

# Abundance and early life history traits of young-of-the-year *Sebastes inermis* in a *Zostera marina* bed

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**ABSTRACT:** Young-of-the-year (YOY) *Sebastes inermis* uses seagrass beds as a temporary nursery ground after completing the planktonic stage in offshore waters. In the present study, the otolith microstructure was used to reveal the early life history of this species in a *Zostera marina* bed in Matsushima Bay, northern Japan. In 1998 and 1999, the settlement season began in early spring and catch per unit effort (CPUE) of YOY decreased markedly during the summer months. The smallest YOY *S. inermis* collected were 20 and 21 mm total length (TL) at 70–80 days after extrusion in 1998 and 1999, respectively. In both years, YOY that were extruded earlier (mostly in January) first appeared in the *Zostera* bed, and they were the first to leave, whereas those YOY extruded later (mainly in February) tended to stay beyond the summer in the *Zostera* belt. Birth dates of YOY showed two distinct cohorts, January and February, which showed a similar pattern of growth in both years; rapid growth after settlement peaking in May in 1998 (mean=0.73 mm/day) and in April in 1999 (mean=0.61 mm/day), decreasing during the summer months, with the lowest mean values in August in both years (mean=0.40 mm/day for 1998 and 0.30 mm/day for 1999). In both years, the decrease in both CPUE and growth rates in summer months synchronized with a decline in biomass, density, leaf length and shoot weight of *Z. marina*. Total CPUE was higher in 1999 than in 1998, whereas the recent growth rate (i.e. 1 week before the fish were collected) was significantly higher in 1998 than in 1999, suggesting a density-dependent mechanism.

**KEY WORDS:** daily growth, otolith microstructure, rockfish, young-of-the-year.

## INTRODUCTION

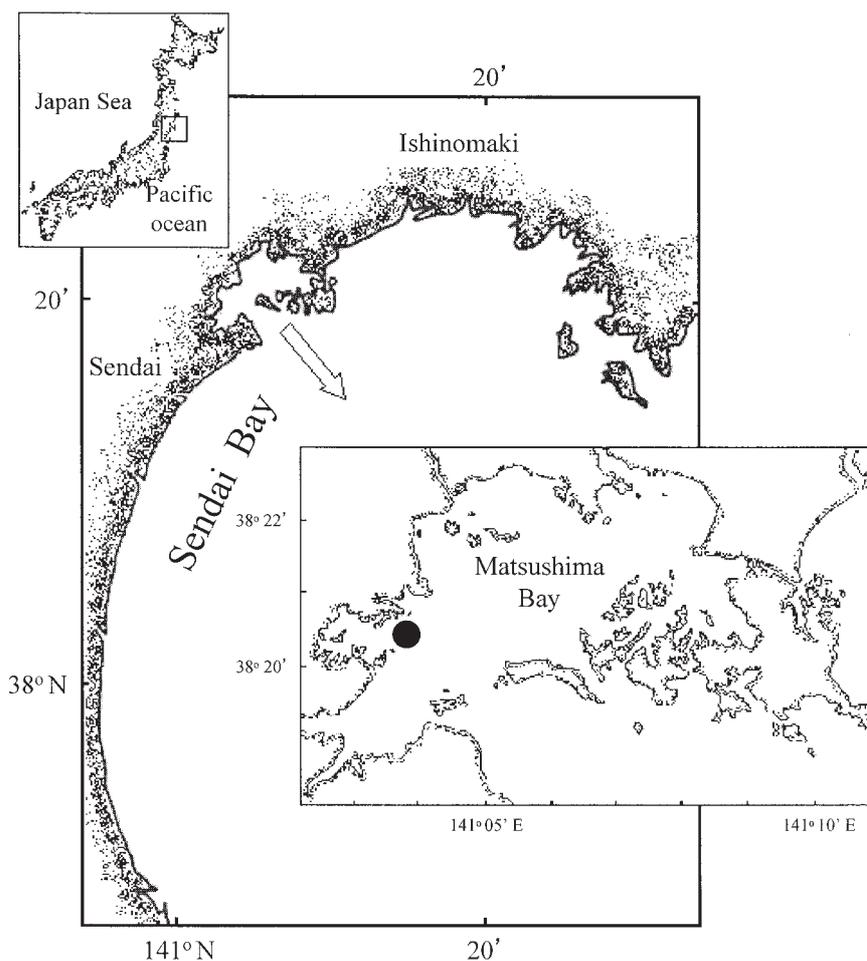
Most rockfish of genus *Sebastes* have reproductive modes and early life-history traits that are poorly understood,<sup>1</sup> in particular, those factors enhancing juvenile survival and allowing young fish to find suitable habitats to settle.<sup>1,2</sup> Thus, some *Sebastes* species develop a strong preference for certain habitats during their juvenile period. Some young-of-the-year (YOY) *Sebastes* occur in association with drifting seaweed in offshore areas,<sup>3–5</sup> whereas in other species, juveniles inhabit nearshore areas, aggregating to seagrass beds, or crowding in communities of algae in rocky shores.<sup>6</sup> Although the pelagic residence has been well studied, the nearshore residence is poorly known, despite the fact that YOY *Sebastes* seem to use the nearshore habitats as an adaptation to avoid offshore dispersal and maximize settlement.<sup>7</sup> The black rockfish *S. inermis*, a commercially important species from southern Hokkaido to Kyusyu in Japan and

in southern Korea,<sup>8</sup> is one of the rockfishes that occupy temporarily *Zostera* and *Sargassum* belts in shallow water during their first year of life, then migrating gradually to the deeper habitat of adults.<sup>6,9–13</sup> Knowledge, to date, has shown that *S. inermis* inhabits simultaneously both habitats from early spring to summer. Those YOY *S. inermis* inhabiting *Zostera* belts begin to move [ $\approx$  60 mm total length (TL)] to the adjacent *Sargassum* belts from summer and during the winter season most of the YOY are inhabiting *Sargassum* belts.<sup>9,12</sup>

In Sendai Bay northern Japan, *S. inermis* mates in early December and extrude their larvae from mid-December to early March in rocky areas (G Plaza *et al.*, unpubl. data, 2000). After a planktonic stage ranging from 50 to 70 days, postflexion and transforming larvae ( $\approx$  12 mm SL) move to benthic habitats in mid-March at a 10 m depth zone. Thereafter, by mid-April, most benthic larval or juvenile fish move into *Zostera* belts or *Sargassum* beds around Sendai Bay;<sup>14</sup> however, it is still unresolved whether YOY *S. inermis* discriminate between these nursery grounds.<sup>9</sup> Both habitats are shallow, up to 2 m in depth, although *Zostera* beds are confined to more enclosed soft-bottom embayment

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**Fig. 1** Map of Matsushima Bay, Miyagi, northern Japan, showing the sampling area.

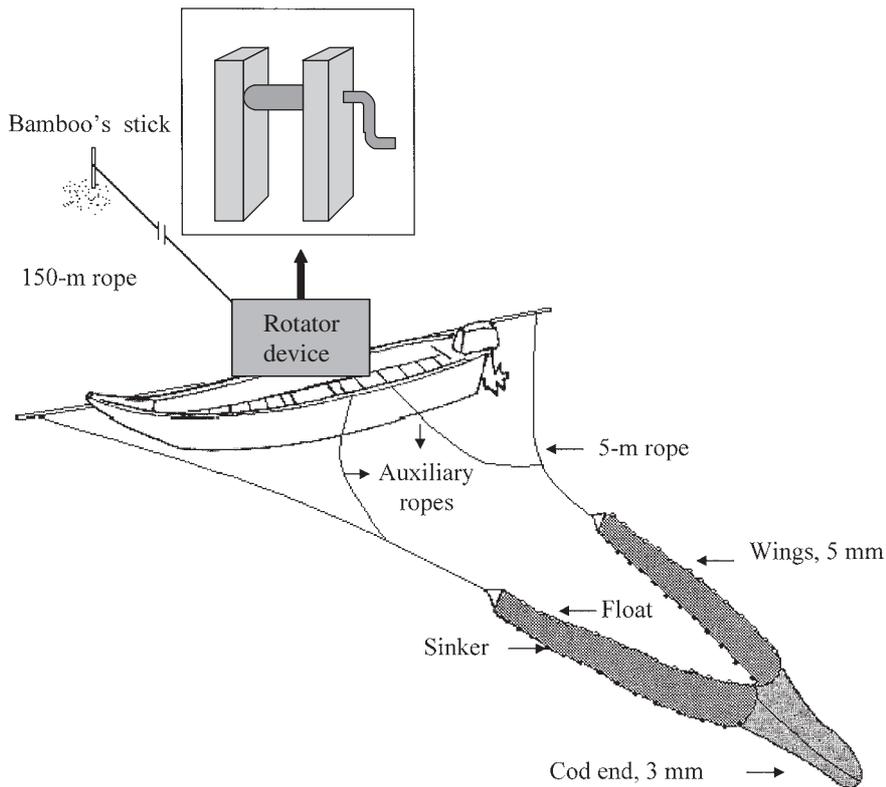
and *Sargassum* beds generally occur adjacent to *Zostera* belts in the subtidal area on the hard sea bottom, representing the shallower algal zonation along the rocky shore. The occurrence of YOY *S. inermis* has been reported for Matsushima Bay, the biggest seagrass area along Sendai Bay, in which *S. inermis* is the dominant species.<sup>10,11</sup> Although these studies have described the trophic relationships of *S. inermis* with other fishes in *Zostera* belts, no author has reported information on the early growth of YOY *S. inermis* at the level of resolution provided by otolith microstructure analysis. This information is needed if we want to discover the relationship between the juvenile period and the population dynamics of the adult stock.

The present study aims to investigate the seasonal changes in the abundance and the early life-history traits of YOY *S. inermis* in a *Zostera marina* bed in Matsushima Bay, northern Japan. We analyzed the daily growth increment of otoliths to estimate birth dates as well as size at age after settlement. We further addressed seasonal variability in growth rates for the 1998 and 1999 years-classes.

## MATERIALS AND METHODS

### Study area and sampling methods

Matsushima Bay is a shallow enclosed embayment located at 38°20'N, connected by a narrow entrance to a larger exposed area, Sendai Bay, which links to the Pacific Ocean at the north-western coast of Japan (Fig. 1). The submerged vegetation is mainly *Z. marina*, which grows on sandy and muddy bottoms forming continuous or patchy covers around the Bay. Samplings were carried out from March to November in 1998 and in 1999, at an area with the major concentrations of seagrass (Fig. 1). All samples were collected in the daytime with a small trawl net (Fig. 2), which was sufficiently large to catch fish larger than juveniles; the net had 14 m of total wing length, 1.5 m in height, 5 mm mesh at wing and 3 mm mesh at codend. The net was designed to trawl at the surface layer bending the vertical shoot of seagrass as the net was drawn. Thus, vertical shoots became a boundary to avoid fish escape from the net. Two 5 m ropes were attached to each end of the wings and tied to



**Fig. 2** Schematic diagram of the sampling procedures to collect young-of-the-year (YOY) *Sebastes inermis* in a *Zostera marina* belt in Matsushima Bay, northern Japan.

two long poles fixed to the front and rear on the right side of a small-engine boat. A 150 m rope was mounted in a rotator device equipped with a cylindrical part and a crank. A bamboo stick, at which the end of the 150 m rope was tied, was sunk in the mud bottom. The whole rope was released as the boat was driven covering the 150 m long rope, and then the boat was turned perpendicular to the rope. At this time, the net was deployed from the left side and was then pulled by turning the crank manually across the 150 m long rope. The hauls were made parallel and/or perpendicular to the shore two to three times haphazardly and non-overlapping. Due to the fragile nature of the seagrass bed, samplings were carried out twice a month in the early spring (March–April) and monthly thereafter. The number of YOY *S. inermis* per haul was used as the index of relative abundance, assuming a constant net efficiency. Juveniles were preserved in 95% ethanol solution for later otolith examination. Total length was measured to the nearest 0.01 mm without correcting for shrinkage. Water temperature and salinity were measured at the surface and bottom layers using an automatic salinometer. Water depth in the site ranged from 1.1 to 2 m (mean = 1.51 m) in 1998, and from 1 to 2.1 m (mean = 1.54 m) in 1999.

Samplings of eelgrass were conducted by SCUBA, with a 50 × 50 cm quadrant. The number of

shoots, leaf length and wet-shoot weight were examined.

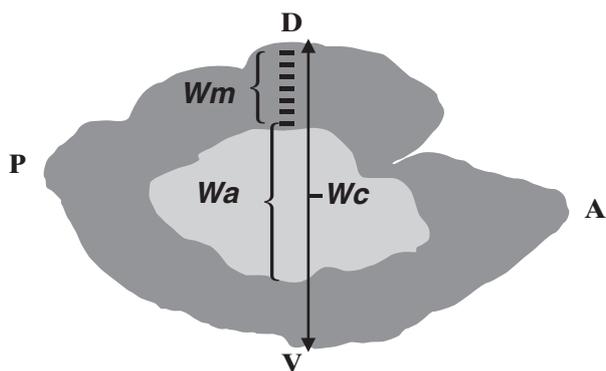
### Otolith analysis

The sagittae otoliths of a subsample of YOY *S. inermis* were used in the present study. Whole otoliths were examined to estimate recent growth rate by examining the outermost seven increments in the otolith margin. Outermost increments in whole otoliths were clearly visible after fixation in the sagittal position on a slide glass with a small portion of epoxy resin; therefore, no further polishing was required. The following procedure was applied (Fig. 3):

1. Otolith width ( $W_c$ ) from the ventral to the dorsal edges of whole sagittae was measured to examine its regression on body length.
2. The otolith width 7 days before catch ( $W_a$ ) was measured at the seventh innermost increment as follows:

$$W_a = (W_c - 2W_m)$$

where  $W_m$  corresponds to the marginal width measured from the margin to the seventh innermost increment in the dorsal edge (consistence was kept upon measuring only the dorsal edge of the right otolith).



**Fig. 3** Medial view of right sagitta of a 50-mm young-of-the-year (YOY) *Sebastes inermis*.  $W_m$ , width from the otolith margin to the seventh innermost increment;  $W_a$ , estimated otolith width (see text);  $W_c$ , otolith width at time of capture. Capital letters outside denote otolith axes; D, dorsal; V, ventral; A, anterior; P, posterior.

3. The otolith width ( $W_a$ ) was used to back-calculate the previous length ( $L_a$ ) by means of the biological intercept method.<sup>15,16</sup> The following function was applied:

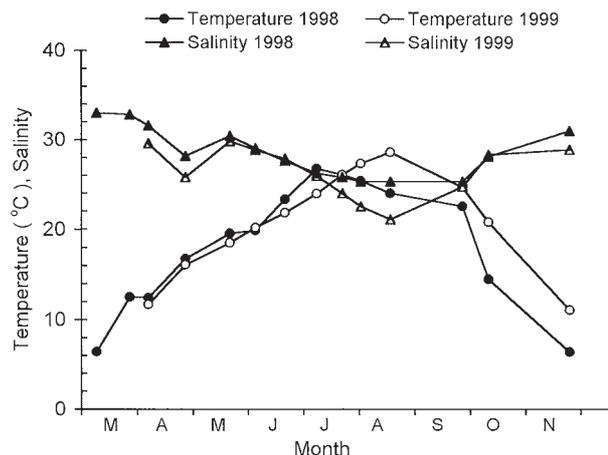
$$L_a = L_c + (W_a - W_c)(L_c - 6.63)(W_c - W_i)^{-1}$$

As above, '6.63' is the mean total length measured from larvae at extrusion under rearing conditions,<sup>17</sup> and  $W_i$  is the otolith width at extrusion.  $L_c$  and  $W_c$  are the fish size and otolith width at the time of capture, respectively. Individual recent growth rate (RGR) was obtained by dividing the change in fish length by the seven increments used.<sup>16</sup>

The subsamples of otoliths were then polished until the nucleus became clearly visible, with 800–2000 grit-lapping films and 4000-grit grinding paste. More detailed information on otolith preparation and age validation for this species is given by Plaza *et al.*<sup>17</sup> Increment counts correspond to age in days. Polished otoliths were used to estimate the age (in days) by counting otolith growth increments from the core along the posterior radius of the sagittae. The senior author made all counts at least twice for each otolith, and the average of the three counts was taken as an estimate of age. Where all three counts differed by more than 5% the otolith was rejected.

### Statistical analysis

One-way ANOVA was used to test for significant differences in  $\log x + 1$  transformed catch per unit effort (CPUE) between years, and to test the differ-



**Fig. 4** Water temperature (°C) and salinity combined for surface and bottom layers from March to November in 1998 and 1999.

ences in both total length and recent growth rate among months. ANOVA was also used to test for significant differences in density, biomass, leaf length and shoot weight of *Z. marina* within season and years.<sup>18</sup> Tukey's multicomparison test was used in the whole ANOVA procedures, whereas the assumptions of ANOVA were examined using box and residual plots. ANCOVA was employed to detect differences in total length at age between cohorts and years.

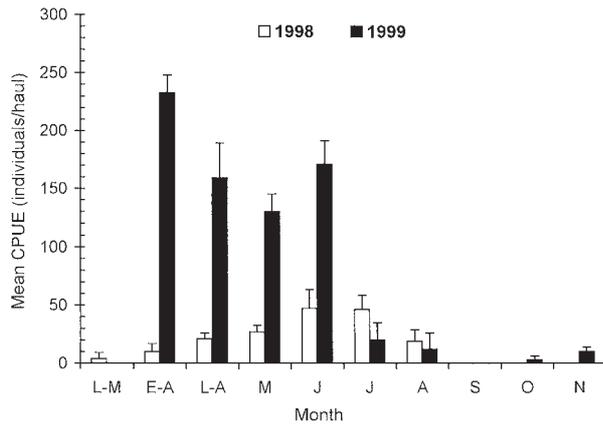
## RESULTS

### Seasonal changes in salinity and water temperature

Water temperature and salinity, at surface and bottom layers, were averaged for all stations (Fig. 4), as they did not show significant differences ( $P > 0.05$ ). Water temperatures ranged from 5°C to 26.8°C in 1998 and from 11.0°C to 29.0°C in 1999, and salinity ranged from 25.5 to 33.0 in 1998 and from 21.1 to 29.6 in 1999. Seasonal mean water temperature was 19.8°C in 1998 and 20.8°C in 1999, differing insignificantly between years ( $P > 0.05$ ). Similar to temperature, mean salinity also did not show significant difference between years (27.8 in 1998 and 26.7 in 1999;  $P > 0.05$ ).

### Seasonal changes in abundance of *S. inermis* and *Z. marina*

Overall, 356 individuals of YOY *S. inermis* were caught in 1998, and 1438 individuals in 1999. New



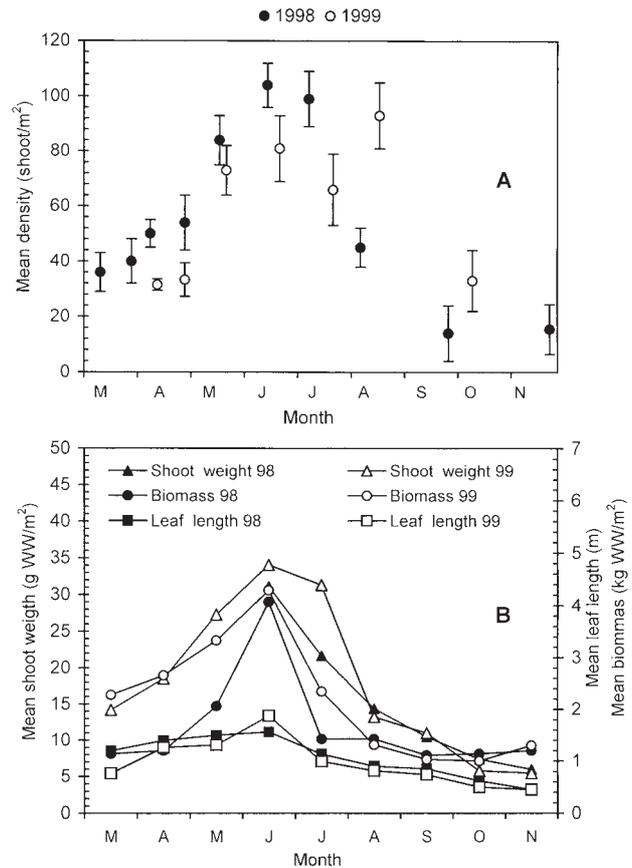
**Fig. 5** Mean catch per unit effort (CPUE) ( $\pm 1$  SD) of young-of-the-year (YOY) *Sebastes inermis* from March to November in 1998 ( $n=356$ ) and 1999 ( $n=1438$ ). Capital letters denote month and letters 'L' and 'E' before months denote 'late' and 'early', respectively. No fish were caught in September 1999.

settlers were found in early April in both years, except for eight individuals collected in late March 1998. Mean CPUE from early April to August was significantly different between years (ANOVA  $P < 0.05$ ). Mean CPUE showed the highest occurrence in June and July in 1998, and from April to June in 1999, and with a similar decline in CPUE during summer months in both years. A few fish were caught in October and November in 1999, and no fish occurred after September in 1998 (Fig. 5).

Seasonal trends of density (Fig. 6a), biomass, leaf length and shoot weight (Fig. 6b) were similar both years, increasing from early spring, peaking in June and decreasing sharply thereafter. When comparing interannually, mean values were not significantly different between 1998 and 1999 ( $P > 0.05$ ): 70–73 shoots/ $m^2$  in density, 2.2–2.7 kg wet weight/ $m^2$  in biomass, 22.7–23.1 g wet weight/ $m^2$  in shoot weight, and 1.28–1.23 m in leaf length.

#### Mean TL and mean age

In both years, length frequency distributions showed an asymptotic shape (Fig. 7), in which mean TL increased significantly as season progressed (ANOVA  $P < 0.05$ ); however, in both years, there were no significant differences in mean TL and age between early and late April. The smallest YOY *S. inermis* collected in late April were 20 and 21 mm total length at 70–80 days in age in 1998 and 1999, respectively. Interannual comparisons of mean age and TL were not possible, because sam-

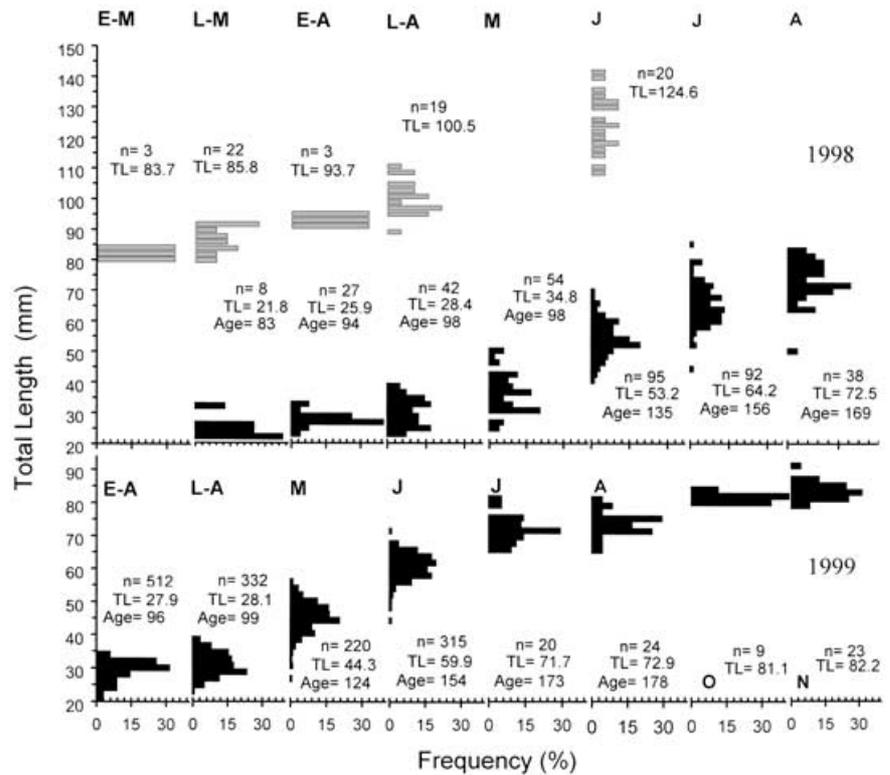


**Fig. 6** (a) Mean shoot density and (b) mean biomass, maximum leaf length and mean wet shoot weight of *Zostera marina* from March to November in 1998 and 1999 at Matsushima Bay, northern Japan. Vertical bars denote  $\pm 1$  SD.

pling dates were not exactly equivalent. The TL of YOY collected in October and November of 1999 also did not differ significantly ( $P > 0.05$ ). These fish ranged from 80 to 93 mm TL, although age could not be estimated due to low resolution of daily growth increment in the otolith margin. Sixty-six 1+ fish were collected in 1998 with a TL range from 78 to 142 mm. In 1999, only 10 1+ fish were collected during April (mean TL=89 mm, range 83–92 mm).

#### Birth date distribution and seasonality of YOY by birth date

Estimated birth date distributions of YOY *S. inermis* showed various peaks in both years, ranging from early January to late February in 1998, and from late December to early March in 1999. To analyze growth patterns by birth dates, for convenience, monthly cohorts were used in the present study. In

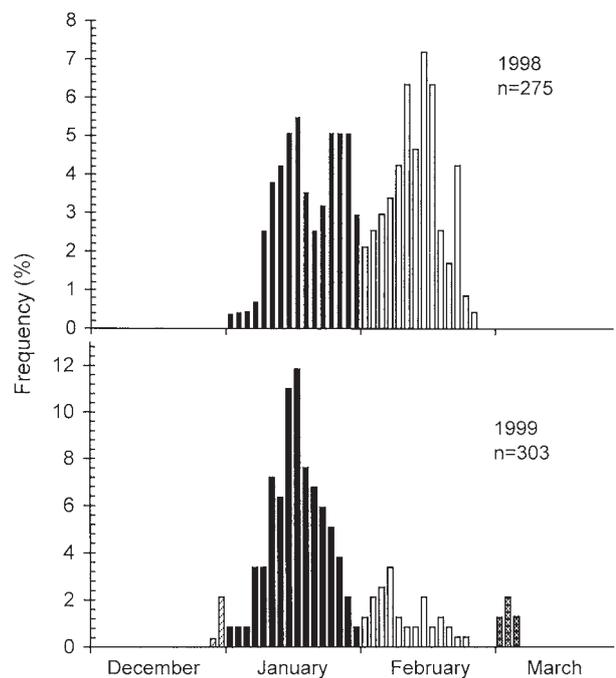


**Fig. 7** Percentage-frequency distribution of total length of young-of-the-year (YOY) (filled bars) and 1+ (gray bars) *Sebastes inermis* in 1998 and 1999. Number of fish, mean total length (TL) and mean age (for YOY) are given. Letters 'L' and 'E' before months denote 'late' and 'early', respectively.

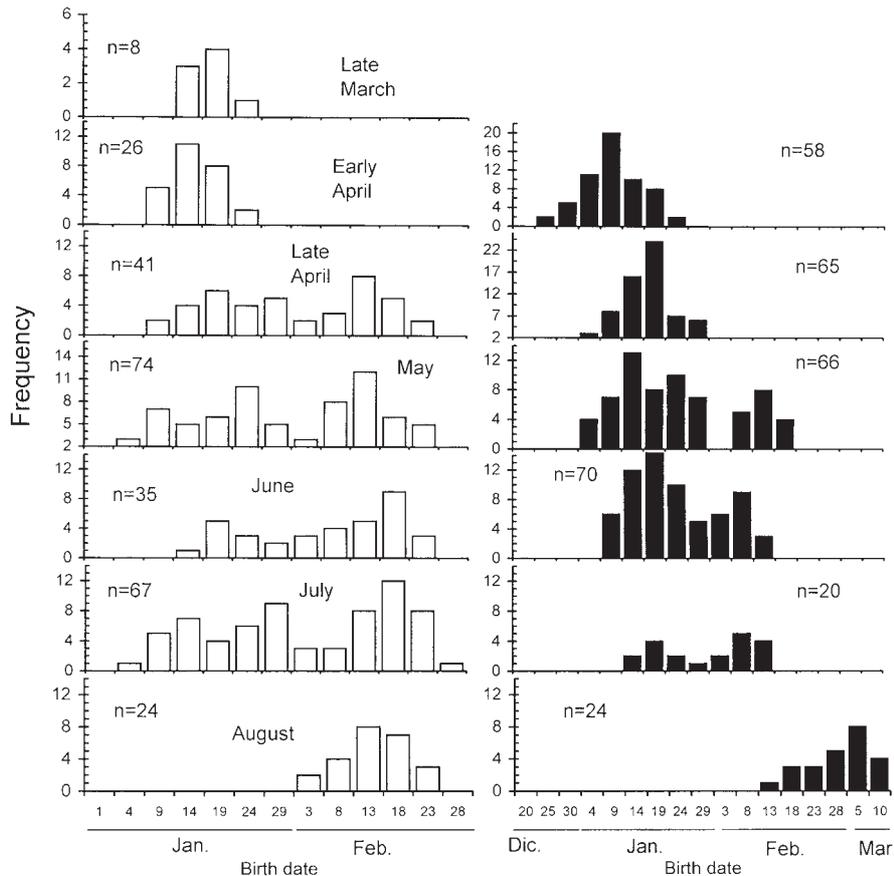
1998, January and February cohorts contributed about 49% and 51%, respectively. In contrast, in 1999, the January cohort represented 74%, in February it was 19%, in March it was 4.2% and there was only a small proportion of 2.6% for the December cohort (Fig. 8). In both years, distribution of birth dates by the time of capture showed that YOY that were extruded earlier (mostly in January) first appeared in the *Zostera* bed, and they were the first to leave. The opposite pattern was observed for those YOY that were extruded later (mainly in February) (Fig. 9). Whole individuals from the age subsample extruded in December and March were collected in early April and August, respectively.

**Growth**

Total length–age relationships fitted by birth months did not have an inflection point; hence linear regressions fitted well for all age ranges analyzed (Fig. 10; Table 1). Only January and February cohorts were available for this analysis, because only a few individuals extruded in December and March were collected at the beginning and the end of the sampling period. Mean daily growth rates ranged from 0.49 to 0.51 mm/day and were not significantly different between cohorts and years (ANCOVA,  $P > 0.05$ ). Otolith width regressed linearly on TL for each cohort in both years (Fig.



**Fig. 8** Frequency distribution of birth dates of young-of-the-year (YOY) *Sebastes inermis* in 1998 and 1999 in Matsushima Bay.



**Fig. 9** Frequency distribution of birth dates of young-of-the-year (YOY) *Sebastes inermis* by month of capture in 1998 (open bars) and 1999 (filled bars). No YOY were collected in early March of 1998.

11; Table 2). Since all regressions were significant ( $P < 0.001$ ), individual recent growth rates (RGR) could be estimated. Monthly mean RGR ranged from 0.31 to 0.73 mm/day in 1998 and from 0.30 to 0.61 mm/day in 1999. In both years and cohorts, mean RGR showed similar seasonal trends with higher values in spring, then declining towards the summer months (Fig. 12). In almost all months ANOVA did not show significant differences of RGR between cohorts within a year. However, pooled RGR differed significantly between years in each month ( $P < 0.05$ , Fig. 13), peaking in May in 1998 (mean = 0.73 mm/day) and April in 1999 (mean = 0.61 mm/day) and decreasing during the summer months, with the lowest mean values in August in both years (mean = 0.40 mm/day for 1998 and 0.30 mm/day for 1999).

## DISCUSSION

### Occurrence and seasonality of juveniles in *Zostera* belts

In both years, the general patterns of the seasonality of YOY *S. inermis* in the *Zostera* belt were

as follows: (i) YOY occurred invariably from early spring in both years; (ii) CPUE of YOY decreased sharply in the summer months synchronizing with a decrease in the phenology of *Zostera marina*; and (iii) the differential seasonality of YOY *S. inermis* in the *Z. marina* bed was related to birth month. The former two patterns agree with the results on the seasonality of YOY in other *Zostera* belts in Japan, which have been well documented.<sup>9,12</sup> However, some clarifications are needed for the decrease of CPUE in summer.

The decrease in occurrence of YOY *S. inermis* in summer months in seagrass beds has been seen as an indication of migration of YOY to adjacent deeper habitats.<sup>9</sup> Nevertheless, the declining in CPUE may also be a result of trawl avoidance and/or natural mortality, and no direct evidence of each of these has been reported to date for *S. inermis*. Trawl avoidance is considered an important source of sampling error in seagrass belts,<sup>19,20</sup> particularly in summer months, because fish begin to swim faster with increasing size.<sup>20</sup> However, the net used in the present study was efficient in catching fish larger than juveniles. Thus, 1+ *S. inermis* and adults of other families were also caught, such as Mugilidae (*Mugil cephalus cephalus*),

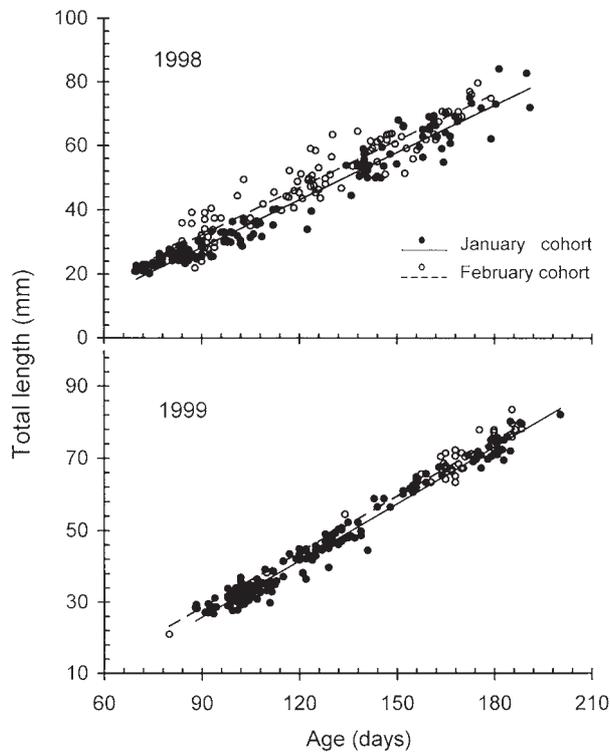
Tetraodontidae (*Takifugu pardalis*, *Takifugu niphobolus*) and Pholididae (*Pholis* spp.). It is also unlikely that the natural mortality rate of YOY *S. inermis* has drastically increased in summer. These facts indicate that the fall in CPUE was due to migration from the study area.

Concerning the third pattern, we found that YOY extruded earlier appeared in the seagrass beds earlier, and they were the first to leave the *Zostera* belt. Consequently, only fishes extruded later, which also settled later, seemed to stay beyond summer in this habitat. These facts suggest that once fish have attained a certain ontogenetic stage (concerning age and growth) they begin to emigrate. In agreement with our argument is the fact that only in 1999 (this year showed higher abun-

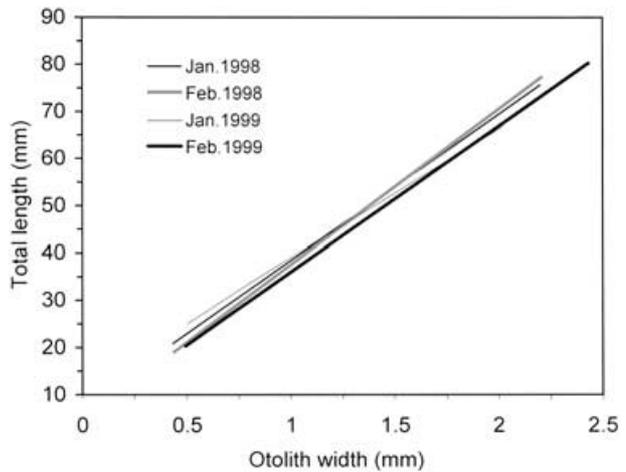
dance and slower growth than 1998) did YOY prolong their stay in the seagrass area, suggesting a feasible relationship among migration, growth and density-dependent mechanisms. The occurrence of 1+ fish in this habitat seems difficult to explain, because results are not conclusive as to whether these fish have returned from adjacent deeper habitats and/or whether they might correspond to a part of overwintering YOY in the *Zostera* area.

**Birth date distribution and dynamics of growth**

An important aspect to be noted is to what extent the interannual difference in both cohort composition and duration of parturition season links to the interannual difference in settlement magnitude of YOY *S. inermis*. In 1999, birth dates were distributed evenly over the season, whereas in 1998, birth dates showed that the main extrusion event occurred in mid-January. This species is a single spawner<sup>21</sup> (i.e. females produce only one brood each year); hence, extrusion pulses ought to be linked to the existence of groups of adult spawn-



**Fig. 10** Linear growth model fitted by cohorts in young-of-the-year (YOY) *Sebastes inermis* collected in Matsushima-seagrass bed, northern Japan in 1998 and 1999.



**Fig. 11** Regressions between total length and otolith width of young-of-the-year (YOY) *Sebastes inermis* fitted by cohort in 1998 and 1999.

**Table 1** Parameters estimated for the total length–age relationship fitted by linear regression for each year and cohorts of young-of-the-year (YOY) *Sebastes inermis* collected in Matsushima Bay, northern Japan

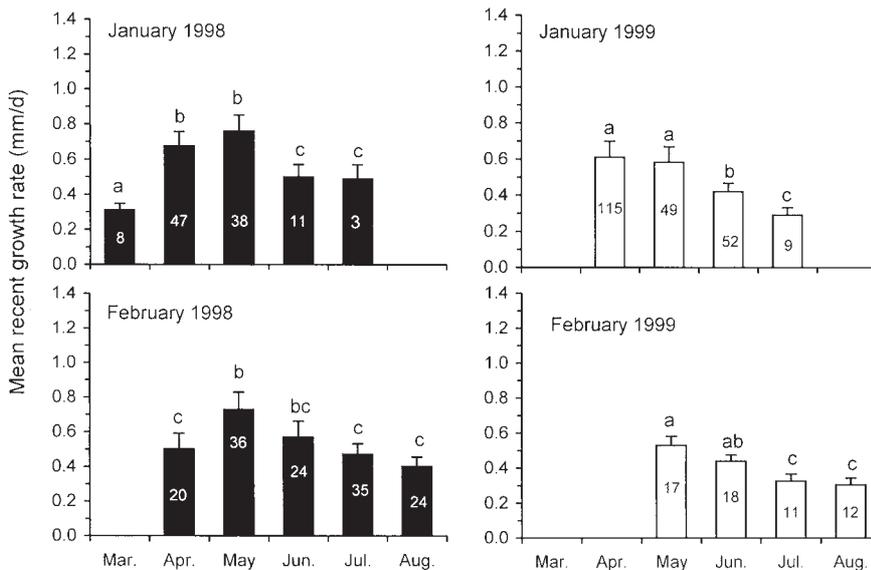
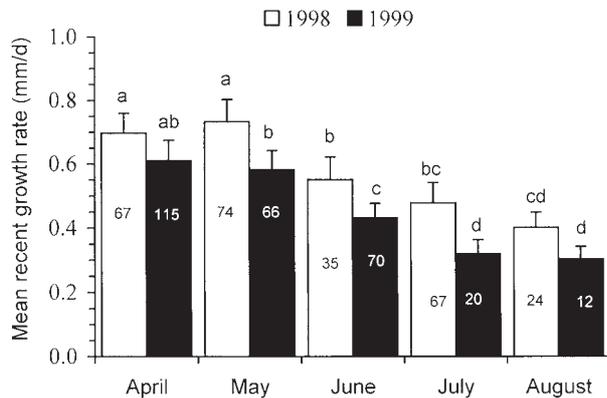
Year	Cohort	<i>a</i> (SE)	<i>b</i> (SE)	<i>r</i> <sup>2</sup>	<i>n</i>	<i>F</i>
1998	January	-16.1 (1.1)	0.49 (0.002)	0.96	136	4314
	February	-12.9 (1.2)	0.49 (0.002)	0.92	139	4769
1999	January	-21.6 (1.1)	0.50 (0.002)	0.98	225	4315
	February	-18.3 (1.3)	0.51 (0.002)	0.95	58	3719

SE, standard error.

**Table 2** Parameters estimated for the otolith width–fish size relationship of young-of-the-year (YOY) *Sebastes inermis* for each year and cohorts in Matsushima Bay, northern Japan

Year	Cohort	<i>a</i> (SE)	<i>b</i> (SE)	<i>r</i> <sup>2</sup>	<i>n</i>	<i>F</i>
1998	January	7.46 (0.75)	0.031 (0.001)	0.98	136	3214
	February	4.62 (0.78)	0.033 (0.001)	0.97	139	2869
1999	January	11.93 (0.57)	0.027 (0.001)	0.93	225	2915
	February	5.29 (2.28)	0.030 (0.001)	0.98	58	719

SE, standard error.

**Fig. 12** Recent growth rate of young-of-the-year (YOY) *Sebastes inermis* among months and between cohorts within each year back-calculated by measuring the width of the outermost seventh-increments of sagittae. No bar denotes absence of cohorts in the collections. Different letters show significant differences (ANOVA, HSD Tukey's test  $P < 0.05$ ). Numbers inside the bars denote sample size.**Fig. 13** Comparison of recent growth rate among months and between years of young-of-the-year (YOY) *Sebastes inermis*, back-calculated by measuring the outermost seventh-increment width of sagittae. Different letters show significant differences (ANOVA, HSD Tukey's test  $P < 0.05$ ). Numbers inside the bars denote sample size.

ers, which shift temporarily and/or spatially their timing of parturition. Further research on the distribution of parturition of this species in Sendai Bay together with information provided by otolith

microstructure would be useful in disclosing the extent of these inferences.

Estimates of mean growth (slopes of the regression of TL on age) and RGR between cohorts followed the same trend in both years. Mean daily growth rates (0.49–0.51 mm/day) found in the present study are comparable to other species of *Sebastes* in other offshore nurseries, such as *Sebastes thompsoni*, 0.32–0.47 mm/day inhabiting drifting seaweed<sup>5</sup> and *Sebastes jordani*, 0.53 mm/day in mid-water residence.<sup>22</sup> Furthermore, both the mean growth rates and the estimates of RGR (maximum values of RGR were substantially higher than mean growth rates) were higher than the growth rate reported for planktonic *S. inermis* (0.13 mm/day).<sup>23</sup> This suggests that YOY *S. inermis* markedly accelerated their growth after arriving in the belts in both years. RGR were estimated without significant errors, due to the high readability of otolith increments, the wide range of fish size analyzed, and the linear relationships between otolith and fish size.<sup>16</sup> Hence, RGR seem to be a useful index to characterize the seasonality of the growth of YOY *S. inermis* in *Z. marina* belts. The fast growth of some juvenile rockfishes has been linked

with a shift in feeding conditions, particularly with the great availability of new prey items in seagrass meadows.<sup>6</sup> *Sebastes inermis* shifts its diet with growth from small planktonic copepods during its planktonic stage to small *Zostera*-associated crustaceans after settlement, such as amphipods, isopods, mysids and caprellids. Then, *S. inermis* begin to feed on amphipods, shrimps and even fishes.<sup>9,24</sup> During summer, the growth of juveniles decreased, perhaps as a result of the loss of habitat, high water temperature and food limitation, which have been suggested as limiting factors for YOY fishes inhabiting temporally in the *Zostera* beds.<sup>6,9,25–27</sup> Here, we found that the marked decline in CPUE of YOY in summer matched the decrease in both phenology of *Z. marina* beds and growth of YOY. The loss of habitat may affect growth of YOY by inducing a lack of phytoplankton. In addition, due to the shallow nature of *Zostera* belts, the high water temperature observed in summer may also become a critical factor for fish growth. However, the differential seasonality of YOY by birth month suggests that beyond the probable effect of limiting factors, there is also an ideal ontogenetic stage at migration, which may be an adaptation developed for this species to increase survival in deeper habitats.

When comparing growth rates interannually, RGR were significantly higher in 1999 than in 1998, whereas the opposite pattern occurred for the estimates of CPUE. This suggests that growth of YOY *S. inermis* was density dependent, which has been reported for other fishes.<sup>28–30</sup> However, the regression of body length on age was not significantly different between years. This regression depends upon various factors (e.g. size-selective mortality and gear avoidance). Furthermore, the population trajectory of the length–age relationship seems to be less efficient in disclosing interannual differences in growth during the post-settlement period if either size or age at settlement differs between years. In fact, age at settlement was higher for 1999 than 1998 ( $P < 0.05$ ; G Plaza *et al.*, unpubl. data, 2001). This fact was apparently sufficient to alter the length–age relationship. Conversely, otoliths of *S. inermis* were thin enough to obtain without further preparation reliable estimates of recent growth rates revealing the interannual variation in growth.

In conclusion, it seems that YOY *S. inermis* adopts the conditions provided by *Z. marina* belts as an efficient temporal habitat for their juvenile period. The fact that body size and age of settlers did not vary significantly in April indicates that settlement season extended during early spring, after which settled juveniles experienced a fast growth, suggesting that *Z. marina* belts are an important

nursery ground for this species. If rapid growth, indeed, provides higher subsequent survivorship, then the 1998 and 1999 classes of YOY *S. inermis* greatly enhanced their chance of surviving due to their stay in this nearshore nursery ground. Further information is needed to discover whether the marked interannual differences in settlement magnitude underlined here are linked to factors such as differential larval survival during the planktonic stage, varying breeding capabilities of the adult stock, and/or habitat selection among nursery grounds.

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