Settlement of Larval Japanese Flounder *(Paralichthys olivaceus)* along Yanagihama Beach, Nagasaki Prefecture

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The settlement of larval Japanese flounder following metamorphosis was studied along the shore line of Yanagihama beach, Nagasaki Prefecture in 1988 and 1989. A total of 1,995 metamorphosing larvae and metamorphosed juveniles, 8.1-61.2 mm with the modal size between 10-13 mm SL, were collected. The size at metamorphosis seemed to decrease with rising water temperature. The settlement started in early March and lasted until early June, with the peak in mid-April. More larvae were collected by night and on neap-tide days.

Key words: *Paralichthys olivaceus;* settlement; sandy beach ichthyofauna

It has been reported that the larvae of Japanese flounder settle in the shallow waters of sandy bottom.[1, 2] However, most of such studies covered the waters outside 2-m to 5-m depth contour, and it is only recently that the settlement of the fish closer to the shore line was documented.[3-5]

We formerly reported that the larval Japanese flounder just after settlement occurred abundantly in wading depths of Yanagihama beach of Ooseto Town, Nagasaki Prefecture,[3] and have been accumulating further data ever since. In this paper we describe the seasonal and diel occurrences of Japanese flounder following metamorphosis along the beach based on the collections made in 1988 and 1989.

Other topics on larval ecology such as distribution of the pelagic larvae before settlement and tidal movements of the settled juveniles over the tidal flat are to be published elsewhere.

Materials and Methods

Yanagihama beach, our study site, is a well protected beach in a small bay (about 400 by 700 m) located at the northern part of the Nishisonogi Peninsula, Nagasaki Prefecture (Fig. 1). During a low water spring tide, about 7.3 ha of tidal flat is exposed and a flow track of seepage can be seen. Sporadical vegetations of *Zostera* grow around 1.5 m below low water level. The bottom of the beach consists of medium to fine sand (Md ϕ 2.0-2.2).

The study in Yanagihama started in early April 1988. Collections were made at least twice a month through 1988 and 1989, but much intensively in the months of March to May when the larval settlement was expected to occur.

Samplings were usually conducted during a low tide in daytime. For diel occurrence study, day-and-night samplings at intervals of about three hours were carried out during neap and spring tides. Samples were collected by pushing the R-H push-net[6] (1.5 m in beam width) along

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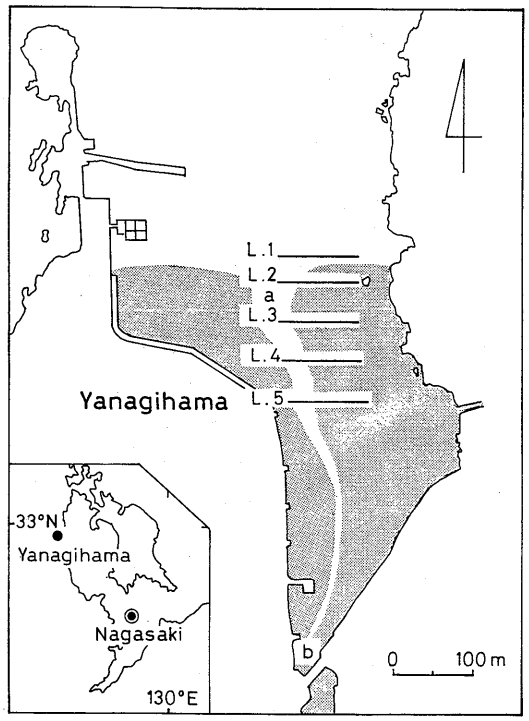

Fig. 1. A map of Yanagihama beach, showing the tidal flat (dotted area) and a flow track of seepage (a-b) at low water spring tide. Day-and-night samplings were conducted along five fixed 100-m lines, L. 1–L. 5.

100 m of beach in the waters within wading depths. In day-and-night samplings, collections were made along five fixed 100-m lines, lines 1 to 5 (Fig. 1). Line 1 was set so that this line would be covered with water of about 15 cm deep at low spring tide. Line 2 was located 30 m apart from line 1 towards the shore; during a neap tide the low water line lies around line 2 or a little shorewards. Lines 3, 4 and 5 were set at a distance of 50, 100 and 150 m, respectively, from line 2 towards the land. Two buoys were installed at both ends of each line.

When the depth of water on any of the lines exceeded 100 cm around high tide, a sledge-net which is quite similar with the R-H push-net in general constructions and dimensions was used (Fig. 2). The gear lowered onto the sea bed at one end of the line was pulled by hand from a boat anchored at the opposite end.

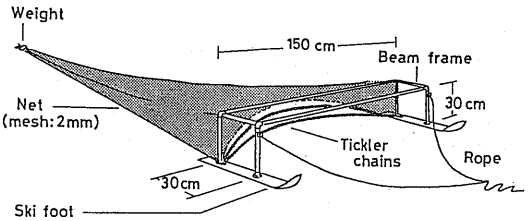

Fig. 2. The set up of the sledge-net used for the collection outside the wading depths. The net is pulled by man from an anchored boat.

Taking into consideration that larval Japanese flounder might sometimes swim up into the water column, samplings with a simple rectangular seine, 1.3 by 5 m and 0.7 mm in mesh width,[7] were simultaneously conducted. The seine was pulled by two persons along 50 m of beach and the operation was repeated four times for one collection.

Temperature and density of water were also recorded during each collection. Most of the specimens collected were preserved in 5% neutral formalin. In the laboratory lengths of specimens were measured to the nearest 0.1 mm. In staging the juveniles through metamorphosis, the system by Imabayashi[1] was adopted.

Results

Settling season and size and stages of the settled larvae

The newly settled larvae first appeared along the beach in early March, and the settling lasted until late June, with the peak in middle April (Table 1). The larvae collected during the study period amounted to 1,995 individuals.

Standard length of the decided majority of the larvae caught ranged from 9.0 to 15.0 mm, with the mode between 11.0 to 13.0 mm, although larger specimens up to 61.2 mm SL were caught in a very little number (Fig. 3). Compositions by metamorphosis stages of the larvae were almost the same in both the years. The larvae of stages D and E,* with the right eye having

* Stages D and E by Imabayashi[1] are collectively categorized as stage I in Minami's staging system.[2]

Table 1. Collection records of *Paralichthys olivaceus* following settlement along Yanagihama beach in 1988 and 1989. Collections with the R-H push-net and sledge-net were made along 100 m, and those with the seine along 50 m, of beach. o, number of operation; n, number of fish

Date			R-H push-net			Sledge-net			Seine			Total fish no.	Moon age
y	m	d	o	n	n/o	o	n	n/o	o	n	n/o		
1988	4	2-3	23	87	3.8		-		22	0	0	87	15.0-16.0
		9-10	31	108	3.5		-		26	0	0	108	22.0-23.0
		16-17	37*	438	11.8		-		26	5	0.2	443	29.0- 0.6
		22	9	51	5.7		-		6	0	0	51	5.6
	5	16	9	18	2.0		-		6	0	0	18	0.2
		17	9	14	1.6		-		6	0	0	14	1.2
		28	3	0	0		-		4	0	0	0	12.2
	6	15	3	0	0		-		4	0	0	0	0.7
		29	3	0	0		-		4	0	0	0	14.7
1989	3	8	3	15	5.0		-		4	0	0	15	0.4
		15	3	3	1.0		-		4	0	0	3	7.4
		22	3	43	14.3		-		4	0	0	43	14.4
		29	3	23	7.7		-		4	0	0	23	21.4
	4	5		-		3.5*	16	4.6		-		16	28.4
		6-7	11	14	1.3	17	39	2.3	12	0	0	53	29.4- 1.0
		13-14	12	123	10.3	18	302	16.8	14	0	0	425	7.0- 8.0
		19	3	60	20.0	3	36	12.0		-		96	13.0
		20-21	10.5*	149	14.2	19	186	9.8	12	0	0	335	14.0-15.0
		27-28	14*	13	0.9	16	224	14.0	8	2	0.3	239	21.0-22.0
	5	10	3	0	0		-		4	0	0	0	4.6
		22	3	4	1.3	3	18	6.0	4	0	0	22	16.6
	6	7	3	3	1.0		-		4	0	0	3	3.3
		21	3	1	0.3		-		4	0	0	1	17.3
			201.5	1167		79.5	821		182	7		1995	

* includes additional 2-3 samplings for 50 m.

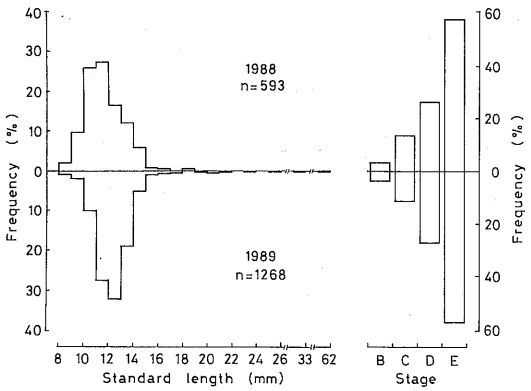

Fig. 3. The size distributions and the stage compositions of Japanese flounder collected at Yanagihama in 1988 and 1989. The stage B represents larvae with a small part of right eye visible from the left side, and the stage E those completed metamorphosis

migrated to the left side of the head, collectively accounted for 84 % of total (Fig. 3).

In spite of the fact that some 16 % of the larvae collected were still at earlier metamorphosing stages of B and C, it was very seldom that they were caught with the seine; only seven fish were obtained by a total of 182 hauls. Although the seine was towed keeping its lower margin apart from the sea bed, the clearance between them was usually smaller than 50 cm. This suggests that the larvae of as early as stages B and C already stay on or close to the sea bed most of the time when they have once reached the beach.

No stage A larva was collected.

The mean sizes of metamorphosing and metamorphosed individuals in 1988 shifted from

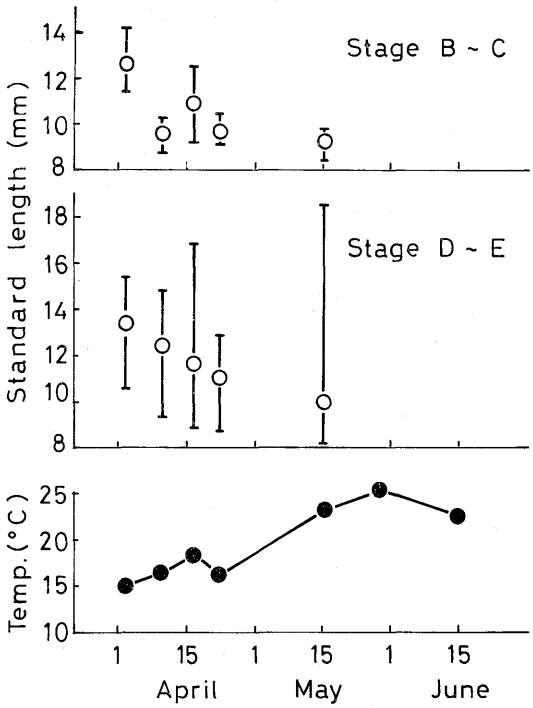

Fig. 4. Seasonal changes in sizes of Japanese flounder collected at Yanagihama in 1988. Means (open dots) and ranges (vertical bars) of standard lengths are shown. The rise in water temperature through the settlement season is also illustrated (bottom).

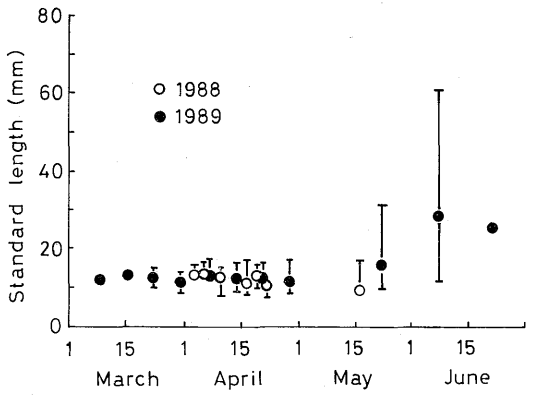

Fig. 5. Seasonal changes in sizes of Japanese flounder collected at Yanagihama in 1988 and 1989. Means and ranges of standard length are shown.

12.5 mm and 13.4 mm in early April to 9.2 mm and 10.0 mm in middle of May, respectively, while the water temperature rose from 14.8°C to 25.4°C (Fig. 4). This trend of decrease in the mean size of fish with rising temperature was not clear in 1989 (Fig. 5). Until middle of May the average length of larvae remained almost constant. Thereafter, the size increased rapidly and a specimen as large as 61.2 mm SL was caught in early June, although the newly settled larvae were also collected at the same time.

Diel occurrence of the larvae

Fig. 6 illustrates the results of two day-and-night collections along lines 1 and 2, both combined, on the days of neap and spring tides in April 1989. Only these two lines were not exposed at any time, making collections over a tidal cycle possible along these lines.

General tendencies are that the larvae were more abundantly distributed along the beach by night than in daytime, and that the

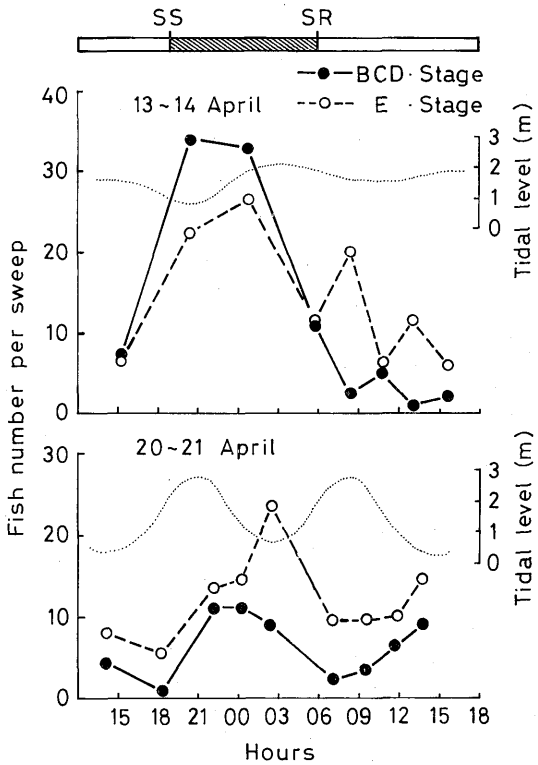

Fig. 6. Diel occurrence of metamorphosing (B, C, D) and metamorphosed (E) stages of Japanese flounder caught at lines 1 and 2 during neap and spring tides. Times of sunset and sunrise (SS and SR) are illustrated on the top.

abundance of the larvae was reversely correlated with tidal level. The first tendency was more marked on neap-tide days, while the second was so on spring-tide days.

The same tendencies are clear in Tables 2 and 3 which summarize the results of four day-and-night collections along lines 1 to 5 made in April 1989.

The diel fluctuation in catch was much greater in the metamorphosing larvae, stages B-D, than in the metamorphosed juveniles, stage E (Fig. 6).

Table 2. Comparison of the day and night catches of larval Japanese flounder of each developmental stage, based on four day-and-night samplings made in April 1989. o, number of operation ; n, number of fish

Stages	Total no. of fish	Day			Night		
		o	n	n/o	o	n	n/o
B	36	49	9	0.2	30	27	0.9
C	126	49	28	0.6	30	98	3.3
D	296	49	88	1.8	30	208	6.9
E	592	49	288	5.9	30	304	10.1

Table 3. Comparison of the day and night catches of metamorphosing stages, stages B-D, during the spring and neap tides, based on four day-and-night samplings made in April 1989. o, number of operation ; n, number of fish

Dates	Type of tides	Total no. of fish	Day			Night		
			o	n	n/o	o	n	n/o
6-7	Spring	17	10	10	1.0	6	7	1.2
13-14	Neap	195	12	36	3.0	9	159	17.7
20-21	Spring	117	14	55	3.9	8	62	7.8
27-28	Neap	129	13	23	1.8	7	106	15.1

Discussions

In intensive surveys on ecology of O-group Japanese flounder carried out at various places over Japan, a usual method to collect the larvae and juveniles after settlement has been to tow a beam trawl by boat. Naturally, in such collections shallow waters of wading depths along beaches have been excluded from survey areas. Thus, it had become a general recognition that the larvae of the fish mainly settle at depths between 3 and 10 m.[1, 8-11] However, the population densities of the settled larvae as expressed by catch per unit of effort in such "deeper waters" is much lower than those obtained in wading depths along beaches as reported here and by other scientists.[3-5, 12, 13]

The fish occurring along the beach were mostly newly settled larvae, indicating a continuous recruit through the occurrence season. On the other hand larger individuals were seldom caught along beaches and their growth as a group could not be traced. It is presently not known whether this shows the rapid dispersal of the juveniles to deeper waters after a short stay along beaches or an extremely high mortality due to predation there. Sudo et al.[12] suggested the possibility of the both.

Decrease in mean sizes of the newly settled larvae with the advance of the season was clear in 1988. A similar phenomenon is also known for larvae settled in Shijiki Bay[4] which is located some 35 km northwest of Yanagihama and for hatchery reared larvae.[14]

Based on a long-term daily sampling in Shijiki Bay, Tanaka et al.[13] concluded that the immigration and settlement of the metamorphosing larvae predominantly occur during spring tides. This tendency was not always apparent in Yanagihama in 1988; the highest catch through the occurrence season was certainly obtained during a spring tide of mid-April, but difference in catch between spring- and neap-tide samplings was not appreciable in early April and May.[3, 15] Even a rather oposite result was obtained in 1989.

Transition from pelagic to demersal life style in the Japanese flounder is by no means clear-cut as experienced in rearing of the fish. Minami[2] observed "benthic phase larvae" swimming up to the surface attracted by fish lamp. Also in our study the fish of metamor-

phosing and metamorphosed stages were collected, though few in number, with the seine designed for pelagic larvae.

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(* in Japanese with English summary ; ** in Japanese)

長崎県柳浜におけるヒラメ仔魚の着底

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1988年から1989年の間に長崎県西彼杵半島に位置する大瀬戸町柳浜より1995個体(8.1-61.2 mm SL)のヒラメ仔稚魚を得た。仔稚魚の発育段階は変態途中のものから既に完了しているものまであったが，体長のモードは10-13 mmの間に見られ，大半は着底直後と思われる，仔魚から稚魚への移行期の個体であった。当浜におけるヒラメ仔魚の着底は3月上旬に始まり，4月中旬にピークをむかえ，6月上旬まで続く。この間，水温の上昇に伴い仔魚の変態体長が小さくなる傾向が見られた。着底後の仔稚魚は大潮干潮線付近に濃密に分布し，採集個体数は小潮日の夜間に多かった。

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