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TITLE

Freshwater migration and feeding habits of juvenile temperate seabass *Lateolabrax japonicus* in the stratified Yura River estuary, the Sea of Japan

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ABSTRACT: Juveniles temperate seabass *Lateolabrax japonicus* were sampled along the Yura River estuary from April to July 2008 to determine their distribution and feeding habits during migration within a microtidal estuary. Juveniles were distributed not only in the surf zone, but also in the freshwater zone and they were particularly abundant associated with aquatic vegetations in the freshwater zone, throughout the sampling period. This distribution pattern suggests that the early life history of the temperate seabass depends more intensively on the river than previously considered. Small juveniles in the freshwater zone fed on copepods and chironomid larvae, and then from ca. 20 mm standard length (SL) on mysids. In contrast, juveniles (ca. 17-80 mm SL) in the surf zone fed mainly on mysids.

KEY WORDS: “estuary”, “feeding habits”, “fresh water”, “juvenile”, “*Lateolabrax japonicus*”, “migration”, “salt wedge”, “Yura River”

INTRODUCTION

Temperate seabass *Lateolabrax japonicus* is a euryhaline fish distributed in temperate coastal waters of Japan and Korea [1]. The temperate seabass is often dominant in coastal areas, and is thus commercially important. The temperate seabass is one of the handful species whose landing has been increasing in the recent 20 years in Japan, while many other species of fish have decreased [2]. The fluctuation of fish stocks is largely dependent on survival during the early life stages [3,4]. Therefore, clarification of the early life history of temperate seabass may enable verification of the mechanism of the recent increase in its landing.

In general, during the early part of the juvenile period, this species migrates from open water areas into estuaries, surf zones, and/or coastal areas to feed on copepods, mysids, amphipods, decapods, or fish larvae [5,6]. The life history of migratory juveniles has been thoroughly investigated in the Chikugo River estuary and the Shimanto River estuary, Japan. The Chikugo River estuary is characterized by its large tide and subsequent productivity [7]. In the Chikuogo River estuary, some early juveniles (ca. 20 mm SL) ascend the river in March then inhabit the upper estuary, including the freshwater zone [8-11], while others reside in the lower estuary [8,9] or in the littoral zone [12]. For early juveniles of temperate seabass, migration to the freshwater zone was only been reported in the Chikugo River estuary. There are two possible reasons; first, in the upper Chikugo River estuary, strong tidal currents form the estuarine turbidity maximum (ETM) [7], where prey items are abundant [13,14]. Second, temperate seabass in the Ariake Bay including the Chikugo River estuary is a hybrid between *L. japonucs* and Chinese seabass *Lateolabrax* sp. [15]. The Chinese seabass has higher performance for osmoregulation to freshwater than temperate seabass [16]. This would lead juveniles in the Chikugo River estuary to ascend the river to the freshwater zone [16]. On the other hand, no ETM is observed in the Shimanto River estuary, although there are some seagrass beds [17]. Early juveniles occur and aggregate in the seagrass beds in brackish waters in the Shimanto River estuary from February, then they inhabit there at least until May [17]. The seagrass beds are therefore regarded to important nursery areas for juveniles in the Shimanto River estuary [17].

In the Tango Sea, which is located in the western Wakasa Bay, temperate seabass is one of the most important fisheries resources. Temperate seabass spawns offshore from December to February [18] (Fig. 1). It was determined that eggs and larvae are transported to inshore areas within a few months [19], but migration pattern after the larval stage is unknown. It is not clarified whether juveniles migrate to upstream of the Yura River, which is the largest river flowing into the Tango Sea, or remain in the littoral zone after aggregation around the river mouth [19]. In addition, feeding habits of temperate seabass in the Yura River estuary are unknown, even though it is of foremost ecological importance.

The Tango Sea is a part of the Sea of Japan, so that the tides are considerably weaker than in the East China Sea and along the Pacific coast [20]. The hydrographic conditions in the Tango Sea and Yura River estuary are therefore apparently different from the aforementioned large-tide estuaries (i.e. the Chikugo and Shimanto River estuaries). The small tides restrict the mixing of seawater and freshwater, and the water thus tends to be stratified in the estuary [20]. Remarkably strong turbidity maximum zones, which are formed by the strong tidal currents in the upper Chikugo River estuary [7], are not observed in the estuaries facing to the Sea of Japan [20]. These differences in environmental conditions may lead to different migration and/or feeding habitats of the juveniles. However, no surveys have been previously conducted on the distribution and feeding habits of the juveniles in the rivers along the Sea of Japan side. The main objective of this study was therefore to determine the temporal distributions of juvenile temperate seabass in the microtidal Yura River estuary. We conducted ca. weekly surveys along the estuary to investigate the upstream migration. In addition, gut contents of juveniles were observed to investigate their feeding habits.

MATERIALS AND METHODS

Study site

Observations and samplings were conducted along the lower reaches of the Yura River and adjacent surf zone during the spring-summer seasons of 2008 (Fig. 1). The Yura

River flows into the Sea of Japan, where the tides are generally small. The typical tidal range in the estuary is less than 0.5m [20], so that the effect of the tide on the fish distributions and environmental conditions were neglected in this study. The river discharge of the Yura River shows typical seasonal variations, which is large in winter and spring due to melting snow, while small in summer and autumn [20]. In winter, freshwater occupied the whole estuary and the water is homogeneous. Seawater starts to intrude into the lower layer of the estuary from early spring and then lower layer is occupied by sea water until ca. 20km upstream from the river mouth in summer, leading to strong stratification [20].

Five stations were set up along the lower reaches of the river from the mouth to 15km upstream (R1-R5, Fig 1c). The distances from river mouth were 0.5, 3.0, 6.5, 9.0 and 15.0 km at R1, R2, R3, R4 and R5, respectively. Almost riversides of the stations are free from bank protection. There are dense aquatic vegetations mainly composed of *Ceratophyllum demersum* close to an embankment at R3. Another station (S1) was set on the sand beach adjoining the river mouth (1.0 km from the river mouth, Fig. 1c). The bottom was sandy at S1, R1 and R2, while muddy at R3, R4 and R5.

Field sampling

In order to collect temperate seabass juveniles, a seine net (0.8 m×10 m, 1.0 mm mesh aperture at the cod end) was towed along the bank or shoreline every week from 18 April to 17 July, 2008. A few minutes tow was performed two or three times at each station. Sampling depth was 0.3 – 1.2 m at every station. Bottom water temperature and salinity were measured with an environmental monitoring system (YSI 556 MPS, YSI Inc., U.S.A.) at the same time as seine net towing. Collected juveniles were sorted and frozen using dry ice immediately after seining. These samples were transported to the laboratory and kept in a freezer until further analyses.

Laboratory analysis

The standard length (SL) and wet body weight (BW) of samples were measured. Ingested gut contents were removed from randomly selected specimens at each station. Gut contents were identified to the lowest possible taxonomic category and counted under a dissecting microscope. The feeding incidence was calculated as the percentage of the number of fish with food in relation to the total number analysed. Randomly selected organisms of each prey item were dried at 60 ℃ for over 24 h and individual dry weight measured to the nearest 0.001 mg after cooling to the air temperature with Mettler Toledo AT21 Comparator (Mettler Toledo Inc, Mississauga, ON, Canada). The composition of each prey item for each size class of fish was evaluated by calculating the percentage numerical composition (*%N*), percentage frequency of occurrence (*%F*) and percentage of dry weight composition (*%W*) as follows:

$$\%N = \frac{N_i}{N} \times 100,$$

where N_i is the number of prey i species and N is the total number of prey.

$$\%F = \frac{F_i}{F} \times 100,$$

where F_i and F are the number of fish fed on prey i species and total number of fish that had stomach content on each prey, respectively.

$$\%W = \frac{N_i \times W_i}{\sum (N_i \times W_i)} \times 100,$$

where W_i is the individual dry weight of prey item i species.

The contribution of a prey item to the diet was determined using the index of relative importance (IRI) [21]. The equation used was:

$$IRI = (\%N + \%W) \times \%F.$$

The IRI was standardized to $\%IRI$:

$$\%IRI = \frac{IRI}{\sum IRI} \times 100.$$

RESULTS

Hydrographic conditions

Temperature increased from 12.6℃ to 29.0℃ during the sampling period (Fig. 2a). There was no clear difference in temperature among the river stations. However, temperature at S1 was mostly lower than those at the other stations after May. Salinity fluctuated from 12.8 to 34.0 (mostly over 25.0) at S1, while it remained low (0.0 to 6.0) at the other river stations (Fig. 2b). Salinity was usually lower than 1.0 in the upper estuaries (R3, R4 and R5), indicating the sampling stations were mostly occupied by fresh water during the sampling period.

Distribution and size of the temperate seabass juveniles

A total of 1906 juveniles (15.0 – 77.9 mm SL) of temperate seabass were collected by the seine surveys from April to July 2008 (Fig. 3). Juveniles were widely distributed in both marine and freshwater environments, although the abundance varied among the stations. The catch at S1 showed a wide variation; 266 ind. were caught on 6 June, while only one fish on 13 June. On the other hand, individuals were consistently sampled at R3, at least until mid June. A relatively small number of juveniles were caught at the other stations. Judging from differences in environmental conditions and larger catches, we hereafter paid more attention to the three stations (S1, R3 and R4). We categorized S1, R3 and R4 as the surf zone, freshwater zone with aquatic vegetations, and freshwater zone without aquatic vegetations, respectively.

The median SLs of fish at S1 were 20.9 mm on 18 April, 28.2 mm on May 8, 40.6 mm on 6 June and 76.1 mm on 17 July (Fig. 4). At R3, the median SLs were 20.7 mm on 18

April, 23.6 mm on 8 May, 30.4 mm on 6 June and 55.8 mm on 17 July (Fig 4). Juveniles at R4 had median SLs of 17.6 mm on 18 April, 23.1 mm on 8 May and 34.9 mm on 6 June (Fig. 4).

Feeding habits

The feeding incidence kept high values of more than 80 % in all sizes at all three stations (Fig. 5). The diet of the juvenile of temperate seabass was composed of 9 types of prey items (Table 1). The dry weight of mysids in fish stomach (0.024 – 0.755 mg/ind.) was considerably heavier than other prey items (0.001 – 0.152 mg/ind.) except for that of polychaetes (5.335 mg/ind.; Table 2). The dry weight of ingested mysids increased with fish growth and mysids in the river were heavier than those in the surf zone at every fish size class (Table 2).

Mysids, composed of *Orientomysis japonica*, *Archaeomysis* spp., and *Nipponomysis* spp. (Table 1), were the most important prey item for all SL classes at S1 (Fig. 6). Amphipods and polychaetes were secondary important prey item for 20 – 60 mm SL classes and 60 – 80 mm SL, respectively, but their contributions were low. The main prey items at R3 were copepods, chironomid larvae and mysid *Neomysis awatschensis* (Table 1, Fig. 6). Copepods were the most important prey item for < 20 mm SL fish, followed by chironomid larvae. In the larger size classes (≥ 20 mm SL), mysid represented more than 55 % of total *IRI*, while contributions of copepods and chironomid larvae were comparatively low. Chironomid larvae was the dominant prey item for smaller size class (< 20 mm SL) at R4, followed by cladocerans, mysid *Neomysis awatschensis* and copepods (Table 1, Fig. 6). The *%IRI* of prey items for larger size classes (≥ 20 mm SL) showed similar pattern to that of R3; mysids were the most important prey item, while contributions of copepods, chironomid larvae and amphipods were low.

DISCUSSION

The temperate seabass juveniles occur in various environments in diverse waters [5,6]. Therefore it is important to investigate and compare the ecology of this species among the different conditions.

Distribution

This study first determined that a certain number of early juveniles of ca. 20 mm SL migrate into the freshwater zone of the stratified Yura River estuary in April, while other juveniles reside in the surf zone (Fig. 3). The two migratory pathways of early juveniles of the temperate seabass are similar to those observed in the well-mixed Chikugo River estuary [10,12], although hydrographic conditions and genetic characteristics of fish populations are considerably different between the two estuaries [7,15,20]. This indicates that the two migratory pathways are the native ecology of juveniles of *L. japonicus* and common for temperate seabass juveniles in other estuaries. This also suggests that the early life history of this species depends more intensively on the river water than previously considered. No previous studies on temperate seabass early juveniles have been conducted in the freshwater zone. It is thus necessary to investigate the distribution in the other estuaries to confirm the generality of the migration of juveniles into freshwater as well as residence in the sea water and brackish water.

Some studies showed that juveniles select the flood tide to achieve effective upstream transport in the Chikugo River estuary [6,9]. A similar migrating mechanism was also reported for other fish species in the other estuaries [22,23]. In the Yura River estuary, however, the tidal range is considerably small and strong tidal current is not induced [20]. Therefore juveniles may ascend the Yura River through the bottom layer which is occupied by sea water rather than the tidal stream transport. The timing of salt wedge intrusion in the Yura River estuary varied annually according to the river discharge in winter [20]. This suggests that the timing of river ascending of juveniles would fluctuate from year to year. The long term investigations are needed to determine this hypothesis.

Ohmi [19] indicated the distribution of juveniles in the coastal area around the Yura River mouth in March with the size range from ca. 10 to ca. 14 mm SL. This study showed some juveniles were already distributed in the freshwater zone in mid April with the size range of ca. 15 to 25 mm SL. The distribution of juveniles was determined in the Yura River from 8 March in 2009 (Fuji T, unpubl. data, 2009). These results suggest that juveniles ascend the river in March in the Yura River estuary at the size of ca. 15 mm SL. Also in the Chikugo River estuary, juveniles begin to gather and ascend the river in March with the size of ca. 15 mm SL [8], corresponding to the case in the Yura River estuary. The spawning season of this species is from December to February and common in various waters in Japan [5], but the distance from spawning areas to the river mouth is farther in the case of enclosed bay (e.g. ca. 40 km from the Chikugo River estuary of the Ariake Bay) than the open bay (e.g. ca. 20 km from the Yura River estuary in the Wakasa Bay) [6]. Despite the difference in the distance of spawning areas from river mouths the corresponding of the river ascending season may come from the difference in the process of the transport mechanism of larvae [24].

In this study, juveniles with the size range from 15 to 77.9 mm SL were collected from April to July both in the freshwater zone and the surf zone. Given the lower number of collected juveniles over 40 mm SL in this study, many larger juveniles (> 40 mm SL) would escape from the net, although some larger juveniles were occasionally collected. However, the distribution of larger juveniles (> 40 mm SL) in the freshwater and surf zone was demonstrated after May in this study. In addition, ca. 900 large juveniles at the size of ca. 80 mm SL were collected in July by the fixed net at the mouth of the Yura River (Ohmi H, unpubl. data, 1995). This indicates that a part of large juveniles would have remained in the freshwater zone or surf zone. Therefore, both the surf zone and freshwater zone are utilized by various sizes of this species juvenile for long time in the Yura River estuary. This indicates that both zones provide sufficient environmental conditions (e.g. ambient prey abundance or low predation) of these habitats for juveniles of various sizes. Suzuki et al [10] also reported juveniles use the lower salinity area (salinity < 10) from March to August in the Chikugo River estuary. Arayama and Imai [25] reported the short residence (less than a month)of temperate seabass juveniles in the surf zone of the outer part of the Tokyo Bay, although Hibino et al. [26] and this study reported the longer utilization (ca. several months) of the surf zone by juveniles. Kinoshita [27] showed that many species use the surf zone in short periods in their juvenile stage. He considered that the surf zone plays an important role for these species juveniles as a place fir their metamorphosis. This study showed that the surf zone would have functions not only as a place for their metamorphosis but also as a nursery area for temperate seabass juveniles. It is necessary to investigate the ecology of temperate seabass juveniles in the surf zone in the other waters to determine the importance of the surf zone for this species. This would lead to determine the other aspects of the surf zone for juveniles.

Feeding habits

Copepods, chironomid larvae, polychaetes and mysids were the important food for juveniles in the Yura River estuary and adjacent surf zone (Table 1, Fig. 6). The importance of these prey items for this species juvenile is reported in many studies [5]. However, the timing of ontogenetic changes of feeding habits varies with waters. In the Chikugo River estuary, juveniles change their main food from copepods to mysids at the size of 40 mm SL [28]. On the other hand, juveniles shift their main prey items from copepods to mysids at 20 mm SL in the Kumihama Bay, adjacent to the Tango Sea [18]. In this study, juveniles at S1 fed on mysids from < 20 mm SL. In the freshwater zone (R3 and R4), smaller juveniles (< 20 mm SL) had mainly copepods, chironomid larvae, and cladocerans, while larger juveniles (≥ 20 mm SL) consumed mainly mysids. These differences in the timing of food change would reflect the ambient prey environment as reported in Japanese flounder *Paralichthys olivaceus* [29]. The earlier dependence on myisds in the surf zone in this study would derived from the high density of some mysid species occurring in shallow waters around the Yura River mouth from March to June (Tane S, unpubl. data, 1992). It is considered that juveniles of this species change their feeding habits flexibly according to the ambient prey environments. Therefore, the ambient prey environment in the Yura River estuary and adjacent surf zone should be investigated to determine the relationship between ontogenetic change of feeding habits and prey environment. It is also important to examine the feeding ecology of this species in various waters with various ambient prey environments to determine the survival strategies of this species.

The aquatic vegetations as a nursery area in the freshwater zone

In the freshwater zone, juveniles were considerably abundant associated with aquatic vegetations (Fig. 3), indicating the aquatic vegetations play an important role in the freshwater zone in the Yura River estuary. This is consistent with the previous studies showing the temperate seabass juveniles intensively depend on seagrass beds in lower salinity waters [5,6]. In the Shimanto River estuary, although there was no difference in *%N* of food items and feeding incidence between seagrass beds and non-seagrass beds, juveniles in seagrass beds fed on more food by weight [17]. In this study, feeding habits for juveniles smaller than 20 mm SL were different between the freshwater zone with and without aquatic vegetations (Fig. 6); copepods were the most important prey item in the aquatic vegetations, while chironomid larvae were most important in the freshwater without aquatic vegetations. The aquatic vegetations in the freshwater zone would give some effects on feeding habits, although some more quantitative surveys for feeding habits are necessary for examining this idea exactly.

Shoji et al. [30] indicated the importance of seagrass beds as a refuge from fish predators for red sea bream *Pagrus major* juveniles. The aquatic vegetations in the freshwater zone may be also important for temperate seabass juveniles as refuges from predators. These functions of the aquatic vegetations in the freshwater zone would correspond to those of ETM in the Chikugo River estuary [31]. The aquatic vegetations or seagrass beds may play important roles in place of ETM in the river without ETM (e.g. the Shimanto River estuary and the Yura River estuary).

Determining the relative value of the freshwater zone and surf zone as nursery areas is important for understanding the ecological strategy of this species juvenile. Stable isotopes and otolith Sr/Ca ratio as migration markers are considered to be necessary for analysing the detailed migration pattern of juveniles [32,33]. In addition, it is also important to measure the width of otolith increments for more information about growth records.

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FIGURE CAPTIONS

Fig. 1 Sampling stations along the Yura River. Hatched sea area indicates the spawning area of temperate seabass in this water [18]

Fig. 2 Temporal changes in (a) temperature and (b) salinity

Fig. 3 Number of temperate seabass juveniles collected at each station. n.d. indicates that no surveys were conducted at the station on the date

Fig. 4 Weekly changes in the frequency of standard length (SL) of juvenile temperate seabass at S1, R3 and R4. N, M and R indicate the number of fish analysed, the median SL, and the range of SL, respectively. n.d. indicates no data

Fig. 5 Feeding incidence of juveniles (< 60 mm SL) for each size class at S1, R3 and R4

Fig. 6 Composition of diet of temperate seabass at S1, R3 and R4 among size classes, based on the percentage index of relative importance (*%IRI*) values of each prey groups. Numbers above the bars show the numbers of stomachs analysed in each size classes

Table 1 Diet composition of juvenile temperate seabass at S1, R3 and R4

Station	Prey item	Size class (mm SL)											
		< 20			20–40			40–60			60–80		
		%N	*%F*	*%W*	*%N*	*%F*	*%W*	*%N*	*%F*	*%W*	*%N*	*%F*	*%W*
S1													
	Copepods	0.0	0.0	0.0	11.1	23.4	0.1	0.0	0.0	0.0	0.8	25.0	0.0
	Mysids	100.0	71.4	100.0	74.9	78.1	95.0	64.3	72.2	78.5	89.9	100.0	24.8
	Neomysis awatschensis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Orientomysis japonica	0.0	0.0	0.0	17.6	15.6	16.6	6.1	9.1	3.2	1.4	40.0	0.4
	Archaeomysis spp.	0.0	0.0	0.0	0.2	1.6	0.2	0.0	0.0	0.0	38.5	100.0	10.6
	Nipponomysis spp.	62.5	42.9	62.5	14.7	20.3	15.1	3.1	18.2	5.3	2.0	40.0	0.6
	Unidentified mysids	37.5	57.1	37.5	49.4	62.5	63.1	55.1	100.0	70.0	48.0	100.0	13.3
	Chironomid larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Insect larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Amphipods	0.0	0.0	0.0	9.5	29.7	4.8	35.7	45.5	21.5	1.4	40.0	0.4
	Cladocerans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Tanaids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Isopods	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	40.0	0.7
	Polychaetes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	80.0	74.1
	Unidentified	+	28.6		+	10.9		0.0	0.0	0.0	0.0	0.0	
	No. fish with empty gut	1			5			0			0		
	No. fish examined	8			69			11			5		

Table 1 continued

Station	Prey item	Size class (mm SL)											
		< 20			20–40			40–60			60–80		
		%N	*%F*	*%W*	*%N*	*%F*	*%W*	*%N*	*%F*	*%W*	*%N*	*%F*	*%W*
R3													
	Copepods	62.5	91.7	13.1	66.2	64.9	2.4	16.9	26.3	0.2	0.0	0.0	0.0
	Mysids	9.6	16.7	47.0	13.4	63.6	87.9	80.5	100	91.0	100.0	100.0	100.0
	Neomysis awatschensis	0.0	0.0	0.0	10.9	44.2	71.2	57.9	78.9	64.9	38.5	100.0	38.5
	Orientomysis japonica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Archaeomysis spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nipponomysis spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Unidentified mysids	9.6	16.7	47.0	2.5	29.9	16.8	22.6	47.4	26.2	61.5	100.0	61.5
	Chironomid larvae	11.0	66.7	30.0	8.7	51.9	4.1	1.7	21.1	0.3	0.0	0.0	0.0
	Insect larvae	0.7	8.3	5.9	0.2	5.2	0.3	0.9	15.8	0.4	0.0	0.0	0.0
	Amphipods	0.0	0.0	0.0	0.1	3.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0
	Cladocerans	14.7	25.0	0.8	10.8	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	Tanaids	1.5	16.7	3.2	0.4	10.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0
	Isopods	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Polychaetes	0.0	0.0	0.0	0.1	2.6	4.8	0.0	0.0	0.0	0.0	0.0	0.0
	Unidentified	0.0	0.0		+	5.2		0.0	0.0		0.0	0.0	
	No. fish with empty gut	1			4			0			0		
	No. fish examined	13			81			11			1		

Table 1 continued

Station	Prey item	Size class (mm SL)											
		< 20			20–40			40–60			60–80		
		%N	*%F*	*%W*	*%N*	*%F*	*%W*	*%N*	*%F*	*%W*	*%N*	*%F*	*%W*
R4													
	Copepods	4.8	66.7	0.8	44.9	77.3	0.7	38.6	64.3	0.6	0.0	0.0	0.0
	Mysids	6.8	33.3	27.3	36.0	86.4	95.1	58.8	100	85.6	100.0	100.0	100.0
	Neomysis awatschensis	2.7	33.3	10.9	16.9	41.3	44.8	17.7	85.7	27.5	46.7	100.0	46.7
	Orientomysis japonica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Archaeomysis spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nipponomysis spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Unidentified mysids	4.1	33.3	16.4	19.1	60.9	50.4	41.2	92.9	58.1	53.3	100.0	53.3
	Chironomid larvae	31.3	66.7	69.5	14.8	32.6	2.8	1.2	28.6	0.2	0.0	0.0	0.0
	Insect larvae	0.0	0.0	0.0	0.8	6.5	0.4	0.6	14.3	0.3	0.0	0.0	0.0
	Amphipods	0.0	0.0	0.0	1.3	6.5	0.7	0.3	7.1	0.2	0.0	0.0	0.0
	Cladocerans	57.1	66.7	2.4	1.6	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Tanaids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Isopods	0.0	0.0	0.0	0.5	2.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0
	Polychaetes	0.0	0.0	0.0	0.0	0.0	0.0	0.6	14.3	12.1	0.0	0.0	0.0
	Unidentified	0.0	0.0		+	6.5		0.0	0.0		0.0	0.0	
	No. fish with empty gut	1			7			0			0		
	No. fish examined	7			53			14			1		

"+" indicates uncountable

Table 2 Dry weight of each prey item (mean±S.D.)

Prey item	Area	N	Dry weight (mg/ind.)
Mysid from < 20 mm SL juveniles	S	9	0.024±0.012
	F	7	0.094±0.121
Mysid from 20 – 30 mm SL juveniles	S	19	0.256±0.556
	F	31	0.710±0.842
Mysid from 30 – 40 mm SL juveniles	S	17	0.418±0.485
	F	14	0.755±0.548
Mysid from 40 – 50 mm SL juveniles	S	10	0.406±0.450
	F	22	0.455±0.318
Mysid from > 50 mm SL juveniles	S	16	0.121±0.110
	F	16	0.294±0.126
Polychaetes	S&F	10	5.335±2.828
Fish larvae	S&F	10	0.096±0.036
Insect larvae	S&F	10	0.152±0.148
Cladocerans	S&F	10	0.001±0.000
Tanaids	S&F	10	0.042±0.016
Isopods	S&F	10	0.149±0.132
Copepods	S&F	10	0.004±0.003
Chironomids larvae	S&F	14	0.052±0.024
Amphipods	S&F	10	0.140±0.138

S; surf zone. F; freshwater zone. N; the number of samples analysed
Copepods, chironomid larvae and mysids from < 20 mm SL juveniles were pooled to measure their dry weights because of their small sizes

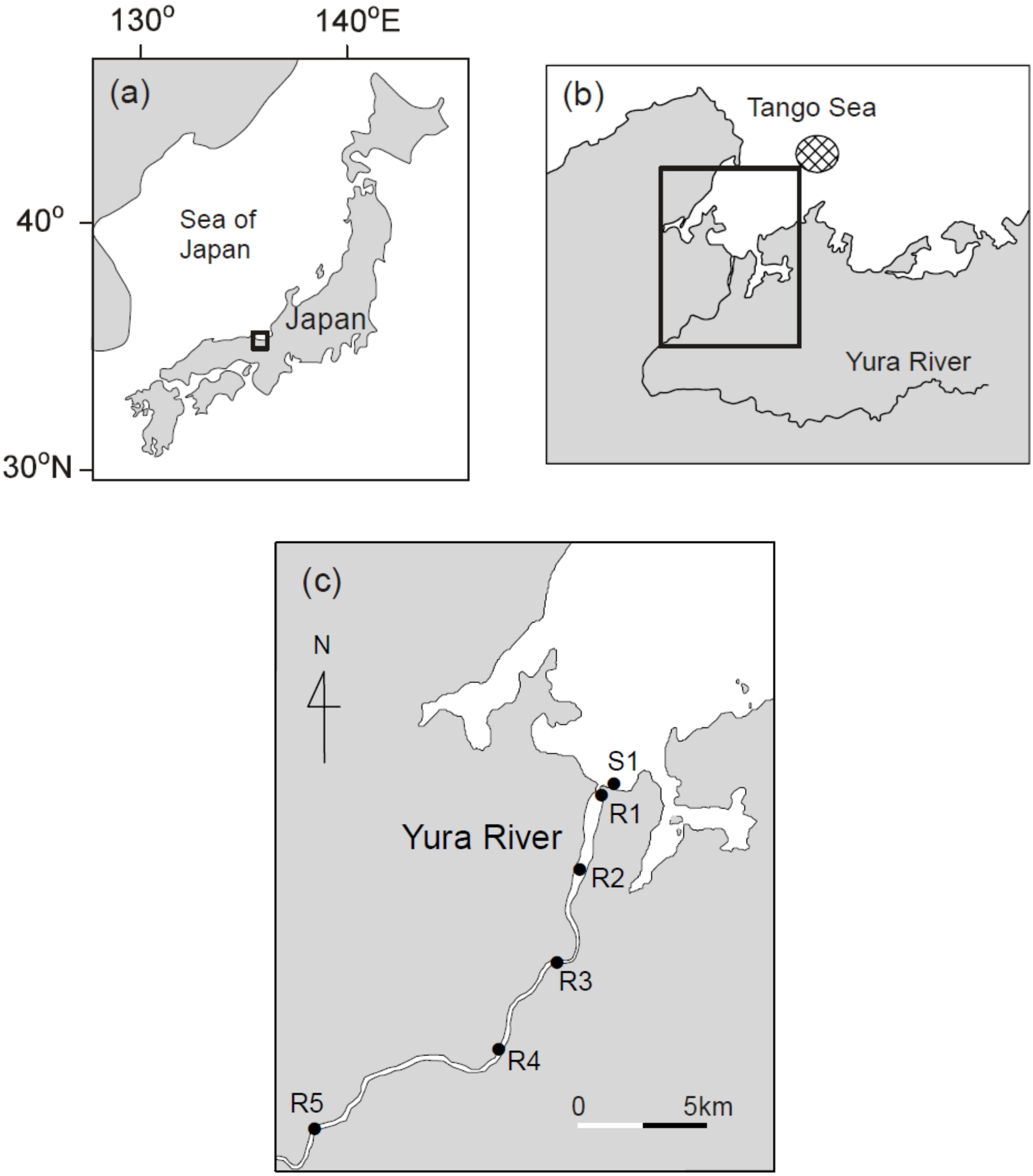

Fig. 1 Fuji et al.

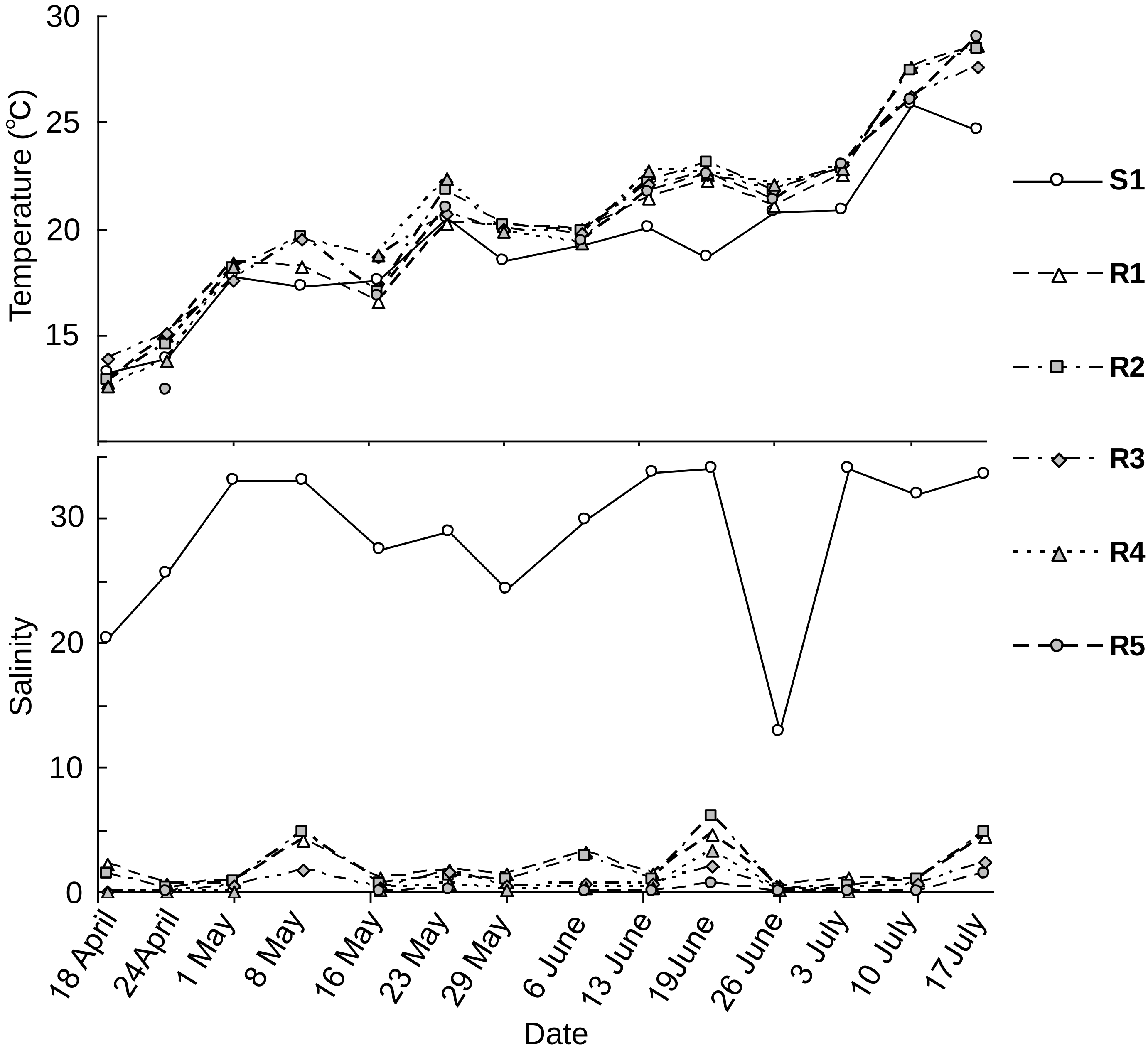

Fig.2 Fuji et al.

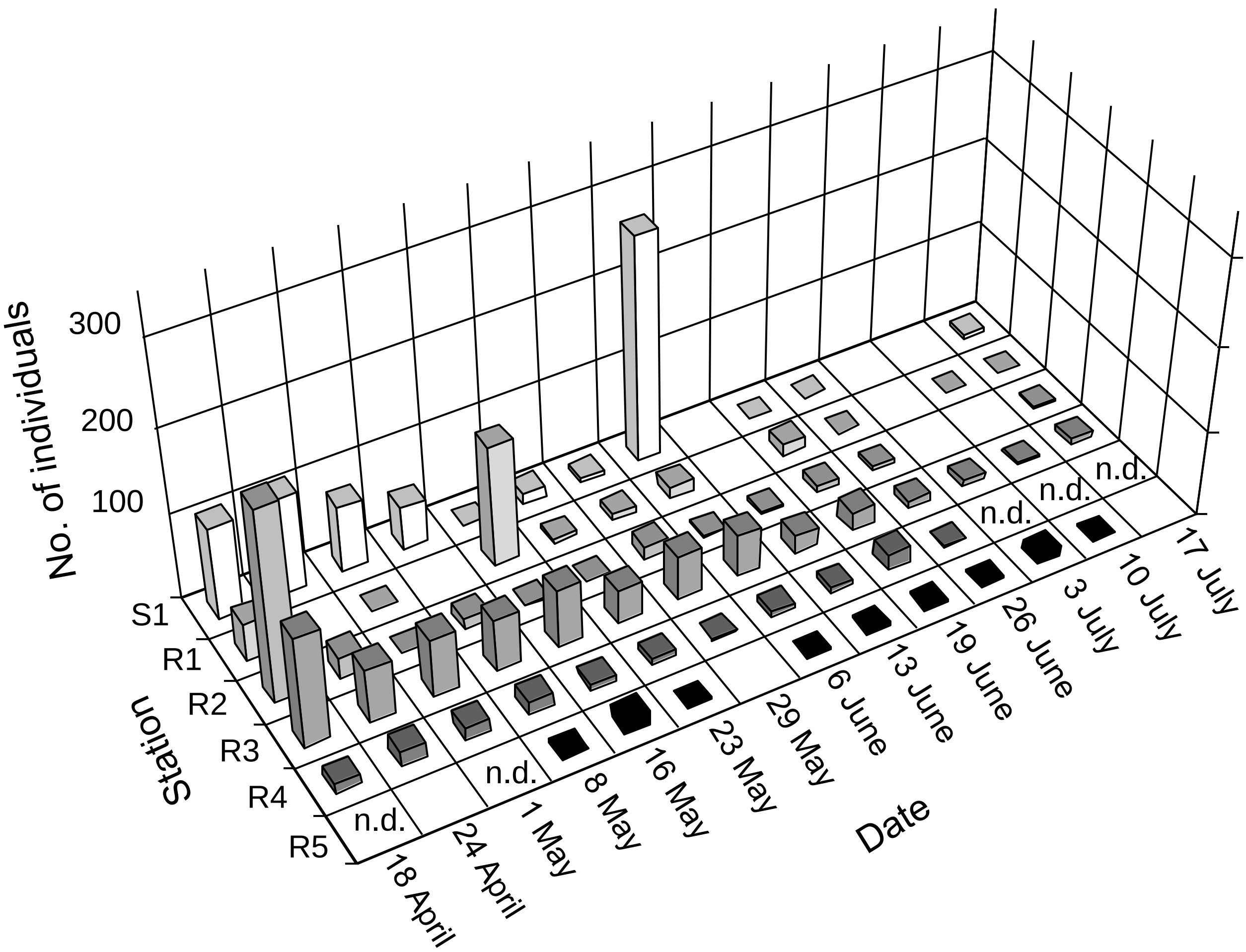

Fig.3 Fuji et al.

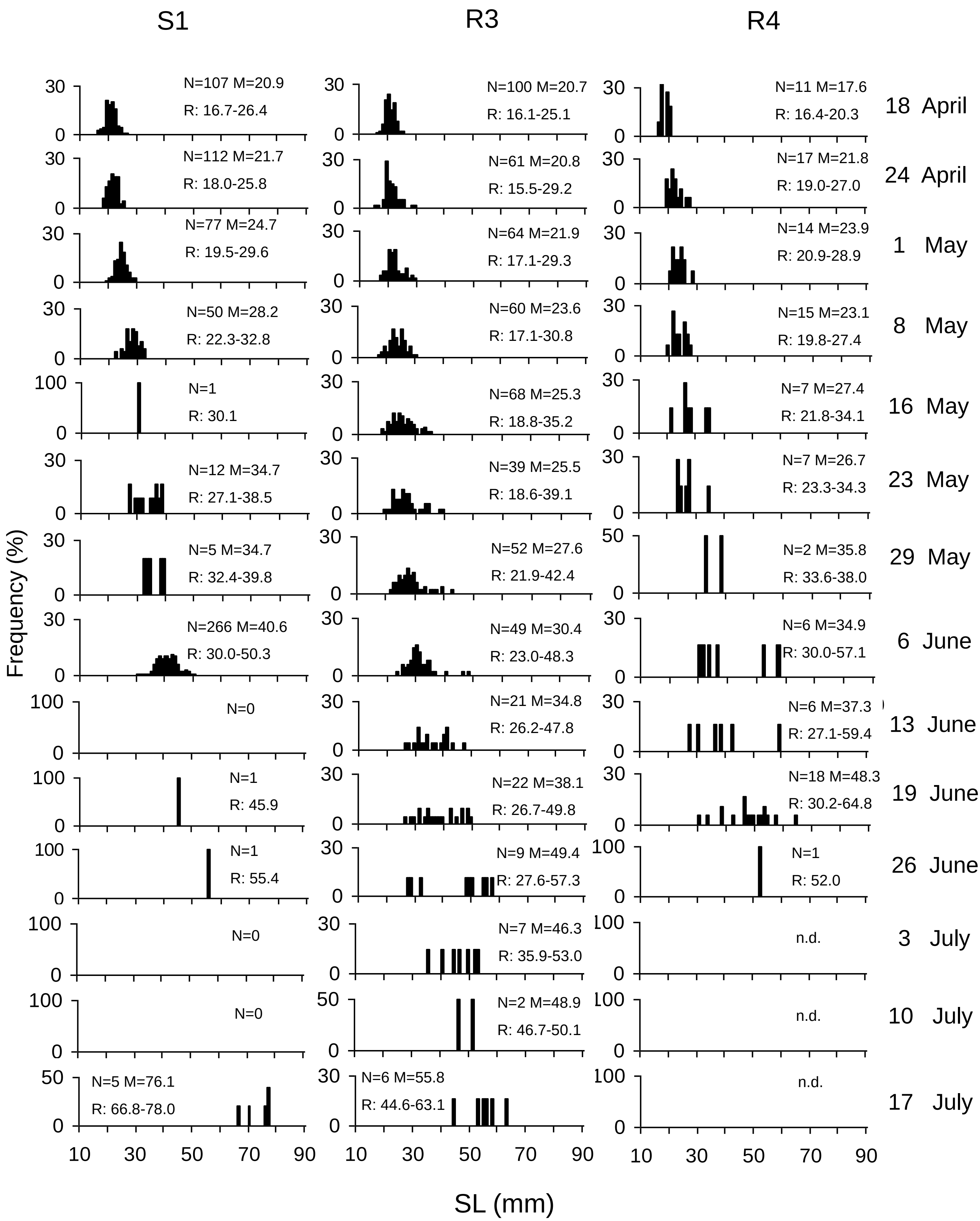

Fig. 4 Fuji et al.

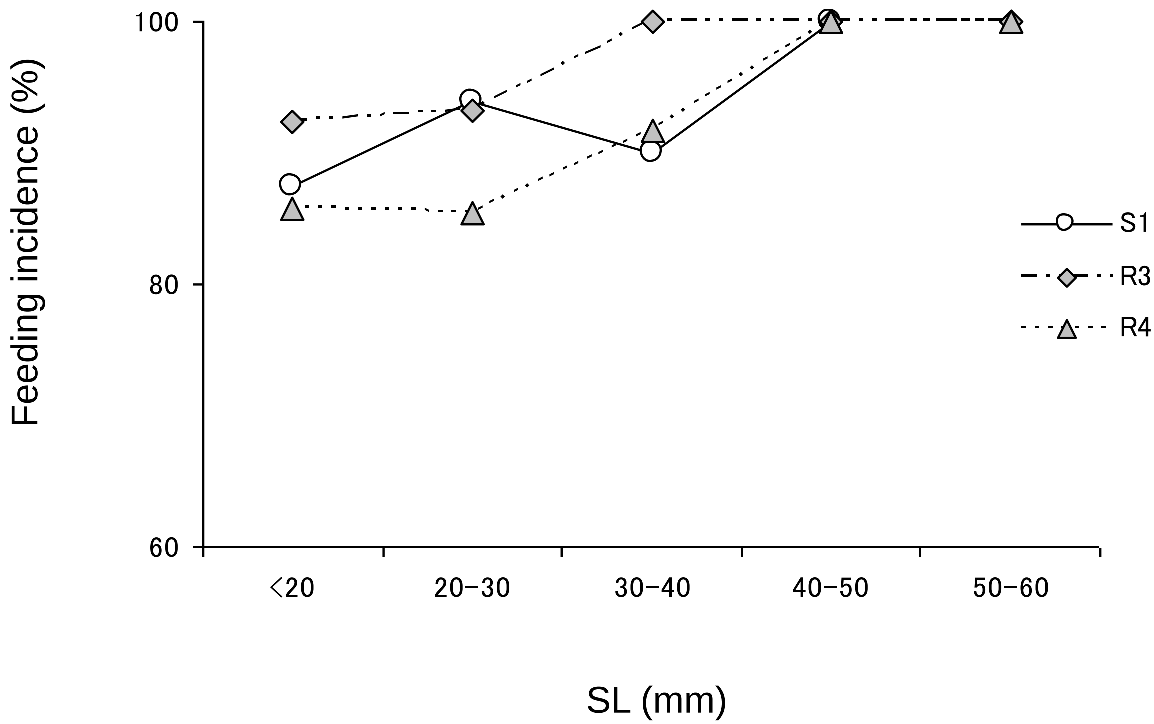

Fig. 5 Fuji et al.

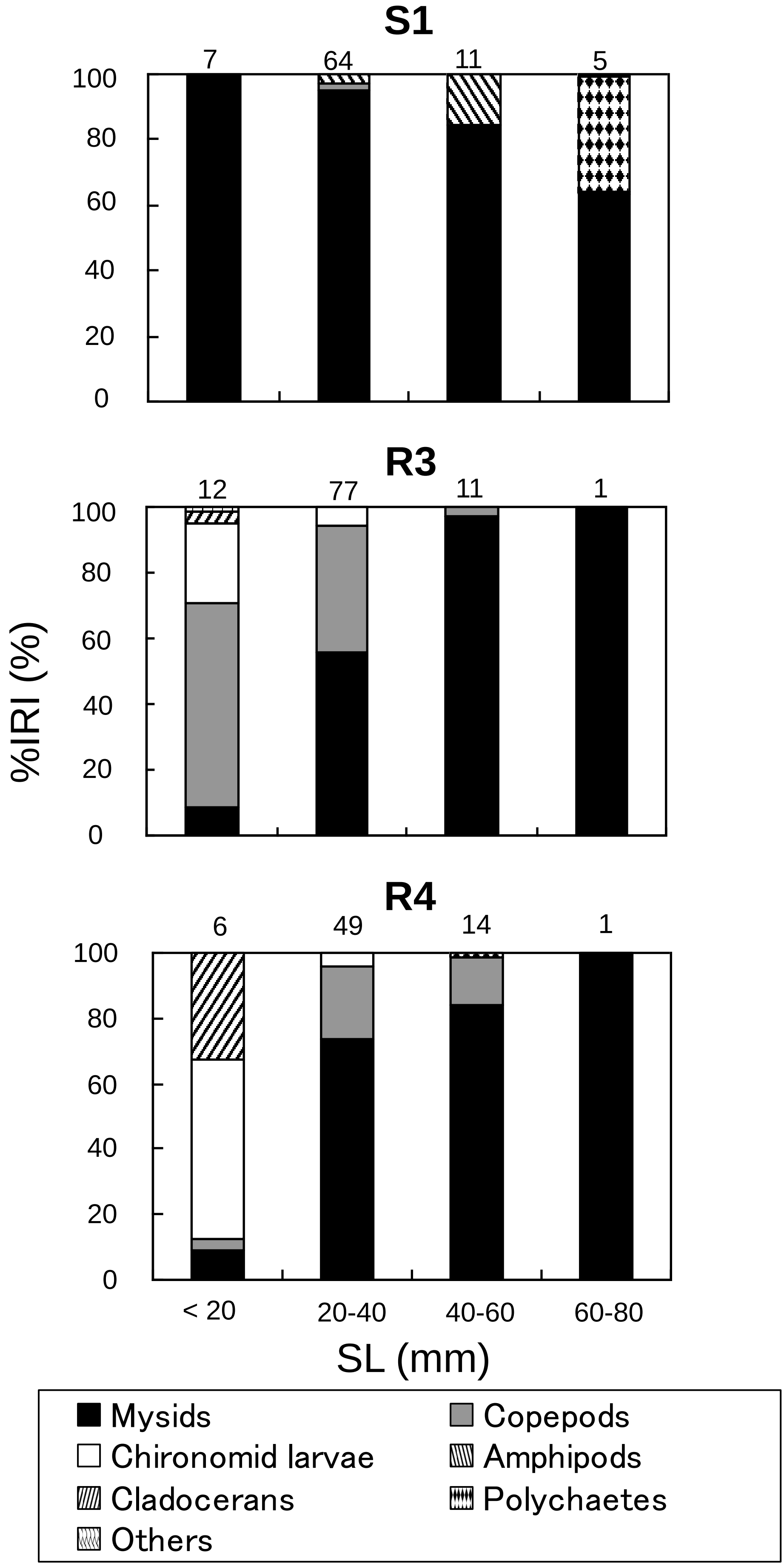

Fig. 6 Fuji et al.