S. Afr. J. mar. Sci. 18: 137–145
1997

INFLUENCE OF PREY AVAILABILITY ON THE DISTRIBUTION OF DUSKY KOB *ARGYROSOMUS JAPONICUS* (SCIAENIDAE) IN THE GREAT FISH RIVER ESTUARY, WITH NOTES ON THE DIET OF EARLY JUVENILES FROM THREE OTHER ESTUARINE SYSTEMS

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The stomach contents of 391 juvenile dusky kob *Argyrosomus japonicus* (23–805 mm total length, *TL*) from the Great Fish River estuary were analysed. Early juveniles (<50 mm *TL*) fed predominantly on mysids and calanoid copepods. As the juveniles increased in size, copepods were replaced by teleost prey, but mysids remained an important dietary component of all dusky kob <600 mm *TL*. Teleosts were the principal prey of dusky kob >100 mm *TL*, but the dominant species varied with predator size: early juveniles of 100–149 mm *TL* preyed mostly on the late larvae and early juveniles of other fish species, particularly the Cape stumpnose *Rhabdosargus holubi*; juveniles of 150–400 mm *TL* fed largely on early juvenile mugilids and on the small, pelagic estuarine round herring *Gilchristella aestuaria*; juvenile dusky kob of >400 mm *TL* fed on several teleost species, including early juvenile conspecifics, but their most important prey item was *G. aestuaria*. Based on the distribution patterns of *A. japonicus* and their predators and prey in the Great Fish River estuary, it is concluded that predator avoidance and prey availability determine the spatial distribution of early juveniles in estuaries, and that the distribution patterns of larger juveniles (>400 mm *TL*) depend on those of their principal prey. Important prey items of early juvenile from three other estuarine systems included calanoid copepods, mysids, insects, amphipods and swimming prawns. The impact of reduced freshwater inflow on the abundance of the principal prey items of *A. japonicus*, and on the nursery potential of estuaries, is discussed.

The dusky kob *Argyrosomus japonicus* is a large sciaenid (maximum size 1.8 m and 75 kg) found on the east coast of southern Africa from Cape Point to Moçambique (Griffiths and Heemstra 1995), along the southern seaboard of Australia between North West Cape and the Burnette River (Kailola *et al*. 1993, Starling 1993), and from Hong Kong northwards along the Chinese coast to southern Korea and Japan (Trewavas 1977). Until recently, this valuable commercial and recreational species was misidentified as *A. hololepidotus* in southern Africa and in Australia, and in South Africa it was also confused with a newly described species, *A. inodorus* (Griffiths and Heemstra 1995).

A recent study on the life history of *A. japonicus* on the east coast of South Africa revealed that adults (>1 070 mm total length, *TL*) occur mainly in the sea to depths of approximately 100 m; that early juveniles (30–150 mm *TL*) recruit into estuaries at about 30 mm; and that juveniles (150–1 070 mm *TL*) are found both in estuaries and in the surrounding surf zone, but not farther offshore (Griffiths 1996). Juvenile dusky kob are found from the head to the mouth regions of estuaries, but those >400 mm *TL* are more abundant in the middle and lower reaches (Griffiths 1996). The factors which determine the distribution patterns of juveniles in estuaries are, however, poorly understood. The distribution of early juveniles has only been studied in two estuaries, with unequivocal results. In the Hawksbury River estuary (Australia) they are most abundant in the middle reaches where salinities are $\pm 12 \times 10^{-3}$ (Gray and McDonall 1993), but in the Great Fish River estuary (South Africa) they are found predominantly in the head region where salinity is $0–4 \times 10^{-3}$ (Griffiths 1996, Ter Morshuizen *et al*. 1996).

It is generally accepted that estuaries are important nurseries for fish because they provide both protection from predators and large quantities of suitable food. Consequently, it is possible that prey availability could play an important role in the spatial distribution of dusky kob in estuaries. The objectives of the present study were therefore to document the diet of the complete size range of *A. japonicus* (26–813 mm *TL*) found in the Great Fish River estuary, and to compare the axial distribution patterns of early and late juveniles in this system with those of their prey.

The diet of *A. japonicus* has previously been studied (as *A. hololepidotus*) in six other South African estuaries (Whitfield and Blaber 1978, Marais 1984, Coetzee and Pool 1991) and in one in Australia (Hall 1986), but all those studies were based on gill-netted specimens (>205 mm *TL*) and therefore did not include early juveniles. Because the present study represents the

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Manuscript received: October 1997

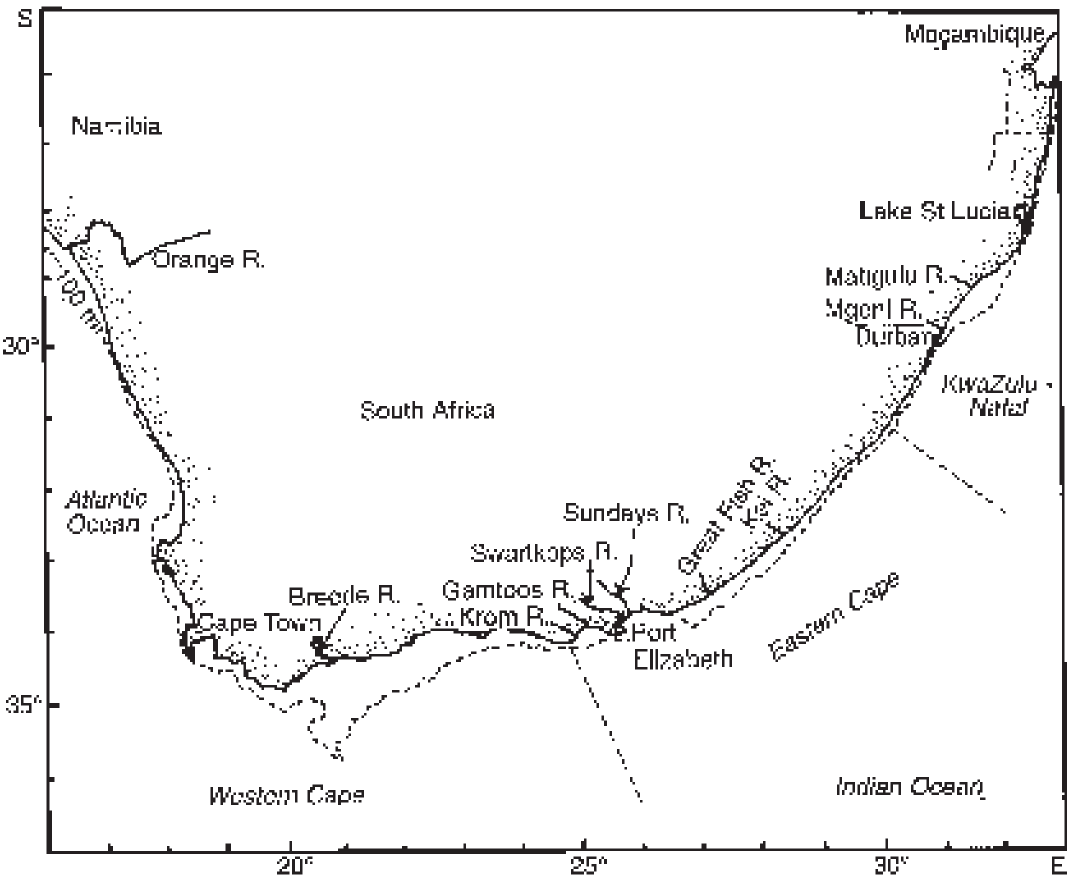

Fig. 1: Map of South Africa, showing the location of the four estuaries from which stomach contents of *A. japonicus* were obtained, and other localities mentioned in the text

first description of the diet of early juvenile *A. japonicus*, information on the stomach contents of specimens obtained opportunistically from the Mgeni and Matigulu estuaries in northern KwaZulu-Natal, and from the Kei River estuary in the Eastern Cape, is included to gain a broader insight into the food requirements of this life history phase. The impact of reduced freshwater inflow on the abundance of primary prey organisms and on the nursery potential of South African estuaries is also discussed.

MATERIAL AND METHODS

The Great Fish River (Fig. 1) is tidal for about 15 km and the farthest extent of saline water ($\geq 1 \times 10^{-3}$) at spring tide may vary from 3 to 10 km from the mouth, depending on river flow (Ter Morshuizen 1996). Dusky kob were caught at various localities between the head and the mouth of the estuary, using both beach-seine and hook-and-line sampling methods, during the period 1990–1993 (Griffiths 1996). Total length (*TL*) of each specimen was measured to the nearest mm and the stomach contents were analysed fresh. Prey items were identified to the lowest possible taxon and counted and weighed (wet) to the nearest 0.01 g. Prey importance was assessed by percentage frequency of occurrence (*%F*), which provides an indication of how often a particular prey item is selected (Hynes 1950), and by percentage by mass (*%M*), which gives a measure of the energy contribution of that

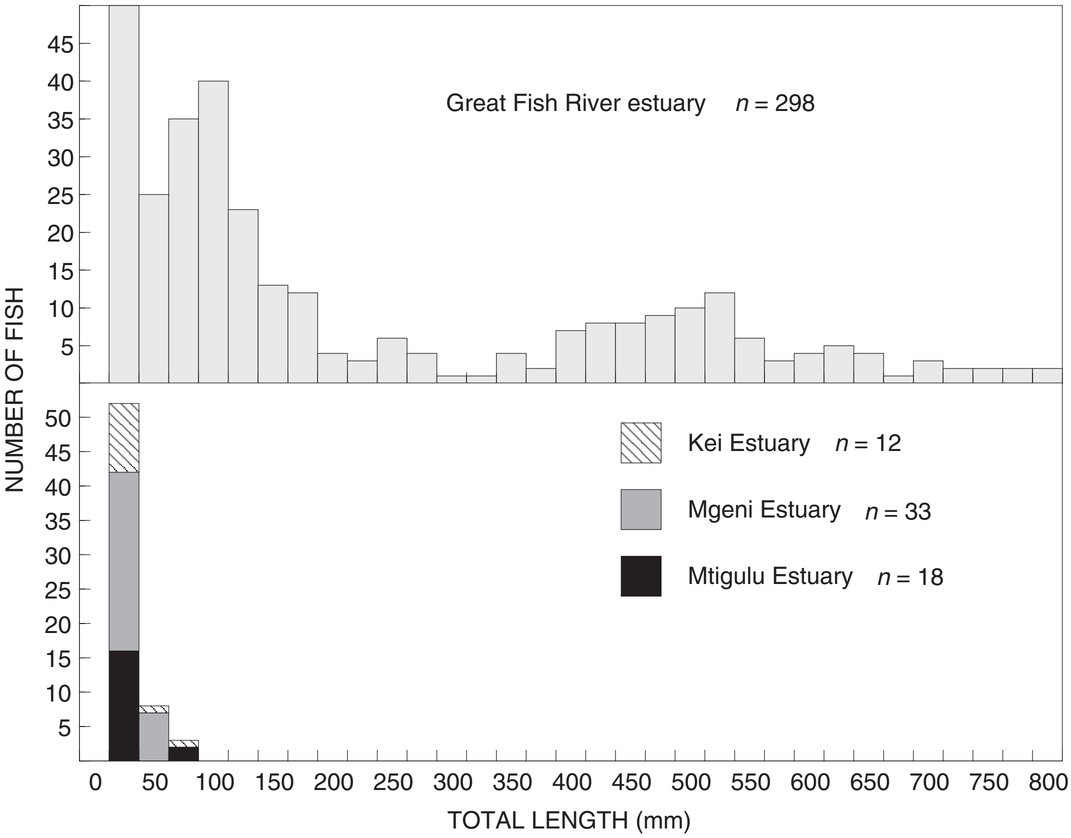

Fig. 2: Length frequency distributions of *A. japonicus* with stomach contents in each of the four estuaries studied

item (Windell and Bowen 1978). Numerical percentage contribution (Pillay 1952) was excluded because *A. japonicus* has a diverse diet and this method biased the results towards small crustaceans, e.g. copepods and mysids, which are not individually selected. An index of relative prey importance (*IRI*) was calculated, where

$$IRI = \%M \times \%F \quad .$$

The distribution patterns of *A. japonicus* in the Great Fish River estuary were then compared with those published for their primary prey species.

The stomach contents of preserved specimens of *A. japonicus* from the Matigulu (collected 1985) and Mgeni (collected 1987) estuaries in KwaZulu-Natal (Council for Scientific and Industrial Research, Durban) and from the Kei River estuary (collected in 1981) in the Eastern Cape (J. L. B. Smith Institute of Ichthyology, Grahamstown) were classified according to broad taxonomic groupings and analysed using the frequency of occurrence method only.

RESULTS

The length frequencies of *A. japonicus* with stomach contents are illustrated in Figure 2 and, in the case of the Great Fish estuary, the lengths of fish containing food were representative of the size range of dusky kob in that system (Griffiths 1996). In the Great Fish River estuary there was an inverse relationship between predator length and the proportion with stomach contents (Fig. 3), indicating that larger dusky kob feed less frequently than smaller ones. The proportions of early juveniles with stomach contents in the Kei (100%), Mgeni (92%) and Matigulu (86%) estuaries

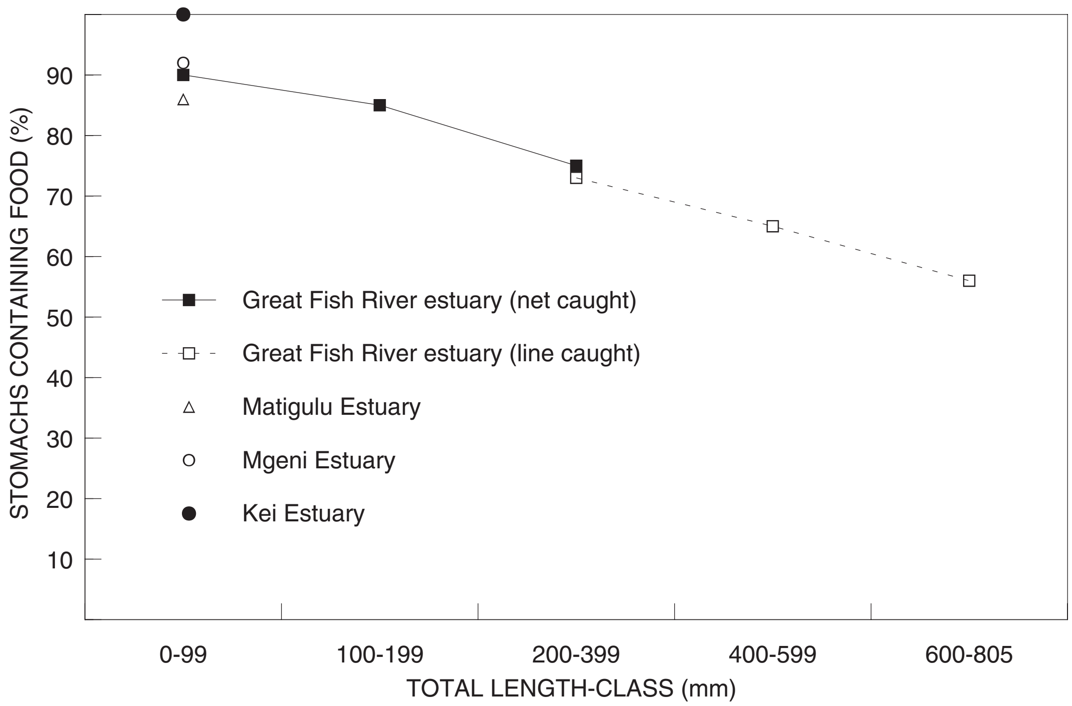

Fig. 3: Proportion of *Argyrosomus japonicus* with stomach contents in each of the size-classes examined

were similar to those of comparable size in the Great Fish River estuary (90%).

Although a wide range of prey organisms was consumed by every size category of dusky kob examined in the Great Fish River estuary, in each case two or three principal prey taxa were dominant (Fig. 4, Tables I and II). There was also considerable dietary change with growth. Early juveniles of <50 mm *TL* fed predominantly on mysids and the calanoid copepod *Pseudodiaptomus hessei* (Fig. 4, Table I). Approximately 97% (by number) of the mysids consumed by dusky kob in the Great Fish River estuary consisted of *Mesopodopsis slabberi*, with the remainder being *Rhopalophthalmus terranatalis*. As the recruits increased in size, copepods were replaced by teleost prey, but mysids remained an important dietary component of all dusky kob <600 mm *TL*. Teleosts were the most important prey taxon of dusky kob >100 mm *TL*, but the principal species varied with predator size. Early juveniles of 100–149 mm *TL* preyed mostly on the late larvae and early juveniles of other species, particularly the Cape stumpnose *Rhabdosargus holubi*. Juveniles of 150–400 mm *TL* fed largely on early juvenile mugilids and on the small, pelagic, estuarine round herring *Gilchristella aestuaria* . Juvenile dusky kob of >400 mm *TL* fed on several teleost species, including early juvenile conspecifics, but their most important prey item was *G. aestuaria*.

The diets of early juvenile recruits varied considerably in the remaining three estuaries studied, suggesting that they are opportunistic and will feed on almost any organism of suitable size (Table III). In the Matigulu Estuary, they contained only calanoid copepods. In the Mgeni Estuary, insects (larvae and pupae) and amphipods were most often consumed, but swimming prawns (Macrura) and teleost eggs were also taken frequently. Mysids were the dominant prey items of early juveniles in the Kei Estuary, but calanoid copepods and amphipods were also important.

DISCUSSION

One of the objectives of the present study was to determine the role of prey abundance in the distribution of *A. japonicus* in the Great Fish River estuary, and in particular, to explain the confinement of early

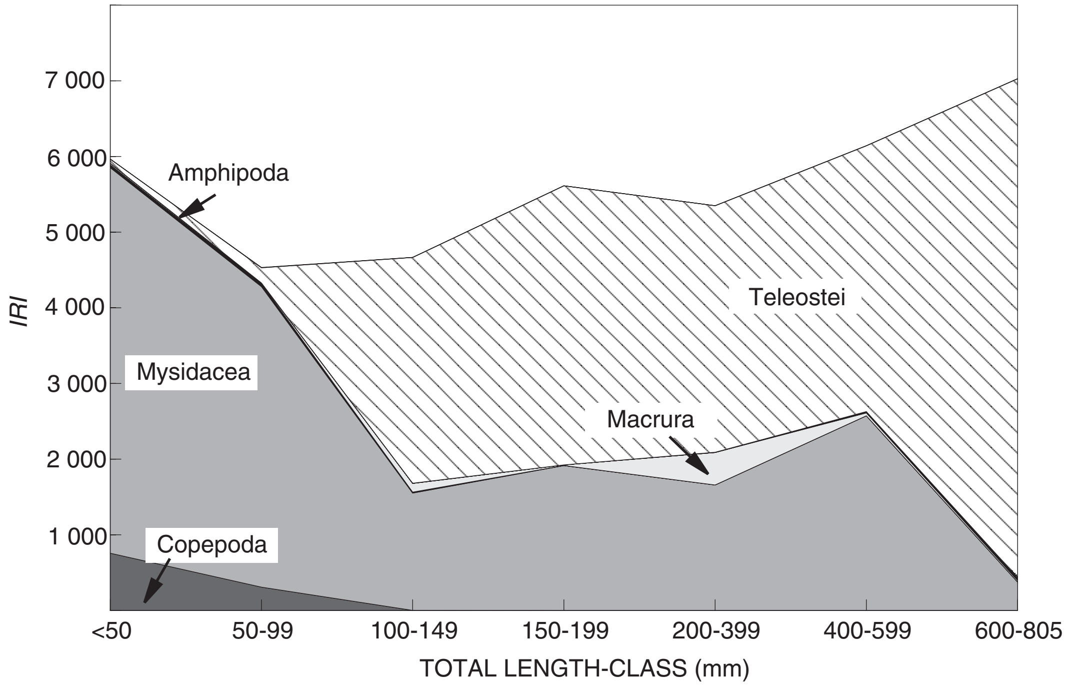

Fig. 4: Changes in diet with size for 298 *A. japonicus* from the Great Fish River estuary. Fish were grouped into 50 mm (<200 mm *TL*) and 200 mm (>200 mm *TL*) size-classes. *IRI* is the index of relative prey importance

juveniles (<150 mm *TL*) to the upper reaches (salinities $0-5 \times 10^{-3}$). The most important prey item of *A. japonicus* <100 mm *TL* in the Great Fish estuary is *M. slabberi*. This mysid is most abundant in the middle and lower reaches of this system where salinities are $10-35 \times 10^{-3}$ (Grange 1992). Theoretical studies on cost-benefit analysis predict that predator avoidance will also influence the response of fish to spatial heterogeneity in their environments (Huntingford 1993). Empirically, fish have also been shown to select areas of lower food abundance when those of increased food availability are associated with a higher risk of predation (Ehlinger 1989, Gotceitas and Colgan 1990, Croy and Hughes 1991). Given that juvenile *A. japonicus* are the dominant piscivores of the Great Fish River estuary, and other turbid systems (Marais 1988), that they are cannibalistic (this study, Marais 1984, Coetzee and Pool 1991), and that the larger specimens (>400 mm *TL*) are more abundant in the middle and lower reaches where salinities are $6-35 \times 10^{-3}$ (Griffiths 1996), it is postulated that both predator avoidance and food availability play effective roles in the distribution of the early juveniles in this system and in other estuaries.

Although *G. aestuaria* were consumed by all *A. japonicus* size-classes examined in the Great Fish River estuary, they were of primary importance only to fish >400 mm *TL*. As *G. aestuaria* is most abundant in salinities $>4 \times 10^{-3}$ (Ter Morshuizen *et al.* 1996) in the Great Fish River estuary, it appears that the pattern of spatial distribution of larger *A. japonicus* juveniles is determined mainly by that of their prey. This is not surprising because *A. japonicus* >400 mm *TL* have few estuarine predators (Griffiths 1996). Whitfield and Blaber (1978) also found that juvenile dusky kob (265–1 110 mm *TL*) in Lake St Lucia, South Africa, were most abundant in areas where the biomasses of their principal prey species were highest. The dominant teleost in the diet of *A. japonicus* <400 mm *TL* in the Great Fish River estuary was initially post-larval and early juvenile *R. holubi* (50–149 mm *TL*), but later switched to early juvenile mugilids (150–199 mm *TL*) and to early juvenile mugilids and *G. estuaria* (200–400 mm *TL*) with increasing predator length (Table I). Both *R. holubi*

Table I: Stomach contents of early juvenile *A. japonicus* from the Great Fish River estuary.expressed as percentages of frequency by occurrence (*%F*) and mass (*%M*). Totals represent the number of stomachs with food and wet mass of prey. *IRI* is the index of relative importance

Prey	Value per predator total length-class											
	23–50 mm			50–99 mm			100–149 mm			150–199 mm		
	%M	*%F*	*IRI*	*%M*	*%F*	*IRI*	*%M*	*%F*	*IRI*	*%M*	*%F*	*IRI*
Crustacea												
Copepoda												
Pseudodiaptomus hessei	14.5	52.1	756.2	9.6	32.1	307.8	0.1	8.6	1.2			
Mysidacea	67.9	75	5 095.8	69.5	57.1	3 971.9	26.4	58.6	1 550.0	30.6	62.5	1 914.3
Amphipoda	3.7	10.4	38.2	3.5	10.7	37.6	1.1	12.1	12.8	0.24	4.2	1.0
Corophium triaenonyx	3.7	10.4	38.2	1.0	8.9	8.5	1.1	12.1	12.8	0.2	4.2	1.0
Unidentified				2.6	1.8	4.6						
Macrura	4.9	4.2	20.4	1.8	5.4	9.6	7.4	15.5	114.5	1.0	8.0	8.0
Palaemon pacificus	0.8	2.1	1.7	1.5	3.6	5.4	7.4	15.5	114.5	1.0	8.0	8.0
Penaeus japonicus	4.1	2.1	8.5	0.3	1.8	0.5						
Anomura				0.8	1.8	1.4	0.3	1.7	0.6	0.1	4.2	0.3
Upogebia africana				0.8	1.8	1.4						
Callianassa kraussi							0.3	1.7	0.6	0.1	4.2	0.3
Isopoda							0.4	5.2	1.9			
Insecta				0.8	5.4	4.1	0.2	6.9	1.2			
Chironomidae				0.8	5.4	4.1	0.15	5.2	0.8			
Carixidae							0.01	0.2	0.02			
Tricorythidae							<0.01	0.2	<0.01			
Teleostei	9.0	6.3	56.1	14.1	14.3	201.2	64.1	46.6	2 984.5	68.1	54.2	3 689.0
Gilchristella aestuaria	6.5	2.1	13.6	3.1	1.8	5.5	2.9	3.5	10.1	9.3	12.5	116.2
Rhabdosargus holubi	0.8	2.1	1.7	10.5	10.7	112.5	25.4	27.6	700.1	5.9	8.3	49.4
Pomadasys commersonnii										5.3	4.2	21.9
Mugilidae							10.2	1.7	17.5	37.9	25	947.6
Elops machnata							0.4	3.5	1.4	5.5	4.2	22.9
Gobiidae							13.3	1.7	22.9			
Solea bleekeri							0.6	1.7	1.0			
Unidentified	1.6	4.2	6.7	0.5	1.8	0.9	11.4	10.3	117.5	4.22	16.7	70.3
Total	1.23	48		3.91	56		15.05	58		16.36	24	

and mugilids occur sympatrically with early juvenile dusky kob in the upper reaches of the Great Fish River estuary (Ter Morshuizen *et al.* 1996), but *R. holubi* recruit to this system at a smaller size (5–10 mm standard length, *SL*) than do the mugilids (15–20 mm *SL*, Whitfield 1994). They are therefore more suitable as food for small predators. Similarly, the *G. estuaria* which inhabit the upper reaches of Great Fish River estuary are generally >30 mm *SL* (Ter Morshuizen 1996).

G. aestuaria was the single most important prey item of juvenile dusky kob >207 mm *TL* in four other Eastern Cape estuaries in South Africa, i.e. Swartkops, Sundays, Krom and Gamtoos (Marais 1984). In contrast to the Great Fish River dusky kob population, mysids were not important food in those systems, and were only significant in the diets of fish <500 mm *TL* in the Sundays Estuary. In Lake St Lucia, in KwaZulu-Natal, *A. japonicus* fed mainly on *G. aestuaria* and on another pelagic fish species, *Thryssa vitrirostris* (Whitfield and Blaber 1978). Teleosts were the dominant prey of juvenile *A. japonicus* in the Breede River estuary in the Western Cape, primarily *G. aestuaria* and the marine catfish *Galeichthys feliceps* (Coetzee and Pool 1991).

The Mgeni River was in flood at the time of sampling (T. D. Harrison, C.S.I.R., Durban, pers. comm.), with the result that many of the insects eaten by early juveniles in that system could have been introduced by the higher rates of freshwater inflow. Nevertheless, certain insects, particularly chironomids, are salinity tolerant and are commonly found in the upper reaches of South African estuaries (F. C. de Moor, Albany Museum, Grahamstown, pers. comm.). It is also noteworthy that chironomids comprised a considerable, but unimportant, component of the diets of

Table II: Stomach contents of juvenile *A. japonicus* from the Great Fish River estuary, expressed as percentages of frequency by occurrence (*%F*) and mass (*%M*). Totals represent the number of stomachs with food and wet mass of prey. *IRI* is the index of relative importance.

Prey	Value of predator total length-class								
	200–400 mm			400–600 mm			600–805 mm		
	%M	*%F*	*IRI*	*%M*	*%F*	*IRI*	*%M*	*%F*	*IRI*
Crustacea									
Mysidacea	30.8	53.9	1 657.7	36.2	71.0	2 572.1	8.2	45.8	375.3
Macrura	27.9	15.4	429.7	2.0	19.4	38.3	1.0	20.8	20.4
Palaemon pacificus	1.0	11.5	11.3	2.0	19.4	38.3	0.9	16.7	14.8
Penaeus japonicus	27.0	3.8	103.7				0.1	4.2	0.4
Anomura				1.8	8.1	14.7	0.5	12.5	5.6
Upogebia africana				1.4	6.4	8.8	0.5	12.5	5.6
Callianassa kraussi				0.5	1.6	0.7			
Isopoda	1.0	3.8	3.7	0.1	3.2	0.3	0.04	4.2	0.2
Brachyura				0.4	6.5	2.4	1.5	4.2	6.3
Varuna litterata				0.3	4.8	1.6			
Hymenosoma orbiculare				0.04	1.6	0.06			
Megalopid				0.05	1.6	0.08			
Mollusca									
Gastropoda				0.6	1.6	0.9	0.2	4.2	0.9
Nassarius speciosus				0.6	1.6	0.9			
Natica tecta							0.2	4.2	0.9
Cephalopoda									
Octopus vulgaris							6.5	4.2	26.9
Teleostei	52.9	61.5	3 258.4	58.9	59.7	3 513.1	83.3	79.2	6 592.0
Gilchristella estuaria	7.3	15.4	1 12.2	26.8	50	1 341.1	20.0	66.7	1 333.0
Rhabdosargus holubi	2.2	3.8	8.5	5.2	9.7	50.4	0.2	4.2	0.9
Pomadasys commersonnii				7.3	6.5	35.0	20.8	8.3	173.3
P. olivaceum				0.4	4.8	1.9			
Mugilidae	10.2	15.4	156.1				0.04	4.2	0.2
Argyrosomus japonicus	2.4	3.8	9.3				30	12.5	374.6
Argyrosomus inodorus				0.7	1.6	1.1			
Elops machnata	8.2	3.8	31.7						
Pomatomus saltatrix	5.7	3.8	22.0				12.6	8.3	105.4
Solea bleekeri				7.8	1.6	12.6			
Galeichthys feliceps				1.0	3.2	3.1			
Sardinops sagax				9.6	1.6	15.5			
Unidentified	4.3	19.2	82.9	0.2	4.8	0.7			
Total	31.5	26		197.2	62		224.6	24	

early juvenile sciaenids, e.g. *Sciaenops ocellatus* and *Pogonias cromis* (Peters and McMichael 1987, 1990), that inhabited areas of reduced salinity in North American estuaries.

The east coast of South Africa has a spring/summer (September – January) rainfall pattern, which coincides with the spawning season of *A. japonicus* (Griffiths 1996). The biomasses of the primary prey organisms of estuarine dusky kob, i.e. calanoid copepods, mysids, insects, *G. aestuaria* and the early juveniles of other teleosts, are positively correlated with the rate of freshwater inflow (Grange 1992, Martin *et al*. 1992, Whitfield 1994, Whitfield *et al*. 1994). Apart from increasing the nursery potential of estuaries through the increased availability of food, freshwater inflow also opens the mouths of many systems that are closed during winter. It provides olfactory cues which assist early juveniles to locate estuaries, and it establishes salinity gradients and turbid conditions which protect them from predators (Griffiths 1996) and improve foraging efficiency (Marais 1988, Griffiths 1997). These findings support the conclusions of Benson (1981, p. 8) who states that ". . . estuaries cannot function ecologically without an adequate supply . . . of freshwater from inland rivers". Unfortunately, the freshwater inflow to many South African estuaries has been reduced through impoundment and excessive abstraction (Whitfield and Bruton 1989). Although

Table III: Stomach contents of early juvenile *A . japonicus* of 25–55 mm *TL* from three South African estuaries, expressed as the percentage frequency by occurrence (*%F*)

Prey	*%F* per estuary		
	Matigulu	Mgeni	Kei
Crustacea			
Copepoda	88.9	6.1	27.3
Mysidacea	6.1	90.9	
Amphipoda	27.3	36.4	
Macrura	18.2		
Isopoda	6.1		
Brachyura	3.0		
Insecta (aquatic phase)	5.6	30.3	9.1
Baetidae	3.0	9.1	
Ceratopogonidae		3.0	
Chironomidae	24.2		
Hydropsychidae		3.0	
Teleostei		9.1	
Teleost eggs	18.2		
Number of fish with stomachs containing food	18	33	11

difficult to quantify, it is intuitive that the potential of many of these estuaries as nursery areas for *A. japonicus*, and many other important fish species, has already been diminished. If *A. japonicus* is to be successfully managed along the east coast of South Africa, it is imperative that those estuaries that still function as important nurseries are accorded special conservation status. In the case of impounded systems, it is necessary that sufficient water be released during periods of highest recruitment, rather than at regular intervals in inadequate quantities. As with the dusky kob, most juvenile marine species that utilize South African estuaries recruit during spring and early summer (Whitfield 1996, Whitfield and Kok 1992). Dusky kob are estuarine dependant from the time they recruit until they are 150 mm *TL*, which, given that they attain 220 mm *TL* at age 1 year (Griffiths and Hecht 1995), represents a period of several months.

ACKNOWLEDGEMENTS

I thank Mr T. D. Harrison of the Council for Scientific and Industrial Research in Durban for providing the specimens of *A. japonicus* from the two KwaZulu-Natal estuaries, the J. L. B. Smith Institute of Ichthyology in Grahamstown for allowing me to remove the stomach contents from early juveniles in their collection, and those recreational anglers who made their catches available for sampling. Dr F. C. de Moor of the Albany Museum, Grahamstown, identified the insect prey. Dr A. K. Whitfield of the J. L. B. Smith Institute and Prof. M. N. Bruton of the Two Oceans Aquarium, Cape Town, commented constructively on the manuscript. This work was funded by the Sea Fisheries Fund.

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