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FEEDING BIOLOGY OF EEL CATFISH *PLOTOSUS CANIUS* HAMILTON IN A MALAYSIAN MANGROVE ESTUARY AND MUDFLAT

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ABSTRACT. — Food habits of the eel catfish, *Plotosus canius* Hamilton 1822, were investigated in two localities, a mangrove estuary and a mudflat, on the west coast of Peninsular Malaysia for approximately two years. The eel catfish is associated with mangrove estuaries, creeks, mudflats, and shallow coastal waters, and is a commercially valuable food fish that is exploited by artisanal fishermen using hook and line, and commercial barrier nets operated on intertidal mudflats. Within the mangrove estuary Sungai [= river] Sementa Kecil, the gut contents of eel catfish consisted predominantly of crustaceans living in the mangrove shore or adjoining mudflats. The fish consumed an average of about 70% by volume of brachyuran crabs comprising of Sesarmidae, and penaeid prawns. At the Sungai Buloh mudflat, 40% of its diet consisted of bivalves such as the blood cockle, *Anadara granosa* (L.), *Xenostrobus* and *Placuna* sp., while other items consumed include fish *Stolephorus* sp., and *Glossogobius* sp. The study indicates that eel catfish living in mangrove estuaries and mudflats consumes resident invertebrates thus utilising benthic resources of the intertidal zone.

KEY WORDS. — food, eel catfish, mangrove estuary, Malaysia

INTRODUCTION

Mangrove estuaries harbour a large number fishes with at least 600 species recorded in the Indo-West-Pacific region (Blaber, 2000), while in Malaysia 119 and 154 species of fishes were recorded in the central Selangor and Matang (Perak) mangrove estuaries respectively (Chong et al., 1990; Then, 2008). Among the common fishes in mangrove estuaries are the predatory catfish *Arius* spp. and the eel catfish *Plotosus canius* which have been observed to ingress mangrove shores at high tide and feed on benthic invertebrates (Sasekumar et al., 1984). The close relationship between marine fishes/prawns and mangrove estuaries has been hotly debated after the publication of a FAO document by Macnae (1974). The occurrence of many fishes in turbid mangrove estuaries has been attributed to reduced predation, abundant availability of food resources, and large living space (Blaber, 2000). Studies using stable isotope ratios of carbon and nitrogen provide proof that fishes and prawns derive substantial nutrition from mangrove detritus (Rodelli et al., 1984; Newell et al., 1995; Chong et al., 2001; Chong, 2007). Though organic matter derived from mangrove plant matter has a low nitrogen content, enrichment by microbial colonisers increases its nutritional value. In a more recent review, Nagelkerken et al. (2008) concluded that mangroves are far less important as a food source than previously assumed. The authors admit there are examples of mangrove-dwelling species which consume leaf litter and thus utilise mangrove plant resources (Lee, 1998; Nordhaus et al., 2005). The consumption of the abundant benthic animals in the mangrove shore or the adjoining mudflat has not been widely recognised.

This study highlights the exploitation of mangrove and mudflat benthic invertebrates by eel catfish which are common in estuaries. Eel catfish of the family Plotosidae are endemic to the estuaries and brackish waters of South Asia (Misra, 1976) where the occurrence of *Plotosus canius* is limited to specific locations from India to Papua New Guinea (Weber & de Beaufort, 1913). Its venomous spine and skin secretions (Gimlette, 1971; Iekhsan et al., 1990) had probably deterred research, thus only few workers have studied the species (Rishi & Singh, 1983; Sinha, 1984; Leh & Sasekumar, 1989). *Plotosus canius* fishery is important on the west coast of Peninsular Malaysia, and constituted 0.21% (1,541 tonnes) of the annual commercial fish landings in 2009. Small scale fishermen or artisanal fisherman harvest the fish and sell them in villages and coastal towns, thus their real harvest data may not be recorded in the national fisheries statistics, and therefore official catch statistics must be considered gross underestimates. The specific objectives of this study are to (i) obtain information on the distribution of *P. canius* in the coastal waters of Selangor on the west coast of Peninsular Malaya, and (ii) describe its food habits.

MATERIAL AND METHODS

Study sites. — This study was carried out in the mangrove estuary of Sungai [= river] Sementa Kecil (SSK) and a mudflat at Sungai Buloh (SB) in Selangor, Malaysia (Fig. 1). SSK is the primary study site where extensive sampling of the eel catfish was carried out in all its tributaries. SSK stretches over a length of 4.1 km. The width at the mouth at high tide is 80 m, reaching a depth of 6.5 m. The estuary drains the surrounding mangrove forests which had been logged for timber. The banks of the estuary are colonised by *Rhizphora apiculata* Bl. or *R. mucronata* Lmk. Away from the creek banks, the dominant trees are *Bruguiera cylindrica* (L.) and *B. parviflora* Wight and Arnold ex Griffith.

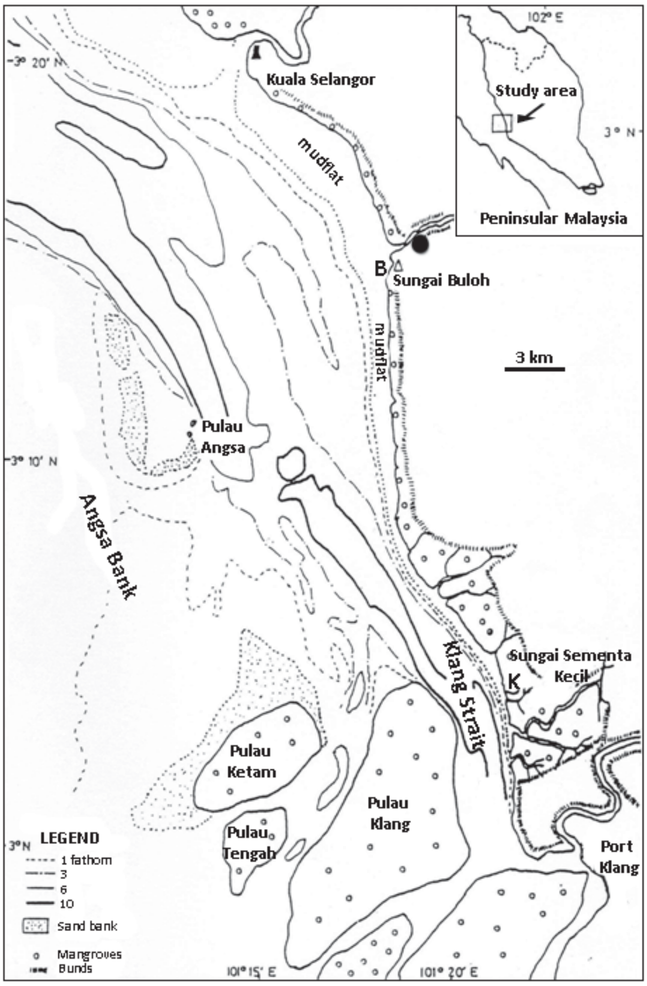

Fig. 1. The mangrove estuary of Sungai Sementa Kecil (K) and a mudflat at Sungai Buloh (B) in Selangor, Malaysia.

The mudflat at SB is extensive, ranging in width from 1.0–2.5 km. The site of sampling was a mudflat with soft sediment (Fig. 1). The mangrove forests here consisted of a foreshore zone of *Avicennia alba* Bl., followed by zones of *Bruguiera* and *Rhizophora* towards the landside (Tee, 1982a).

Rainfall and hydrology. — Rainfall recorded at three weather stations showed maximum rainfall between March to May and September to November each year. The mean annual rainfall of three locations near the study site SSK was 2474 ± 269.6 mm while that for three locations near SB was 2233.4 ± 371.4 mm in 1988.

Tides on the Selangor coast are semi-diurnal with diurnal tides occurring only twice monthly. The maximum tidal height recorded was 5.6 m above Chart Datum and the lowest minus 0.4 m in Port Klang during the past decades. Water movements in the Straits of Malacca are generated by tidal currents. Tidal velocities ranged from 1.5–2.2 knots during spring tides and 0.1–0.7 knots during neap tides. Secchi disc readings for turbidity varied from 32–72 cm. Air temperatures ranged from 28–32.4°C with an annual range of 4.3°C. Surface water temperatures were relatively constant and varied between 28.9–31.7°C with an annual range of 2.8°C. Surface water salinity at SSK ranged from 26. 1–31.8 ppt with annual fluctuations affected by rainfall pattern. During periods of low rainfall, salinity increased to above 30 ppt. At the mudflat site in SB, water salinity did not fluctuate greatly with distance from the sea. Dissolved oxygen of the surface water at SSK varied from a minimum of 3.00 mg l^{-1} to a maximum of 5.65 mg l^{-1}.

Food and feeding habits. — Fish were collected monthly from SSK over a 24-month period from Jan.1988 – Jan.1990 while at SB mudflat, the second site, fish samples were collected bimonthly from Feb.1988 – Feb.1990. Sampling was restricted to times between high and ebb tides. Samples from SSK were obtained by hook and line and a 2-m wide beam trawl of mesh size 14 mm (Warbuton, 1989). On the mudflat (SB), eel catfish were collected from commercial barrier trap nets of 24-mm mesh size. After capture, fish were euthanized in ice and then brought back to the laboratory where standard length, wet weight, and sex were determined. Each stomach was cut open longitudinally. The degree to which each stomach was filled was estimated and expressed as a percentage (Ball, 1961). The contents of the stomach were analysed to establish the food habits of the species. Two methods of analysis were used. The frequency of occurrence is expressed as a percentage of the total number of occurrences for a particular grouping of fish size rather than the usual method of expressing it as a percentage of stomachs that contained food (Hynes, 1950; Pillay, 1952). Food categories in stomachs were estimated volumetrically (Hellawell & Abel, 1971; Hyslop, 1980).

Stomach contents were examined under a low powered stereo dissecting microscope and where necessary, under high-power magnification. Intact food items were identified to the most precise taxonomic level possible. Fish with standard lengths of more than 28.1 cm were considered adults while those less than 28.0 cm were considered juveniles (Leh, 1990).

Multivariate analysis. — To show the relative importance of food items consumed by different size classes of *P. canius*, the principal component analysis (PCA) was applied based on the arcsine-transformed percentage volumetric data. The PCA was performed using the CANOCO 4.5 software and the results depicted by a two-dimensional ordination biplot diagram.

RESULTS

Distribution and economic importance of* Plotosus canius *in Malaysia. — *Plotosus canius* is a fish of commercial importance in Malaysia, and are always sold alive in wet markets. The distribution of this catfish is often associated with the presence of mangrove forests. As an estuarine inshore catfish, it is exploited by traditional small-scale fishermen operating gears like small trawl net, gill net, drift net, barrier net, beach seine, cast net, eel trap, and hook and line. In Selangor, 50.9% of the eel catfish landings were harvested with barrier nets while hook and line caught 20.9%, and trawl nets landed 14%. Distinct peaks of eel catfish catches were observed in the months of June, July, August, and December (Annual Fisheries Statistics, 1987,1988).

The monthly landings of eel catfish on the west coast of Peninsular Malaysia fluctuated throughout the years from 1980 to 2009 and contributed between 915 to 2,653 tonnes annually to the national fisheries catches (Table 1).

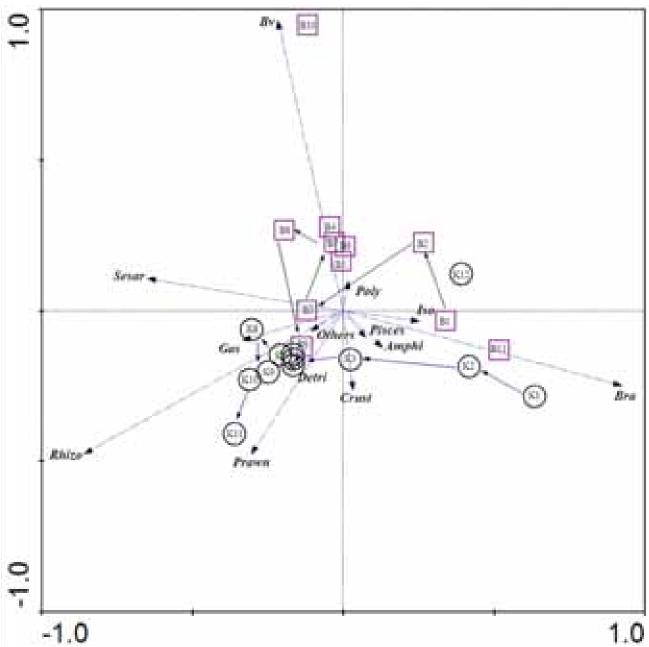

Fig. 2. PCA biplots based on composition of food items (percentage volume) consumed by *P. canius* in Sementa Kecil estuary (K) and Sungai Buloh mudflat (B). Dotted arrows denote major food items: Sesar = Sesarminae, Rhizo = Rhizopinae, Bra = other brachyurans, Prawn = prawns and shrimps, Amphi = hyperiid amphipods, Iso = Isopoda, Crust = miscellaneous crustaceans, Poly = Polychaeta, Gas = Gastropoda, Bv = Bivalvia, Pisces = Pisces, Detri = mangrove detritus, Others = others. Symbols denote size classes as in Table 2: Sungai Buloh mudflat: B1 to B11 size classes from 41–480 mm at 40 mm intervals. Sungai Sementa Kecil: K1 to K12 size classes from 41–480 mm at 40 mm intervals. Ontogenetic shift in food composition is indicated by solid thin arrows.

Feeding habits. — Brachyuran crabs of the families Sesarmidae, and other brachyurans (Ocypodidae and Porcellanidae) were the most frequently occurring and volumetrically important food items consumed by the eel catfish at SSK (Table 2; Fig. 2). Among the sesarmids *Perisesarma eumolpe* de Man, *Perisesarma onychophorum* de Man, *Episesarma versicolor* Tweedie, and *Cleistocoeloma merguiensis* de Man were the dominant food items while *Typhlocarcinus* sp. was of equal importance. Prawns of the genera *Penaeus*, *Metapenaeus*, and sergestid *Acetes* were also consumed. Other food items consumed in lesser amounts were hyperiid amphipods, copepods, isopod *Sphaeroma*, gastropods *Littoraria*, *Nerita*, *Syncera*, bivalve *Gelonia*, bottom living fish *Glossogobius* sp., nekton fish *Thryssa* and mangrove detritus. Miscellaneous food items found were shell fragments of barnacles and oyster, eggs of horse shoe crab, animal tissues, and small amounts of sand particles.

The PCA ordination biplot indicates differential food consumption by *P. canius* between sites and among size classes (Fig. 2). In SSK, brachyuran crabs from the families Ocypodidae and Porcellinidae constituted the major food for small classes of *P. canius* that ranged between 41–160 cm (K1–K3, Fig.2), while sesarmid and rhizopinid crabs, and to some extent bivalves, became increasingly important in the diet of larger catfish size classes (K4–K11, see also Table 2). Compared with SSK, *P. canius* in SB mudflat was much more dependent on bivalves through all size classes despite the importance of brachyuran crabs in their diet.

DISCUSSION

The pattern of monthly food intake was similar for each year during 1988 and 1990 at SSK. Minimum food intake occurred in July and December in both years. At the mudflat in SB, fish had low stomach fullness in June and August indicating low feeding intensity. This period also correlated with the periods of low rainfall suggesting that the intensity of food intake is inversely related to gonadal maturity and breeding time of the fish (Sinha, 1984).

Plotosus canius consumed an average of about 70% by volume of brachyuran crabs each month. This is comparable to a study in Hooghly-Matlah estuary in India (Sinha, 1984). A similar importance of crabs in the diet of this eel catfish was shown in a Malaysian mangrove shore (Sasekumar et al., 1984). Other fishes that had a similar diet were *Plicofollis tenuispinis* (see Mojumder & Dan, 1979) and *Netuma thalassina* (see Mojumder, 1969). Other important food items were gastropods and bivalves but their consumption varied considerably. Crustaceans such as *Alpheus*, *Squilla*, copepods, *Balanus*, and Xiphosuran *Tachypeleus* were also important food items. The few fish consumed belonged to the genera *Glossogobius*, *Liza*, and *Thryssa*. Mangrove plant detritus was always present in the diet of *P. canius*. The ingestion of mangrove plant detritus such as *Avicennia* root hairs may be

Table 1. Landings (tonnes) of the eel catfish *P. canius* by State (Selangor, Sabah, Sarawak and Labuan), and east and west coast of Peninsular Malaysia, and Malaysia from 1980–2009 based on Malaysian Fisheries Statistics (1980–2009). na = not available.

Year	Selangor	West Coast (P. Malaysia)	East Coast (P. Malaysia)	Peninsular Malaysia	Sarawak	Sabah	Labuan	Malaysia
1980	142.04	777.19	0.67	777.86	156	na	na	na
1981	94.26	940.51	31.75	972.26	515.18	na	na	na
1982	112.08	1366.04	14.78	1380.82	296.84	na	na	na
1983	69.38	1466.24	18.96	1485.2	289.38	na	na	na
1984	38.56	820	50.5	870.5	94.66	na	na	na
1985	34.09	850	25.06	875.06	113.7	na	na	na
1986	65	1615	11	1626	120	na	na	na
1987	70	819	5	824	109	na	na	na
1988	38	582	1	583	253	150	0	986
1989	261	826	4	830	63	22	0	915
1990	64	1294	32	1326	31	97	2	1456
1991	56	707	11	718	29	589	2	1338
1992	55	700	67	767	49	265	7	1088
1993	44	916	27	943	60	1130	0	2133
1994	39	915	5	920	48	1529	3	2500
1995	56	1086	6	1092	43	873	2	2010
1996	82	861	10	871	21	879	32	932
1997	104	628	9	637	25	785	0	1447
1998	111	665	34	699	19	941	0	1659
1999	203	868	27	895	18	836	0	1749
2000	159	1478	25	1503	14	705	0	2222
2001	252	1338	19	1357	11	619	0	1987
2002	179	1303	150	1453	25	640	0	2118
2003	199	1238	65	1303	11	585	0	1895
2004	221	1180	77	1257	18	689	0	1962
2005	199	1081	81	1162	15	860	0	2036
2006	260	1518	92	1610	9	877	13	2509
2007	286	1435	90	1525	55	681	4	2265
2008	291	1355	141	1496	9	786	5	2297
2009	288	1541	176	1717	20	916	0	2653

Table 2. Frequency of occurrence (%) of food items of *P. canius* with different size classes in Sementa Kecil estuary and Sungai Buloh mudflat. n_1 = total number of fish stomachs examined; n_2 = number of stomachs with food; na = not available.

	Location	Size class (mm)											
		41–80	81–120	121–160	161–200	201–240	241–280	281–320	321–360	361–400	401–440	441–480	481–520
n_1,	Sementa Kecil	3	10	81	247	179	99	136	62	28	17	5	3
	Sungai Buloh	1	44	46	85	140	89	76	23	12	2	2	na
n_2,	Sementa Kecil	1	10	77	209	147	82	111	51	25	13	2	1
	Sungai Buloh	1	42	58	70	104	71	68	21	10	2	1	na
Food items													
Crustacea													
Sesarminae[1]	Sementa Kecil	—	9.0	10.1	16.7	14.9	17.4	19.2	21.9	14.6	17.4	25.0	20.0
	Sungai Buloh	—	4.9	14.4	11.2	7.8	13.3	13.3	19.6	8.0	50.0	—	na
Rhizopinae	Sementa Kecil	—	—	8.2	14.8	21.3	16.5	17.9	16.2	25.5	21.9	25.0	—
	Sungai Buloh	—	—	10.5	2.8	6.4	6.0	4.6	8.9	29.3	—	—	na
Other brachyurans[2]	Sementa Kecil	33.3	25.7	23.1	16.1	13.1	15.4	13.8	3.3	10.9	10.6	—	40.0
	Sungai Buloh	16.7	22.7	14.2	14.2	19.3	21.1	19.5	6.6	13.2	—	20.0	na
Prawns[3] and *Acetes*	Sementa Kecil	33.3	9.5	3.4	3.6	2.7	1.8	1.4	3.8	3.6	3.9	25.0	20.0
	Sungai Buloh	—	2.2	2.0	6.2	6.6	4.2	3.7	—	4.9	—	—	na
Hyperiid amphipods	Sementa Kecil	—	6.2	1.8	3.3	0.6	1.2	0.2	1.6	—	—	—	—
	Sungai Buloh	—	—	—	—	1.0	0.5	1.0	—	—	—	—	na
Isopoda	Sementa Kecil	—	3.9	3.2	2.3	1.1	0.4	0.1	—	—	—	—	—
	Sungai Buloh	—	—	1.8	9.1	0.8	0.9	0.4	—	—	—	20.0	na
Miscellaneous crustaceans	Sementa Kecil	33.3	19.4	11.1	6.8	6.8	6.6	5.3	6.5	3.2	8.8	—	—
	Sungai Buloh	16.7	7.6	3.4	6.8	12.6	8.9	12.6	9.1	7.9	—	20.0	na
Polychaeta	Sementa Kecil	—	—	4.8	2.7	0.9	2.2	3.5	2.2	—	—	—	—
	Sungai Buloh	16.7	10.4	1.1	1.2	1.9	4.9	2.6	2.9	—	—	—	na
Gastropoda[4]	Sementa Kecil	—	7.8	7.4	5.0	9.4	6.9	—	3.8	6.8	7.6	—	—
	Sungai Buloh	—	9.7	5.1	4.5	3.0	2.8	3.1	—	6.4	—	—	na
Bivalvia[5]	Sementa Kecil	—	1.0	6.9	7.7	11.6	12.6	11.6	18.8	16.1	9.0	—	20.0
	Sungai Buloh	16.7	18.2	22.1	30.1	22.7	20.3	24.1	31.5	9.4	50.0	20.0	na
Pisces[6]	Sementa Kecil	—	—	0.7	2.0	0.3	0.5	3.5	—	—	—	25.0	—
	Sungai Buloh	—	0.8	2.3	0.3	5.9	0.9	1.7	3.6	4.9	—	20.0	na
Mangrove detritus	Sementa Kecil	—	16.7	12.5	16.1	15.5	15.6	14.8	11.9	14.8	14.6	—	—
	Sungai Buloh	16.7	10.1	15.3	7.8	8.4	10.1	8.4	13.7	12.2	—	—	na
Others	Sementa Kecil	—	0.6	7.0	3.1	1.8	3.1	4.1	9.0	4.5	6.3	—	—
	Sungai Buloh	16.7	13.6	7.8	5.9	3.6	5.8	5.0	4.2	3.8	—	—	na

Sesarminae[1] = *Perisesarma eumolpe*, *P. onychophorum*, *Episesarma versicolor*, *Clieistocoeloma merguieneis*; Other brachyurans[2] = Ocypodidae, Porcellinidae; Prawns[3] = *Penaeus* spp. , *Metapenaeus* sp.; Gastropods[4] = *Littoraria* sp.; *Nerita* sp., *Syncera* sp.; Bivalvia[5] = *Xenostrobus mangle*, *Anadara granosa*, *Placuna* sp.; Pisces[6] = *Glossogobius* sp., *Thryssa* sp.

accidental with the consumption of food items such as crabs and bivalves from the mangrove substrate.

At the SB mudflat, 40% of the diet of *P. canius* consisted of bivalves such as *Anadara granosa*, *Xenostrobus mangle*, and *Placuna* which were abundant in the lower shore mangroves or mudflat (Broom, 1982; Tee, 1982b). The consumption of brachyuran crabs by *P. canius* averaged about 50% by volume. Fish consumed include *Stolephorus* and *Glossogobius*. Other items consumed include insect larvae, peanut worm *Phascolosoma arcuatum*, jellyfish, sponge and *Onchidium* and small amounts of fine sediment.

There were obvious differences in the diet of fish of different size classes (Fig. 2). Essentially, the differences in the diets of small and large *P. canius* were quantitative although food items such as crab megalopae and copepods were found only in small juveniles. Juvenile *P. canius* of 81–120 mm standard length consumed an increasing volume of sesarmid crabs at SSK until they reached a size of 321–360 mm when they consumed 11.5–28.3% of sesarmid crabs in their diet. Eel catfish of the sizes 361–400 mm consumed less sesarmid crabs, but increased the intake of *Typhlocarcinus* crabs. This trend was also observed at the SB mudflat although bivalves were increasingly important in the diet of large fish. Sesarmid crabs were abundant in the upper mangrove forest floor (Sasekumar, 1974) while *Typhlocarcinus* was common on mudflats and mudbanks (Macintosh, 1979).

The variation in the diet with size may also imply changing feeding periodicity with size. At both sites, juvenile *P. canius* (41–80 mm) fed mainly on brachyuran megalopae, copepods, polychaetes, small *Meretrix* bivalves, penaeid prawns, and *Acetes*. Juveniles of the same species have been noted to feed on small animals like amphipods, isopods, mysids, and small prawns in the coastal waters of Madras, India (Basheeruddin & Nayar, 1961). Similarly, Kaliyamurthy & Rao (1972) observed that *P. canius* (33–80 mm) from an estuarine lake (Pulicat Lake) in Southeast India fed on copepods, diatoms, and amphipods, while larger fish (81–185 mm) fed on prawns, fish, polychaetes, and hermit crabs. The predominance of amphipods in the diet of young *P. canius* has also been observed in eastern Johore Strait, Singapore (Hajisamae et al., 2003). Another study carried out in Chilka Lake (north west India), indicated that crabs, mollusks, and fish were important components of *P. canius*'s diet (Rajan, 1965). Local variation in the percentage of food items may be due to the variability of food items in the specific environment (Sinha, 1984). Plotosid *Cnidoglanis macrocephalus* in algal beds of south west Australia feed mainly on amphipods common in nearshore marine areas (Lenanton, 1982; Lenanton et al., 1982).

Plotosus canius had been classified as a predatory carnivore (Sinha, 1984) and as a benthic feeder (Kaliyamuthry & Rao, 1972). Based on the food items consumed by the *P. canius* in mangrove and mudflat habitats, the present study indicates it to be a carnivorous benthic feeder. The similarity of food types of the different size classes of *P. canius* indicates intraspecific competition for food. Such competition may be minimised by seasonal variation in the relative abundance of different food items in the diet of different size groups. Jones (1968) considered the proportion of the food types eaten and the foraging methods as a means of food resources partitioning by fish species in a habitat.

Predation of intertidal invertebrates has been observed in mangrove shores (Austin & Austin, 1971; Sasekumar et al., 1984) and salt marshes (Vince et al., 1976), but not quantified. To what extent intertidal benthic resources in mangroves and salt marshes are exploited by shallow water fishes for their nutrition remains to be investigated. In fact, the benthic community structure of intertidal habitats may be regulated by regular cropping by fishes that ingress during high tides. Furthermore, destruction by of mangrove forests by reclamation will cause a decline in fish populations dependent on mangroves for food resources.

In conclusion, there is good evidence that fishes in coastal waters ingress into the mangrove shore at high tide and consume benthic invertebrates, and thus there is transfer of energy from intertidal habitats to inshore and estuarine waters (Zijlstera, 1988).

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