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Feeding habits of two sillaginid fishes, *Sillago sihama* and *S. aeolus*, at Sikao Bay, Trang Province, Thailand

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Abstract : The feeding habits of juveniles and adults of two sympatric sillaginid fishes, *Sillago sihama* and *S. aeolus*, were examined on the basis of 892 (127 juveniles and 765 adults) and 734 (159 and 575) specimens, respectively, collected from the sandy bottom at Sikao Bay, Trang Province, Thailand, from May 2003 to April 2004. The diets of juveniles (<130 mm in standard length) of both species changed progressively with increasing body size, with a shift from capturing small zooplankton, such as calanoid copepods, to larger benthic prey, such as polychaetes, shrimps, and crabs. The latter three items were also the most important prey of adults of the two species, together constituting >70% of stomach contents by volume. Pronounced seasonal changes in adult diet were not detected in either fish species. In addition, considerable overlaps of juvenile and adult diets between the two coexisting *Sillago* species were found during the study period, indicating that there may be little or no competition between them at Sikao Bay.

***Keywords** : feeding habits, Sillago sihama, Sillago aeolus, Sikao Bay*

1. Introduction

Sillaginidae is a commercially and recreationally important fish family in many regions, two species, *Sillago sihama* and *S. aeolus*, being widely distributed throughout coastal waters in the west-central Pacific and Indian oceans (MCKAY, 1999). In Sikao Bay, Trang Province, Thailand, our preliminary observations indicated that these two species were the most dominant sillaginids, coexisting in shallow sandy areas throughout the year.

Despite their abundance and popularity as food fishes, little is known about the feeding habits of *S. sihama* and *S. aeolus*, except for studies of the former from Taiwan (LEE, 1976) and North Queensland, Australia (GUNN and MILWARD, 1985). Studies on the feeding habits of juvenile and adult sillaginids should be useful for understanding the overall ecology of sillaginids and determining future management strategies.

The objectives of the present study were (1) to describe the stomach contents of juvenile and adult *S. sihama* and *S. aeolus*, (2) to clarify dietary differences among different size classes of juveniles of each species, (3) to determine monthly changes in the diets of adults of each species, and (4) to compare feeding habits between the sympatric congeners.

2. Materials and Methods

The study site, Sikao Bay (7°30′ N, 99°13′ E), opening broadly to the Andaman Sea, is located in Trang Province on the southwest coast of Thailand. It is a large-sized bay, with a length and mouth width of approximately 40 km and 30 km, respectively. The bay has a relatively flat sand surface with several small rocky reefs along the coast. Maximum water depth is about 20 m.

Sikao Bay has relatively short dry (January to April) and long rainy (May to December) seasons. Salinity in the sampling area was essentially marine. Water temperatures at a sandy beach (Rajamangala Beach) at Sikao

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varied from 27.0 to 30.9 ℃, but no seasonal trends were apparent.

Individuals of *Sillago sihama* and *S. aeolus* of 130 mm in standard length (SL) or more were defined as adults, following histological examination of the gonads. To examine seasonal dietary differences, adults of the two species were collected monthly from gill net fishery landings conducted within Sikao Bay from May 2003 to April 2004. Gill nets (500 m wide, 1 m deep, and 25 mm × 25 mm square mesh) were set primarily on the sandy bottom in the central area of the bay (water depth about 15 m) between 05:00 and 07:00 hours, and retrieved between 09:00 and 10:00 hours. Both species were collected during the same gill net operations.

To clarify ontogenetic dietary shifts, most juveniles (<130 mm SL) of the two species were captured from Rajamangala Beach using a small seine net (10 m wide, 1 m deep, and 1 mm × 1 mm square mesh with a 4.5 m long central purse-bag). Sampling was conducted monthly at flood tide (water depth about 1 m) between 6:00 and 9:00 hours from December 2003 to February 2004, when juveniles of both species were abundant. Some large juveniles (101–129 mm SL) collected from gill net fishery landings during the above three months were added to the juvenile samples. Juvenile specimens were pooled for each month for dietary analysis. Immediately after collection, adult and juvenile specimens were preserved on ice.

In the laboratory, within 4 hours of collection, SL and body weight were measured for each adult and juvenile specimen to the nearest 1 mm and 0.1 g, respectively. Juveniles were sorted into 5 size classes (≤10 mm SL, 11–40 mm SL, 41–70 mm SL, 71–100 mm SL, and 101–129 mm SL), although no specimens were included in the 71–100 mm SL size class.

Food items from the stomach contents of each specimen were identified to the lowest possible taxon and the percentage volume of each in the diet visually estimated under a binocular microscope, as follows. Initially, the stomach contents were squashed on a slide glass with a 1 mm × 1 mm grid to a uniform depth of 1 mm, and the area covered by each item measured. The measured area was then divided by the total area of the stomach contents in order to calculate the percentage volume of that item in the diet (HORINOUCHI and SANO, 2000; NAKAMURA *et al.*, 2003). Food resource use was expressed as mean percentage composition of each item by volume (%V), which was calculated by dividing the sum of the individual volumetric percentage for the item by the number of specimens examined (HOBSON, 1974; SANO *et al.*, 1984). Specimens with empty guts were excluded from the analysis.

To measure the degree of feeding intensity of each adult in each species, the Stomach Fullness Index (*SFI*) was used:

$$SFI = [SCW/(BW - SCW)] \times 100,$$

where SCW is a weight of stomach contents and BW is a fish body weight. Specimens with empty stomachs were included in the comparisons of mean *SFI* among months and species (*S. sihama* and *S. aeolus*).

A two-way analysis of variance (ANOVA) with unequal replication (ZAR, 1999) was used to test (1) for species and month effects on percentage composition of main food items in adults and (2) for species and body size effects on percentage composition of main food items in juveniles. Prior to the analyses, homogeneity of variances was improved by transformation of data to arcsin $\sqrt{x}$. If the ANOVA results indicated significant treatment effects ($P<0.05$), the Gabriel test was used to determine which means were significantly different. If ANOVA revealed a significant interaction between species and month for adults or between species and body size for juveniles, a one-way ANOVA and post-hoc Gabriel test were used to compare the mean of one factor separately at each level of the other factor and vice versa (UNDERWOOD, 1997). Some ANOVA results are not presented in the present study because of space limitations.

3. Results

3.1 Juveniles

Of the 127 stomachs of juvenile *Sillago sihama*, 117 individuals contained food items, 10 (8%) being empty. Among 159 stomachs of juvenile *S. aeolus*, 133 contained food items, 26 (16%) being empty.

Table 1. Percentage volume (%V) of food items in the diets of juvenile *Sillago sihama* and *S. aeolus*.

Food items	*S. sihama* %V	*S. aeolus* %V
Copepods	47.2	38.2
Polychaetes	33.5	26.1
Decapods		
Shrimps	5.0	11.1
Crabs	2.3	3.2
Hermit crabs	0.9	0.9
Mud lobsters	0.8	0.3
Larvaceans	4.0	4.4
Fish	3.0	1.6
Trumpet worms	1.6	5.8
Arrow worms	0.7	0
Ostracods	0.3	+
Molluscs	+	1.2
Amphipods	+	0.5
Isopods	+	0.1
Sea anemones	0	5.3
Stomatopods	0	0.3
Unidentified fragments	0.7	1.0
Number of fish with food examined	117	133
Standard lenght (mm)	8–129	7–128

+ : <0.1.

The overall feeding habits of juvenile *S. sihama* and *S. aeolus* are shown in Table 1. The major food items of the two species were calanoid copepods and polychaetes, those categories accounting for 80.7% and 64.3% of the stomach contents by volume in *S. sihama* and *S. aeolus*, respectively.

Based on the %V data, size-related and species differences in the dietary composition of the two major food items (calanoid copepods and polychaetes) were examined. The remaining (minor) prey items were excluded from this analysis. A two-way ANOVA revealed that %V differed significantly among the size classes in each of the two food items, species × size class effects being insignificant for each item (Table 2). In both *S. sihama* and *S. aeolus*, copepods were taken mainly by juveniles in the ≤10 and 11–40 mm SL size classes (Fig. 1, Table 3). In larger size classes, however, this prey item was replaced by polychaetes. The ANOVA results also indicated that the %V of copepods differed significantly between *S. sihama* and *S. aeolus*, with greater %V in the former, whereas that of polychaetes did not (Fig. 1, Table 2).

3.2 Adults

Of the 765 adult specimens of *S. sihama*, 652 contained food items, 113 (15%) being empty. Among the 575 adult specimens of *S. aeolus*, on the other hand, 393 contained food items, 182 (32%) being empty. The overall mean *SFI* of specimens was 0.561 and 0.415 in *S. sihama* and *S. aeolus*, respectively. Monthly changes in *SFI* for each species are shown in Fig. 2. Mean *SFI* values varied little from month to month for both species, except for January in *S. aeolus*.

The overall feeding habits of adult *S. sihama* and *S. aeolus* are shown in Table 4. The two species consumed a variety of food, including small invertebrates and fishes. In both species, polychaetes were the most important prey item, followed by crabs and shrimps, the three categories constituting 80.1% and 74.0% of the stomach contents by volume in *S. sihama* and *S. aeolus*, respectively.

Based on the %V data, seasonal and species differences in the dietary composition of the three major food items (polychaetes, crabs, and shrimps) were examined. The remaining (minor) prey items were excluded from this analysis. A two-way ANOVA revealed that there

Table 2. Results of a two-way ANOVA testing the effects of species and size class on percentage volume of each main food category in the diets of juvenile *Sillago sihama* and *S. aeolus*.

Source	*DF*	*MS*	*F*	*P*
Copepods				
Species	1	0.87	4.72	0.030
Size class	3	16.8	91.7	<0.001
Species × Size class	3	0.41	2.24	0.084
Error	242	0.18		
Polychaetes				
Species	1	0.32	1.98	0.160
Size class	3	11.5	70.8	<0.001
Species × Size class	3	0.23	1.42	0.237
Error	242	0.17		

Data transformed to arcsin $\sqrt{x}$.

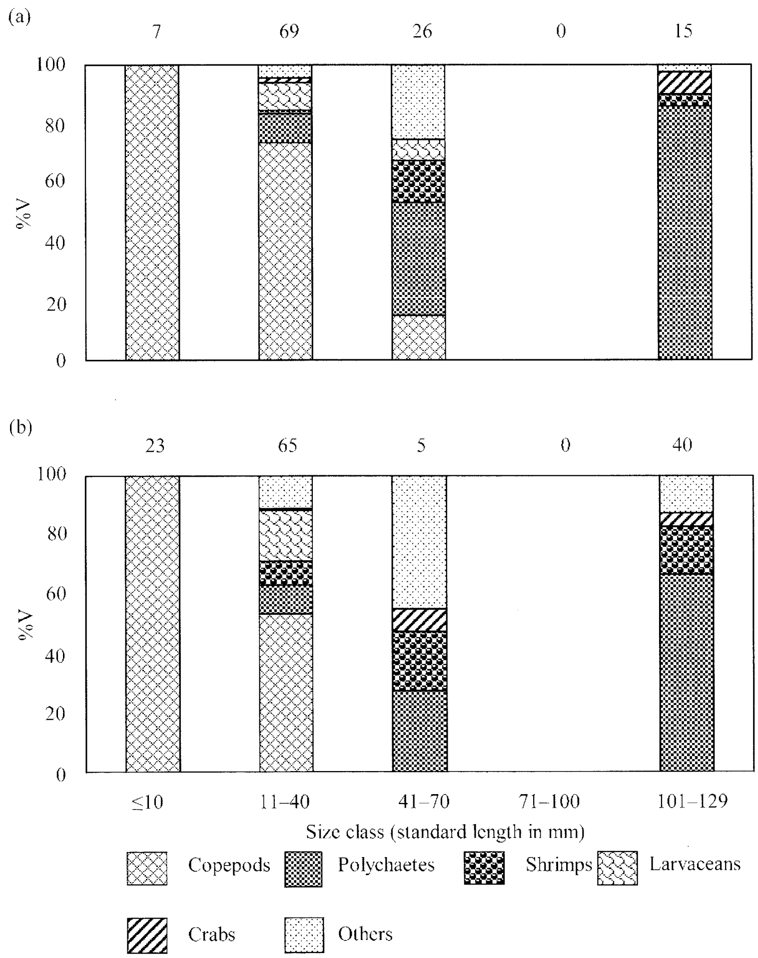

Fig. 1. Percentage volume (%V) of prey items in the diets of four size classes of juvenile *Sillago sihama* (a) and *S. aeolus* (b). Number of individuals containing food given above each column.

Table 3. Results of Gabriel multiple comparison test examining differences in percentage volume of each main food item of juvenile *Sillago sihama* and *S. aeolus* among size classes.

Species	Food item	Size class (standard length in mm)
S. sihama	Copepods	101–129 41–70 1–40 ≤10
	Polychaetes	≤10 11–40 41–70 101–129
S. aeolus	Copepods	101–129 41–70 11–40 ≤10
	Polychaetes	≤10 11–40 41–70 101–129

Size classes not significantly different ($P \geq 0.05$) are linked by underlining and arranged in order of increasing percentage volume.

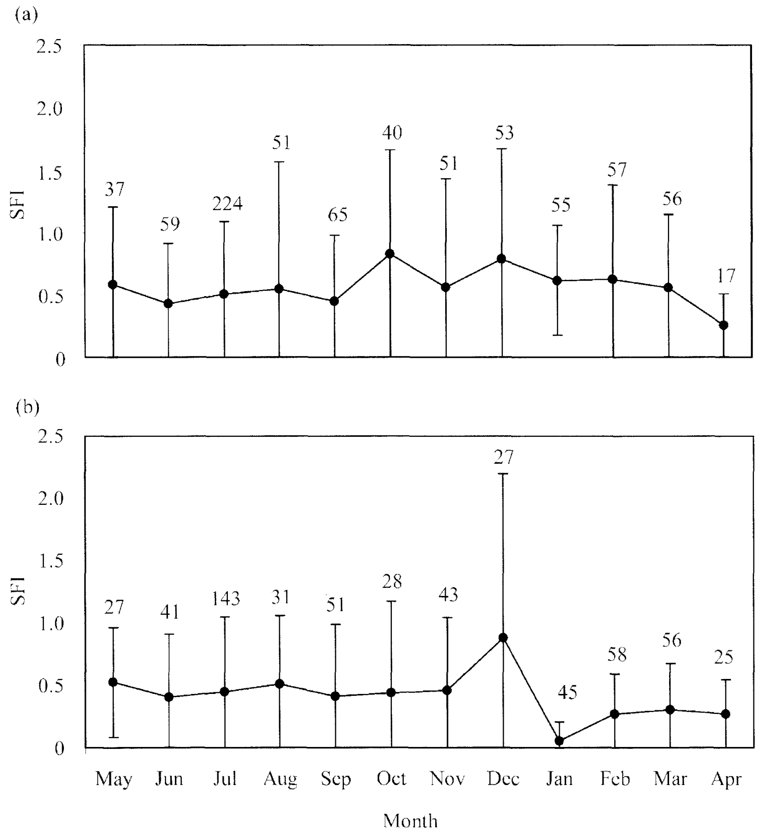

Fig. 2. Monthly changes in Stomach Fullness Index (*SFI*) of adult *Sillago sihama* (a) and *S. aeolus* (b). Bars indicate standard deviation. Number of specimens examined given above each bar.

was a significant interaction between month and species for the major items (Table 5). The %V of each item, therefore, was compared among months for each species, using a one-way ANOVA and post-hoc Gabriel test. These tests indicated that the %V of each of the three items in *S. sihama* and *S. aeolus* differed significantly among the various months of the study, but no apparent seasonal variations were detected (Fig. 3, Table 6). Comparing the %V of each food item between the two species in each month, differences were statistically

Table 4. Percentage volume (%V) of food items in the diets of adult *Sillago sihama* and *S. aeolus*.

Food items	*S. sihama* %V	*S. aeolus* %V
Polychaetes	58.7	46.8
Decapods		
Shrimps	12.4	11.3
Crabs	9.0	15.9
Mud lobsters	4.1	3.9
Hermit crabs	0.9	2.2
Mole crabs	0.4	2.4
Trumpet worms	2.8	6.0
Stomatopods	2.6	3.1
Fish	2.6	0.8
Molluscs		
Bivalves	0.7	1.6
Squids	0.2	0.3
Sea slugs	0.1	0.6
Bristtlestars	0.9	0.6
Sea anemones	0.5	0.8
Amphipods	0.2	0.1
Isopods	0.2	0
Crustacean fragments	3.0	2.1
Unidentified fragments	0.7	1.5
Number of fish with food examined	652	393
Standard lenght (mm)	130–233	130–200

Table 5. Results of a two-way ANOVA testing the effects of species and month on percentage volume of each main food item in the diets of adult *Sillago sihama* and *S. aeolus*.

Source	*DF*	*MS*	*F*	*P*
Polychaetes				
Species	1	7.26	18.1	<0.001
Month	11	1.27	3.16	<0.001
Species × Month	11	1.55	3.86	<0.001
Error	1021	0.40		
Crabs				
Species	1	2.61	12.1	0.001
Month	11	1.17	5.43	<0.001
Species × Month	11	0.64	2.97	0.001
Error	1021	0.21		
Shrimps				
Species	1	0.002	0.01	0.9
Month	11	0.83	6.02	<0.001
Species × Month	11	0.40	2.87	0.001
Error	1021	0.13		

Data transformed to arcsin $\sqrt{x}$

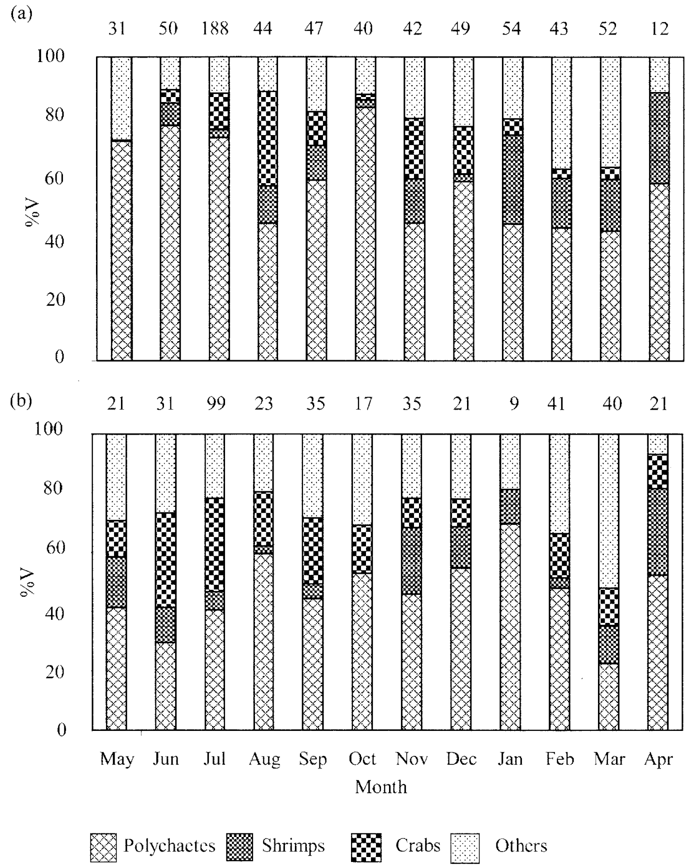

Fig. 3. Monthly changes in percentage volume (%V) of prey items in the diets of adult *Sillago sihama* (a) and *S. aeolus* (b). Number of individuals containing food given above each column.

Table 6. Results of Gabriel multiple comparison test examining differences in percentage volume of each main food item of adult *Sillago sihama* and *S. aeolus* among months.

Species	Food item	Month
S. sihama	Polychaetes	Feb Mar Nov Aug Jan Apr Sep Dec Jul May Jun Oct
	Shrimps	May Dec Jul Oct June Sep Aug Nov Mar Feb Jan Apr
	Crabs	May Apr Oct Feb Jun Mar Jan Sep Jul Dec Nov Aug
S. aeolus	Polychaetes	Mar Jun Jul May Sep Nov Oct Feb Aug Apr Dec Jan
	Shrimps	Oct Aug Feb Sep Jul Jun Jan Mar Dec May Nov Apr
	Crabs	Jan Dec Nov Apr May Mar Oct Feb Sep Jul Aug Jun

Months not significantly different ($P \geq 0.05$) are linked by underlining and arranged in order of increasing percentage volume.

significant in some months: *S. sihama* had higher %V of polychaetes in May, June, July, and October, and of shrimps in January, whereas *S. aeolus* showed greater %V of polychaetes in January, and of crabs in June and July (Fig. 3).

4. Discussion

The dietary compositions of juveniles of both *Sillago sihama* and *S. aeolus* changed progressively with increasing body size. This change included a shift from the ingestion of small zooplankton, such as calanoid copepods, by small juveniles, to the consumption of larger benthic prey, such as polychaetes, shrimps, and crabs, by larger juveniles, the latter diet being similar to those of adults of the two species. Such ontogenetic changes in food items have been found in several other sillaginid species (HYNDES *et al.*, 1997; SCHAFER *et al.*, 2002).

A shift from capturing small zooplankton to larger benthic prey organisms with growth in juveniles of the two *Sillago* species may be partly the result of continuing morphological development of feeding-related characters, including an increase in mouth width (e.g. DEVRIES *et al.*, 1998; KREBS and TURINGAN, 2003; KANOU *et al.*, 2005) and the ability to extend the jaws downward and forward (GUNN and MILWARD, 1985; HYNDES *et al.*, 1997; SCHAFER *et al.*, 2002). Such protrusible jaws would facilitate the taking of benthic prey on and in the substrate.

The diets of adult *S. sihama* and *S. aeolus* at Sikao Bay consisted mainly of polychaetes, crabs, and shrimps. These food items were essentially similar to those described for *S. sihama* from Taiwan (LEE, 1976) and North Queensland, Australia (GUNN and MILWARD, 1985), and other sillaginid species from tropical and temperate waters (KAKUDA, 1970; BREWER and WARBURTON, 1992; HYNDES *et al.*, 1997; PLATELL and POTTER, 2001; SCHAFER *et al.*, 2002).

Our results showed that the diets of adult *S. sihama* and *S. aeolus* did not undergo pronounced seasonal changes, although the %V of the three major food items in each of the two species differed significantly among some months of the study. The lack of seasonal changes in diet may be attributable to relatively little seasonal fluctuations in food resource abundance at the study site, as also reported in other tropical coastal waters (COLES and MCCAIN, 1990; MCCARTHY *et al.*, 2000). This inference may be supported by the fact that the overall mean *SFI* of specimens varied little from month to month for either species.

In the present study, a considerable overlap in dietary composition in juveniles and adults between the two coexisting *Sillago* species was recognized during the study period, although the %V of major food items was somewhat different between the species in some months, suggesting that there is little or no competition between the two species at Sikao Bay. Several studies have demonstrated that diets among related cohabiting fishes greatly overlap where food resources are relatively abundant, while lower food abundance results in greater trophic and/or habitat segregation through interspecific competition (e.g. ROSS, 1986; HOLBROOK and SCHMITT, 1989; HORINOUCHI *et al.*, 1998). The considerable diet and habitat overlap between the two *Sillago* species at Sikao Bay may be due to the relative abundance of food resources, although we did not examine food resource abundance at the study area. The relationship between diet compositions of the two species and prey abundance appears to be a subject for further research.

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References

BREWER, D.T. and K. WARBURTON (1992) : Selection of prey from a seagrass/mangrove environment by golden lined whiting, *Sillago analis* (Whitley). J. Fish Biol., **40**, 257–271.

COLES, S.L. and J.C. MCCAIN (1990) : Environmental factors affecting benthic infaunal communities of the western Arabian Gulf. Mar. Environ. Res., **29**, 289–315.

DEVRIES, D.R., R.A. STEIN and M.T. BREMIGAN (1998) : Prey selection by larval fishes as influenced by available zooplankton and gape limitation. Trans. Am. Fish. Soc., **127**, 1040–1050.

GUNN, J.S. and N.E. MILWARD (1985) : The food, feeding habits and feeding structures of the whiting species *Sillago sihama* (Forsskål) and *Sillago analis* Whitley from Townsville, North Queenland, Australia. J. Fish Biol., **26**, 411–427.

HOBSON, E.S. (1974) : Feeding relationships of teleostean fishes on coral reefs in Kona, Hawaii. Fish. Bull., **72**, 915–1031.

HOLBROOK, S.J. and R.J. SCHMITT (1989) : Resource overlap, prey dynamics, and the strength of competition. Ecology, **70**, 1943–1953.

HORINOUCHI, M. and M. SANO (2000) : Food habit of fishes in a *Zostera marina* bed at Aburatsubo, central Japan. Ichthyol. Res., **47**, 163–173.

HORINOUCHI, M., M. SANO, T. TANIUCHI and M. SHIMIZU (1998) : Food and microhabitat resource use by *Rudarius ercodes* and *Ditrema temmincki* coexisting in a *Zostera* bed at Aburatsubo, central Japan. Fish. Sci., **64**, 563–568.

HYNDES, G.A., M.E. PLATELL and I.C. POTTER (1997): Relationships between diet and body size, mouth morphology, habitat and movements of six sillaginid species in coastal waters: implications for resource partitioning. Mar. Biol., **128**, 585–598.

KAKUDA, S. (1970) : Studies on the ecology and fishing stock of *Sillago sihama* (FORSKÅL) through the analysis of its bottom drift-net fishery. J. Fac. Fish. Anim. Husb., Hiroshima Univ., **9**, 1–55 (In Japanese with English summary).

KANOU, K., M. SANO and H. KOHNO (2005) : Ontogenetic diet shift, feeding rhythm and daily ration of juvenile yellowfin goby, *Acanthogobius flavimanus*, on a tidal mudflat in the Tama River estuary, central Japan. Ichthyol. Res., **52**, in press.

KREBS, J.M. and R.G. TURINGAN (2003) : Intraspecific variation in gape-prey size relationships and feeding success during early ontogeny in red drum, *Sciaenops ocellatus*. Environ. Biol. Fish., **66**, 75–84.

LEE, S.C. (1976) : Diet of juvenile *Sillago sihama* (FORSKÅL) from inshore waters near Hsinchu, Taiwan. Bull. Inst. Zool., Academia Sinica, **15**, 31–37.

MCCARTHY, S.A., E.A. LAWS, W.A. ESTABROOKS, J.H. BAILEY-BROCK and E.A. KAY (2002) : Intra-annual variability in Hawaiian shallow-water, soft-bottom macrobenthic communities adjacent to a eutrophic estuary. Estuar. Coast. Shelf Sci., **50**, 245–258.

MCKAY, R.J. (1999) : Sillaginidae. *In* FAO Species Identification Guide for Fishery Purposes. The Living Marine Resource of the Western Central Pacific. Vol. 4. Bony Fishes Part 2 (Mugilidae to Carangidae). CARPENTER, K.E. and V.H. NIEM (eds.), Food and Agriculture Organization of the United Nation, Rome, p. 2614–2629.

NAKAMURA, Y., M. HORINOUCHI, T. NAKAI and M. SANO (2003) : Food habits of fishes in a seagrass bed on a fringing coral reef at Iriomote Island, southern Japan. Ichthyol. Res., **50**, 15–22.

PLATELL, M.E. and I.C. POTTER (2001) : Partitioning of food resources amongst 18 abundant benthic carnivorous fish species in marine waters on the lower west coast of Australia. J. Exp. Mar. Biol. Ecol., **261**, 31–54.

ROSS, S.T. (1986) : Resource partitioning in fish assemblages: a review of field studies. Copeia, **1986**, 352–388.

SANO, M., M. SHIMIZU and Y. NOSE (1984) : Food habits of teleostean reef fishes in Okinawa Island, southern Japan. Univ. Mus. Univ. Tokyo Bull., **25**, 1–128.

SCHAFER, L.N., M.E. PLATELL, F.J. VALESINI and I.C. POTTER (2002) : Comparison between the influence of habitat type, season and body size on the dietary composition of fish species in near shore marine water. J. Exp. Mar. Biol. Ecol., **278**, 67–92.

UNDERWOOD, A.J. (1997) : Experiments in Ecology: Their Logical Design and Interpretation Using Analysis of Variance. Cambridge University Press, Cambridge, 504 pp.

ZAR, J.H. (1999) : Biostatistical Analysis, 4th edn. Prentice Hall, London, 663 pp.

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