Vol.49, n. 4 : pp. 623-629, July 2006
ISSN 1516-8913 Printed in Brazil

BRAZILIAN ARCHIVES OF
BIOLOGY AND TECHNOLOGY
A N I N T E R N A T I O N A L J O U R N A L

Diet and Feeding Behavior of *Kyphosus* spp. (Kyphosidae) in a Brazilian Subtropical Reef

Renato Azevedo Matias Silvano [1*] **and Arthur Ziggiatti Güth** [2]
[1]Departamento de Ecologia; UFRGS; C. P. 15007; 91501-970; silvano@ecologia.ufrgs.br; Porto Alegre - RS - Brasil. [2] Instituto Costa Brasilis; Desenvolvimento Sócio Ambiental; C. P. 32; 11680-970; azguth@gmail.com; Ubatuba - SP - Brasil; Departamento de Oceanografia Biológica; Instituto Oceanográfico da USP; 05508-900; São Paulo - SP - Brasil

ABSTRACT

The present study analyzed and compared diet and feeding behavior (substrate use, position in water column, interactions with other fishes) of Kyphosus *spp. (sea chubs) in a Brazilian subtropical reef. Juveniles (≤160 mm) of* Kyphosus incisor *consumed both algae and invertebrates, which were mainly calanoid copepods. Juvenile and small adults* of *also observed foraging in the water column. We thus provide the first record of omnivory for Kyphosids in the southwest Atlantic Ocean.*

Key words: Herbivory, Kyphosidae, omnivory, ontogenetic diet shift, coastal fishes

INTRODUCTION

Herbivorous fishes usually constitute most of the fish biomass in tropical and subtropical reefs, playing an important role in nutrient cycling (Choat and Clements, 1998; Ferreira et al., 2004). However, the influence of these fishes on reef benthic fauna and algae may vary according to the diet and behavior of herbivores. Territorial herbivorous reef fishes, such as those from the families Pomacentridae and Blennidae, among others, influence the composition and diversity of algae and its associate invertebrate communities, as well as the relative abundances of algae and corals in tropical and subtropical reefs (Sammarco, 1983; Hixon and Brostoff, 1996; Ferreira et al., 1998; McManus et al., 2000; Townsend and Tibbetts, 2004). Large roving herbivores, such as those from the families Kyphosidae and Sparidae, among others, might consume large amounts of algae and detritus, being thus important to biomass turnover from the primary producers to the upper levels of the food chain (Ferreira et al., 2004). Furthermore, some reef fishes usually regarded as herbivores consume considerable amounts of detritus, and only some fish species, including the sea chubs, *Kyphosus* spp. (Kyphosidae), may be considered as "truly herbivores" (Choat et al., 2004). Sea chubs are diurnal fishes, which occur in tropical and temperate rocky reefs (Randall, 1967; Topp, 1970) and are primarily herbivores with morphological and physiological traits suited for consumption of algae, such as microbial fermentation in the gut (Rimmer, 1986; Clements and Choat, 1997; Moran and Clements, 2002). Density of herbivorous fishes, which rely on low quality food sources (algae and detritus) decreased in abundance from tropical to temperate latitudes in Western Atlantic (Floeter et al., 2004). Such pattern also holds for herbivorous reef fishes along

* Author for correspondence

the Brazilian coast, with the exception of kyphosids, which increase in abundance in south and southeastern Brazilian reefs at lower latitude, possibly because the digestive adaptations of these fishes allow algae consumption at lower water temperatures (Ferreira et al., 2004). Nevertheless, despite the potential importance of kyphosids as algae consumers, there are scarce information about the diet and feeding behavior of these fishes in subtropical reefs in southwest Atlantic Ocean. There are studies dealing with the diet of *Kyphosus incisor* (Cuvier) in Caribbean (Randall, 1967) and with the feeding behavior of *Kyphosus sectatrix* (Lacepede) in southeast Brazilian coast (Sazima, 1986). Furthermore, few studies of Brazilian marine fishes have used both behavioral observations and gut content analysis (Ferreira et al., 1998; Zahorcsak et al., 2000; Silvano, 2001), and this approach was not yet applied to survey sea chubs. We aimed to analyze and compare diet and feeding behavior (substrate use, position in water column, interactions with other fishes) of sea chubs in a Brazilian subtropical reef, reporting evidence that these fishes could also eat invertebrate besides algae.

MATERIALS AND METHODS

The present study was conducted on a subtropical reef in the Búzios Island, southeast Brazilian coast ($23^0$47'S and $45^0$10'W), consisting in a rocky shore made up of rocks and boulders, most of them covered with algae (mostly *Sargassum*), macrobenthos, such as anthozoans, sponges, etc. and some sparse corals, ending in sand bottom (Silvano, 2001). This study site was thus similar to other previously studied south and southeast Brazilian rocky reefs (Ferreira et al., 2001). Topp (1970) considered *Kyphosus elegans* individuals ≤ 160 mm as juveniles. In the absence of information on size of first maturity for *K. incisor*, juveniles with ≤ 160 mm standard length (SL) were considered. Individuals between 160 mm and 300 mm were considered as small adults (possibly sub adults) and fishes ≥ 300 mm as adults. Stomach contents of seven *K. incisor* juveniles and 10 sub adults were analyzed. Fishes were collected with gillnets during the night, and hook-and-line during the afternoon. Seven fishes were collected on June 1998 (winter), the remainder being caught in November and December 1998, January 1999, February 2000 (summer) and June 2000 (winter). Fish collections and underwater observations were opportunistic and made when sea conditions were suitable for diving, mainly during summer. The food items were stored in 70% ethanol and identified to the highest possible level of taxonomic resolution. The amount of algae in the fish stomachs was measured as dry mass (g) only, as it could not be sorted and counted. However, the invertebrates were counted based on whole individuals or recognizable fragments, such as heads. These invertebrates were separated from algae in fish's stomachs during dietary analysis. Total amount of food was divided by fish size (mm SL), in order to control for possible effects of gut size in amount of invertebrates consumed.

Considering that both *K. incisor* and *K. sectatrix* occured at the study site and the two species were indistinguishable underwater, behavioral data were assigned to these two fish species. The length of observed fish was estimated using handbreadth as measure units (Silvano, 2001). Considering that such measure of fish length was not too accurate, observations of feeding behavior of juveniles and sub adults were grouped. Feeding behavior of juvenile and sub adult fish was observed during 31 h of snorkeling between 1100 and 1700 h, totaling 33 observations, lasting from 30 s to 7 min, on same months previously mentioned in diet analysis except for June 1998 (when no observation was made), and April 1999 (when fishes were observed but not collected). For details of observation methods, see Silvano (2001). Observations were made after finding an individual and allowing a few minutes for acclimation to observer. The methods of focal animal and one-zero sampling were used (Lehner, 1979), where all occurrences of behaviors were recorded during each short observation period. Considering that most of observed behaviors lasted less than observation period and intervals between observations were usually longer than duration of behavior acts, frequency of observation of each behavior, here measured as percent of times a given behavior was observed considering the total number of focal observations, was used as a proxy to time budget (time spent in each behavior) (Lehner, 1979). Observations were made where the fishes were feeding or swimming (close to the rocks or in the water column) and if the fish was chased by the pomacentrid damselfish *Stegastes fuscus* (Cuvier). Most of the data on behavior and diet were gathered during same seasons and years, and fish

observed and collected probably belonged to the same population. Although Kyphosids are regarded as roving herbivores, which may show wide horizontal displacements along the reefs (Floeter et al., 2004), these fishes usually do not move long distances away from reef habitat. In Caribbean, *Kyphosus sectatrix* shows attachment to preferred reef habitats, notwithstanding its somewhat high mobility (Eristhee and Oxenford, 2001).

For comparative purposes, three *K. incisor* adults (large fishes, 325, 340 and 355 mm SL) were collected for stomach content analysis in June 1997 and April 1999 and the feeding behavior of four large *Kyphosus* spp. adults were observed in April 1999, each observation lasting from 1 to 4 min, following the same methods as above described for juveniles.

RESULTS AND DISCUSSION

Both small (n=17) and large (n=3) *K. incisor* individuals consumed mainly algae and crustaceans, which were found in 80 and 95 %, respectively of the 20 stomachs analyzed. Most of the sub adults and adults (9 of 13) fed mainly on *Sargassum*, while juveniles (six of seven) consumed mostly other algae (Table 1). Despite the small sample size, large *K. incisor* could be regarded as herbivorous, eating mainly *Sargassum* from the rocks; these fishes were observed swimming close to the rocks (Fig. 1). They were not, however, observed grazing on the algae (Fig. 1), which could be due to a short sampling time. Previous studies in southeast Brazil and the Caribbean also recorded adult *K. incisor* and *K. sectatrix* as being herbivorous (Randall, 1967, Sazima, 1986).

Table 1 - Abundance of food items in the diet of sampled *Kyphosus incisor* individuals, expressed by number of invertebrates (n mm $^{-1}$) and dry mass of algae (g mm $^{-1}$).

	Invertebrates (n mm $^{-1}$)				Algae (g mm $^{-1}$)
Fish (mm)	**Copepoda [a]**	**Amphipoda [a]**	**Others [b]**	**Total**	
121.5	0.36	0.11	0.04	0.51	0.02 [c]
128	9.29	0.02	0.16	9.47	0.02 [c]
134.6	1.58	0.03	0.03	1.64	0.02 [c]
140.6	9.95	0	0.08	10.03	< 0.01 [c]
143	2.59	0.03	0.2	2.83	< 0.01 [c]
147.3	6.36	0.01	0.03	6.4	0.01 [c]
160	0	0.08	0	0.08	0
182	0	0.04	0	0.04	0.01 [d]
205	0	0.55	0	0.55	0.01 [d]
206	0.02	0.01	0.03	0.06	0.02 [c]
208	0	0.09	0	0.10	0.01 [c]
210	0.14	0.10	0.03	0.27	0.01 [d]
215	0	0	0	0.01	0.01 [d]
220	0	0.16	0.03	0.20	0
225	0	0.04	0	0.04	0.01 [d]
230	0.01	0.14	0.07	0.23	< 0.01 [d]
235	0.02	0.08	0.03	0.13	0.01 [d]
325	0	0	0.02	0.02	0.01 [d]
340	0.01	0.16	0.10	0.28	0.03 [c]
355	0	0.06	0.01	0.06	0.02 [d]

[a] Copepods are mostly from the order Calanoidea; Amphipods are mostly from the families Caprellidae (*Caprella dilatata, C. scaura*) - suborder Caprellidea, Hyalidae (*Hyale nigra*) and Ischyroceridae, (*Jassa* sp.) - suborder Gammaridea.
[b] Crustaceans from the orders Decapoda and Isopoda, molluscs, insects (mostly order Hymenoptera) and annelids (Polychaeta).
[c] Algae are mostly *Chaetomorpha* sp. and Dictyotaceae (*Dictyopteris* spp., *Padina* spp.).
[d] Algae is mostly *Sargassum* spp. (Sargassaceae).

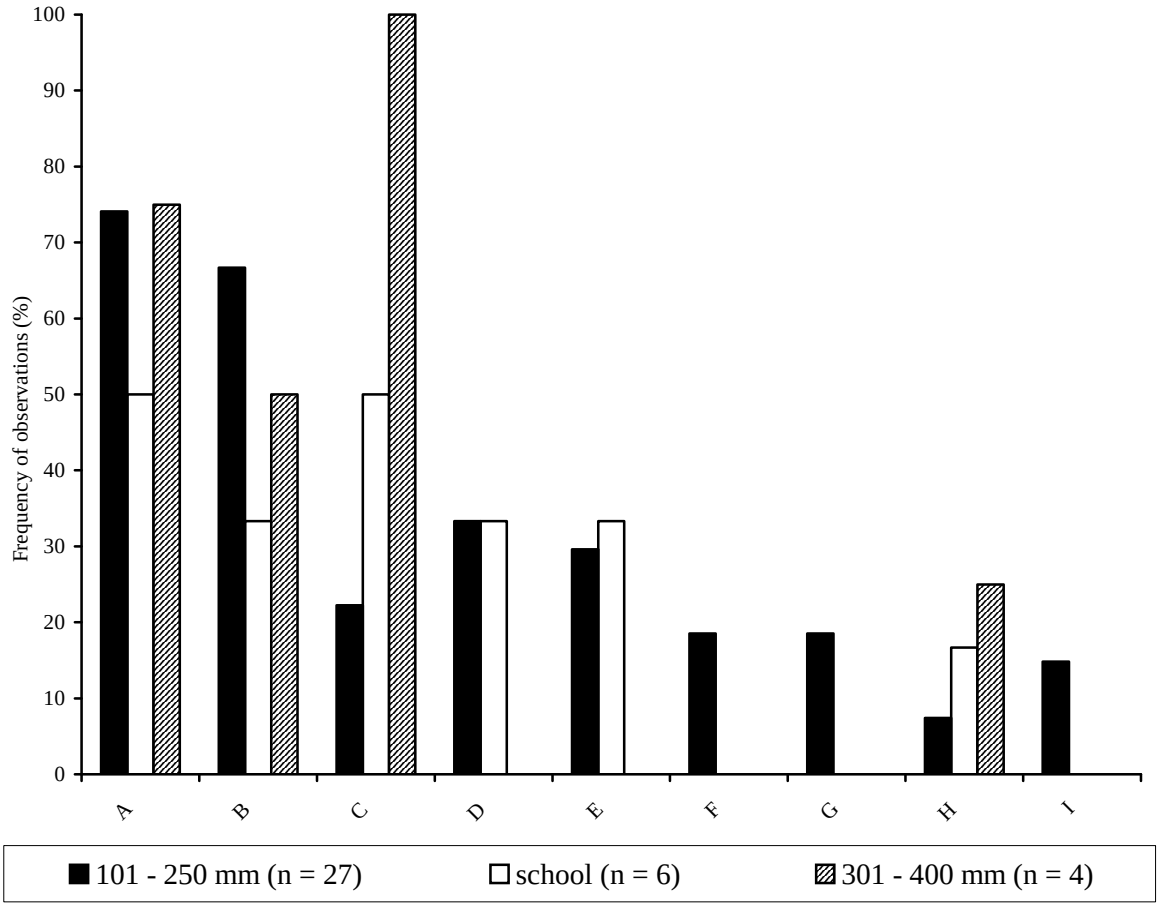

Figure 1 - Behaviors displayed by foraging sea chubs at the study site. Frequency of observations refers to the percentage that the behavior was observed, considering total focal observations of individuals (n) of each size category. A = swimming close (30-100 cm) to the rocks, B = swimming in mid-water, C = swimming near (10- 30 cm) to rocks, D = attacked by *Stegastes fuscus*, E = biting algae from the rocks, F = observed touching the rocks with the body's side, G = bitting in the water column, H = stationary, near (10- 30 cm) to rocks, I = stationary, close (30-100 cm) to the rocks.

The number of invertebrates consumed was negatively correlated with fish size (mm SL) (r_s= -0.6, n= 20, P< 0.05), indicating that juveniles ingested more invertebrates than bigger fish (Table 1). Fish ≥ 160 mm consumed mainly benthic amphipods (Table 1), which usually occur on *Sargassum* (Jacobucci, 2000) and were thus probably consumed incidentally. Juveniles (≤ 160 mm), on the other hand, ate mainly calanoid copepods (Table 1), which are usually pelagic (Kaestner, 1970). The large numbers of copepods eaten (Table 1) indicated that small *K. incisor* was preying on copepods in the water column. Although invertebrates' biomass was not measured, it could be assumed that algae would be more important in biomass than invertebrates when both items were consumed (Table 1), given the small size of invertebrates eaten (usually < 5mm). However, potential sampling biases were unlikely to lead to an overestimate of the amount of invertebrates eaten, as animal prey are usually more easily digested by fishes than algae (Choat and Clements, 1998). Indeed, the water column was more frequented by Kyphosids ≤ 300 mm;

only these juveniles and small adults were recorded feeding there (Fig. 1).

Both the diet and feeding behavior analysis indicated that small adults and juveniles of *K. incisor* on this Brazilian subtropical reef were omnivorous, thus providing new evidence of invertebrates as a food source for post-settlement kyphosids in the Western Atlantic. In the Pacific, these fishes are known to be herbivorous throughout their post-settlement life, only incidentally ingesting animals (Clements and Choat, 1997; Moran and Clements, 2002). Invertebrates have been recorded, however, in the diets of the blue sea chub *Kyphosus cinerascens* (Forsskål) (Senta et al., 1993), and the juveniles of the buffalo bream *Kyphosus cornelii* (Whitley) (30-92 mm) (Rimmer, 1986).

The observed differences between the feeding habits of large and small *K. incisor* suggested an ontogenetic shift from omnivory to herbivory. An ontogenetic shift from carnivorous or omnivorous to an herbivorous diet has been documented for other fishes in the Pacific, such as kyphosids (Barry and Ehret, 1993), *Odax pullus* (Forster) (Clements and Choat, 1993), and *Stegastes nigricans* (Lacepède) (Letourneur, 2000). Morphological and physiological ontogenetic changes, as well as animal protein requirements for growth, may influence the intake of animal prey by juveniles of herbivorous fishes (Rimmer, 1986; Clements and Choat, 1993; Choat and Clements, 1998; Letourneur, 2000). Notwithstanding the lack of information about *K. incisor* development, algae have been reported in the diet of juveniles of *Kyphosus*, indicating a capacity to digest plant food (Rimmer, 1986; Clements and Choat, 1997; Moran and Clements, 2002). Gerking (1994) argues that ingestion of animals may not be obligatory for growth of juveniles, as an herbivorous diet can potentially provide all the fish's food requirements. However, consumption of animal prey may provide a high protein intake to juveniles of herbivorous fishes, accelerating their growth during a critical life phase, when they are more subjected to predation. Such pattern, observed for *Stegastes fuscus* in a Brazilian reef, where juveniles of this species eat animal prey while adults eat algae (Ferreira et al., 1998), might also apply to sea chubs in the studied reef site.

The herbivorous territorial damselfish *Stegastes fuscus* (Ferreira et al., 1998) is abundant at the study site. Territorial damselfishes influence foraging activities and reduce the availability of algae to other herbivorous fishes (Reinthal and Lewis, 1986). Therefore, agonistic interactions between *S. fuscus* and juveniles of sea chubs (Fig. 1), indicated that the former, which chased small kyphosids away from the algae covered rocks, could be constraining the foraging activity in the later at southeast Brazilian reefs. The agonistic behavior of *Stegastes* towards *Kyphosus* has not been previously reported (Harrington and Losey, 1990). Other factors not investigated in this survey that might influence feeding habits of sea chubs were the presence of predators and seasonal availability of algae.

Despite limited sample size, results suggested that juveniles of *K. incisor* were omnivores. Therefore, this fish could have an important role in the food web of subtropical Brazilian reefs, to the extent that fishes eating zooplankton and sheltering in the reef enhance the organic carbon transfer between the pelagic and reef communities (Bray and Miller, 1981).

ACKNOWLEDGEMENTS

We thank the fishermen from Búzios Island and P. Zahorcsak for their cooperation with fieldwork, A. Begossi, J.A.S. Zuanon and J.G.W. Marques for useful comments on the manuscript, I. Sazima and J.L. Figueiredo for help with fish identifications and useful comments on manuscript, F.P.P. Leite for help with crustaceans identifications and the FAPESP for a research grant to R.A.M. Silvano (97/04446-9).

RESUMO

Este trabalho analisa e compara a dieta e comportamento alimentar (uso do substrato, posição na coluna d'água, interações com outros peixes) de peixes do gênero Kyphosus, em um recife subtropical no Brasil. O estudo foi realizado na Ilha de Búzios, litoral sudeste do Brasil, de 1998 a 2000. Para as análises da dieta os peixes foram coletados com redes de emalhar de espera durante a noite e anzol e linha durante à tarde. Também foram efetuadas observações subaquáticas do comportamento alimentar dos peixes. Juvenis de *Kyphosus incisor* se alimentaram tanto de algas como de invertebrados,

que consistiram principalmente de copépodes calanoides. Juvenis e adultos pequenos de peixes do gênero Kyphosus foram observados forrageando na coluna d'água. Nós apresentamos o primeiro registro de hábito alimentar onívoro em peixes do gênero Kyphosus no sudeste do Oceano Atlântico.

REFERENCES

Barry, J. P. and Ehret, M. J. (1993), Diet, food preference, and algal availability for fishes and crabs on intertidal reef communities in southern California. *Environmental Biology of Fishes*, **37**, 75-95.

Bray, R. N. and Miller, A. C. (1981), The fish connection: a trophic link between planktonic and rocky reef communities? *Science*, **214**, 204-205.

Choat, J. H. and Clements, K .D. (1998), Vertebrate herbivores in marine and terrestrial environments: a nutritional ecology perspective. *Annual Review of Ecology and Systematics*, **29**, 375-404.

Choat, J. H.; Robbins, W. D. and Clements, K. D. (2004), The trophic status of herbivorous fishes on coral reefs - II Food processing modes and trophodynamics. *Marine Biology*, **145**, 445-454.

Clements, K. D. and Choat, J. H. (1993), Influence of season, ontogeny and tide on the diet of the temperate marine herbivorous fish *Odax pullus* (Odacidae). *Marine Biology*, **117**, 213-220.

Clements, K. D. and Choat, J. H. (1997), Comparison of herbivory in the closely-related marine fish genera *Girella* and *Kyphosus*. *Marine Biology*, **127**, 579-586.

Eristhee, N. and Oxenford, H. A. (2001), Home range size and use of space by Bermuda chub *Kyphosus sectatrix* (L.) in two marine reserves in the Soufrière Marine Management Area, St Lucia, West Indies. *Journal of Fish Biology* **59** : (A), 129-151.

Ferreira, C. E. L.; Gonçalves, J. E. A.; Coutinho, R. and Peret, A. C. (1998), Herbivory by the dusky damselfish *Stegastes fuscus* (Cuvier, 1830) in a tropical rocky shore: effects on the benthic community. *Journal of Experimental Marine Biology and Ecology*, **229**, 241-264.

Ferreira, C. E. L.; Gonçalves, J. E. A. and Coutinho, R. (2001), Community structure of fishes and habitat complexity on a tropical rocky shore. *Environmental Biology of Fishes*, **61**, 353-369.

Ferreira, C. E. L.; Floeter, S. R.; Gasparini, J. L.; Ferreira, B. P. and Joyeux, J. C. (2004), Trophic structure patterns of Brazilian reef fishes: a latitudinal comparison. *Journal of Biogeography*, **31**, 1093-1106.

Floeter, S. R.; Ferreira, C. E. L.; Dominici -Arosemena, A. and Zalmon, I. R. (2004), Latitudinal gradients in Atlantic reef fish communities: trophic structure and spatial use patterns. *Journal of Fish Biology*, **64**, 1680-1699.

Gerking, S. D. (1994). *Feeding Ecology of Fish*. San Diego: Academic Press.

Harrington, M. E. and Losey, G. S. (1990), The importance of species identification and location on interspecific territorial defense by the damselfish, *Stegastes fasciolatus*. *Environmental Biology of Fishes*, **27**, 139-145.

Hixon, M. A. and Brostoff, W. N. (1996), Succession and herbivory: effects of differential fish grazing on hawaiian coral-reef algae. *Ecol. Monogr*., **66**, 67-90.

Kaestner, A. (1970), *Invertebrate Zoology, Volume III, Crustacea*. New York: Interscience Publishers.

Jacobucci, G. B. (2000), *Distribuição Vertical e Flutuação Sazonal da Macrofauna Vágil Associada a Sargassum cymosum C. Agardh, em uma Praia do Litoral Norte do Estado de São Paulo*. M.S. Thesis, PPG IB/ UNICAMP, São Paulo.

Lehner, P.N. (1979), *Handbook of ethological methods*. New York: Garland S. T. P. M.

Letourneur, Y. (2000), Spatial and temporal variability in territoriality of a tropical benthic damselfish on a coral reef (Réunion Island). *Environmental Biology of Fishes*, **57**, 377-391.

McManus, J. W.; Meñez, L. A. B.; Kesner-Reyes, K. N.; Vergara, S. G. and Ablan, M. C. (2000), Coral reef fishing and coral-algal phase shifts: implications for global reef status. *ICES Journal of Marine Science*, **57**, 572-578.

Moran, D. and Clements, K. D. (2002), Diet and endogenous carbohydrases in the temperate marine herbivorous fish *Kyphosus sydneyanus*. *Journal of Fish Biology*, **60**, 1190-1203. DOI:10.1006/ JFBI.2002.1936.

Randall, J. E. (1967), Food habits of reef fishes of the West Indies. *Studies in Tropical Oceanography Miami*, **5**, 665-847.

Reinthal, P. N. and Lewis, S. M. (1986), Social behaviour, foraging efficiency and habitat utilization in a group of tropical herbivorous fish. *Animal Behaviour*, **34**, 1687-1693.

Rimmer, D. W. (1986), Changes in diet and the development of microbial digestion in juvenile buffalo bream, *Kyphosus cornelii*. *Marine Biology*, **92**, 443-448.

Sammarco, P. W. (1983), Effects of fish grazing and damselfish territoriality on coral reef algae. I. algal community structure. *Mar. Ecol. Prog. Ser.*, **13**, 1-14.

Sazima, I. (1986), Similarities in feeding behaviour between some marine and freshwater fishes in two tropical communities. *Journal of Fish Biology*, **29**, 53-65.

Senta, T.; Kimura, M. and Kanbara, T. (1993), Predation of fishes on open-ocean species of sea-skaters (*Halobates* spp.). *Japanese Journal of Ichthyology*, **40**, 193-198.

Silvano, R. A. M. (2001), Feeding habits and feeding interespecific associations of *Caranx latus* (Carangidae) in a subtropical reef. *Environmental Biology of Fishes*, **60**, 465-470.

Topp, R. W. (1970), Behavior and color change of Rudderfish, *Kyphosus elegans*, in Gulf of Panama. *Copeia*, **4**, 763-765.

Townsend, K. A. and Tibbetts, I. R. (2004), The ecological significance of the combtoothed blenny in a coral reef ecosystem. *Journal of Fish Biology*, **65**, 77-90.

Zahorcsak, P.; Silvano, R. A. M. and Sazima, I. (2000), Feeding biology of a guild of benthivorous fishes in a sandy shore on south-eastern Brazilian coast. *Revista Brasileira de Biologia*, **60**, 511-518.

Received: February 02, 2005;
Revised: August 22, 2005;
Accepted: February 09, 2006.