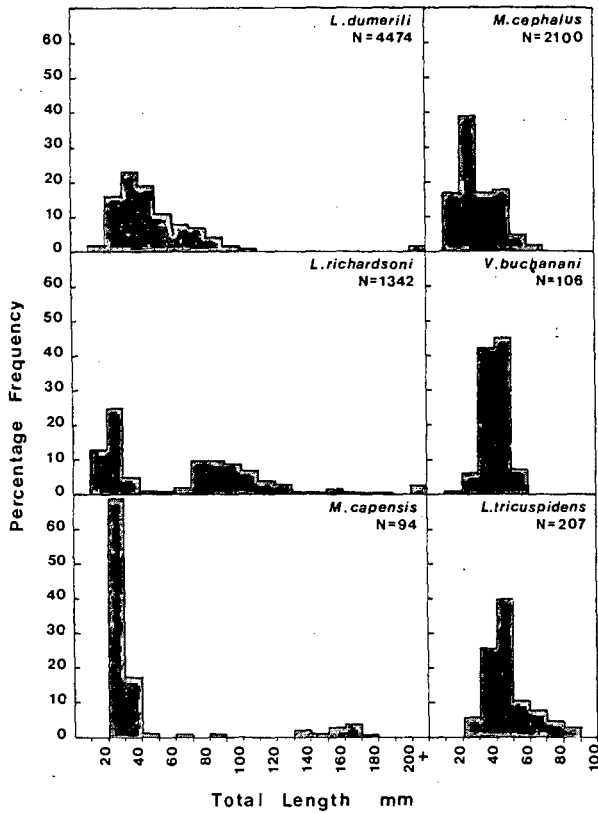


Fig. 3. Length frequency distributions for total catches of *Liza dumerili*, *Mugil cephalus*, *Liza richardsoni*, *Valamugil buchanani*, *Myxus capensis* and *Liza tricuspidens*.

complete their life cycles in the estuary though the latter does also breed in the sea (Day et al. 1981). Melville-Smith and Baird (1980) have recorded numerous early larvae of these species in the ichthyoplankton of the adjacent Swartkops Estuary and Woolridge and Bailey (1982) have also encountered these larvae in the plankton of the Sundays Estuary.

Juveniles of *Liza dumerili*, *Mugil cephalus* and *Liza richardsoni* were the most numerous of the mullet found in the Sundays Estuary. Early juveniles entered the estuary throughout the year, with peak recruitment periods in April/May for *L. dumerili*, August/September for *M. cephalus* and December/January for *L. richardsoni*. These recruitment peaks follow the spawning peaks recorded for *L. dumerili* (van der Horst and Erasmus 1981), *M. cephalus* (Wallace 1975) and *L. richardsoni* (Lasiak 1982). The lower numbers of *Liza tricuspidens* and *Valamugil buchanani* recorded are probably explained by the two species being near the

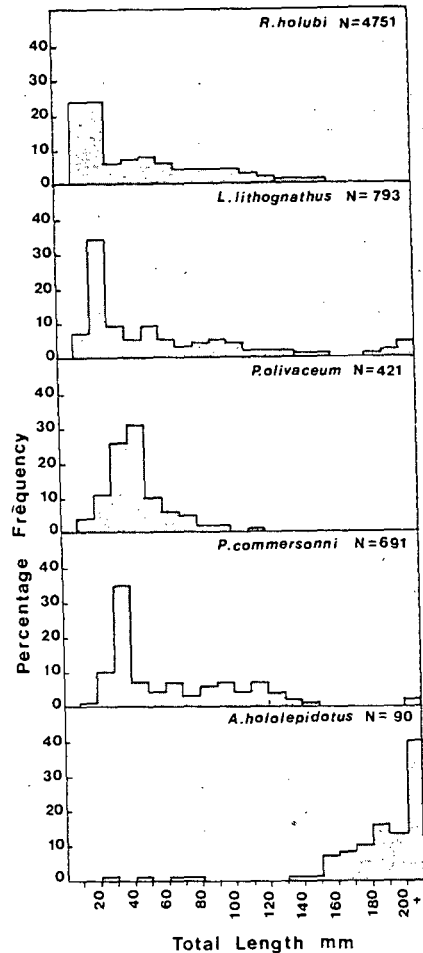


Fig. 4. Length frequency distributions for total catches of *Rhabdosargus holubi*, *Lithognathus lithognathus*, *Pomadasys olivaceum*, *Pomadasys commersonni* and *Argyrosomus hololepidotus*.

southern limit of their distribution. *Myxus capensis* has a specialized catadromous life cycle and its juveniles move rapidly through eastern Cape estuaries in a strong upstream migration to the riverine environment (Bok 1979).

The two sparids *Rhabdosargus holubi* and *Lithognathus lithognathus* utilize the Sundays Estuary extensively during the juvenile phase of their life cycles and appear to be dependent on estuaries as nursery areas for first year juveniles. The low number of *R. holubi* greater than 120 mm in the estuary indicates that this species returns to the sea during the second year where it occurs over reefs and sandy substrata. Lasiak (1982) found the majority of *R. holubi* occurring off sandy beaches in Algoa Bay to be 170–230 mm in length, while SCUBA diving surveys of reef specimens revealed them to

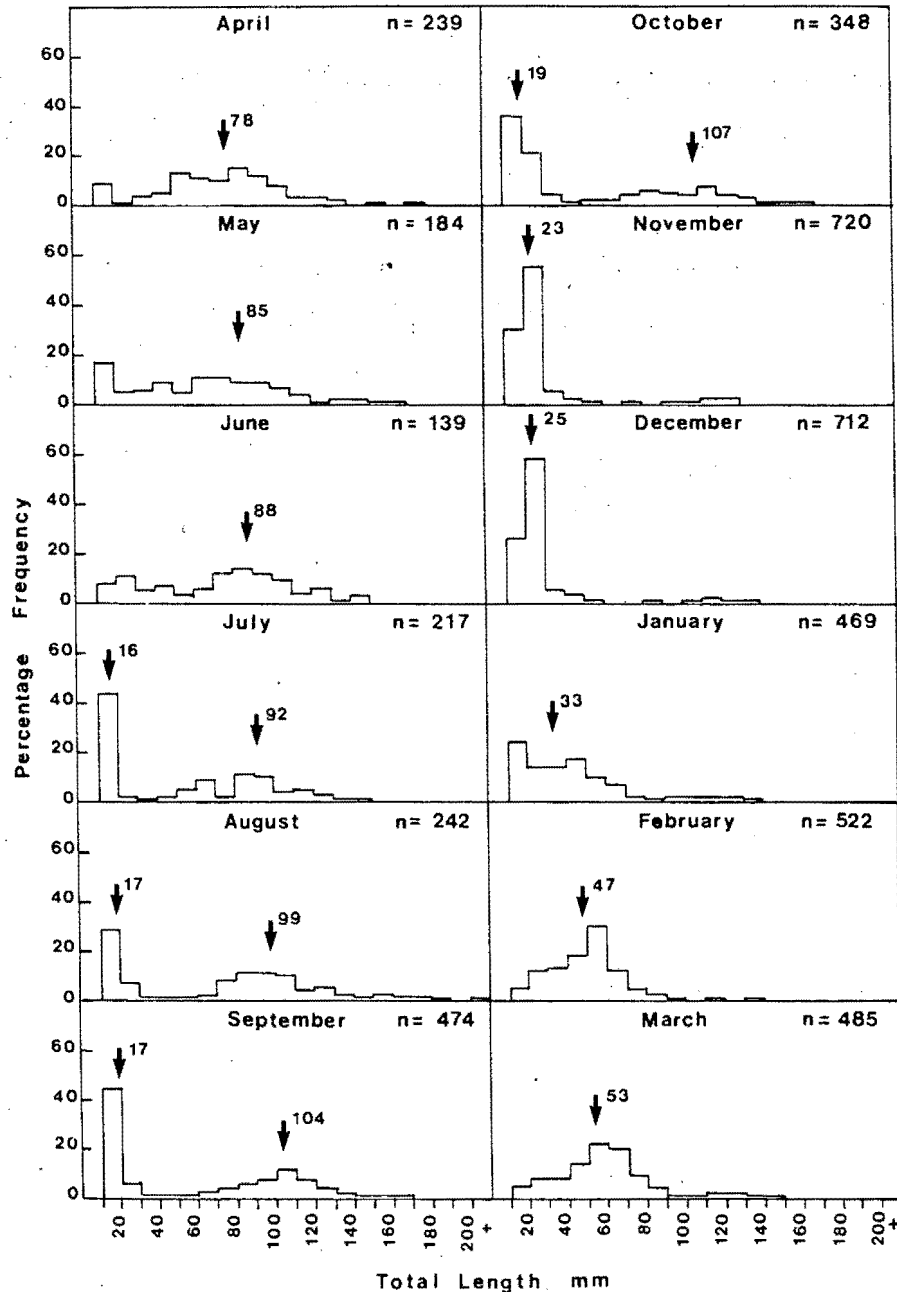


Fig. 5. Monthly length frequency distributions for *Rhabdosargus holubi* in the Sundays Estuary from April 1980 to March 1981. Cohort means are indicated with arrows.

be greater than 150 mm (personal observation). The growth rate of juvenile *R. holubi* during their first year in the Sundays Estuary, is similar to that found by Wallace and van der Elst (1975), Winter (1979) and Beckley (1983) for this species in other open estuaries in South Africa but is greater than the 60 mm growth increment recorded by Blaber (1974) for *R. holubi* during their first year in a closed estuary.

Lithognathus lithognathus also returns to sea during the second year and Lasiak (1982) found the majority of individuals caught off sandy beaches to be in the 180–270 mm size range. Mehl (1973) calculated the age of *L. lithognathus* from otoliths and scales and concluded that after attaining a fork length of 100 mm by the end of their first year, they have an annual growth increment of 50 mm. Growth rate of juveniles in the

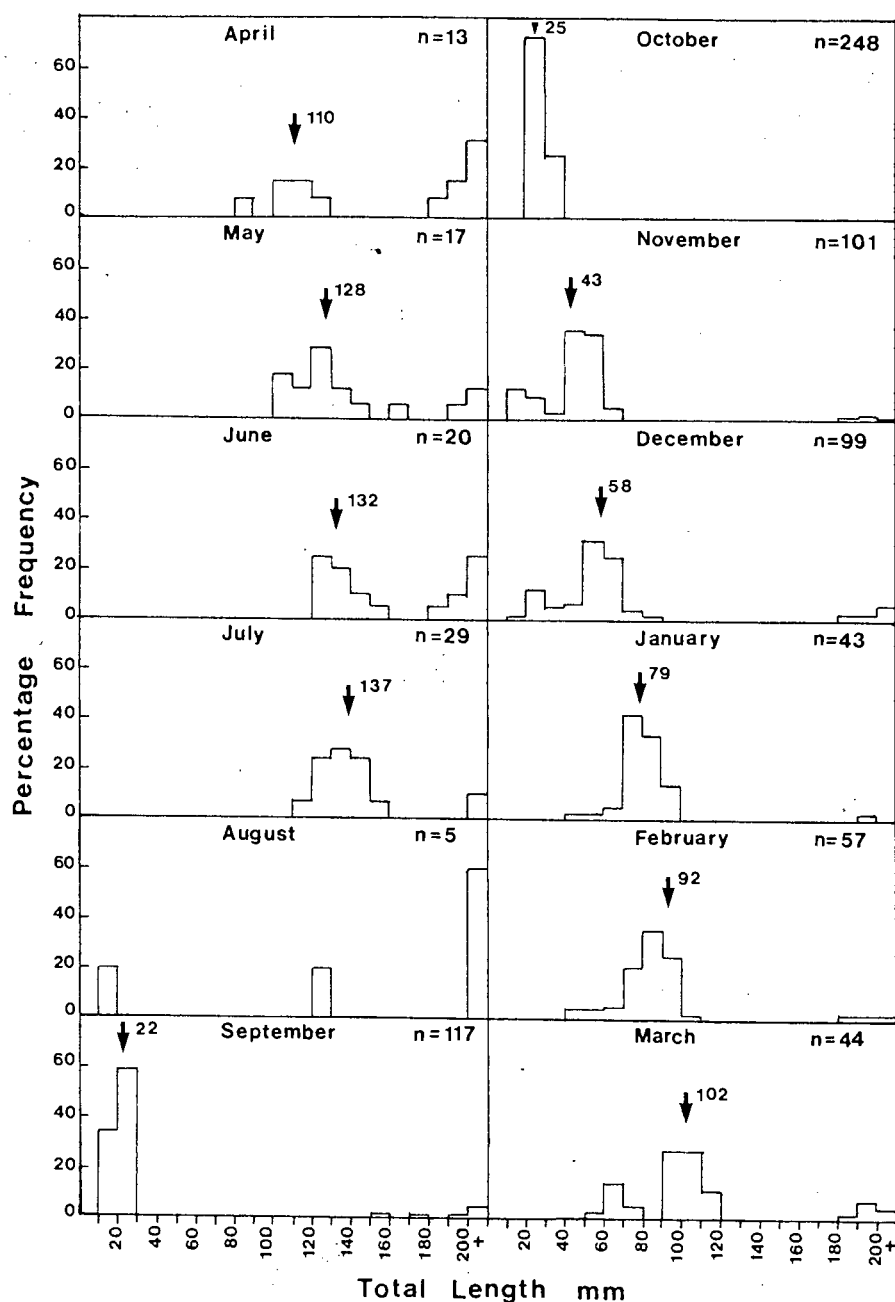


Fig. 6. Monthly length frequency distributions for *Lithognathus lithognathus* in the Sundays Estuary from April 1980 to March 1981. Cohort means are indicated with arrows.

Sundays Estuary is similar and the spring influx of juveniles corresponds to the winter spawning found by Mehl (1973).

Juveniles of *Monodactylus falciformis* favor the vegetated upper reaches of estuaries and were abundant in the *Potamogeton* in the Sundays Estuary but infrequent in the *Zostera* beds of the lower reaches of the Swartkops Estuary (Beckley 1983). *M. falciformis* is sexually mature from 170 mm

and Lasiak (1982) only captured adults of 170–254 mm off sandy beaches in Algoa Bay. These fish have a breeding peak from October to February (Lasiak 1982) which correlates with the observed recruitment peak from January to March, in the Sundays Estuary.

Juvenile *Pomadourus commersonni* less than 50 mm length entered the Sundays Estuary mainly in the summer months and

this estuary seems to be close to the southern limit for early juveniles of this species. Natal estuaries to the north appear to be more important as nursery areas for this species (Wallace and van der Elst 1975). Juveniles grow to 150 mm during their first year (Wallace and Schleyer 1979) and then emigrate out to sea. Sexual maturity occurs at 400 mm and spawning takes place during spring, after which adults are found in high numbers in estuaries along the east coast of southern Africa (Wallace 1975). Though juvenile *Pomadasys olivaceum* were found throughout the year in the lower reaches of the Sundays Estuary, the shallow marine environment appears to be the primary nursery area of this species (Joubert 1981; Lasiak 1983). Sexual maturity is attained at 130 mm and no adults were recorded from the estuary.

The catches of *Atherina breviceps* and *Heteromycteris capensis* consisted of juveniles. *A. breviceps* was concentrated in the lower reaches and juveniles of this species numerically dominated catches in the *Zostera* beds of the Swartkops Estuary (Beckley 1983). Adults dominated catches off sandy beaches in Algoa Bay (Lasiak 1982) and it appears that this species utilizes estuaries as a nursery area. *H. capensis* juveniles occurred throughout the estuary but there is little information on the life cycle of this species, although (Lasiak 1982) has recorded 21 ripe specimens from the Algoa Bay surf zone.

First year juveniles of *Argyrosomus hololepidotus* were infrequent in the present study but Marais (1981) found that specimens from 160–720 mm dominated gill net catches in terms of biomass. Recent trawling studies along the Cape south coast (Wallace and Kok 1983) indicate that shallow bays are an important nursery area for juveniles of this species. *A. hololepidotus* matures at a length of 750 mm (van der Elst 1981) and it appears that subadults of the 1+, 2+ and 3+ year classes enter estuaries to feed on the abundant prey species.

Elops machnata is common in both gill net and anglers' catches in eastern Cape estuaries (Marias and Baird 1980a, 1980b; Marais 1981) and some juveniles were captured in the present study. This species spawns at sea (Day et al. 1981), larvae and

juveniles occur in estuaries but detailed information on the life cycle of this species is not available. *Galeichthys feliceps* was the most abundant species caught in the gill nets by Marais (1981) but very few juveniles were captured in the present study. Their relatively unimportant contribution to the juvenile component of both the Sundays Estuary and the Swartkops Estuary (Winter 1979) ichthyofauna and the capture of large numbers of juveniles on the Cape coast (Wallace and Kok 1983) is contrary to the opinion of van der Elst (1981) who states that eastern Cape estuaries are used as nursery areas by juveniles.

Lichia amia is a large predatory species frequently captured as subadults in both the Sundays and Swartkops Estuaries (Marais and Baird 1980a, 1980b; Marais 1981). Spawning occurs off the Natal coast in spring and the Agulhas current distributes juveniles southwards to the Cape (van der Elst 1981). First year juveniles, however, only occur in low numbers in the Sundays Estuary, Swartkops Estuary (Winter 1979), south coast estuaries (Coetzee 1982) and off Algoa Bay sandy beaches (Lasiak 1982). If these relatively few juveniles maintain the adult stock it suggests a low natural mortality and it is proposed that this is achieved by fast growth (Blaber 1974 has recorded 110 mm growth in six months), swiftness and camouflage. Thus, although there are low numbers of juvenile *L. amia* in east Cape estuaries, they are probably important nursery areas for this species.

Estuarine fishes from various parts of the world have been reviewed by Gunter (1967), McHugh (1967) and Pillay (1967) and they have emphasized the nursery function of estuaries and offshore estuarine zones such as the reduced salinity areas of the North Atlantic and Indian Oceans. Along the South African coast offshore estuarine zones do not occur and estuaries only cover a total area of 600 km² (Heydorn 1979). This limited estuarine area, as shown by earlier studies and the present investigation of the Sundays Estuary ichthyofauna, is however utilized by juveniles of many marine fish species. Further, using the Sundays Estuary results in conjunction with currently available information from other coastal environments, it can be concluded that juveniles

of at least four marine species important to recreational fishing (*Lithoganthus lithoganthus*, *Monodactylus falciformis*, *Pomadasys commersonni* and *Rhabdosargus holubi*) are dependent on estuarine nursery areas. Careful management to prevent degradation of South African estuaries would thus appear to be essential for the maintenance of stocks of these estuarine-dependent species.

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South African Estuaries and Their Importance to Fishes

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In this article environmental conditions typical of South African estuaries are contrasted with those of marine inshore waters in order to emphasize that estuarine fishes comprise a specialised component of the marine fauna. The life cycle of estuarine fishes is described and related to important physical and biological characteristics of estuaries. The fish fauna is divided into six categories according to the extent of their dependence on estuaries. This is followed by discussion of the effects of estuarine degradation on these groups. It is concluded that continuing degradation will result in a decline in South Africa's estuarine fish fauna and consequently in recreational angling, in the yield of high-protein food and in economic activities dependent upon this natural resource. It is recommended that higher priority be accorded to the conservation of estuaries in the face of development projects that impinge on this environment.

South Africa's estuaries represent an extremely valuable national resource which is increasingly threatened by urban, industrial and agricultural development. Whereas development goals and conservation ideals can sometimes be reconciled, this is the exception rather than the rule and in the past development has all too often been unsympathetic to the environment and resulted in permanent damage to South African estuaries. Perhaps one of the reasons for this is that the case for conservation has not been sufficiently clearly stated.

There are many reasons for conserving estuaries, not the least of which is their recreational value and it is in this respect that fish and fishing are particularly significant. The authors of this article are specialists in the study of estuarine fish and are consequently able to present an authoritative statement on South African estuaries, their

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importance to fishes and the need for greater attention to be given to their conservation.

Basic facts about the estuarine environment and estuarine fishes

Conditions in South African estuaries differ markedly from those that prevail in the sea. The marine inshore waters adjoining the Republic's 3000-km coastline is typified by turbulent wave action, a lack of sheltered shores, and by a narrow continental shelf on the east and south-east coasts. In contrast, the estuarine environment is very much smaller in area, is typically calm, sheltered and shallow, as well as being subject to greater variation in salinity, turbidity and temperature. As a result, South African estuaries represent a specialised environment¹ and of a total of approximately 1500 species of fishes found on the continental shelf, fewer than 100 species are able to make use of our estuaries.

The life cycle of most of these species involves the spawning by adults at sea, often close inshore and in the vicinity of estuary mouths. Egg and larval development also take place at sea, but there is a mass migration into estuaries by small juveniles when they are approximately 15 mm and upwards in length. This instinct for migration is very marked and during late winter, spring and early summer millions of fish fry enter estuaries, where the high temperatures and rich food supply favour rapid growth, and where they are also protected from most marine predators.²⁻⁵ Juveniles spend vary-

ing lengths of time in estuaries, but generally migrate back to sea with the onset of adolescence, which often occurs at an age of about a year. These sub-adult fish tend to inhabit marine inshore areas, where they join the adult spawning populations once they become mature.⁶ Adult fish increase in abundance seasonally when they enter estuaries to feed. At these times of the year they are readily accessible to sport anglers and constitute a valuable recreational and food resource⁷⁻⁹ (e.g. during the famous grunter 'run').

From the foregoing it is obvious that the migration of fish in and out of estuaries is dependent upon each estuary being in contact with the sea, either through a permanently open mouth, or via a mouth which opens naturally at certain times of the year in response to seasonal rains and other environmental factors. It is also clear that fish benefit from the rich feeding-grounds provided by estuaries, and that human disruption of this function can degrade estuaries to the point where they are of little value to fishes. Particularly significant are the submerged aquatic plants and the vegetation supported by the adjacent wetlands, both of which supply much of the plant detritus basic to the estuarine food web.^{3,10-12}

How dependent are these fish on estuaries?

From research conducted in estuaries, biologists have long maintained that the most important role of this environment as regards fish populations is the provision of nursery grounds for juveniles. Recent studies have examined this role in more detail and have sought to show whether these fishes also utilize nursery grounds at sea. It is important to know this, because it tells us whether the survival of South African populations of these species is dependent on estuaries.

The search for nursery grounds at sea was concentrated on the Cape south and south-west coasts, and supplemented by research in Natal. It involved sandy-beach seine net-

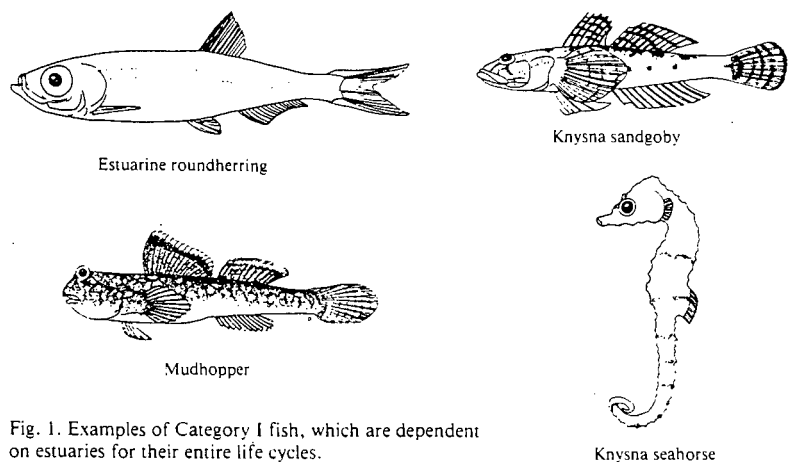


Fig. 1. Examples of Category I fish, which are dependent on estuaries for their entire life cycles.

Table 1. Fishes associated with South African estuaries.

Category I: Truly estuarine species, dependent on estuaries for entire life cycle.

Species	Common name	Utilization
<i>Caffrogobius multifasciatus</i>	prison-goby, tronk-dikkop	prey
<i>Caffrogobius natalensis</i>	baldy, kaalkop	prey
<i>Clinus</i> sp. nov.	Bot river clinid	prey
<i>Gilchristella aestaurius</i>	estuarine roundherring, rivier-rondeharing	prey
<i>Gobionellus keiensis</i>	Kei river goby	prey
<i>Hippocampus capensis</i>	Knysna seahorse, Knysna-seeperdjie	prey
<i>Periophthalmus sobrinus</i>	kingfin mudhopper, grootvin modderspringer	prey
<i>Psammogobius knysnaensis</i>	Knysna sandgoby, Knysna-sanddikkop	prey

Category II: Species dependent on estuaries during juvenile phase of life cycle.

Species	Common name	Utilization
<i>Acanthopagrus berda</i>	river bream, slimjannie	angling, food
<i>Ambassis gymnocephalus</i>	bald glassy, kaalkop-glasvis	prey
<i>A. natalensis</i>	slender glassy, slank glasvis	prey
<i>A. productus</i>	longspine glassy, langstekel-glasvis	prey
<i>Caranx sexfasciatus</i>	bigeye kingfish, grootoog-koningvis	angling, food
<i>Chanos chanos</i>	milkfish, melkvis	food, prey
<i>Elops machnata</i>	ten-pounder, tienponder, springer	angling, food
<i>Hyporhamphus capensis</i>	Knysna halfbeak, Knysna-halfbek	prey
<i>Lichia amia</i>	leervis	angling, food
<i>Lithognathus lithognathus</i>	white steenbras, witsteenbras	angling, food
<i>Liza macrolepis</i>	largescale mullet, grootskub-harder	food, prey
<i>Monodactylus argenteus</i>	Natal moony, Natalse maanvis	food, prey
<i>M. falciformis</i>	Cape moony, Kaapse maanvis	food, prey
<i>Mugil cephalus</i>	flathead mullet, platkop-harder	food, prey
<i>Myxus capensis</i>	freshwater mullet, varswaterharder	food, prey
<i>Pomadasys commersonni</i>	spotted grunter, spikkel-knorder	angling, food
<i>Rhabdosargus holubi</i>	Cape stumpnose, Kaapse stompneus	angling, food
<i>R. sarba</i>	Natal stumpnose, Natalse stompneus	angling, food
<i>Terapon jarbua</i>	thornfish, doringvis	angling, prey
<i>Thyrssa vitrirostris</i>	orangemouth glassnose, oranjelbeelglasvis	food, prey
<i>Valamugil cunnesius</i>	longarm mullet, langarm-harder	food, prey
<i>V. robustus</i>	robust mullet, wilde harder	food, prey

Category III: Species whose juveniles occur mainly in estuaries, but are also found at sea.

Species	Common name	Utilization
<i>Carcharhinus leucas</i>	Zambesi shark, Zambesihaai	angling, food
<i>Gerres acinaces</i>	smallscale purse-mouth, kleinskubplooi-bek	food, prey
<i>G. filamentosus</i>	threadfin purse-mouth, sweepvinnplooi-bek	food, prey
<i>G. oblongus</i>	oblong purse-mouth, langwerpige plooi-bek	food, prey
<i>G. oyena</i>	slenderspine purse-mouth, slankstekel-plooi-bek	food, prey
<i>G. rappa</i>	evenfin purse-mouth, gelykvin-plooi-bek	food, prey
<i>Hepsetia breviceps</i>	Cape silverside, Kaapse spierinkie	prey
<i>Heteromycteris capensis</i>	Cape sole, Kaapse tongvis	prey
<i>Liza alata</i>	diamond mullet, diamant-harder	food, prey
<i>L. dumerili</i>	groovy mullet, keepharder	food, prey
<i>L. tricuspidens</i>	striped mullet, streep-harder	angling, food, prey
<i>Ophisurus serpens</i>	sand snake-eel	prey
<i>Pomadasys hasta</i>	javelin grunter, spies-knorder	angling, food
<i>Pristis pectinata</i>	largetooth sawfish, groot-tand-saagvis	angling, food
<i>Rhabdosargus thorpei</i>	bigeye stumpnose, grootoog-stompneus	angling, food
<i>Scomberoides lysan</i>	doubledotted queenfish, dubbelgekolde koninginvis	angling, food
<i>Solea bleekeri</i>	blackhand sole, swarthand-tongvis	prey
<i>Sphyrna barracuda</i>	great barracuda, groot barrakuda	angling, food
<i>S. jello</i>	pickhandle barracuda, piksteel-barrakuda	angling, food

Continued on next page.

ting,¹³ rotenone poisoning of intertidal rocky-pool ichthyofauna, near-shore sampling using beam trawls, try-nets and plankton nets, as well as SCUBA surveys of the ichthyofauna of sub-tidal reefs down to 30 m. In addition, a small-mesh trawling survey was conducted in the depth range

6–90 m between Algoa Bay in the east (33°53'S, 26°28'E) and St Sebastian Bay (34°06'S, 29°09'E) in the west.¹⁴

The inshore trawling survey revealed the occurrence of 12 species of estuarine-associated fishes over soft substrates and the SCUBA survey an additional four species

over rocky bottoms on the Cape south coast.¹⁴ These valuable new data together with the results of other near-shore research currently being prepared for publication, have enabled the authors to divide South Africa's fish fauna associated with estuaries into six categories according to the extent of

Continued from previous page.

Category IV: Species whose juveniles occur mainly at sea, but are also abundant in estuaries.

Species	Common name	Utilization
<i>Argyrosomus hololepidotus</i>	kob	angling, food
<i>Arothron immaculatus</i>	blackedged blaasop, swartrand-blaasop	prey
<i>Caffrogobius nudiceps</i>	barehead goby, blesdikkop	prey
<i>Caranx ignobilis</i>	giant kingfish, reus-koningvis	angling, food
<i>Crenimugil crenilabris</i>	fringelip mullet, fraaingbek-harder	food, prey
<i>Diplodus sargus</i>	blacktail, dassie	angling, food
<i>Hemirhamphus far</i>	spotted halfbeak, gevlekte halfbek	prey
<i>Hilsa kelee</i>	kelee shad, kelee-haring	prey
<i>Johnius belengerii</i>	minikob, mini-kob	prey
<i>Leiognathus equulus</i>	slimy, slymvis	prey
<i>Liza richardsoni</i>	southern mullet, suiderlike-harder	food, prey
<i>Lutjanus fulviflamma</i>	dory snapper,	angling, food
<i>Omobranchus woodii</i>	kappie blenny, kappie blienne	prey
<i>Pelates quadrilineatus</i>	trumpeter, trompeter	food, prey
<i>Platycephalus indicus</i>	bartail flathead, (river gurnard), balkstert-platkop	angling, food
<i>Pomatomus saltatrix</i>	elf	angling, food
<i>Pranesus pinguis</i>	hardyhead silverside, klipkop-spierinkie	food, prey
<i>Rhabdosargus globiceps</i>	white stumpnose, witstompneus	angling, food
<i>Sarpa salpa</i>	strepie	angling, food
<i>Scomberoides commersonianus</i>	largemouth queenfish, grootbek-koningvis	angling, food
<i>Sillago sihama</i>	silver sillago, silwer sillago	angling, food, prey
<i>Stolephorus commersoni</i>	tropical anchovy, tropiese ansjovis	prey
<i>S. holoden</i>	thorny anchovy, doring-ansjovis	prey
<i>Syngnathus acus</i>	longnose pipefish, langneus-pypvis	prey
<i>S. djarong</i>	belly pipefish, boepens-pypvis	prey
<i>Tachysurus feliceps</i>	sea catfish, seebaber	angling, food
<i>Tylosurus leiurus</i>	needlefish, naaldvis	angling, food
<i>Valamugil buchanani</i>	bluetail mullet, bloustert-harder	food, prey

Category V: Species whose juveniles occur at sea, but sometimes stray into estuaries.

Approximately 100 species of marine inshore fishes fall into this category.

Category VI: Miscellaneous species not dependent on estuaries.

(a) Freshwater species whose juveniles sometimes stray into estuaries. A total of 14 species fall into this group.

(b) Other species. A total of 11 species fall into this group. Some breed in both estuaries and fresh water (e.g. *Glossogobius giurus*, tank goby, tenk-dikkop; *Oreochromis mossambicus*, Mocambique tilapia, blou-kurper).

their dependence upon them. The species included in each category, their common names and an indication of whether they are utilized for angling, for human food or as prey by larger fish and bird predators, are set out in Table 1.

Category I comprises eight species which are dependent upon estuaries for their entire life cycles. Severe degradation of South African estuaries could threaten the extinction of these fishes in our waters.

These species are all small in size and include gobies, a mudhopper, a whitebait, and the Knysna seahorse (Fig. 1). Although of no direct significance for angling or food, they are eaten by predatory fish and birds. As a result they form an important part of the estuarine food web and losses in population or their extinction would have adverse ecological consequences. The reduced abundance of larger predatory angling fish in estuaries would be one such consequence.

Category II comprises 22 species which are dependent on estuaries during the juvenile phase of their life cycles and whose survival in South African waters is determined by the existence of ecologically viable

estuaries along our coast. Angling fish in this category (Fig. 3) are the spotted grunter, white steenbras, leervis, ten-pounder, Cape and Natal stumpnoses, a kingfish and the river bream. These fish also constitute a valuable food resource, as do an additional nine non-angling species that include the

milkfish and five species of mullet (Fig. 2). The remaining species are not directly exploited by man but are integral to the food web and are preyed upon by larger angling fish.

Category II also includes an additional four species that are dependent upon

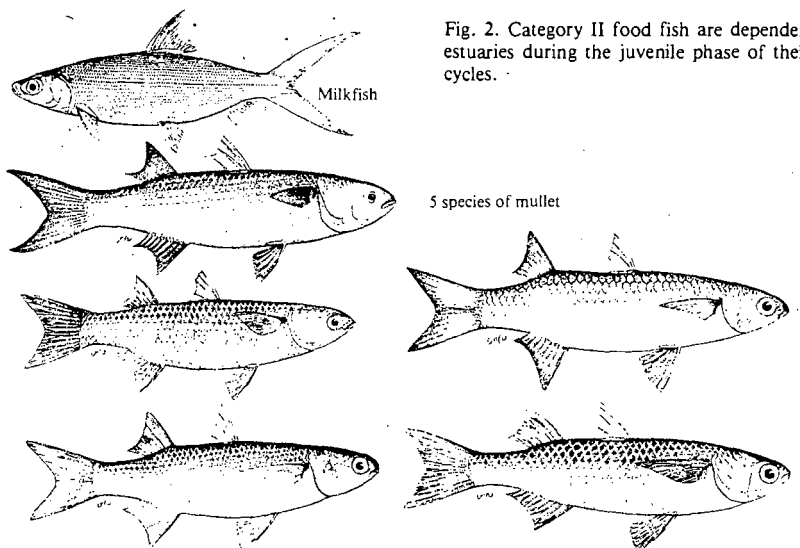


Fig. 2. Category II food fish are dependent on estuaries during the juvenile phase of their life cycles.

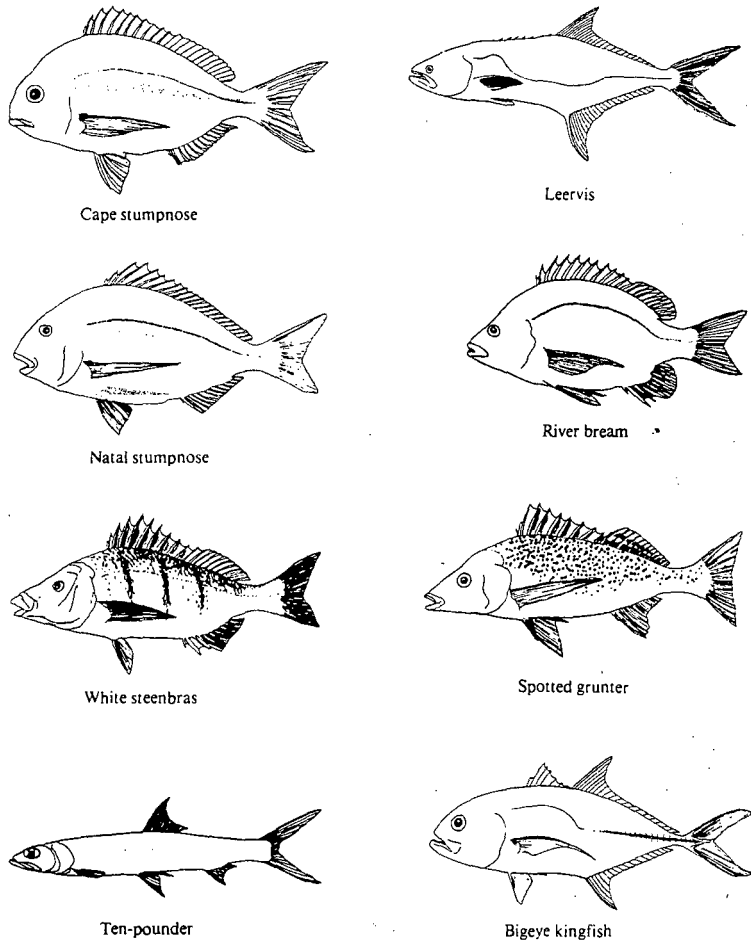


Fig. 3. Category II angling fish are dependent on estuaries during the juvenile phase of their life cycles.

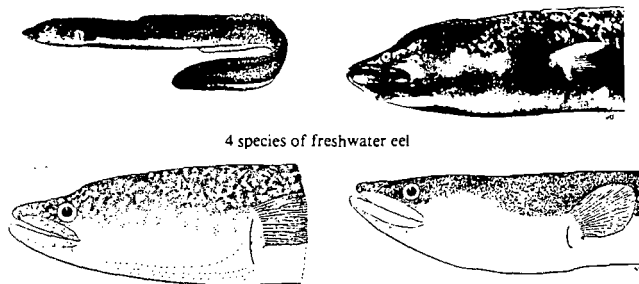
estuaries for short periods during their life cycles. These are the freshwater eels, whose small elvers pass through estuaries in their migration from the sea into South African rivers, and which again occur in estuaries as adults during their migration back to sea to spawn (Fig. 4). The degradation of our estuaries would have serious consequences for these eel populations.

Category III includes 19 species whose juveniles are found mainly in estuaries but also at sea (Fig. 5). As a result these species are not entirely dependent on estuarine nurseries and, although they would survive in South African waters if extensive estuarine degradation occurred, their

numbers would be drastically reduced. Angling species comprise a grunter, a stumpnose; a barracuda, a queenfish, a shark and a sawfish. Food fish include five species of pursemouth and three species of mullet, which are also taken by predatory fish and birds.

Category IV comprises 28 species whose juveniles are found mainly at sea, but are also abundant in estuaries. Although estuaries are not essential for their survival, these areas do make a contribution to the adult stocks because juveniles that grow up in estuaries migrate to sea to join the breeding populations.

Some of the better known angling species



4 species of freshwater eel

Fig. 4. Category II includes the eels which depend on estuaries when they migrate between South African rivers and the sea.

in this category are the kob, elf, blacktail, white stumpnose, giant kingfish and large-mouth queenfish. An additional 11 species are also of value as human food, while the remaining 11 prey species are not directly utilized by man.

Category V consists of approximately 100 species whose juveniles occur at sea and sometimes stray into estuaries. For these fish the estuarine environment is of no particular significance.

Category VI comprises 25 species which are associated with fresh water and whose juveniles are seldom found in estuaries. These areas are consequently of no significance to the survival of these fishes.

The above analysis of the dependence of fish on estuaries can be summarised as follows:

Category	No. of species	Relationship to South African estuaries
I	8	Dependent on estuaries during entire life cycle.
II	22	Dependent on estuaries during juvenile phase of life cycle.
	4	Dependent on estuaries during migration between rivers and the sea.
III	19	Largely, but not entirely, dependent on estuaries during juvenile phase of life cycle.
IV	28	Benefit from, but only partially dependent on, estuarine nursery areas.
V	c. 100	Stray into estuaries from the sea, not dependent on estuaries.
VI	25	Miscellaneous species not dependent on estuaries.

From this summary it is apparent that 81 species of fish are wholly or partially dependent on South African estuaries.

Discussion

Of the 81 species which depend on estuaries, 29 are taken by anglers and an additional 21 species are suitable for human food. Unfortunately, estuarine and marine inshore catch statistics for these species are not available, and the potential catch is also unknown. Consequently, we are unable to assess the value of the catch to the South African economy.

Equally important to consider is the rand value of activities associated with angling for sport in estuaries, such as the manufacture of boats, sales of outboard motors, fishing tackle, protective clothing and bait, the hire of accommodation, the sale of local real estate, and so on. Also relevant but even more difficult to quantify in monetary terms is the benefit of fishing as a healthy, outdoor recreational activity which provides relaxation and escape from the tensions of modern urban life.

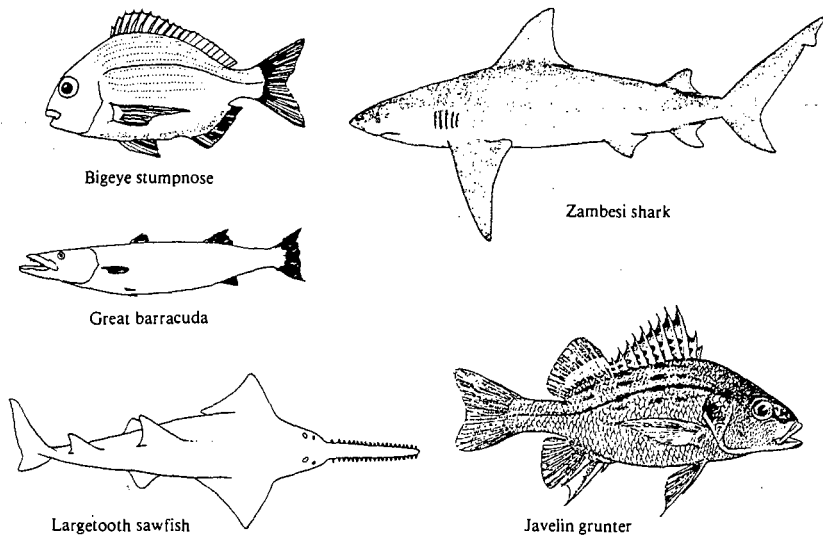


Fig. 5. Category III angling fish are largely dependent on estuaries during the juvenile phase of their life cycles.

Although it is not possible to place a value on these various factors, estuarine fish are undoubtedly of great significance to the national economy. Furthermore, as this resource is largely dependent on estuaries, it is in the national interest to manage estuarine systems so as to maintain their biological productivity and ecological diversity. This means that conservation of estuaries must be accorded a high priority when assessments are made of the merits of proposed development projects, many of which have quantifiable short-term benefits, but may cause degradation of the estuarine environment and its fauna in the longer term.

The relevance of the above is emphasized by the fact that extensive degradation of South African estuaries has already taken place,^{13,14} as a result of ignorance and disregard for the consequences of man's activities in and around these sensitive systems. One common practice known to be detrimental to the fish fauna involves the artificial opening of estuary mouths, thereby interfering with the natural cycle of migration of juveniles into their nursery areas, and in their premature release to the sea. Another particularly detrimental practice involves encroachment onto wetlands adjacent to estuaries by agriculture, industry and transport systems, thus reducing the amount of plant detritus available to the base of the estuarine food web, and consequently reducing the size of the fish populations that can be supported. The impairment of normal tidal water exchange and the damming of flood waters by embankments and bridges also have adverse ecological consequences for estuaries, and consequently for their fishes.

We predict that if these and other forms of degradation continue there will be a continuing decline in the biological viability of South Africa's estuaries. The fish fauna will

consequently become increasingly impoverished, it will provide less food and fewer opportunities for recreation for our growing population. The fishing tackle, boating, accommodation and real estate industries will also suffer.

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