Spawning of riverbream, *Acanthopagrus berda*, in Kosi estuary

P.A. Garratt

Oceanographic Research Institute, P.O. Box 10712, Marine Parade, Durban, 4056 Republic of South Africa

Received 23 January 1992; accepted 27 July 1992

The spawning habits of *Acanthopagrus berda*, an estuary-dependent seabream (Family Sparidae), are investigated. Spawning takes place in the Kosi estuary at night and eggs are transported out to sea during peak ebb tides. There is a preponderance of males in the spawning aggregation (sex ratio — 8,8 : 1 m/f) and indirect evidence suggests that males and females are continually recruiting to the aggregation, spawning, and moving back up into the lakes so that there are no more than 2000 individuals at the mouth at any one time. Sexed fish were tagged in an effort to produce evidence of protandrous sex change in this species. It is noted that the degradation of estuarine habitats could have serious effects on an estuarine-dependent species which has developed a spawning strategy of this nature.

Die broeigewoontes van *Acanthopagrus berda*, 'n riviermond-afhanklike seebras (Familie Sparidae) is nagevors. In die Kosi tregtermonding vind kuitskiet in die nag plaas en die eiers word gedurende piek ebgetye na die see weggevoer. By die broeisameloop is daar oorwegend mannetjies (geslagsverhouding — 8,8 : 1 m/v) en onregstreekse bewyse toon dat mannetjies en wyfies voortdurend by die sameloop aansluit, broei en dan na die mere terugbeweeg, sodat op 'n gegewe tyd daar nooit meer as 2000 individue by die tregtermond voorkom nie. Visse waarvan die geslag bepaal is, is gemerk in 'n poging om bewyse van protandriese geslagsverandering by die spesie te vind. Daar word kennis geneem dat die agteruitgang van die tregtermondhabitatte 'n ernstige uitwerking sal hê op riviermond-afhanklike spesies wat 'n broeistrategie van dié aard ontwikkel het.

The riverbream *Acanthopagrus berda* is a fairly small euryhaline, estuary-dependent seabream (Family Sparidae) (Begg 1978; van der Elst 1988) which is widespread in the Indo–West Pacific region, occurring from South Africa to India and extending to Japan, the East Indies and nothern Australia (Kuronuma & Abe 1972; Fischer & Bianchi 1974, 1984; Masuda, Kamaoko, Araga, Uyeno & Yoshino 1984; Smith & Heemstra 1986). Lengths of 450–750 mm have been recorded in Japan (Masuda *et al.* 1984), Kuwait (Kuronuma & Abe 1972) and South Africa (van der Elst 1988), but few exceed 300 mm in South African waters.

Considering the wide distribution of this species, surprisingly little is known about its biology. In South Africa its presence and status in various estuarine systems has been noted (Wallace 1975; Begg 1978; Grindley & Heydorn 1979), including a particularly notable decline, but little work has been directed specifically at its life history here or elsewhere. Spawning, based on macroscopic gonad staging and GSI values, is known to occur between May–August, with peak spawning in May and June (Wallace 1975; Kyle 1986). Wallace (*op. cit.*) noted an increase in abundance of *A. berda* near the mouth of the St Lucia estuary between April and July and suggested that spawning occurs close inshore in the vicinity of the mouth. Kyle (1986) recorded increased trap catches in the Kosi estuary which coincided with an annual migration to the mouth during the spawning season and, using tagging, estimated the number of fish moving to the mouth each year to be in the region of 45 000. As recruitment from the sea into the estuarine systems of the east coast is well documented (Begg 1978; Kyle 1986; van der Elst 1988), it has been assumed that spawning occurs in the sea and that mature adults move out into inshore waters to spawn.

The aggregation of large numbers of *A. berda* in spawning condition at Kosi mouth, coincidental with activity at the surface and the collection of large volumes of eggs in plankton nets deployed for prawn larvae (A.T. Forbes, University of Natal, pers. comm. 1989), prompted an investigation into the possibility that *A. berda* spawn in the mouth of this estuary and not out at sea. As *A. berda* is suspected of being a protandrous hermaphrodite (based on histological evidence and the fact that this reproductive style has been reported for other members of the genus (Kinoshita 1939; Abu-Hakima 1984; Chao & Liao 1984; Pollock 1985), a further consideration was that *A. berda* could represent an ideal species to study in terms of spawning behaviour and the reproductive strategy of protandrous seabreams. Moreover, the Kosi estuary is the only estuary along the east coast of South Africa which has sufficiently clear water for such a study.

Seabreams form an important component of the linefish resources of southern Africa and much work has been focussed on them in recent years. Emerging from this, and work elsewhere, is the fact that many species change sex during their lives. There appear to be two reproductive styles in the family — sex change (protogyny and protandry) and gonochorism (Buxton & Garratt 1990) — and there has been considerable debate as to whether or not fishes which change sex require special management. This has prompted further research into the reproductive styles of seabreams, especially their spawning behaviour and the disruptive effects that fishing may have on spawning shoals. *Acanthopagrus berda* may be one of only three protandrous seabreams in southern Africa, the other two being the Natal stumpnose, *Rhabdosargus sarba* (Yeung & Chan 1987) and the west coast steenbras, *Lithognathus aureti* (Lucks 1970).

The aims of this investigation were thus to determine the size and sex composition of the aggregation at Kosi mouth; to determine whether or not *A. berda* spawns in the mouth and, if so, when and where spawning takes place; and to tag sexed fish in order to establish whether or not this species changes sex.

Methods

The number of *A. berda* in the aggregation at Kosi mouth was estimated by divers. Sampling extended from one neap tide through a spring tide (full moon) to the following neap tide. In order to identify *A. berda* eggs, eggs and sperm were removed from ripe fish which were speared by divers and the eggs were artificially fertilized. The larvae were raised through to the first feeding stage and were described at 4, 30, 54 & 78 h after hatch.

To determine the time and location of spawning, surface plankton samples were taken at set intervals on outgoing and incoming tides (half hour and one hour respectively) from two dinghies, one moored below the reef at the mouth (Station A) and the other above (Station B) (Figure 1). Sampling was sometimes staggered, reducing the interval between samples to 15 min. Samples were collected by streaming the plankton nets behind the moored dinghies, allowing tidal flow to maintain them horizontally. Flow-meters were used to determine the flow of water passing through the 200 μm plankton nets. Three plankton-sampling regimes were selected. The first consisted of 10-min 'tows' every 20 min for the duration of both outgoing tides (day and night) every third day. The second consisted of 10-min 'tows' every 20 min for the first 2 h after the turn of the tide on all other outgoing tides. The third consisted of (i) five 10-min 'tows' taken at 20-min intervals on incoming tides (day and night) immediately prior to slack water at high tide on every third day, and (ii) 10-min 'tows' taken at 50-min intervals during an entire incoming tide.

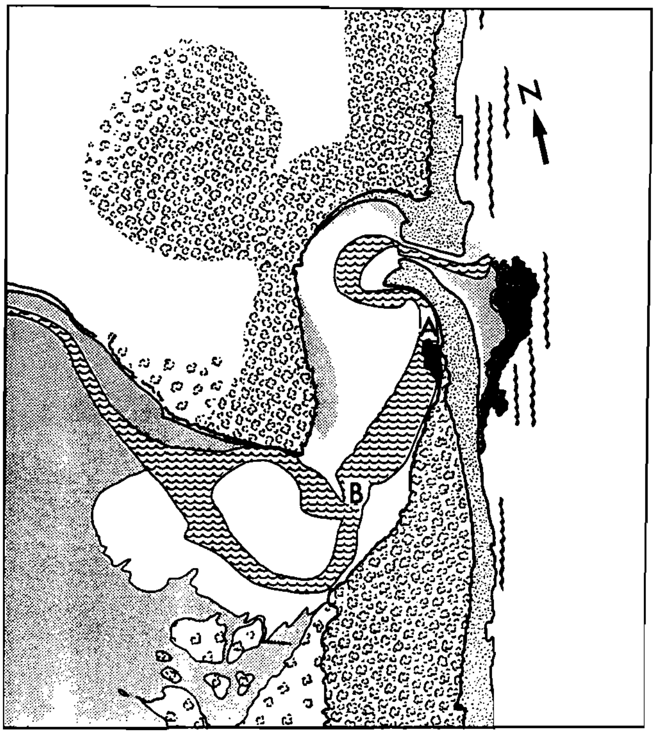

Figure 1 Study site at Kosi Mouth, showing the reef inside the mouth and the two sampling stations (A & B) at which plankton samples were taken. ▒ beach; ■ reef; ☰ main channel; □ sand banks exposed at low tide; ▦ shallow water at low tide.

The volume of eggs collected in each sample was recorded and the percentage contribution of each species was determined from subsamples once the species had been identified. The number of *A. berda* eggs per millilitre was determined and a subsample from each 'tow' was placed in an incubation jar to check their identification.

Fish caught by line were tagged with colour coded dart tags (Hallprint PDS) to monitor movement in the area and to determine if the fish at the mouth represented one or more shoals. These fish were also sexed, by stripping, in an effort to produce evidence of sex change, if it occurs in this species. The size composition and sex ratio of the shoal was determined through netting, line fishing and spearing, and attempts were made to catch/spear any previously tagged and sexed fish to determine if they had changed sex.

Results

Two divers, who made repeated dives throughout the study period, estimated the number of *A. berda* in the vicinity of the reef at the mouth to be in the region of 1000–1500 fish. No juveniles were present. Originally it was thought that there may be two discrete shoals, the second being situated some 300 m up the estuary. Colour-coded tags showed, however, that there was mixing amongst these fish and that the aggregation could be considered as one shoal. The sex ratio of the shoal was determined from samples caught by line, nets and traps and random spearing (Table 1).

The fish ranged in size from 215–320 mm fork length and the sex ratio (all capture methods) was 8,8 : 1 males to females. All males were in ripe-running condition and 295 were tagged and released. Several fish with tags from the previous year were seen and three were recaptured. Each was a male and had not changed sex.

The live eggs and early larvae of *A. berda* are distinctive from all other seabreams because of the presence of an oil globule which is heavily pigmented with yellow melanophores around its entire surface (Figure 2a, b, c) (A.D. Connell, CSIR Durban, pers. comm. 1991). Another distinctive larval feature is four clusters of yellow melanophores in the head region, two in front of the eyes and two behind (Figure 2b).

The first plankton-sampling regime revealed that *A. berda* spawn in the estuary above the reef and in its immediate vicinity. Spawning occurs only at night (Table 2, Figure 3) on outgoing tides for 1–3 h, beginning 1 h after the turn of the tide. The flow meter at Station B malfunctioned, so the

Table 1 The number and sex ratio of *A. berda* sampled from the spawning aggregation at the mouth of Kosi estuary

Method of capture	Number of males	Number of females	Total number	Sex ratio (m/f)
Line fishing	260	30	290	8,7 : 1
Spear	66	8	74	8,3 : 1
Seine nets & traps	36	3	39	12,0 : 1
Total	362	41	403	8,8 : 1

results are not directly comparable with those at Station A, but the pattern was clearly the same (Figure 4). Generally the volume of eggs collected at Station A was greater than that at Station B (Table 2), indicating that more spawning occurred between the two stations than above Station B. One day after the spring tide, however, greater volumes of eggs were collected at Station B.

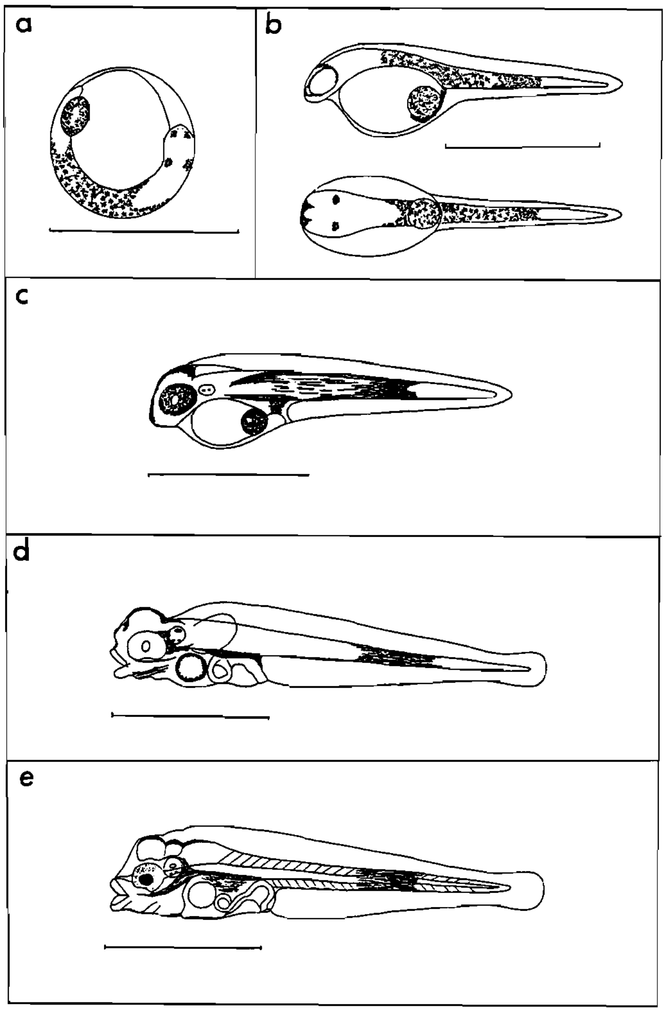

Figure 2 Egg and early larval development of *A. berda* showing characteristic yellow melanophore patterns: a = egg 29 h after fertilization; b, c, d, e = larvae 4, 30, 54 & 78 h post-hatch. (Scale bar = 1 mm).

The second sampling regime showed that *A. berda* spawned virtually every night between, and including, spring and neap tides on waxing and waning moons. Spawning was suspended only when outgoing tides at night occurred 2–3 h before sunrise (Figure 3) and the second outgoing tide occurred before sunset. The third sampling regime showed that insignificant numbers of eggs enter the estuary on incoming tides and that no *A. berda* eggs are amongst them. It was also determined from these samples that *A. berda* do not spawn earlier in the tidal regime, which would allow the eggs to be transported up the estuary and back down again.

Using the number of eggs per unit of water passing through the nets (first sampling regime) it was determined that spawning was more intense after the spring tide (Table 2, Figures 3 & 4).

Discussion

The successful artificial fertilization of *A. berda* eggs, and the rearing of their larvae, was critical to this study for identification purposes, especially as a second species, the large-scale mullet (*Liza macrolepis*), was also spawning in the estuary at the time, producing large quantities of eggs. The eggs and early developmental stages of *A. berda* have not previously been described and, while the descriptions presented in this paper are of live specimens which are not directly comparable to fixed specimens normally used for identification purposes, they are necessary for studies of this nature and can be added to a growing collection of such descriptions for species in this region (A.D. Connell, unpubl. data). These early stages are, in any case, not normally included in ichthyoplankton studies. Fixed eggs cannot be identified as they are denatured and post-hatch larvae are usually fragmented beyond recognition during the netting process.

The results presented above have shown that *A. berda*

Table 2 The occurrence and mean numbers of *A. berda* eggs sampled at each station on both outgoing tides every third day (– = no sampling/data)

		Eggs present */absent 0		Mean # eggs / sample		Mean # eggs.m^{-3}	# samples	
Date	Ebb tides	Stn A	Stn B	Stn A	Stn B	Stn A	Stn A	Stn B
03.06.90	1410–2013	0	–	0	–	0	7	–
	0130–0800	*	–	338	–	160	6	–
06.06.90	0350–1000	0	0	0	0	0	12	12
	1630–2220	*	*	165	135	25	11	12
08.06.90			SPRING	TIDE				
09.06.90	0530–1130	0	0	0	0	0	9	8
	1800–2400	*	*	511	2594	81	10	10
12.06.90	0710–1321	0	0	0	0	0	9	8
	1930–0130	*	*	1465	561	363	9	10
15.06.90	0930–1530	–	–	–	–	–	–	
	2200–0320	*	–	1800	–	207	7	–

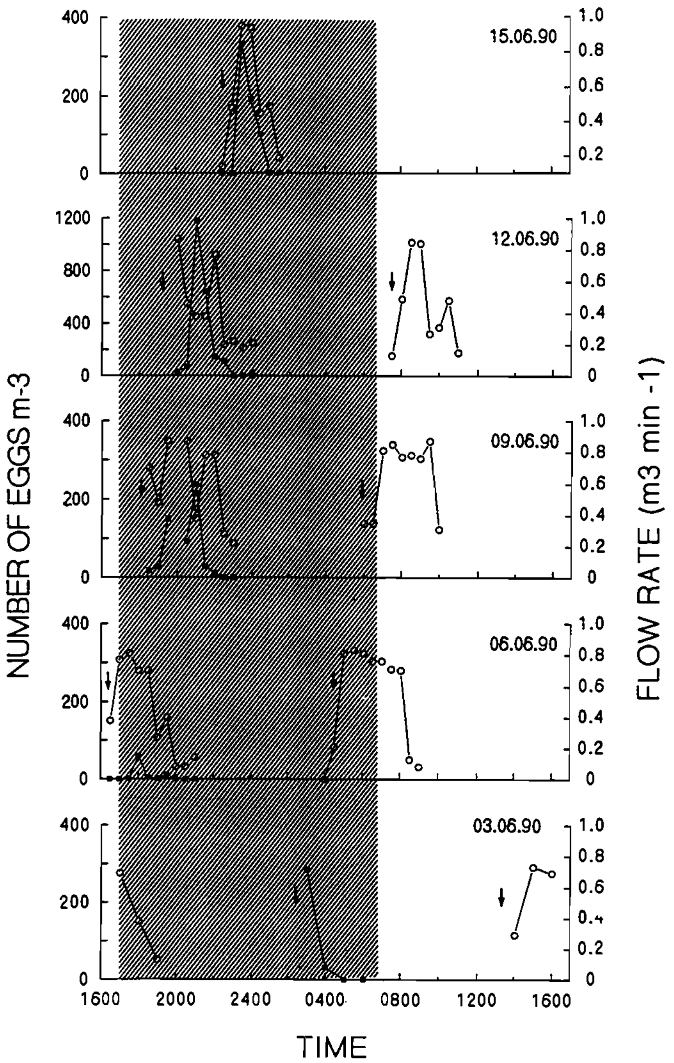

Figure 3 The number of *A. berda* eggs.m^{-3} sampled at Station A (■——■) and the duration of spawning in relation to the turn of the tide (↓), flow rates through the nets during outgoing tides (○——○) and hours of darkness (hatched).

aggregate at Kosi mouth to spawn and that spawning occurs in the estuary at night in the vicinity of the reef. The larger volume of eggs collected at Station B one day after the spring tide indicates that spawning occurred closer to Station B on that occasion and that the eggs had dispersed before they reached Station A. Assuming that flow rates were similar at both stations, this suggests that the spawning shoal had shifted slightly upstream with stronger incoming tidal flow. As the dinghy at Station B was positioned immediately downstream from a deep hole situated near the first bend of the estuary above the reef, some spawning probably occurred in this hole. Larger volumes of eggs at Station A on other occasions, however, suggest that most spawning occurred in the immediate vicinity of the reef.

A spawning strategy has thus developed in which spawning occurs in a relatively sheltered environment and the eggs are transported out into the marine environment during peak ebb tides. Spawning also occurs only at night and is curtailed when outgoing tides approach dawn. This behaviour suggests that the spawning strategy has evolved in response to predation and, as predation on the adults at the mouth can be considered minimal (pers. obs.), the development of nocturnal spawning is most likely in response to predation on their eggs by large numbers of planktivorous teleosts which also aggregate in the mouth during the spawning season. It appears, therefore, that *A. berda* has developed a spawning strategy which has overcome the necessity to move out into the marine environment to spawn and that the assumption made to this effect by previous workers (Wallace 1975; Kyle 1986; van der Elst 1988) is incorrect. A similar transportation of eggs by ebb tides into the marine environment has been assumed, but not shown, for the congeneric *Acanthopagrus australis* (Pollock & Weng 1983).

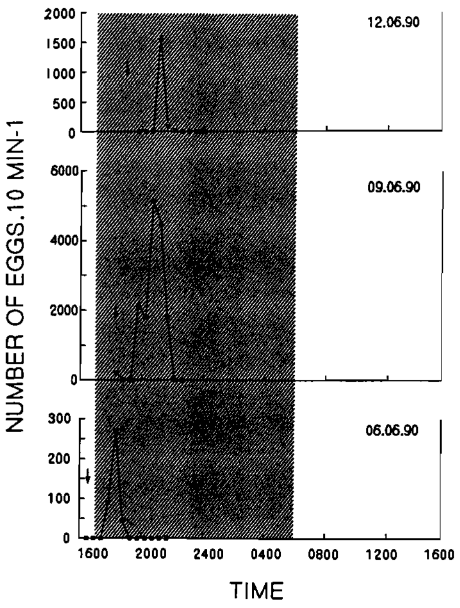

Figure 4 The number of *A. berda* eggs.10 min^{-1} in each plankton haul at Station B and the duration of spawning in relation to the turn of the tide (↓) and hours of darkness (hatched).

Estimations of the size of the aggregation at the mouth each year have been made by several people over a number of years and they have been confirmed by our observations. The fluctuating size of the aggregation (200–1500 individuals) suggests that it does not represent a discrete shoal, as such, but rather that individuals are continually recruiting to it, whilst others are leaving it, throughout the spawning season. Estimates (made from tagging) of the total number of adult fish which move down to the mouth during the months April–July each year support this hypothesis. Trap catches of *A. berda* are fairly constant from one year to the next and estimates of the number of fish moving down to the mouth each year range from 32 000–76 915 (95% confidence limits) (Kyle 1986). Even if this is an overestimate, the fact remains that thousands of *A. berda* move down to the mouth each year, yet the aggregation seldom consists of more than 1500 fish at any one time. It appears, therefore, that both sexes recruit to the aggregation randomly or in groups, remain at the mouth for a limited period, and move back up into the lakes once they have spawned.

The spawning strategy outlined above may be common to the major estuarine systems of Natal and possibly the smaller systems which still function as estuaries (Begg 1978). Analysing monthly gill-net catches in the St Lucia estuary and narrows, Wallace (1975) showed an increase in abundance of *A. berda* at the mouth during April–July. The presence of gravid fish in these samples and in anglers' catches, and the absence of such fish further up in the system, led him to suggest that spawning occurs close inshore in the vicinity of estuary mouths. Similar increases in abundance of spawning fish have been noted in the Richards Bay sanctuary estuary (P.A. Garratt, unpubl. data) and *A. berda* eggs have been recently collected in plankton samples taken from the entrance channel of Durban harbour on outgoing tides, indicating that spawning continues in this system (A.D. Connell, pers. comm. 1991).

Acanthopagrus berda featured prominently in estuarine anglers' catches in earlier years, but several workers have noted a marked decline (Wallace 1975; Begg 1978; Grindley & Heydorn 1979; van der Elst 1988). Begg (1978) ascribed this decline to the degradation of Natal's estuaries and the evidence presented in this paper lends support to this hypothesis: the degradation of this habitat could have serious effects on an estuarine-dependent species which has developed a spawning strategy of this nature. Further support comes from the Kosi estuary itself which is the least disturbed estuary along the Natal coast (Begg 1978). In this system anglers' catches and those made in traditional fish traps have remained fairly constant from one year to the next over a prolonged period (Kyle 1986). *Acanthopagrus berda* has been, and remains, the third most important fish caught in traps in the system.

In order to qualify as a protandrous hermaphrodite, *A. berda* must function (i.e. spawn) as a male for one or more seasons and thereafter function as a female (Buxton & Garratt 1990). Owing to the nature of sparid hermaphrodite gonads, in which male and female components are separated by connective tissue (Atz 1964), there is little direct evidence of sex change in this family. Bimodal size-frequency distributions and sex ratios which differ from unity are evident in many species, but these are not reliable indicators of sex change (Sadovy & Shapiro 1987). Degenerating tissue of the one sex coinciding with the development of tissue of the opposite sex is considered strongly indicative of sex change but it does not constitute direct evidence of sex change. Fluctuations between masculinity and femininity have been recorded in this family (Zohar, Abraham & Gordin 1978). Furthermore, protandry is usually more difficult to diagnose histologically than protogyny (Yeung & Chan 1987). Conclusive evidence of protandrous sex change in sparids is restricted to captive fish, in which individuals have matured as one sex and subsequently functioned as the opposite sex (Zohar *et al.* 1978). It cannot be ruled out, however, that such sex change occurs in response to a captive situation. Tagging of sexed fish can provide conclusive evidence of sex change in wild populations. The results of the tagging exercise will be published in another paper as this aspect of our work will extend over several years.

Acknowledgements

I thank Professor Tony de Freitas and Dr Mike Schleyer for their comments on preliminary drafts and Simon Chater, Derek Arthur, Glen Hyman, David Hlatswayo and Dr Allan Connell who assisted with fieldwork. The Directors and staff of the Kwazulu Bureau of Natural Resources and the Natal Parks Board are gratefully acknowledged for assistance, accommodation and permits to work in the Kosi estuary. Special thanks to Dr Scotty Kyle for his assistance and hospitality. This work was supported by grants from the South African Association for Marine Biological Research and the Council for Scientific and Industrial Research.

References

ABU-HAKIMA, R. 1984. Some aspects of the reproductive biology of *Acanthopagrus* spp. (Family: Sparidae) *J.Fish Biol.* 25: 515–526.

ATZ, J.W. 1964. Intersexuality in fishes. pp. 145–232. In: Intersexuality in vertebrates including man, (eds) A.J. Marshall & C.N. Armstrong. Academic Press, New York.

BEGG, G.W. 1978. The Estuaries of Natal. *Natal Town and Regional Planning Report.* 41: 1–657.

BUXTON, C.D. & GARRATT, P.A. 1990. Alternative reproductive styles in seabreams (Pisces: Sparidae). *Environ. Biol. Fishes* 28: 113–124.

CHAO, NAI-HSEIN & LIAO, I-CHIU. 1984. Status and problems of propagation of marine finfish in Taiwan. *TML Conference Proceedings* 1: 33–49.

FISCHER, W. & BIANCHI, G. (eds). 1974. FAO species identification sheets for fishery purposes. Eastern Indian Ocean and Western Central Pacific (Fishing Area 57). Prepared and printed with the support of the Danish International Development and Agricultural Organization of the United Nations. Vol. 1–4.

FISCHER, W & BIANCHI, G. (eds) 1984. FAO species identification sheets for fishery purposes. Western Indian Ocean (Fishing Area 51). Prepared and printed with the support of the Danish International and Agricultural Organization of the United Nations. Vol. 1–6.

GRINDLEY, J.R & HEYDORN, A.E.F. 1979. Man's impact on estuarine environments. *S. Afr. J. Sci.* 75: 554–560.

KINOSHITA, Y. 1939. Studies on the sexuality of the genus *Sparus* (Teleostei). *J. Sci. Hiroshima Univ.* BI 7: 25–37.

KURONUMA, K & ABE, Y. 1972. Fishes of Kuwait. Dai Nippon Printing Co. Ltd., Tokyo. 123pp. 20 plates.

KYLE, R. 1986. Aspects of the ecology and exploitation of the fishes of the Kosi Bay system, KwaZulu, South Africa. Ph.D. thesis, University of Natal, Pietermaritzburg. 245pp.

LUCKS, D.K. 1970. Aspects of the biology of the white steenbras (*Lithognathus aureti* Smith, 1962) from the Sanwichhawe estuary. M.Sc. thesis, University of Stellenbosch, Stellenbosch. 49pp.

MASUDA, H., AMAOKA, K., ARAGA, C., UYENO, T. & YOSHINO, T. (eds.) 1984. The fishes of the Japanese archipelago. Tokai University Press. 437pp.

POLLOCK, B.R. 1985. The reproductive cycle of yellowfin bream *Acanthopagrus australis*. *J. Fish Biol.* 26: 301–311.

POLLOCK, B.R. & WENG, H. 1983. The seasonal occurrence of postlarval stages of yellowfin bream, *Acanthopagrus australis* (Gunther), and some factors affecting their movement into an estuary. *J. Fish Biol.* 22: 409–415.

SADOVY, Y & SHAPIRO, D.Y. 1987. Criteria for the diagnosis of hermaphroditism in fishes. *Copeia.* 1987: 136–156.

SMITH, M.M. & HEEMSTRA, P.C. (eds) 1986. Smith's sea fishes, Macmillan, Johannesburg. 1–1046pp.

VAN DER ELST, R.P. 1988. A guide to the common sea fishes of Southern Africa, (2nd edn.). C. Struik, Cape Town, 398pp.

WALLACE, J.H. 1975. The estuarine fishes of the east coast of South Africa. III Reproduction. *Invest. Rep. Oceanogr. Res, Inst.* Durban 41: 1–51.

YEUNG, W.S.B. & CHAN, S.T.H. 1987. The gonadal pattern of the protandrous sex-reversing fish, *Rhabdosargus sarba* (Teleosteri: Sparidae). *J. Zool., Lond.* 212: 521–532.

ZOHAR, Y., ABRAHAM, M. & GORDIN, H. 1978. The gonadal cycle of the captivity-reared hermaphroditic teleost *Sparus aurata* (L.) during the first two years of life. *Ann. Biol. Anim. Biochem. Biophys.* 18: 877–882.