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DIET OF JUVENILE KING GEORGE WHITING *SILLAGINODES PUNCTATA* (PISCES: SILLAGINIDAE) IN THE BARKER INLET - PORT RIVER ESTUARY, SOUTH AUSTRALIA

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Summary

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The diet of juvenile King George whiting, *Sillaginodes punctata* (Cuvier & Valenciennes), was determined by examining the stomach contents of fish collected over two years from shallow eelgrass and unvegetated habitats in the Barker Inlet - Port River estuary, South Australia. Estimates of weight of prey actually ingested by fish were made by combining abundances and sizes of prey found in stomachs with data on the size - weight relationship of potential prey items collected separately. Fish ate epifaunal invertebrates exclusively. A range of crustaceans formed the main prey, with smaller fish taking mostly harpacticoid copepods. Amphipods were more prominent in the diet of larger fish, which also fed upon polychaete worms. Fish fed mainly during the day. Fish collected at night typically had very little food in their stomachs, as measured by a fullness index (ratio of estimated ash-free dry weight of ingested prey to dry weight of fish). Relatively few fish were caught over unvegetated habitat, but where comparisons could be made, polychaetes rather than crustaceans predominated.

KEY WORDS: *Sillaginodes punctata*, fish diet, predation, crustacea, seagrass, *Zostera*.

Introduction

Fish from shallow, soft-substratum habitats are typically carnivorous, preying mainly on small, motile invertebrates. Invertebrates associated with the seagrass canopy or sediment surface (epifauna) are more important than invertebrates from within sediment (infauna) (Klumpp *et al.* 1989). Despite the high levels of primary production sustained by shallow seagrass meadows (Hillman *et al.* 1989), few fish actually consume seagrass in temperate waters (Klumpp *et al.* 1989).

The diets of small fish from seagrass habitats in South Australia have not been reported. The diets of fish in Western Port, Victoria, an enclosed waterway with vegetation similar to that in the Barker Inlet - Port River region, have been studied by Robertson (1984) and Edgar *et al.* (1993)[1] who confirm the importance of epifaunal invertebrates, especially crustaceans. The diet of juvenile King George whiting (*Sillaginodes punctata*) in Western Port is described in Robertson (1977). Fish of this species fed on crustaceans (harpacticoid copepods, mysids and amphipods) after settling from a planktonic larval stage into eelgrass beds. Larger juveniles (>40 mm length) fed upon ghost prawn (*Callianassa*) larvae and polychaetes, primarily in unvegetated patches adjacent to eelgrass.

A wide variety of measures and indices involving gut analyses has been used in attempts to quantify the relative importance of food categories to fish (Berg 1979; Hyslop 1980). Frequency of occurrence, abundance, weight and volume have been used but any one of these may be misleading (Berg 1979). Indices combining in various ways the basic measures listed above have been devised (e.g. Pinkas *et al.* 1971) but no index is advantageous in all situations. Different food categories gain prominence depending on the weighting given to the different variables in the index. Berg (1979) recommends that where an index combining abundance, weight or volume, and perhaps frequency of occurrence, is used, values for the separate variables should also be shown. I consider that it may be as informative to forego the index, given that it is influenced by the weighting given to each variable, and simply present results based on, for example, abundances and weights.

Decisions about the importance of food categories to fish are best based not on the weight or volume of prey remaining in the gut but on the weight or volume of prey ingested. The ideal way of calculating weight or volume of food intake for prey such as motile invertebrates is to determine the weight - size (e.g. length) relationship for all prey categories using whole animals, and then to estimate the weight or volume of ingested prey based on the number and size of individual items found in fish. Edgar *et al.* (1993)[1] describe an approximate method for estimating weights in which prey items are allocated to a size-class known to represent the range of sizes retained on a particular

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[1]EDGAR, G. J., HAMMOND, L. S. & WATSON, G. F. (1993) Consequences for commercial fisheries of loss of seagrass beds in southern Australia. Report to Fishing Industry Research & Development Committee (unpubl.).

sieve mesh size within a stack of hierarchically arranged sieves. The size of invertebrates is then used to estimate their weight (Edgar 1990).

In calculating the relative importance of food types by dividing the number or weight of a food type by the number or weight of all food in a particular fish, no distinction is made between a fish having in its stomach one harpacticoid copepod and one calanoid copepod and a fish having 50 harpacticoids and 50 calanoids. Many studies therefore include some estimate of gut fullness. The most common method has been to assign guts to one of several subjective categories of fullness (Berg 1979). A measure more repeatable by other workers is *l' indice de repletion* of Hureau (1969, described by Berg 1979) in which the weight of ingested food is presented as a proportion of the total weight of the fish.

The primary aim of the present study was to record the diet of juvenile *S. punctata* in the Barker Inlet - Port River estuary. This estuary has been declared an aquatic reserve in recognition of its importance in providing habitat for juvenile fish, especially *S. punctata* (Jones 1984); the most important species economically in both the commercial and recreational fisheries of South Australia. A secondary aim was to compare diets of fish from eelgrass (*Zostera muelleri*) and unvegetated habitats.

TABLE 1. Sillaginodes punctata *examined for stomach contents: number of sites at which* S. punctata *were caught, number of fish examined, and median length of fish, separately for each habitat at each sampling period.*

All fish were collected during the daytime except those marked **Night**.

Habitats: E = eelgrass, U = Unvegetated.

Sampling period	Habitat	Number of sites	Number of fish examined	Median length (mm)
January 1990	E	8	66	80
	U	2	11	110
April 1990	E	9	68	110
	U	1	4	130
August 1990	E	8	65	24
	U	2	2	25
October 1990	E	8	68	32
	U	4	17	35
February 1991	E	8	71	90
	U	4	15	110
June 1991	E	4	34	21
	U	4	7	24
June 1991 **Night**	E	7	54	21
	U	1	4	22
October 1991	E	8	67	25
	U	4	17	29
Oct. 1991 **Night**	E	3	28	26
	U	1	1	28

Materials and Methods

Juvenile *Sillaginodes punctata* were collected over two years during surveys comparing the fish fauna of eelgrass and unvegetated habitats in the Barker Inlet - Port River region (138° 30′ E, 34° 45′ S) (for descriptions of the estuary and the surveys, see Connolly 1994a). At each sampling period, the stomachs and oesophagi of all fish (or of 10 randomly selected fish where more than 10 fish were caught) from each site were removed, and the contents examined. The number of sites and total number of fish examined at each period are shown in Table 1.

The most satisfactory way of determining what fish eat is to examine items only from the anterior part of the tract. This is because food items from the oesophagus and stomach are more likely to be intact and are more easily recognised than items further along the gut, the bias caused by differential gut passage rates or digestion rates of different food items is likely to be reduced (Berg 1979) and items towards the anterior end of the tract give a more reliable guide to the diet of fish just prior to capture. This is an advantage for the secondary aim of this study, namely comparison of the diet of fish caught over eelgrass and unvegetated habitat. The tract of *S. punctata* less than about 25 mm long is a simple, uncoiled tube, narrowing posteriorly; contents of these smaller fish were examined from the section anterior to the narrowing.

Individual items were mostly either intact or nearly so, and were identified to major taxa and counted. Animals were measured using a graticule in the microscope eye-piece and were assigned to a sieve mesh size-class so that weights of ingested prey could be estimated using the length - weight relationship described by Edgar (1990). The majority of prey items were crustaceans and where individuals were not whole, sizes were estimated by roughly piecing together parts of an animal (in the case of large crustaceans such as amphipods and mysids) or by using other individuals of the same taxon as a guide (for copepods). The only taxa recorded other than crustacea were polychaetes and chironomid larvae. Chironomid larvae were rare and were always whole. Although polychaetes were often whole, they were sometimes in pieces; estimating sizes of polychaetes chopped into pieces was the most problematic part of this method. In these cases the number of anterior ends was counted and lengths were estimated to try to take account of the general size of individuals.

Each prey item was assigned to a size-category relating to the range of lengths of that taxon retained on different mesh sizes. These size ranges were determined by measuring the length of numerous specimens of each taxon from epifaunal samples taken at the time of fish collections. For each taxon, relative length - frequency histograms were plotted for each mesh size, and a range of lengths was chosen as representative of a mesh size by selecting upper and lower limits where histograms from adjacent mesh sizes crossed. Size ranges for each taxon are shown in Table 2. The mean ash-free dry weight (AFDW) of invertebrates can be related to sieve mesh size using Edgar's (1990) equation, $\log B = a + b \log S$ (where B = AFDW (mg), S = sieve size (mm) and a and b vary depending on broad taxonomic category). Since each sieve size retains animals ranging from that sieve size to the next, S is expressed as a geometric mean calculated using the equation, $\log S = (\log S_i + \log S_{i+1})/2$, in which S_i = mesh size of the i^{th} sieve and S_{i+1} = mesh size of the next size up (Edgar 1990).

For each fish, the percentage abundance of each food category was calculated as n/N, where n is the number of individuals of the food category and N is the total number of individuals of all categories in that fish. The same calculation was made for each category based on estimated weight (AFDW). The average percentage abundance and weight of each food category were calculated for each site. The average percentage abundance and weight at each sampling period (with night collections in June and October 1991 treated as sampling periods) were then calculated separately for eelgrass and unvegetated sites.

TABLE 2. *Size ranges (mm) of prey types matching mesh sizes.*
Blank cells indicate that prey type was not found on that mesh.

Prey type	Mesh size (mm) 4	2	1	0.5	0.25	0.125	0.075
Harp				>0.8	>0.68-0.8	0.55-0.68	<0.55
Porc				>0.6	≤0.6		
Cycl					>0.65	0.55-0.65	<0.55
Cala				>1	0.7-1	<0.7	
Ostr			>1.6	>0.8-1.6	0.5-0.8	<0.5	
Amph	>10	>5-10	>2-5	1-2	<1		
Capr		>7	3.8-7	<3.8			
Mysi		>5	3-5	<3			
Tana		>5	>2.6-5	1.2-2.6	<1.2		
Cuma		>6.5	4-6.5	<4			
Cari	>9.5	6-9.5	<6				
Poly	>11	>5-11	>2.9-5	>1.3-2.9	0.6-1.3	<0.6	
Chir		>4.8	>2.6-4.8	1.2-2.6	<1.2		

The total estimated weight (AFDW, mg) of the stomach contents of a fish was recorded as a proportion of the estimated total weight of the fish (dry weight, g). This proportion gives the same information as Hureau's (1969, described by Berg 1979) *indice de repletion*, although Hureau's index used the same units in numerator and denominator and is reported as a percentage. By using mg as the unit for the numerator, the ratio (fullness index) used here minimises the occurrence of numbers less than one. The weight of the whole fish, including stomach contents, was estimated using the relationship between dry weight and fish length. Fifty *S. punctata* collected from different periods and ranging from 18 to 133 mm total length were weighed after being dried to constant weight (at least 48 h) at 60°C. The dry weight of a fish is best estimated by its length using the relationship $\log W = 3.261 \log L - 6.396$, where W is dry weight (g) and L is total length (mm) ($r^2 = 0.997$)

Fullness indices of fish from eelgrass and unvegetated sites were compared using Mann-Whitney U-tests at periods when fish were collected from enough unvegetated sites to make useful comparisons. Indices were also compared for fish from eelgrass sites between day and night samplings at June and October 1991. The Mann-Whitney U-test is less powerful than a t-test if data meet the assumptions of normality and homoscedasticity but, in cases such as these where sample sizes are very small and tests of normality are impossible, it is a more reliable method of testing differences in central tendencies (here, medians).

Results

The diet of juvenile *Sillaginodes punctata* consisted entirely of invertebrates. Thirteen categories were recorded, as shown in Table 3. Prey were either crustaceans or polychaetes, except for a small number of chironomid larvae taken in October 1990. Porcellid harpacticoids and caprellid amphipods were counted separately from their general taxa (harpacticoids and amphipods, respectively) because of their different form. Porcellid harpacticoids have a wide, flattened, shield-like shape and caprellids are extremely long and thin compared to gammarid amphipods. The prominence of small items such as copepods, especially harpacticoids, was greater when based on abundance than when based on weight. The prominence of larger items such as amphipods and polychaetes was, conversely, more obvious when based on weights. Notwithstanding these different emphases, the change

TABLE 3. *Stomach contents of* Sillaginodes punctata *based on abundances.*
Habitats: E = eelgrass, U = Unvegetated. Numbers are mean percentage of food category from all sites, with standard errors (SE) in parentheses. * = no SE because fish were caught at only one unvegetated site. ** = no SE because only polychaetes were recorded from fish at unvegetated sites. Food category abbreviations are as follows: Harp = Copepoda - Harpacticoida; Porc = Copepoda - Harpacticoida - Porcellidiidae; Cycl = Copepoda - Cyclopoida; Cala = Copepoda - Calanoida; Ostr = Ostracoda; Amph = Amphipoda - Gammaroidea; Capr = Amphipoda - Caprellidae; Mysi = Mysidacea; Tana = Tanaidacea; Cuma = Cumacea; Cari = Caridea; Poly = Polychaeta; Chir = Chironomidae, larvae

Sampling period	Habitat	Harp	Porc	Cycl	Cala	Ostr	Amph	Capr	Mysi	Tana	Cuma	Cari	Poly	Chir
January 1990	E	7 (4.5)					24 (10)		2.5 (2.5)	7 (4)			60 (11.5)	
	U						13 (13)		3 (3)				83 (17.5)	
April 1990	E						31 (12.5)		14 (7.5)				55 (14.5)	
	U												100 (**)	
August 1990	E	87 (3)	1 (0.6)	3 (1)	0.5 (0.5)	0.4 (0.4)	7 (2.7)			1.1 (1.1)			0.7 (0.7)	
	U	83 (3)					17 (3)							
October 1990	E	69 (8)		0.1 (0.1)	5.1 (2.2)		21 (6)	1.5 (1.2)	1.2 (1.9)					2.3 (2.3)
	U	73 (12)		3.8 (3.8)	1.3 (0.9)		2 (1.5)						20 (11)	
February 1991	E						14 (11)		9.5 (4.5)	6.3 (5.6)		2.5 (2.5)	68 (11)	
	U									1.3 (1.3)			99 (1.3)	
June 1991	E	92 (3)		1.1 (1.1)	3 (3)		3.5 (1.5)							
	U	78 (11)		1.4 (1.4)	2.5 (2.5)	0.5 (0.5)	2.7 1.7						15 (9)	
June 1991 **Night**	E	82 (14)			7 (7)		11 (7)							
	U	100 (*)												
October 1991	E	74 (5)		2.1 (2.1)	1.2 (0.8)		20 (6)	2 (1)	0.1 (0.1)		1 (0.5)			
	U	72 (14)			4 (4)		12 (4)		1 (1)				11 (11)	
October 1991 **Night**	E	59 (29.5)			31.5 (27)		8 (4)						1.6 (1.6)	
	U	87 (*)											13 (*)	

in diet of *S. punctata* as fish grew larger is shown clearly in Tables 3 and 4. The median length of fish at each period is reported in Table 1.

At sampling periods in the second half of the year (August, October 1990; June, October 1991), when fish were small, harpacticoid copepods were the most conspicuous prey by abundance, and amphipods along with harpacticoids were dominant by weight. The abundance and weight of amphipods were noticeably lower in June 1991 than at later periods and this may be attributable to the smaller size of fish at this period. Cyclopoid and calanoid copepods, which are typically more planktonic than harpacticoids, were taken consistently at these periods but were small contributors to diet by abundance or weight. Ostracods, caprellid amphipods, mysids, tanaids and polychaetes occurred occasionally but were not important by abundance or weight. Cumaceans were recorded in

TABLE 4. *Stomach contents of* Sillaginodes punctata *based on weight.*
All labels and symbols as for Table 3.

Sampling period	Habitat	Harp	Porc	Cycl	Cala	Ostr	Amph	Capr	Mysi	Tana	Cuma	Cari	Poly	Chir
January 1990	E	6 (4)					11 (5)		2.5 (2.5)	11 (7)			69 (10)	
	U						4 (4)		10 (10)				87 (13)	
April 1990	E						22 (11)		14 (8)				64 (13)	
	U												100 (**)	
August 1990	E	59 (7)	3 (2)	6 (2.7)	0.7 (0.7)	0.9 (0.9)	25 (8.6)			4.6 (4.6)			0.1 (0.1)	
	U	58 (20)					42 (20)							
October 1990	E	38 (8)		0.1 (0.1)	10 (4)		37 (9)	7 (4.5)	4.5 (2.9)					3.1 (3.1)
	U	54 (8)		3.1 (3.1)	3.9 (2.5)		11 (6.2)						29 (11)	
February 1991	E						10 (8.5)		8.2 (4)	2.8 (2.7)		2.5 (2.5)	76 (8)	
	U									0.3 (0.3)			100 (0.3)	
June 1991	E	85 (6)		1.1 (1.1)	5.5 (5.5)		8 (3)							
	U	68 (16)		1.4 (1.4)	5.5 (5.5)	2.8 (2.8)	(6) (5)						(17) (10)	
June 1991 **Night**	E	76 (16)			7 (7)		17 (11)							
	U	100 (*)												
October 1991	E	50 (7)		4 (4)	3 (2)		33 (11)	7 (4.5)	1.5 (1.5)		2.2 (2)			
	U	66 (13)			5.5 (5.5)		11 (4)		3 (3)				15 (15)	
October 1991 **Night**	E	37 (20)			25 (14)		27 (15)						10 (10)	
	U	48 (*)											52 (*)	

small numbers in October 1991.

At sampling periods in the first half of the year (January, April 1990; February 1991), when larger fish were examined, polychaetes were the main food category by abundance and weight. There was an obvious difference in the size of polychaetes taken by fish in periods in the second half of the year compared with the first half of the year. Polychaetes taken in June 1991 were small, ranging from less than 1 mm to 3 mm long (although the larger of these are large relative to other prey). Polychaetes taken in October 1990 and 1991 were 2 - 10 mm. Polychaetes in fish from periods in the first half of the year ranged from 7 - 50 mm in length. Amphipods were the second most important category by abundance, although by weight amphipods were no more prominent than the other two frequently-recorded categories, mysids and tanaids. Harpacticoids were found in a small number of fish in January 1990. Fish in which harpacticoids were found had no other categories of prey present, so that although the harpacticoids were not numerous and were small, they comprised 100% of the food in those fish based, on abundance or weight. Caridean shrimps were recorded infrequently in February 1991.

The percentage of fish having empty stomachs is shown in Table 5. Very few of the fish caught during the day had empty stomachs at any sampling period and no difference is evident between sites from eelgrass and unvegetated habitat. The weight of stomach contents, as a proportion of total fish weight, varied markedly from site to site but did not seem to vary consistently with season (Table 5). In periods when fish were caught at enough unvegetated sites to make a reasonable comparison possible, the weight of stomach contents did not differ between eelgrass and unvegetated habitats (Mann-Whitney U-test results: October 1990, $p = 0.234$; February 1991, $p = 0.734$; June 1991, $p = 0.773$; October 1991, $p = 0.174$). Results of tests were identical for all periods whether or not fish with empty stomachs were included.

TABLE 5. *Numbers of fish with no food in stomach, and fullness indices, separately for each habitat at each sampling period.*
Habitats: E = eelgrass, U = Unvegetated. The number of fish with empty stomachs is shown firstly by number (n) and secondly as a percentage (%), but percentages should be interpreted cautiously for unvegetated habitat where total fish numbers are very small. Fullness index is weight of stomach contents (mg AFDW) as a proportion of weight of whole fish (g dry weight). Fullness indices are shown as means of site means, with standard errors in parentheses (n/a = fish caught at one site only, therefore no SE available). (a) = excluding fish with empty stomachs (b) = including fish with empty stomachs (and fullness index of zero).

Sampling period	Habitat	Empty (n)	Empty (%)	Fullness index (a)	Fullness index (b)
January 1990	E	3	5	4.18 (0.51)	4.01 (0.50)
	U	0	0	4.80 (1.84)	4.80 (1.84)
April 1990	E	0	0	2.94 (0.49)	
	U	0	0	2.04 (n/a)	
August 1990	E	0	0	4.07 (0.81)	
	U	0	0	2.55 (0.26)	
October 1990	E	2	3	4.29 (0.71)	4.20 (0.69)
	U	0	0	2.60 (1.36)	2.60 (1.36)
February 1991	E	7	10	4.23 (1.23)	4.06 (1.26)
	U	0	0	3.60 (0.63)	3.60 (0.63)
June 1991	E	0	0	2.52 (0.73)	2.52 (0.73)
	U	1	14	3.33 (0.89)	3.11 (1.04)
June 1991 **Night**	E	33	61	1.14 (0.33)	0.52 (0.14)
	U	2	50	0.96 (n/a)	0.48 (n/a)
October 1991	E	3	5	4.94 (0.84)	4.72 (0.79)
	U	0	0	3.35 (0.76)	3.35 (0.76)
October 1991 **Night**	E	18	64	2.99 (0.91)	1.00 (0.21)
	U	0	0	0.98 (n/a)	0.98 (n/a)

More than half the fish caught at night in June and October 1991 had empty stomachs. In fish caught at night with food in their stomachs, the types of food were similar to those in fish caught during the day. For a given period, the quantity of food in fish caught at night was significantly less than in fish caught during the day when fish with empty stomachs were included (Mann-Whitney U-test results: June 1991, $p = 0.047$; October 1991, $p = 0.014$), but was not significantly different when fish with empty stomachs were excluded (June 1991, $p = 0.186$; October 1991, $p = 0.221$).

Comparisons of the diet of fish caught over eelgrass and unvegetated habitat are limited by the small number of *S. punctata* caught over unvegetated habitat and the small number of unvegetated sites at which fish were caught. Over all periods, polychaetes seemed to predominate in fish from unvegetated habitat. In October 1990 and 1991, when fish were caught at 4 unvegetated sites, increasing the chance that the data are representative of the habitat more generally, only fish from unvegetated sites had taken polychaetes. Fish from eelgrass sites tended to contain a greater range of crustaceans. Caprellid amphipods, for example, were recorded only from fish caught over eelgrass at both periods.

Discussion

The diet of *Sillaginodes punctata* fits within the typical diet for fish from shallow, soft-substratum habitats. Stomach contents at the periods sampled give no indication of feeding on anything other than motile invertebrates. Juvenile *S. punctata* caught at periods in the first half of the year were large enough to be able to take small individuals of other fish species but there was no evidence of this. Although gastropods are eaten by some fish species, none was found in the present study. The prominence of harpacticoids and amphipods in the diet of smaller juveniles and an increased prominence of polychaetes in older juveniles matches the pattern in *S. punctata* from Western Port, Victoria (Robertson 1977).

Bruce (1995) has suggested that the shift in diet towards larger crustaceans and polychaetes with increasing fish size may be related to the timing of gut coiling. Bruce's study of larval and postlarval *S. punctata* from South Australian waters shows that coiling of the gut tube and migration of the anus begin in fish 21 - 24 mm long, and are complete in fish of 26 mm. Most fish caught in October 1990 and 1991 during the present study were >26 mm long and did have coiled guts. These fish had a predominance of small crustaceans such as harpacticoids, however, indicating that the shift towards larger crustaceans and polychaetes does not happen until after gut coiling.

Results suggest that *S. punctata* feed on a narrower range of prey and include more polychaetes in their diet when over unvegetated habitat. Lubbers *et al.* (1990) have also reported that for juveniles of several species of fish from an estuary in Chesapeake Bay, USA, diets of fish collected from unvegetated areas included a much greater proportion of polychaetes than diets of fish collected from vegetated areas. Evidence from the present study is, however, obtained from only a small number of fish from very few sites. The small number of fish examined from unvegetated sites could account for the failure to find food types such as caridean shrimps recorded infrequently in fish from eelgrass sites.

Evidence from the two night sampling periods suggests that juvenile *S. punctata* feed mainly during the day. The stomachs of fish collected at night were often either empty or contained only a small quantity of food. Either fish feed in a limited way at night or food in the stomach of fish collected at night remained from feeding during daylight hours. The time between sundown and collection of fish at night ranged from four to seven hours. The rate at which food is evacuated by juvenile, carnivorous, marine fish of a similar size to the fish studied here has been shown to range variously from 2.7 to 4.8 h (Rosenthal & Paffenhofer 1972), 6 h (Archambault & Feller 1991) and from 10 to 30 h (Ryer & Boehlert 1983). These laboratory estimates of gut evacuation times, however, tend to be overestimates (Lockwood 1980). Food is presumably clear of the stomach before it is fully evacuated from the gut, so stomach emptying times could be shorter than those mentioned above. On the other hand, gut passage rates are much slower in colder water (Durbin *et al.* 1983; Ryer & Boehlert 1983) and, in the evening water temperatures of June and October 1991 of about 14°C, food may have remained in guts much longer. It is therefore impossible to distinguish between the possibilities of limited nocturnal feeding and food remaining in stomachs from daytime feeding.

The ratio of ingested food to total fish weight did not seem to vary consistently with the size of fish taken at different periods. This contrasts with the study of silver hake (*Merluccius bilinearis*) and Atlantic cod (*Gadus morhua*) by Durbin *et al.* (1983), using the same measure, in which it was found that the ratio was greater in larger fish. Durbin *et al.* (1983), however, used a much larger size range, including juvenile and adult fish. Differences in the ratio for *S. punctata* might occur in larger fish.

Any differences in gut passage rates or rates of digestion for different food types could have affected the apparent relative importance of food types. These biases were not determined during the present study but should have been limited by examining food only from the oesophagus and stomach of fish. Differential digestion rates tend to underestimate the importance of soft-bodied invertebrates (Scholz *et al.* 1991) and, for juvenile *S. punctata*, this means that polychaetes are the taxon most likely to be underestimated.

This study confirms that juvenile *S. punctata* within the Barker Inlet - Port River estuary feed on epifaunal invertebrates. Experiments in the same estuary have shown that removal of eelgrass canopy reduces epifaunal invertebrate productivity (Connolly 1995). Abundances of juvenile *S. punctata* are not reduced directly by removal of eelgrass canopy but are correlated with levels of invertebrate productivity (Connolly 1994b). The ongoing threat to the health of eelgrass in the estuary from human activities such as treated sewage and stormwater discharge should therefore be viewed as a potentially detrimental influence on *S. punctata* populations.

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References

ARCHAMBAULT, J. A. & FELLER, R. J. (1991) Diel variations in gut fullness of juvenile spot, *Leiostomus xanthurus* (Pisces). *Estuaries* **14**, 94-101.

BERG, J. (1979) Discussion of methods of investigating the food of fishes, with reference to a preliminary study of the prey of *Gobiusculus flavescens* (Gobidae). *Mar. Biol.* **50**, 263-273.

BRUCE, B. D. (1995) Larval development of King George whiting, *Sillaginodes punctata*, school whiting, *Sillago bassensis*, and yellow fin whiting, *Sillago schomburgkii* (Percoidei: Sillaginidae), from South Australian waters. *Fish. Bull.* **93**, 27-43.

CONNOLLY, R. M. (1994a) A comparison of fish assemblages from seagrass and unvegetated areas of a southern Australian estuary. *Aust. J. Mar. Freshw. Res.* **45**, 1033-1044.

______ (1994b) Removal of seagrass canopy: effects on small fish and their prey. *J. Exp. Mar. Biol. Ecol.* **184**, 99-110.

______ (1995) Effects of removal of seagrass canopy on assemblages of small, motile invertebrates. *Mar. Ecol. Prog. Ser.* **118**, 129-137.

DURBIN, E. G., DURBIN, A. G., LANGTON, R. W. & BOWMAN, R. E. (1983) Stomach contents of Silver Hake, *Merluccius bilinearis*, and Atlantic Cod, *Gadus morhua*, and estimation of their daily rations. *Fish. Bull.* **81**, 437-454.

EDGAR, G. J. (1990) The use of the size structure of benthic macrofaunal communities to estimate faunal biomass and secondary production. *J. Exp. Mar. Biol. Ecol.* **137**, 195-214.

HILLMAN, K., WALKER, D. I., MCCOMB, A. J. & LARKUM, A. W. D. (1989) Productivity and nutrient availability pp. 635-685 *In* Larkum, A. W. D., McComb, A. J. & Shepherd, S. A. (Eds) "Biology of seagrasses" (Elsevier, Amsterdam)

HUREAU, J. C. (1969) Biologie comparee de quelques poissons antarctique (Nothotheniidae). *Bull. Inst. oceanogr. Monaco* **68**, 1-44.

HYSLOP, E. J. (1980) Stomach contents analysis - a review of methods and their application. *J. Fish Biol.* **17**, 411-429.

JONES, G. K. (1984) The importance of Barker Inlet as an aquatic reserve; with special reference to fish species. *Safic* **8**, 8-13.

KLUMPP, D. W., HOWARD, R. K. & POLLARD, D. A. (1989) Trophodynamics and nutritional ecology of seagrass communities pp. 394-457 *In* Larkum, A. W. D., McComb, A. J. & Shepherd, S. A. (Eds) "Biology of Seagrasses" (Elsevier, Amsterdam).

LOCKWOOD, S. J. (1980) The daily food intake of 0-group Plaice (*Pleuronectes platessa* L.) under natural conditions. *J. Cons. Int. Explor. Mer.* **39**, 154-159.

LUBBERS, L., BOYNTON, W. R. & KEMP, W. M. (1990) Variations in structure of estuarine fish communities in relation to abundance of submersed vascular plants. *Mar. Ecol. Prog. Ser.* **65**, 1-14.

PINKAS, L., OLIPHANT, M. S. & IVERSON, I. L. K. (1971) Food habits of Albacore, Bluefin Tuna, and Bonito in Californian waters. *Californian Dept. Fish & Game. Fish Bulletin.* **152**, 1-105.

ROBERTSON, A. I. (1977) Ecology of juvenile King George Whiting *Sillaginodes punctatus* (Cuvier & Valenciennes) (Pisces: Perciformes) in Western Port, Victoria. *Aust. J. Mar. Freshw. Res.* **28**, 35-43.

______ (1984) Trophic interactions between the fish fauna and macrobenthos of an eelgrass community in Western Port, Victoria. *Aquat. Bot.* **18**, 135-153.

ROSENTHAL, H. & PAFFENHOFER, G. A. (1972) On the digestion rate and calorific content of food and feces in young Garfish. *Naturwissenschaften* **59**, 274-275.

RYER, C. H. & BOEHLERT, G. W. (1983) Feeding chronology, daily ration, and the effects of temperature upon gastric evacuation in the pipefish, *Syngnathus fuscus. Environ. Biol. Fishes* **9**, 301-306.

SCHOLZ, D. S., MATTHEWS, L. L. & FELLER, R. J. (1991) Detecting selective digestion of meiobenthic prey by juvenile spot *Leiostomus xanthurus* (Pisces) using immunoassays. *Mar. Ecol. Prog. Ser.* **72**, 59-67.