

Early Life History of Yoroi-mebaru, *Sebastes hubbsi*, in the Sado Strait, Sea of Japan

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Abstract

Larvae of viviparous rockfish *Sebastes hubbsi* are extruded as flexion larvae of about 5.5 mm SL. Notochord flexion occurs by 7 mm SL. Transformation from postflexion larvae to pelagic juveniles occurs between 10-13 mm SL. Larvae and pelagic juveniles of *S. hubbsi* were sampled in nearshore waters, but were not found in offshore regions such as the Chokai Bank. Planktonic larvae and pelagic juveniles mainly inhabit in the surface layers. Flexion larvae fed mainly on calanoid copepodites, with copepod nauplii as second most important by number. Postflexion and transforming larvae also fed mainly on calanoid copepodites with invertebrate eggs as second most important by number. Pelagic juveniles also fed on calanoid copepodites. I estimate that large size of larvae at parturition, rapid development and short planktonic period ensures minimum offshore dispersal in this species.

Key words : *Sebastes*, larval development, distribution, feeding, Sea of Japan, Sado Strait

Introduction

Viviparous rockfishes, genus *Sebastes* is an important component of the shelf and slope fish faunas of temperate and subarctic regions (BOEHLERT and YAMADA 1991). This genus shows a great diversity on the west coast of North America and also in the waters of Japan. Although ecologically important in many habitats, the early life history features of the nearshore species are poorly known (MOSER and BOEHLERT 1991). Yoroi-mebaru, *Sebastes hubbsi* (MATSUBARA) is one of the common rockfish inhabiting rocky coastal waters of southern Japan and adjacent area. The coastal waters of Niigata is the most northward area in which *S. hubbsi* inhabits in the Sea of Japan (NAKABO 1993). This species is mainly caught by angling and gill net, but from a commercial fisheries point of view is not so important because of its low abundance. NAKAMURA (1936) and KOJIMA (1988) briefly described the development of larvae and juveniles of *S. hubbsi*. Although they also reported seasonal occurrence of larvae and juveniles, they did not report any other ecological aspects of the early life history of this species. OKABE (1993, 1996) reported seasonal occurrence of larvae on the rocky shore of Jyogashima, Miura Peninsula and Kominato, Boso Peninsula in detail. However he did not report other ecological aspects such as horizontal distribution, habitat shift, feeding etc..

In this paper, I provide some ecological features including the horizontal distribution and

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food items of planktonic larvae and pelagic juvenile stages of *S. hubbsi* in the Sado Strait with descriptions of the early development. I also discuss characteristics of their early life history compared with other species of *Sebastes*.

Materials and methods

I sampled most of the specimens used in this study by surface tows using 130 cm ring nets (mouth diameter 1.3 m, cylindrical part 2.0 m long and conical part 2.7 m long with 0.5 mm mesh) in November 1994 and November 1995 in the Sado Strait and adjacent waters. I also conducted oblique tows of 0-100 m depth using 70 cm bongo nets (mouth diameter 0.7 m, cylindrical part 1.5 m long and conical part 1.7 m long with 0.5 mm mesh) at the same stations in a survey in 1994. I also sampled ichthyoplankton in December 1990 using both tows. I conducted all surveys aboard the R.V. *Mizuho-maru* of the Japan Sea National Fisheries Research Institute.

To describe the larval development, I selected 25 well preserved specimens from among all the samples. My approach to identification, methods for making counts, measurements and terminology of the developmental stages follow RICHARDSON and LAROCHE (1979). Terminology of the head spination follows MOSER and AHLSTROM (1978). For observations of general development and head spines, specimens were stained lightly with saianin 5-R or cleared and stained following DINGERKUS and UHLER (1977), respectively. Observations, measurements, and illustrations were made with the aid of a camera lucida and micrometer attached to a binocular dissecting microscope.

For stomach contents analysis, I used 21 specimens of larvae and juveniles. I removed the entire stomach from each specimen and placed it in a drop of lactic acid. Then I teased apart the stomach using probes to release any organisms, which were identified and counted using a phase contrast microscope.

Results

1 Description of development

(1) Distinguishing features

Heavy pigmentation on the lateral portion is a unique feature of *S. hubbsi* throughout the larval and juvenile periods. Early larvae of *S. hubbsi* were very similar to those of *S. longispinis* (TAKAI and FUKUNAGA 1971), I could not find any distinct morphological characters for differentiation. After transformation, however, we can differentiate *S. hubbsi* from *S. longispinis* by counts of the dorsal spines (D XIV,11-12; A III, 8-10; P₁ 16-18 in *S. hubbsi*, D XIII,12-13; A 8-10; P₁ 16 in *S. longispinis*). In addition to these, *S. longispinis* is only distributed from Wakayama Pref. to Shimonoseki and Korea, and therefore we can identify early larvae as *S. hubbsi* with no doubt in other areas. Although early larvae of *S. oblongus* are also similar to those of *S. hubbsi*, reared larvae of the former have pigment along the pectoral fin rays (FUJITA 1958).

(2) General development and morphology

In the collection examined, the smallest flexion larva (5.4 mm NL) is regarded as newborn.

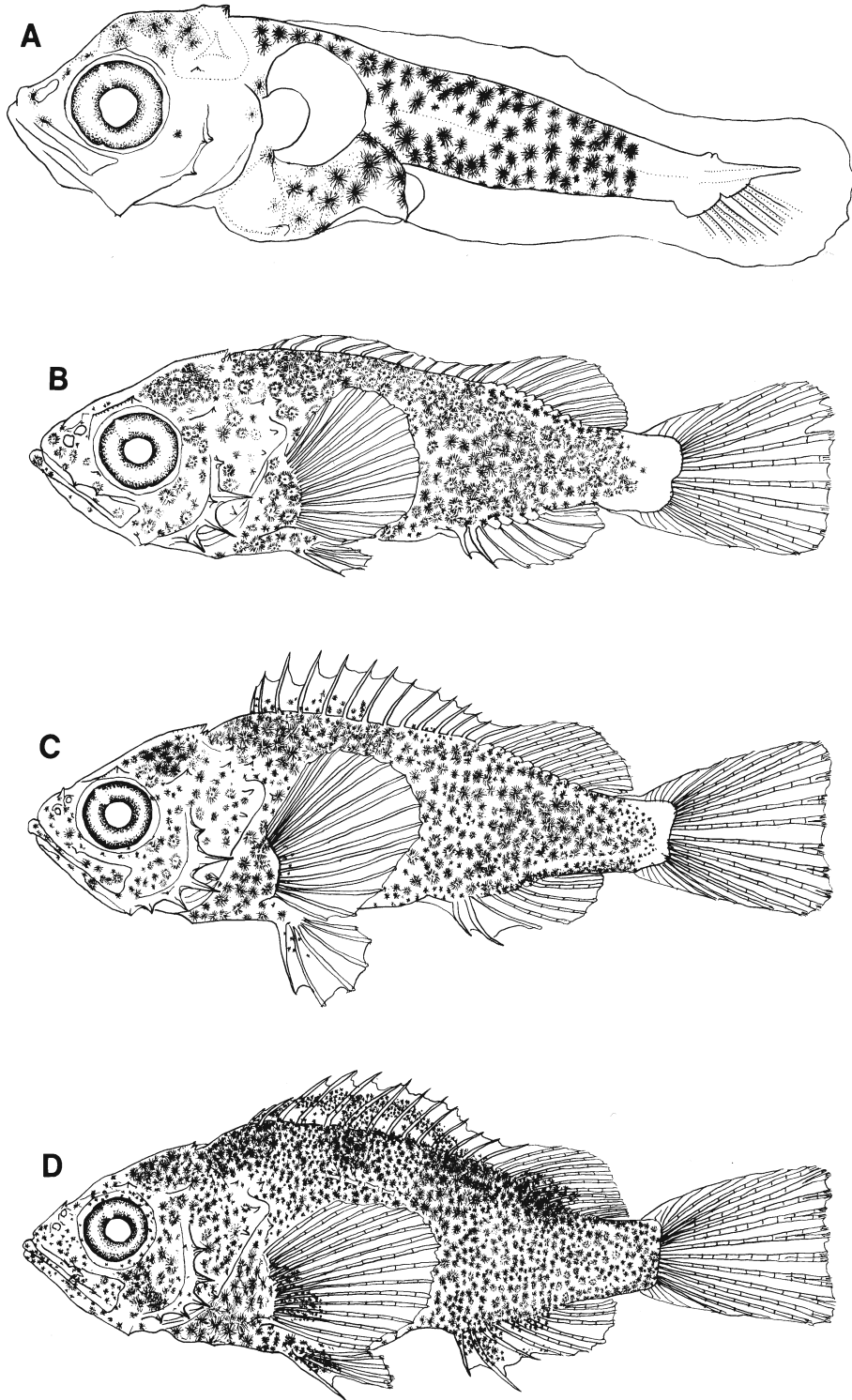


Fig. 1. Developmental series of *Sebastes hubbsi*. A) Flexion larva 5.6 mm NL; B) Postflexion larva 9.2 mm SL; C) Transforming larva 11.8 mm SL; D) Pelagic juvenile 14.5 mm SL.

This larva has a large head, with well-formed eyes and functional jaws (Fig. 1A). The guts is short and bulbous. Notochord flexion occurs by 7 mm SL. Transformation from postflexion larvae to juveniles, indicated by a structural changes of the most posterior spines of the dorsal and anal fin “prespine” to sharp, hard spines, occurs between 10–13 mm SL.

Figure. 2 shows the allometry of four body parts of *S. hubbsi*. The relative eye diameter (ED) with respect to head length (HL) of newborn larvae is rather small (about 40% HL) compared with other species of *Sebastes* (NAGASAWA and DOMON 1997; NAGASAWA and KOBAYASHI 1995). ED decreases during flexion larval stage. The relative length of the other three parts increase during notochord flexion. The relative body depth of newborn larvae is rather deep, more than 25% and increases to about 30% SL in transforming larvae and juveniles. The relative head length of flexion larvae is also rather long, 25–30% SL, becoming more than 30% SL in postflexion larvae and about 35% SL in pelagic juveniles. The relative preanal length is about 50% SL in flexion larvae and becomes 60–65% SL in postflexion larvae.

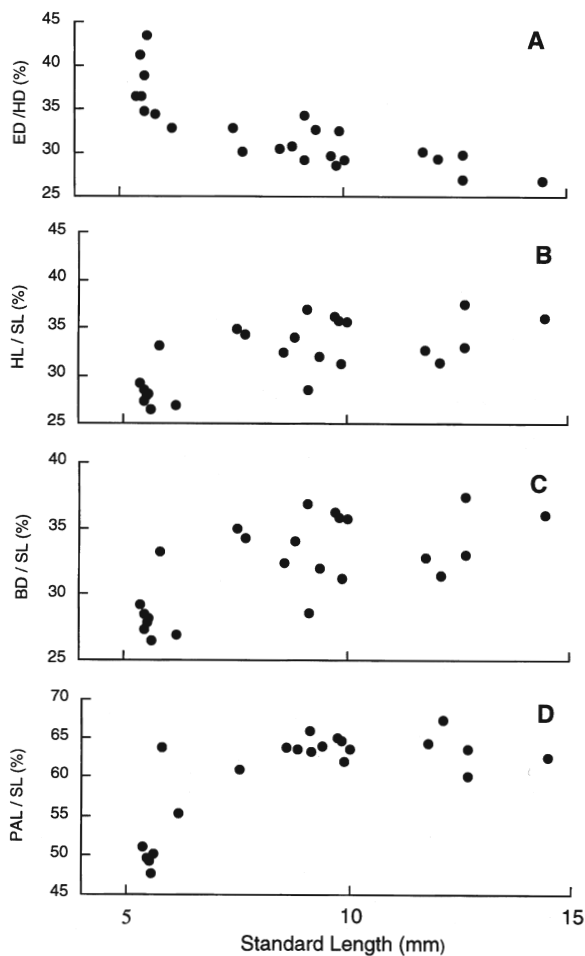


Fig. 2. Allometry of larvae and juveniles of *S. hubbsi*. A) Relationship of eye diameter (ED)/ head length (HL) ratio against standard length (SL); B) relationship of HL/SL ratio against SL; C) relationships of body depth (BD)/SL ratio against SL; D) relationship of preanal length (PAL)/SL ratio against SL.

(3) Fin development Flexion larvae have fan-shaped pectoral fins (Fig. 1A). Fin rays appear at about 7 mm SL, almost at the end of the flexion larval period. Postflexion larvae larger than 9 mm SL and more advanced specimens have full complements of 16-18 pectoral rays (Figs. 1B-D).

New born flexion larvae have pelvic fin as fleshy buds (Fig. 1A). Postflexion larvae larger than 9 mm SL have the full complements of I, 5 pelvic rays (Fig. 1B).

Newborn flexion larvae have some caudal fin rays, partially supporting the fin fold (Fig. 1A). The rays develop and support the most portion of the caudal fin membrane by the end of flexion larval stage (about 7 mm SL). Branching of the caudal fin rays occurs in transforming larvae ca. 10 mm SL.

Although, flexion larvae do not have dorsal or anal fin rays, they have well developed fin folds, being continuous with the caudal portion (Fig. 1A). Most spines and rays of both fins appear in the postflexion larvae (Fig. 1B). In transforming larvae larger than 10 mm SL, the total number of both dorsal and anal fin rays reaches the adults complement (Figs. 1C, D).

(4) Pigmentation

In flexion larvae, large melanophores cover many portions of the body (Fig. 1A). But melanophores are absent on the membranes of each fin and the caudal peduncle portion, and only a few on the opercular and cheek portions.

In postflexion larvae, melanophores on each portion increase in number (Fig. 1B). The pigmented region of the lateral side of tail extends posteriorly. Dense rows of melanophores appear on the base of the pterygiophores of both the dorsal and anal soft rays. Melanophores also increase around the nostril, cheek, opercular portion and base of the pectoral fins. In living specimens, iridiphores cover pigmented regions of the lateral surface of the head, trunk and tail.

Although the pigmentation of transforming larvae of *S. hubbsi* is similar to that of postflexion larvae, melanophores appear on the membranes near the base of the spinous dorsal fin, pectoral fin and pelvic fin (Fig. 1C). The number of melanophores on the lateral side of the body also increases during this stage. About 70% of larvae in early postflexion stages have some melanophores on the pectoral fin membranes (Fig. 1C).

In pelagic juveniles, four faint saddles of melanophores appear on the dorsal portion (Fig. 1D). Four melanistic blotches appear on the dorsal fin membrane just above the four saddles of melanophores. Blotches of melanophore also appear on the membranes of the base portion of the pectoral fins, pelvic fins, and anal fin. Each blotch extends ventrally from the base of the dorsal fin. In this stages, melanophores cover even on the caudal peduncle portion.

(5) Head spination

Newborn flexion larvae have pterotic, 2nd posterior preopercular, 3rd posterior preopercular, parietal, and 2nd anterior preopercular spines (Table 1). Among them, the 2nd anterior preopercular spines disappear during transformation, but the other spines are retained in adults. The sequence of spine appearance of the posterior preopercular series is 3/2-4-5/1. After that the postocular, lower posttemporal, 4th anterior preopercular, and 4th posterior preopercular spines appear by the end of the flexion larval period. Second and 4th anterior preopercular spines become conspicuous in the late flexion and early postflexion larvae, but these spines disappear during transformation.

Nuchal, upper posttemporal, upper opercular, lower opercular, 1st and 5th posterior preopercular, 1st upper infraorbital, 1st and second lower infraorbital, 3rd anterior preopercular and supracleithral spines appear in the postflexion larval stage. Among these, the first upper infraorbital also disappear during transformation. The first and 2nd lower infraorbital spines change into fan-shape projections.

Nasal spines newly appear in transforming larvae and cleithral spines appear in juveniles. Both sets of spines remain in adults.

Table 1. Sequence of development of the head spines of *Sebastes hubbsi*. Presence of spines is indicated by +. Terms of the head spines follow MOSER and AHLSTROM (1978).

Spine	Standard length (mm)															
	5.4	5.6	5.9	6.2	7.5	7.7	8.6	9.1	9.4	9.8	10.0	11.8	12.1	12.6	12.7	14.5
	Flexion Larva				Postflexion Larva					Transforming L.			P. Juv.			
Parietal	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Nuchal					+	+	+	+	+	+	+	+	+	+	+	+
Postocular		+		+	+	+	+	+	+	+	+	+	+	+	+	+
Pterotic	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Tympanic															+	+
Lower posttemporal		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Upper posttemporal						+	+	+	+	+	+	+	+	+	+	+
Upper opercular					+	+	+	+	+	+	+	+	+	+	+	+
Lower opercular							+	+	+	+	+	+	+	+	+	+
Inter opercular				+	+	+	+	+	+	+	+	+	+	+	+	+
2nd anterior preopercular	+	+	+	+	+	+	+	+	+	+	+	+				
4th anterior preopercular				+	+	+	+	+	+	+	+	+				
1st posterior preopercular					+	+	+	+	+	+	+	+	+	+	+	+
2nd posterior preopercular	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3rd posterior preopercular	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
4th posterior preopercular			+	+	+	+	+	+	+	+	+	+	+	+	+	+
5th posterior preopercular					+	+	+	+	+	+	+	+	+	+	+	+
1st upper infraorbital					+	+	+	+	+	+	+	+				
1st lower infraorbital					+	+	+	+	+	+	+	+	+	+		
2nd lower infraorbital						+	+	+	+	+	+	+	+	+		
Nasal												+	+	+	+	+
Supracleithral					+	+	+	+	+	+	+	+	+	+	+	+
Cleithral															+	+

2 Horizontal distribution of larvae and pelagic juveniles

In November 1994, larvae and juveniles of *S. hubbsi* occurred at 5 stations out of the 47 sampling stations, the percentage occurrence (number of positive stations ÷ number of sampling stations × 100) was 11% (Fig. 3). All larvae sampled were from surface tows. I caught neither larvae nor juveniles by oblique tows using bongo nets in this cruise. Larvae and juveniles mainly occurred in coastal waters around Sado Island and Honshu of the survey area. They did not occur

in deeper waters of Sado Strait, offshore waters of Niigata City nor offshore banks such as the Mukou-se Bank. In November 1995, larvae and juveniles occurred at 9 stations out of 28 sampling stations, the percentage occurrence was 32% (Fig. 4). In this cruise, larvae and juveniles mainly occurred in coastal waters around Sado Island and Honshu of the survey area, and did not occur in offshore waters. Although postflexion larvae, transforming larvae, and pelagic juveniles occurred in the coastal waters of both Honshu and Sado Island, flexion larvae only occurred along the southern coast of Sado Island. In December 1990, neither larvae nor juvenile occurred in Sado Strait.

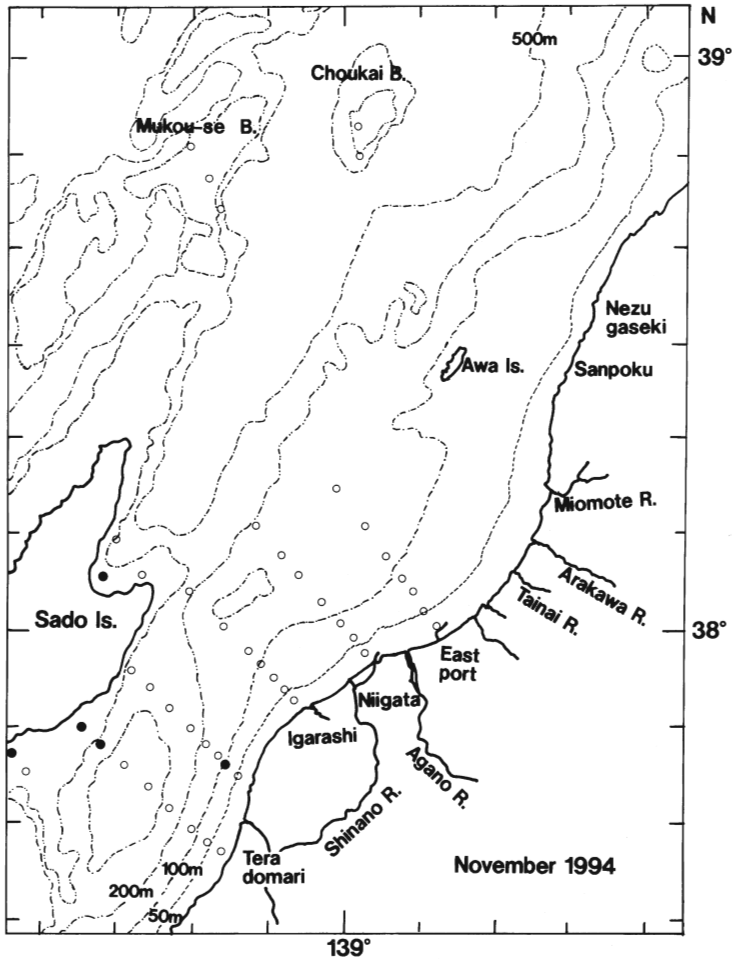


Fig. 3. Distribution of larvae and juveniles of *S. hubbsi* in the Sado Strait and adjacent waters in November 1994; negative stations (○) and positive stations (●).

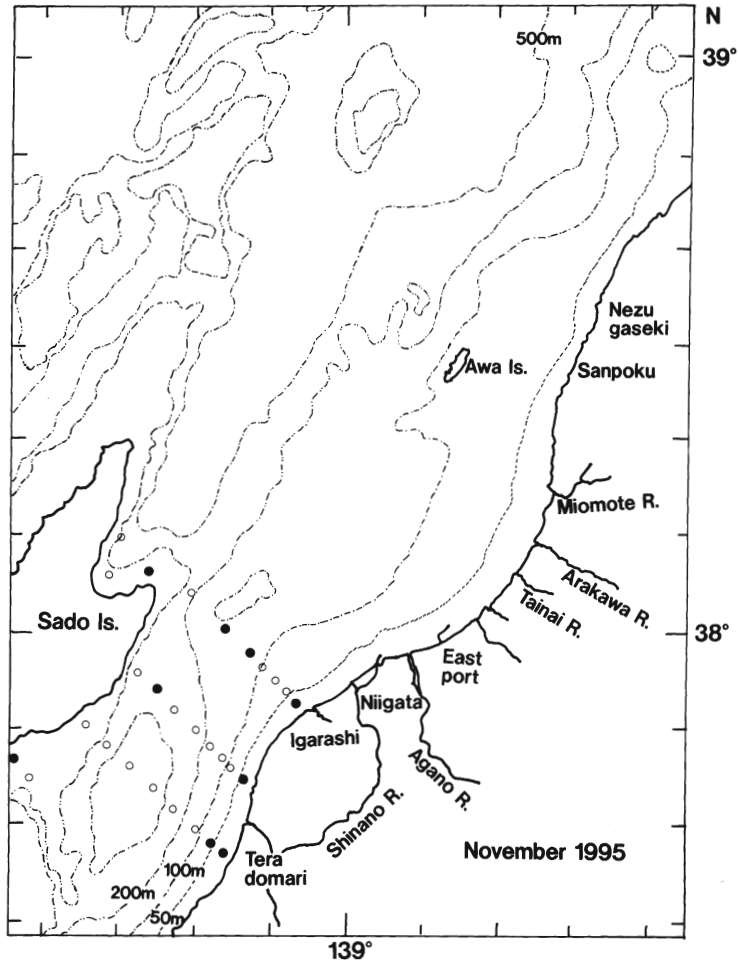


Fig. 4. Distribution of larvae and juveniles of *S. hubbsi* in the Sado Strait and adjacent waters in November 1995 ; negative stations (○) and positive stations (●).

3 Feeding

I examined the stomach contents of 21 specimens of *S. hubbsi* ranging from 5.2 to 14.5 mm SL. Food items occurred in the stomach of 20 out of 21 specimens examined (Table 2). calanoid copepodites smaller than 1 mm (57%) were dominant food organisms of flexion larvae smaller than 7 mm SL, copepod nauplii (29%) were the second. In postflexion larvae 7-10 mm SL, dominant food organisms were calanoid copepodites smaller than 1.0 mm (56%), calanoid copepodites of 1.0 mm or larger (13%). Although invertebrate eggs (20%) were also dominant by number, the size of the eggs was rather small (about 0.1 mm in diameter). So that invertebrate eggs were not so important food items for postflexion larvae 7-10 mm SL. In transforming larvae and pelagic juveniles 10 mm in SL and larger, about 70% of food items were also calanoid copepodites smaller than 1.0 mm, larger calanoid copepodites were the second (18%), although one specimens mainly fed on Cumacea spp. and *Corycaeus* spp..

Table 2. Percentage composition by number of food organisms in the stomach of *Sebastes hubbsi*.

Standard Length (mm)	<7	7–10	10≤
No. of fish examined	10	6	5
No. of fish with food	9	6	5
Food organisms (% in number)			
Invertebrate eggs	0	20	0
Nauplii	29	4	1
Calanoida spp. ≥1.0mm	7	13	18
Calanoida spp. <1.0mm	57	56	69
<i>Oithona</i> spp.	5	7	2
<i>Corycaeus</i> spp.	0	0	2
Cumacea spp.	0	0	4
Others	2	0	4

Discussion

MATSUBARA (1943) regarded *S. hubbsi* as a member of the subgenus *Pteropodus* which includes 4 Japanese species: *S. trivittatus*, *S. nivosus*, *S. longispinis*, and *S. hubbsi*. Among these, the external features of *S. longispinis* is very similar to that of *S. hubbsi* (MATUBARA 1936, 1943). Early larvae of *S. hubbsi* and *S. longispinis* are also very similar to each other and I can not find any effective distinguishing features for these two species. Ontogenetic evidence also supports that these two species are closely related. On the other hand, newborn larvae of *S. trivittatus* are very different from those of *S. hubbsi* in many features: pigmentation, head spination, and proportions of some body parts etc. (NAGASAWA 1991). Therefore, from ontogenetic evidence, there is some doubt as to whether these two species are closely related. KENDALL (1991) classified the postflexion larvae of 34 species into 11 groups based on larval characters: pigmentation, size of head spines and body shape. *S. hubbsi* was included in Group 4, together with, *S. longispinis* and *S. oblongus*. Considering the ontogenetic evidence, *S. oblongus* may be closely related to *S. hubbsi*, instead of *S. trivittatus*. As advanced larvae of *S. trivittatus* are unknown, I can not compare the developmental series of these two species in detail. The phylogenetic relationships of these species are still unclear.

However size of larvae at parturition of *S. hubbsi* is larger than those of three common rockfish (*S. schlegeli*, *S. thompsoni*, *S. vulpes*) in the Sea of Japan, notochord flexion and transformation occurs at a smaller size than those of these three species (NAGASAWA and KOBAYASHI 1995; NAGASAWA and DOMON 1997). FUKUHARA (1992) reported that the structural development from continuous fin-folds into separated fins provides the sharp rise of swimming speed in larvae of *Pagrus major*. Therefore I think these smaller sized structural developments observed in *S. hubbsi* means that larvae of *S. hubbsi* have a higher locomotion ability than larvae at the same size of the other species.

In this study, all larvae and pelagic juveniles were collected by surface tows, no specimens were collected by oblique tows. These results show that the main habitat of larvae and pelagic

juveniles is the surface layer. Even in the newborn larvae, most of the body portion of *S. hubbsi* were heavily pigmented. As heavy pigmentation provides protection from ultraviolet radiation (MOSER 1981), this character is effective for a neustonic life style.

As adults of *S. hubbsi* mainly inhabit rocky coastal bottoms of less than 10 m deep, larvae will be extruded in those area. OKABE (1993, 1996) collected newborn flexion larvae and juvenile of *S. hubbsi* using a light-trap on the rocky shore at Boso Peninsula and Miura Peninsula, but he also reported that he could not collect postflexion larvae by the same method. In this study, I reported that postflexion larvae mainly occurred in the coastal waters around Sado Island. Considering this, I suggest that the habitat of postflexion larvae of *S. hubbsi* is the sea surface of coastal waters.

In the Sado Strait, larvae and juveniles of *S. hubbsi* only occurred in November. OKABE (1996) also reported that the occurrence period of larval *S. hubbsi* was rather short. NAGASAWA (1998) estimated the early growth rate of five rockfishes including *S. hubbsi*, *S. schlegeli*, *S. vulpes*, *S. thompsoni* and *S. inermis*. Estimated growth rate of postflexion larvae of *S. hubbsi* was the second fastest (0.58 mm/day) among these species, and the largest pelagic juvenile 14.5 mm SL was 25 days old after extrusion. As juveniles of *S. hubbsi* larger than 15 mm SL occurred in neither the surface nor the 0-100 m stratum of coastal waters, larger juveniles are not pelagic. These results indicate that the pelagic larval and juvenile period of *S. hubbsi* is rather short.

Compared with other rockfishes in the Sea of Japan such as *S. minor*, *S. thompsoni* and *S. schlegeli*, the horizontal distribution area of larval *S. hubbsi* is limited to the nearshore zone (NAGASAWA 1993; NAGASAWA and KOBAYASHI 1995; NAGASAWA and DOMON 1997). Considering this, the large size of larvae at parturition, rapid development and shorter planktonic period will provide a minimum offshore dispersal in this species. I suggest that this early life strategy is a typical one for the *Sebastes* which inhabit the nearshore zone, as MOSER and BOEHLERT (1991) hypothesized.

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佐渡海峡におけるヨロイメバルの初期生活史

永沢 亨

胎生であるヨロイメバルは体長約5.5 mmの屈曲期仔魚として産出され、体側を黑色素胞が広く覆うことを特徴とする。脊索後端の上屈は体長7 mmまでに終了し、後屈曲期仔魚となる。変態は体長10-13 mmで行われ、その後は浮遊期稚魚となる。浮遊期稚魚は沿岸の海域で出現し、向瀬や鳥海礁などの沖合岩礁域では出現しない。浮遊期の仔稚魚は海表面近くに分布する。また、出現期間が短いことから浮遊期間も短いものと推定された。産出直後の屈曲期仔魚から餌生物の主体は体長1 mm台のカラヌス目かいあし類であり、これは浮遊期を通じて共通であった。ヨロイメバルは比較的大きなサイズで産出され、発育も早く、浮遊期間が短いという初期生活史の特性を有する。このパターンは浮遊期における沖合への逸散を最小限にするのに有効で、沿岸・岩礁性種の生活史戦略としては典型的なものの一つであると考えられる。