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Eggs, Larvae and Juveniles of the Fishes Occurring in the Nagara River Estuary, Central Japan

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Abstract

The larval and juvenile fish fauna in the Nagara River estuary, central Japan, was surveyed during the period from July 1994 to April 1997, and the effects of the recently-completed estuary dam were considered. A total of 4,771 fish eggs collected represented 11 taxa, being mainly coastal marine species. Larvae and juvenile fishes collected totaled 17,848 representing 27 families and 37 species, including brackish, diadromous migratory and coastal marine forms. The lower Nagara River estuary, below the dam, played an important role as spawning and nursery grounds for some marine fishes, which the dam did not directly effect. The larval fish fauna in the upper Nagara River estuary, above the dam, was less diverse than that in the lower estuary, with some upper estuarine marine and brackish-water species disappearing after the closure of the dam gates. Catadromous *Plecoglossus altivelis altivelis* larvae, usually dominant in the lower reaches of the Nagara River in November, became trapped in the dam backwater after the dam gates were closed, a large proportion of the larvae overall thus being unable to migrate normally to the lower estuarine area. Before the dam gates were closed, *Salangichthys microdon* was distributed widely throughout the Nagara River estuary, its spawning ground apparently being located in the upper estuary. Following the closure of the gates, the spawning and nursery grounds were destroyed and the species completely disappeared from the lower reaches of the Nagara River. The dam apparently did not affect catadromous *Cottus reinii* larvae, although it influenced on the anadromous juveniles when they passed over it.

Key Words : fish larva • fish juvenile • Nagara River estuary dam • *Plecoglossus altivelis altivelis* • *Salangichthys microdon*

Introduction

Coastal zones are generally recognized as important nursery areas for larval and juvenile marine fishes because of their high nutritious environments and topographical variability. In fact, many fishes spend

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their early life history stages in such zones.[1-3] Amongst coastal zones and offshore areas, estuaries have the highest primary productivity and most abundant zooplankters,[4,5] being one of the most important nursery grounds for larvae and juveniles of various marine fishes.[6-8] However, various human activities offer to affect estuarine environments directly and / or indirectly, resulting in serious implications for the resident. This has happened seriously in Japan. However, studies on larval and juvenile fish faunas in Japanese estuaries are few, being known only for the Yamakuni River, Oita Prefecture, Kyushu,[9] Rokkaku River, Saga Prefecture, Kyushu,[10] Kaeda River, Miyazaki Prefecture, Kyushu,[11] and Shimanto River, Kochi Prefecture, Shikoku.[8]

The Nagara River originates in the Hida highlands, Gifu Prefecture, central Honshu, Japan, joining with the Ibi River near its mouth and draining into the innermost part of Ise Bay at Kuwana, Mie Prefecture (Fig. 1). Because the lower Nagara River passes through low-lying, non-undulant plains, its estuary extended some 20 km upstream from the river mouth. Euryhaline fishes, *Lateolabrax japonicus* (Percichthyidae),

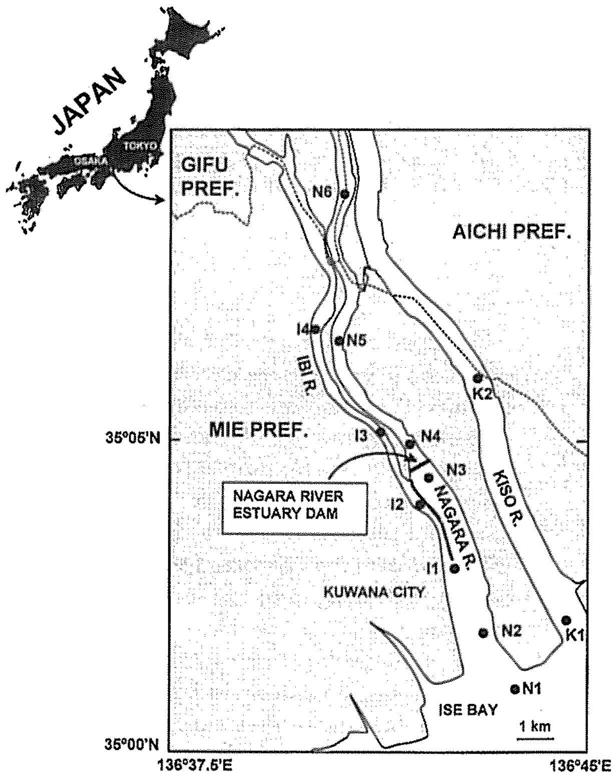

Fig. 1. Map of the lower reaches of the Nagara River.

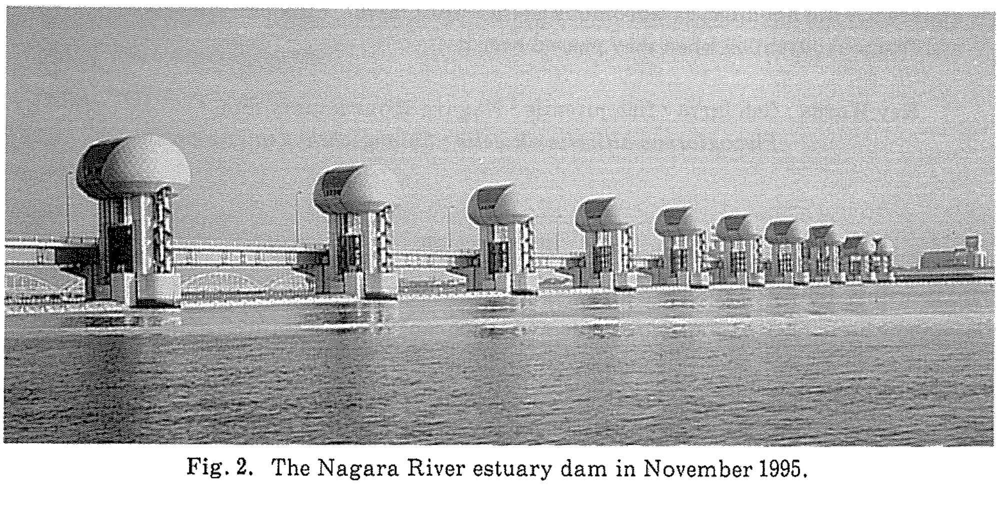

Fig. 2. The Nagara River estuary dam in November 1995.

Mugil cephalus (Mugilidae) and *Chelon haematochilus* (Mugilidae) occurred more than 14 km upstream from the mouth, and coastal fishes, *Konosirus punctatus* (Clupeidae) and "Magochi" *Platycephalus* sp. (Platycephalidae) more than 7 km.[12] In addition, commercial fisheries for *Salangichthys microdon* (Salangichthyidae) and *Corbicula japonica* (Bivalvia) were well established. However, construction of a larger estuary dam (called "Nagara-gawa kako zeki") began ca. 5 km upstream from the Nagara River mouth in 1988 and was completed in 1994 (Figs. 1, 2). The dam includes several vertically movable gates in order to adjust the water level behind the dam. The gates were closed tentatively from May 1994 and began permanent operation in July 1995. Subsequently, the lower reaches of the Nagara River have been divided into a large stagnant, lake-like backwater area and small estuary.

The aims of this paper are to clarify the changes in the larval and juvenile fish fauna in the lower reaches of the Nagara River from 1994 to 1997, and to determine the influences of the estuary dam on the larval and juvenile fish assemblages.

Materials and Methods

Study area

Field collections, made around neap tide once for each season of the year, were carried out 12 times from July 1994 to April 1997 (Table 1). The gates of the Nagara River estuary dam were open during the

Table 1. Date and Time, Lunar Age, and Time of High and Low Tides at Each Field Collection

	2Jul. '94	12Nov. '94	25Feb. '95	22Apr. '95	5Aug. '95	3Nov. '95	10Feb. '96	25May. '96	27Jul. '96	16Nov. '96	15Feb. '97	12Apr. '97
Lunar age	22.8	8.6	25.2	22.0	8.5	9.9	20.6	7.6	11.4	4.9	7.5	4.7
High tide	-	00:48	03:36	10:31	-	02:54	09:05	10:26	02:13	09:48	11:13	08:25
	12:37	14:00	14:30	-	12:52	15:29	21:37	23:43	16:18	20:53	-	21:39
Low tide	06:47	07:10	08:50	05:01	06:11	08:59	02:49	04:27	09:08	02:51	04:50	02:34
	18:12	20:24	21:21	17:45	18:27	21:37	15:11	17:01	21:41	15:19	18:40	15:08
Time when each haul started												
Station N1	13:37	13:22	13:29	14:44	13:54	15:03	08:51	13:42	15:19	11:37	11:23	11:31
Station N2	12:49	11:27	11:27	13:42	13:18	11:05	08:25	11:20	14:50	11:04	10:55	10:59
Station N3	08:49	11:04	10:46	11:20	11:21	10:31	09:34	10:43	13:59	10:29	10:21	10:21
Station N4	09:11	10:08	10:11	10:27	10:23	09:37	11:52	09:55	10:22	09:48	09:40	09:43
Station N5	09:42	09:36	09:35	09:48	09:50	-	11:16	09:22	09:46	09:14	09:08	09:12
Station N6	10:18	08:40	08:46	09:00	09:11	08:44	10:42	08:45	09:05	08:41	08:35	08:38
Station K1	13:51	13:55	14:03	15:04	14:28	14:33	-	-	-	-	-	-
Station K2	15:10	14:37	14:46	16:01	15:24	13:55	-	-	-	-	-	-
Station I 1	-	-	-	-	-	-	-	-	14:15	14:31	11:47	12:08
Station I 2	-	-	-	-	-	-	14:07	14:10	-	-	-	-
Station I 3	-	-	-	-	-	-	14:45	14:55	11:54	13:59	13:02	12:26
Station I 4	-	-	-	-	-	-	-	-	11:23	13:16	12:30	12:59

first to third collections (July1994 to February 1995), but they were closed thereafter. Six sampling stations, N1-N6, were established in the lower reaches of the river, stations N1-N3 (lower Nagara River stations) being situated below the dam and N4-N6 (upper Nagara River stations) above (Fig. 1, Table 2). In addition, 2 and 4 stations, respectively, in the Kiso (K1 and K2) and Ibi (I1-I4) Rivers were established for comparative purposes (Fig. 1, Table 2). Water temperature and salinity at the time of each field collection are shown in Table 3. Water salinity was noted at all stations during the "open gates" period, but not at the upper Nagara River stations after the gates were closed (except in April 1995 when the gates were closed tentatively and brackish water remained in the bottom layer just above the dam).

Sample gear and procedures

Fish eggs, larvae and juveniles were collected using a ring larval net with mouth diameter 1.3 m, length 4.5 m and 0.33 mm cod end mesh. The net ring was fitted with a flowmeter (after February 1995) and a buoy, by which the net depth was adjusted. The net was towed horizontally at 1.5−2.5 kt for 5 min. Surface and bottom tows were generally carried out at each station. The surface tows targeted 1 m depth (at the center of the net ring) and the bottom tows 3.7 m depth. At stations shallower than 4.5 m depth, the target depth of the bottom tow was adjusted to 1.2 m above the riverbed. Station N1, being located in the shallowest area, was often shallower than 3.0 m depth. In these cases, bottom tows were aborted. Water volumes sampled ranged from 200 to 400 m^3. Each catch was preserved in 10 % formalin diluted with water taken from the respective station.

Laboratory procedures

The samples were entirely sorted using a dissecting microscope at 6-10 X. All fish eggs, larvae and juveniles were removed and identified to the lowest taxon possible, following Nakabo [13] and Okiyama [14]. Definition of the early life history stages of fishes was followed Kendall et al.[15] Body length

Table 2. Locality and Depth of Each Station

Station	River	Approx. distance from river mouth (km)	Depth (m)
N1	Nagara	-1.7	2.5-3.5
N2	Nagara	0.0	3.5-5.5
N3	Nagara	4.7	5.0-6.5
N4	Nagara	6.5	5.0-7.5
N5	Nagara	10.0	5.5-6.5
N6	Nagara	14.3	5.5-7.5
K1	Kiso	-0.5	4.5-6.5
K2	Kiso	7.0	5.0-6.5
I1	Ibi	2.0	3.5-5.0
I2	Ibi	4.0	4.0-6.0
I3	Ibi	7.0	3.5-5.5
I4	Ibi	10.0	5.5-7.0

Table 3. Water Temperature (℃) and Salinity (PSU) at Each Collection

Station	Jul. '94		Nov.'94		Feb.'95		Apr.'95		Aug.'95		Nov.'95		Feb.'96		Nov.'96		Feb.'97		Apr.'97	
	S*	B**	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B
Temperature																				
N1	26.1	24.6	20.0	20.0	9.0	8.8	13.0	13.1	26.7	23.8	18.6	18.8	6.7	7.0	16.4	17.8	7.2	8.8	11.8	12.3
N2	26.2	24.5	17.3	19.4	8.0	8.4	12.7	12.8	29.4	23.3	17.5	18.4	4.9	6.0	15.3	17.9	6.9	8.6	11.7	11.4
N3	24.4	24.1	16.6	18.8	7.7	8.5	12.8	12.5	27.3	23.9	17.3	18.5	5.3	6.9	14.5	15.9	8.0	8.8	12.8	11.9
N4	24.2	24.2	16.0	17.8	7.0	8.4	12.9	12.6	29.1	27.1	15.2	15.5	4.3	4.3	12.7	12.7	6.9	6.8	12.8	12.5
N5	23.7	24.2	15.5	17.7	7.4	8.2	13.2	12.8	29.2	27.7	-	-	5.0	4.9	12.4	12.5	6.9	7.1	12.8	12.6
N6	23.1	23.0	15.5	15.2	7.4	7.5	12.8	12.8	28.5	27.5	14.8	14.8	4.8	4.8	11.6	11.5	6.8	6.9	12.7	12.6
K1	25.8	24.1	18.3	19.6	7.9	8.2	12.3	12.6	29.4	23.6	18.0	18.2	-	-	-	-	-	-	-	-
K2	26.0	24.0	17.3	19.3	7.8	8.7	12.1	12.4	29.6	25.2	16.4	17.5	-	-	-	-	-	-	-	-
I1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.2	16.8	7.7	8.9	11.6	11.5
I2	-	-	-	-	-	-	-	-	-	-	-	-	4.9	5.0	-	-	-	-	-	-
I3	-	-	-	-	-	-	-	-	-	-	-	-	5.2	5.4	12.1	13.3	7.1	7.9	12.1	11.9
I4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11.5	11.5	6.8	7.7	12.4	12.0
Salinity																				
N1	24.3	27.2	28.5	28.5	29.7	-	7.6	25.5	24.5	29.0	30.4	30.7	32.5	32.8	27.4	31.6	18.0	29.7	23.2	31.4
N2	10.7	26.5	15.2	28.5	24.5	-	8.5	27.7	14.0	29.8	22.1	29.1	20.3	28.8	23.1	32.0	15.1	30.1	21.4	29.7
N3	5.6	19.5	9.1	27.5	12.5	31.1	6.8	28.4	12.9	27.1	16.1	28.0	13.5	28.7	13.6	28.2	17.8	28.5	8.4	28.2
N4	5.6	13.9	7.1	21.5	10.8	29.3	0.0	8.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N5	5.6	6.2	2.5	21.5	13.1	29.1	0.0	1.0	0.0	0.0	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N6	5.7	5.7	0.1	0.2	5.4	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K1	15.0	26.9	14.5	29.5	27.4	-	1.0	25.3	14.0	29.7	26.8	28.2	-	-	-	-	-	-	-	-
K2	5.5	21.6	8.0	26.5	17.5	32.1	0.9	23.1	5.5	23.3	13.5	20.2	-	-	-	-	-	-	-	-
I1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.8	31.4	15.4	29.9	6.8	30.6
I2	-	-	-	-	-	-	-	-	-	-	-	-	6.2	11.5	-	-	-	-	-	-
I3	-	-	-	-	-	-	-	-	-	-	-	-	1.0	3.0	4.0	9.7	6.0	24.0	0.0	0.0
I4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	0.8	3.5	15.8	0.0	0.0

Data for May and July 1996 not available.
* surface layer.
** bottom layer.

(BL) was defined as the notochord length in yolksac, preflexion and flexion larvae and the standard length in postflexion larvae and juveniles.[16] All of the specimens collected during the study are deposited at the Fisheries Research Laboratory, Mie University (FRLM).

Results

General aspect of fish egg distribution

A total of 4,771 eggs collected were classified into 11 taxa (Table 4). *Sardinella zunasi* (Clupeidae) eggs occurred most abundantly in the lower stations of the Nagara and Kiso Rivers (N1-N3 and K1) in summer. *Konosirus punctatus* and *Triacanthus biaculeatus* (Triacanthidae) eggs were also abundant, being recorded in spring and summer, respectively. Although cyprinid and *Salangichthys microdon* eggs are adhesive, they were collected by the larval net, the former probably having become detached from substrata prior to sampling. *Salangichthys microdon* eggs were collected when the net just touched the riverbed. Three types of unidentifiable eggs were caught in the vicinity of the river mouths. They were spherical in shape, buoyant and with a single oil globule, but could not be identified (type A: ca. 0.6 mm in egg diameter and ca. 0.15 mm in oil globule diameter; type B: ca. 0.7 mm in egg diameter and ca. 0.15 mm in oil globule diameter; type C: ca. 1.0 mm in egg diameter and ca. 0.30 mm in oil globule diameter).

The lower stations, N1-N3 and K1, were more abundant in both number of eggs and number of taxa than the upper stations (Figs. 3, 4). The upper Nagara River stations were very poor in fish eggs, none at all being at station N5. The overall number of eggs increased in summer at the lower stations, owing

Table 4. List of Fish Eggs Collected

Taxa	No. of eggs	Station(s)*	Season(s)**
Clupeidae			
Sardinella zunasi	2608	N1-N4(O), K1, K2	Su
Konosirus punctatus	665	N1-N3, K1, I1-I3	Sp
Engraulidae			
Engraulis japonicus	16	N1-N3, K1	Sp-A
Cyprinidae	7	N6	Sp-Su
Salangichthyidae			
Salangichthys microdon	8	I2	W
Callionymidae			
Repomucenus sp.	130	N1-N3	Sp, A
Solenoidei	2	N1, N2	Su
Triacanthidae			
Triacanthus biaculeatus	659	N1, N2, K1	Su
Unidentifiable A	421	N1, N2, K1	Su
Unidentifiable B	247	N1, N2, K1	Su
Unidentifiable C	8	K1, I2	Sp

*"(O)"indicates collection made when the dam gates were open.
**A: autumn (November); Sp: spring (April-May); Su: summer (July-August); W: winter (February).

to spawning of *Sardinella zunasi* and *T. biaculeatus*. *Konosirus punctatus* and *Repomucenus* (Callionymidae) eggs were captured abundantly at stations N3 in May 1996 and N1 and N2 in November 1996, respectively.

General aspect of larval and juvenile fish fauna

A total of 17,848 larvae and juveniles collected were classified into 23 families and 37 species, including *Repomucenus* sp (p)., *Chaenogobius urotaenia* complex (Gobiidae) and 4 forms of unidentifiable gobiids (Table 5). The lower stations, N1 - N3, K1, K2 and I1 showed a greater diversity of species' composition than the upper stations (Fig. 5). Species' compositions at the two uppermost stations in the Nagara River (N5 and N6) were very simple, consisting of mainly unidentifiable Gobiidae NA in summer, *Plecoglossus altivelis altivelis* (Plecoglossidae) in autumn, and *Salangichthys microdon* (during the "open gates" period) or *Cottus reinii* (Cottidae; after gate closure) in winter. Dominant species at the lower Nagara River stations were similar to those at the lower stations in the Kiso (K1 - K2) and Ibi (I 1 - I 2) Rivers, but differed from those at the upper stations in the Nagara (N4 - N6) and Ibi (I 3 - I 4) Rivers (Table 6). Dominant species were similar at the upper stations in the Nagara and Ibi Rivers.

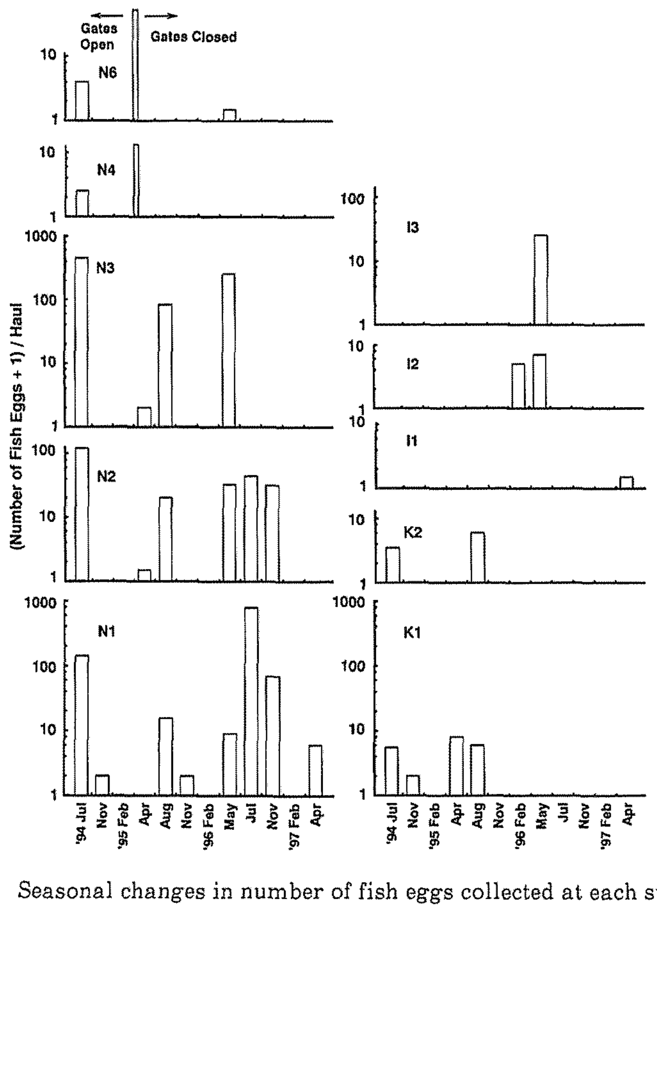

Fig. 3. Seasonal changes in number of fish eggs collected at each station.

The number of species generally increased in summer and winter, except at the upper Nagara River stations, where only a few species were found and the seasonal change in number of species was minimal (Fig. 6). There were no clear seasonal changes in numbers of individuals at each station (Fig. 7), the annual fluctuations in number of larvae and juveniles at each station being somewhat large and obscuring any effect of seasonal changes. The November 1996 and 1997 peaks at the upper Nagara River stations resulted from a large number of *P. a. altivelis* larvae. The peaks in August 1995 at stations N3 and K2 were attributable to *Sardinella zunasi*, in April 1995 at N2 and K1 and in April 1997 at I1 to *Acanthogobius flavimanus* (Gobiidae), and in February 1997 at N3 to *Cottus reinii*.

Simpson's index of diversity [17] for the larval and juvenile fish assemblage at each station generally increased in summer and winter (Fig. 8), but decreased gradually from the lower to the upper stations in the Nagara and Ibi Rivers. At station N4, it clearly decreased after April 1995, following closure of dam gates. However, no significant changes in the index before and after gate closure were apparent at the other stations.

Pianka's indices of similarity [18] of the larval and juvenile fish assemblages between station N1 (lowermost) and the other Nagara River stations decreased somewhat gradually in an upstream

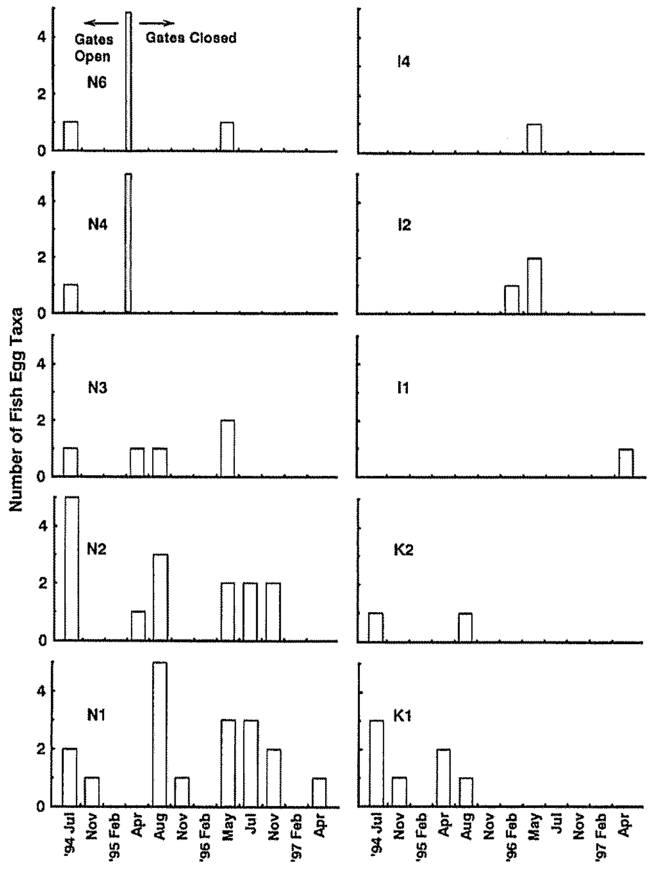

Fig. 4. Seasonal changes in number of fish egg taxa collected at each station.

Table 5. List of Larval and Juvenile Fishes Collected

Species	No. of inds.	Station(s)*	Season(s)**	Stage(s)***	Body length (mm)
Clupeidae					
Sardinella zunasi	553	N1-N4(O), N5(O), K1, K2, I1	Su	L1-L4	1.6-10.5
Konosirus punctatus	25	N1-N3, I1-I3	Sp-Su	L2	4.9-11.1
Engraulidae					
Engraulis japonicus	171	N1-N4(O), K1, K2, I1, I2	Sp, A	L2-L4	2.3-16.4
Cyprinidae					
Tribolodon hakonensis	1	N4(C)	Sp	L3	10.6
Plecoglossidae					
Plecoglossus altivelis altivelis	7608	N1-N6, K1, K2, I1, I3, I4	A-W	L2-L4	4.4-27.5
Salangichthyidae					
Salangichthys microdon	1097	N1-N6(O), K1, K2, I1-I4	W-Su	L2-J	4.8-32.3
Scorpaenidae					
Sebastes inermis	1	N3	W	L4	9.4
Sebastiscus marmoratus	6	N1-N3, K1, I2	A-Sp	L2, L3	3.3-6.7
Platycephalidae					
Platycephalus sp. "magochi"	2	N1	Su	L3, J	5.9-11.2
Cottidae					
Cottus reinii	1316	N1-N6, K1, K2, I1, I3, I4	W-Sp	L2-J	5.5-16.5
Cottus kazika	5	N2, N3, K1	W	L2-J	6.5-12.0
Percichthyidae					
Lateolabrax japonicus	30	N1, N3, I4	W-Sp	L4-J	12.5-20.0
Centrarchidae					
Lepomis macrochirus	1	I3	Su	L4	10.0
Carangidae					
Trachurus japonicus	3	K1	Su	J	9.6-12.5
Decapterus maruadsi	37	N1-N3, K1, K2	Su	L3-J	5.5-20.0
Leiognathidae					
Leiognathus nuchalis	12	N1-N3, K1	Su	L2, L3	1.7-4.7
Sparidae					
Acanthopagrus schlegeli	2	I1, I2	Sp	L2	3.0-3.4
Sparidae					
Nibea mitsukurii	10	N1-N3, K2	Su	L2	1.8-3.3
Pholididae					
Pholis nebulosa	202	N1-N3, I1, I3, I4	W	L2-L4	13.1-27.5
Blenniidae					
Parablennius yatabei	1	N1	A	L3	5.9
Omobranchus loxozonus	3	N1, K1	Su	L2	2.8-3.0
Omobranchus elegans	92	N1-N4(O), K1, K2, I1	Su	L2-J	1.8-16.0
Ammodytidae					
Ammodytes personatus	118	N1-N3, I1-I4	W	L2-L4	4.6-21.5
Callionymidae					
Repomucenus sp(p).	182	N1-N3, K1, K2, I1, I2	Su-W	L1-L4	1.2-8.0
Gobiidae					
Tridentiger bifasciatus	1	N3	Su	J	10.4
Chaenogobius urotaenia complex	103	N1-N6, K1, K2, I1, I3, I4	A-Sp	L2, L3, J	3.8-30.0
Acanthogobius flavimanus	4639	N1-N3, N6(O), K1, K2, I1-I4	W-Sp	L1-J	3.9-18.0
Acanthogobius lactipes	6	N1-N3, N4(O), K1	Su	L1, L2	2.3-3.2
Gobiidae NA	908	N1-N6, K1, K2, I1-I4	Sp-Su	L1-L3	1.8-6.0
Gobiidae NB	111	N1-N6, K1, K2, I1, I3	Sp-A	L2, L3	2.1-4.5
Gobiidae NC	33	N4-N6, K2	Su	L2	2.2-4.0
Gobiidae NK	4	I1	Su, W	L2	1.6-5.8
Damaged (unidentifiable) Gobiidae	298	N1-N6, K1, I1	Su		
Centrolophidae					
Psenopsis anomala	1	N2	Su	J	12.0
Pleuronectidae					
Pleuronectes yokohamae	3	N1, I4	W	L3-L4	8.3-11.2

(To be continued)

Table 5. List of Larval and Juvenile Fishes Collected (Continued)

Species	No. of inds.	Station(s)*	Season(s)**	Stage(s)***	Body length (mm)
Triacanthidae					
Triacanthus biaculeatus	27	N1-N3, K2	Su	L2	1.0-1.9
Monacanthidae					
Rudarius ercodes	2	N1, N3	Su-A	L2-L3	2.5-3.6
Damaged (unidentifiable) larvae	231				

*"(O)"and"(C)"indicate collection made only when dam gates were open and closed, respectively.
**A: autumn (November); Sp: spring (April-May); Su: summer (July-August); W: winter (February).
***L1: yolksac larvae; L2: preflexion larvae; L3: flexion larvae; L4: postflexion larvae; J: juveniles.

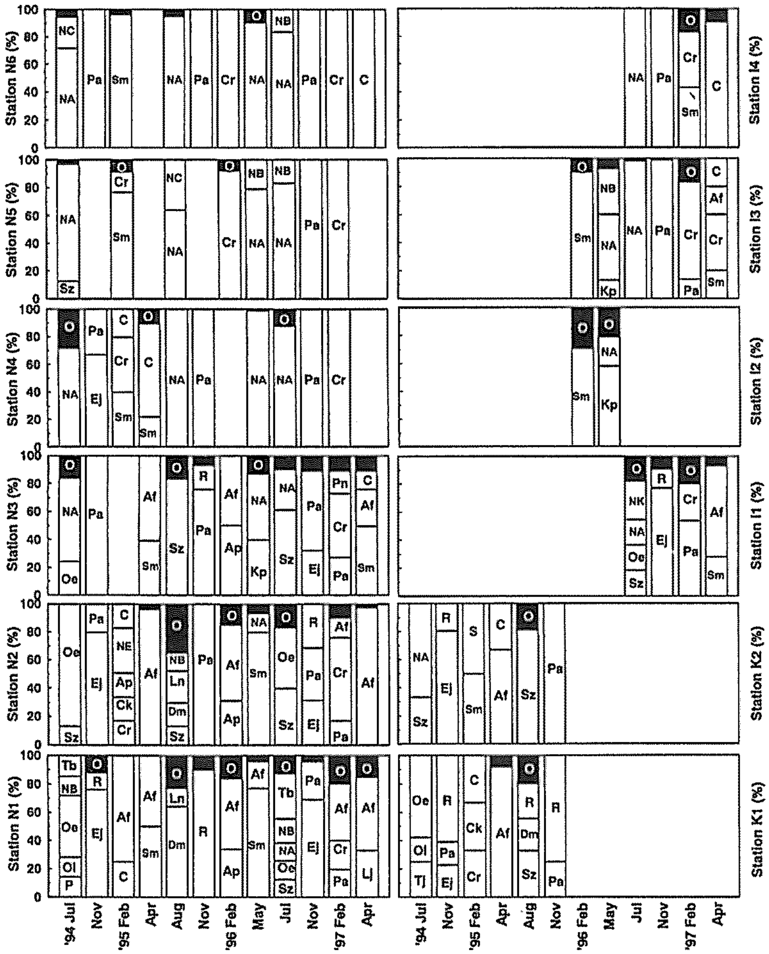

Fig. 5. Seasonal changes in species composition of larval and juvenile fishes at each station.
Af : *Acanthogobius flavimanus*; Ap: *Ammodytes personatus*; C: *Chaenogobius urotaenia* complex; Ck : *Cottus kazika*; Cr: *Cottus reinii*; Dm: *Decapterus maruadsi*; Ej: *Engraulis japonicus*; Kb: *Kareius bicoloratus*; Kp: *Konosirus punctatus*; Lj: *Lateolabrax japonicus*; Ln: *Leiognathus nuchalis*; NA: Gobiidae NA; NB: Gobiidae NB; O: Others (less than 13% in proportion); Oe: *Omobranchus elegans*; Ol: *Omobranchus loxozonus*; P: "Magochi" *Platycephalus* sp.; Pa: *Plecoglossus altivelis altivelis*; Pn: *Pholis nebulosa*; R: *Repomucenus* sp(p).; S: *Sebastiscus marmoratus*; Sm: *Salangichthys microdon*; Sz: *Sardinella zunasi*; Tb: *Triacanthus biaculeatus*; Tj: *Trachurus japonicus*.

Table 6. List of Dominant Larval and Juvenile Fish Species in Station Groups for Each Season

Station group	Summer	Autumn	Winter	Spring
N1-N3 (Gates open)	*Omobranchus elegans* Gobiidae NA *Sardinella zunasi*	*Engraulis japonicus* *Plecoglossus altivelis altivelis* *Repomucenus* sp(p).	*Chaenogobius urotaenia* complex *Acanthogobius flavimanus* *Cottus reinii*	No data No data No data
N4-N6 (Gates open)	Gobiidae NA Gobiidae NC Gobiidae NB	*Plecoglossus altivelis altivelis* *Engraulis japonicus*	*Salangichthys microdon* *Cottus reinii* *Chaenogobius urotaenia* complex	No data No data No data
N1-N3 (Gates closed)	*Sardinella zunasi* *Omobranchus elegans* Gobiidae NB	*Repomucenus* sp(p). *Plecoglossus altivelis altivelis* *Engraulis japonicus*	*Cottus reinii* *Plecoglossus altivelis altivelis* *Pholis nebulosa*	*Acanthogobius flavimanus* *Salangichthys microdon* Gobiidae NA
N4-N6 (Gates closed)	Gobiidae NA Gobiidae NB Gobiidae NC	*Plecoglossus altivelis altivelis*	*Cottus reinii* *Chaenogobius urotaenia* complex	Gobiidae NA Gobiidae NB *Chaenogobius urotaenia* complex
K1-K2	*Sardinella zunasi* Gobiidae NB *Omobranchus elegans*	*Repomucenus* sp(p). *Plecoglossus altivelis altivelis* *Engraulis japonicus*	*Salangichthys microdon* *Cottus reinii* *Cottus kazika*	*Acanthogobius flavimanus* *Salangichthys microdon* *Chaenogobius urotaenia* complex
I1-I2	Gobiidae NK *Sardinella zunasi* *Omobranchus elegans*	*Engraulis japonicus* *Plecoglossus altivelis altivelis* *Repomucenus* sp(p).	*Plecoglossus altivelis altivelis* *Cottus reinii* *Salangichthys microdon*	*Acanthogobius flavimanus* *Salangichthys microdon* *Konosirus punctatus*
I3-I4	Gobiidae NA	*Plecoglossus altivelis altivelis*	*Cottus reinii* *Salangichthys microdon* *Plecoglossus altivelis altivelis*	*Chaenogobius urotaenia* complex Gobiidae NA Gobiidae NB

Species are arranged in order of abundance.

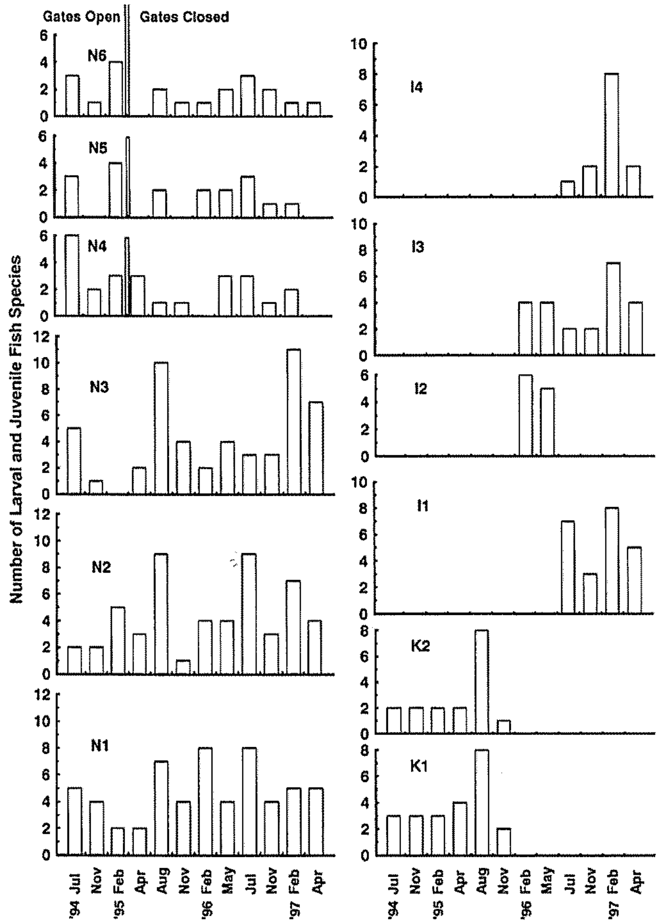

Fig. 6. Seasonal changes in number of larval and juvenile fish species collected at each station.

direction (Fig. 9). The indices between neighboring stations decreased abruptly between N2 and N3, and between N3 and N4, except in November 1995 and 1996, and February 1997 when catadromous larvae of *P. a. altivelis* or *Cottus reinii* were dominant and distributed widely throughout the lower reaches of the Nagara River (Fig. 9).

Plecoglossus altivelis altivelis larvae

Catadromous preflexion larvae of *Plecoglossus altivelis altivelis* (4.4-8.8 mm BL), were collected in November at all stations, except station I2 where no collections were made in that month. The larvae occurred abundantly at station N6 in 1994, at N4 and N6 in 1995, and at N4-N6 and I4 in 1996 (Fig. 10). The mean body lengths of the larvae collected at the lower (N1-N3; 6.85 mm) and upper (N4-N6; 6.49 mm) Nagara River stations and Kiso River stations (K1-K2; 6.22 mm) were almost the same, there being no significant differences ($p > 0.05$) in 1994 (Fig. 11). However, the mean body length at the lower Nagara River stations (6.37 mm) was significantly less than at the upper Nagara River stations (7.20

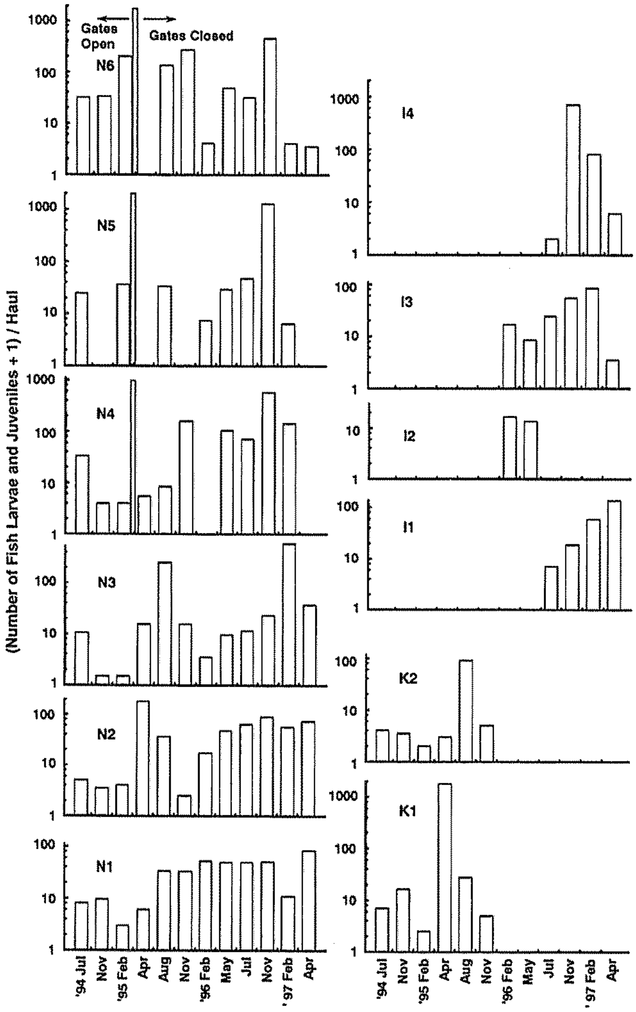

Fig. 7. Seasonal changes in number of fish larvae and juveniles collected at each station.

mm; $p<0.01$), and was almost the same as at the Kiso River stations (6.16 mm; $p>0.05$) in 1995. In 1996, the mean length at the lower Nagara River stations (5.73 mm) was almost the same as at the lower Ibi River station (I1; 5.92 mm; $p>0.05$), but significantly less than at the upper stations of the Nagara (7.22 mm) and Ibi (I3-I4; 6.50 mm) Rivers ($p<0.01$). The mean body length at the lower Ibi River station (I1) was also significantly less than at the upper stations ($p<0.01$). After the dam gates were closed, larvae were collected in large quantities at the upper Nagara River stations, the mean body length at N4 being significantly greater than at N6 ($p<0.01$) (Table 7).

By February, the larvae had grown to the flexion or postflexion stages, 11.4-27.5 mm BL (Fig. 11), occurring at the lower Nagara River stations in 1996 and 1997, and the Ibi River stations in 1997 (Fig. 10). In February 1997, the mean body lengths at the lower Nagara River stations (15.6 mm) and the upper (15.6 mm) and lower (15.9 mm) Ibi River stations were almost the same ($p>0.05$).

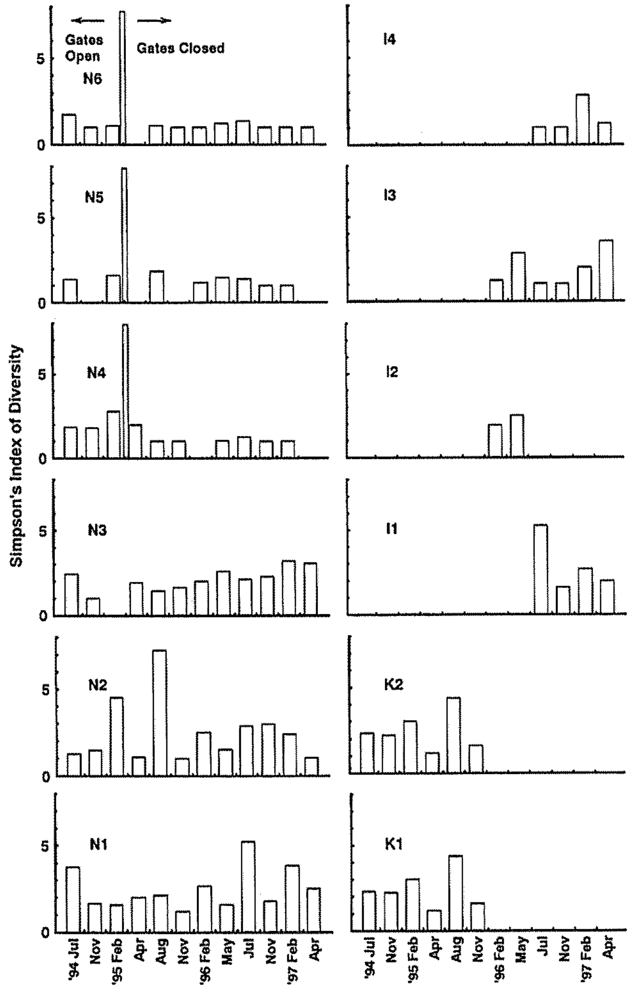

Fig. 8. Seasonal changes in Simpson's index of diversity at each station.

Salangichthys microdon larvae and juveniles

Preflexion larval to juvenile stages of *Salangichthys microdon* were collected from February to July (Figs. 12, 13), although in February, only preflexion larvae (4.9-8.2 mm BL) occurred. In February 1995, when the dam gates were open, numerous larvae were collected at the upper Nagara River stations. In February 1996, when the gates were closed, no *S. microdon* larvae were collected at the Nagara River stations, although they occurred in the Ibi River stations. In February 1997, only 11 larvae (2 tows) were collected in the Nagara River at station N3.

The larvae generally reached to the flexion or postflexion stages in April or May, and the juvenile stage in July. In April or May, the larvae usually occurred at the lower stations in the three Rivers, having wide ranges in body length. The length composition in April 1995 showed a unimodal distribution, but those in May 1996 and April 1997 were bimodal (Fig. 14). Moreover, in April 1997, smaller preflexion larvae were dominant.

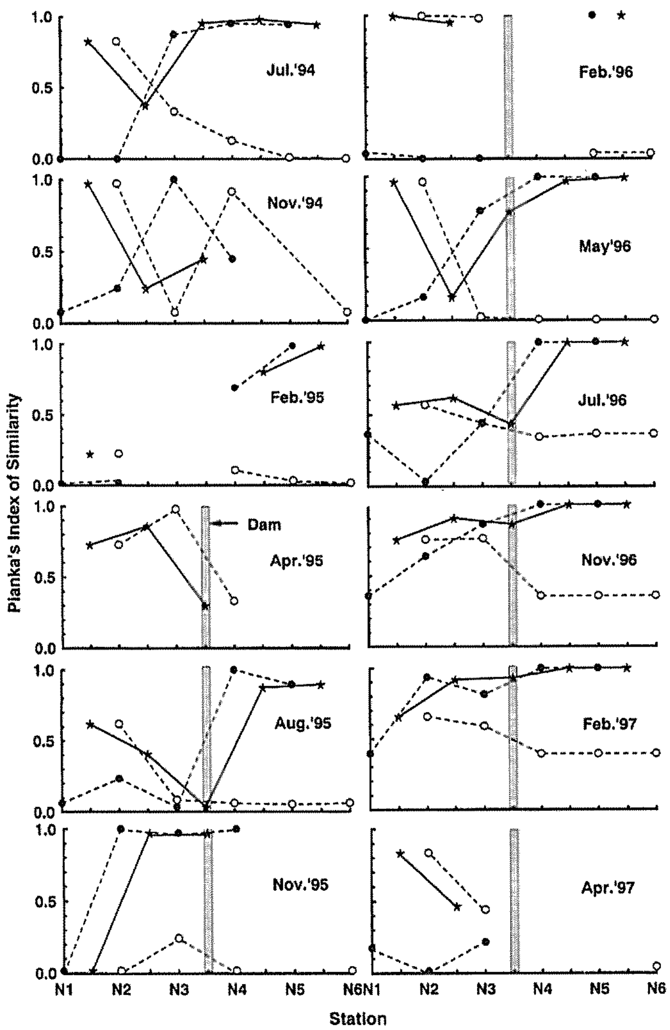

Fig. 9. Pianka's index of similarity for each sampling date. Open circles indicate indices between station N1 and the other stations; solid circles, indices between station N6 and the other stations; and stars, indices between neighboring stations.

***Cottus reinii* larvae and juveniles**

Preflexion larval to juvenile stages of *Cottus reinii* were collected in February and April. Although less abundant in 1995 and 1996, they were extremely abundant in 1997 (Fig. 15). In February 1997, preflexion to postflexion larvae (5.5-10.6 mm BL) were collected (Fig. 16), the mean body lengths at the upper stations of both the Nagara (N4-N6) and Ibi (I3-I4) Rivers being significantly greater than at the lower stations (N1-N3 and I1; $p < 0.01$).

In April 1997, larvae only occurred at the lower Nagara River stations and both larvae and juveniles at the Ibi River stations. Samples collected at the Nagara River stations consisted of only flexion larvae (8.5-10.7 mm BL), with a rather narrow body length range (Fig. 16). However, those at the Ibi River

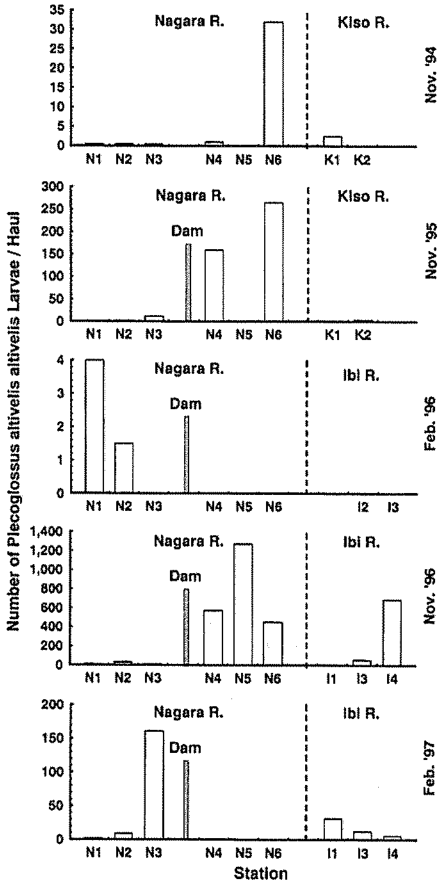

Fig. 10. Number of *Plecoglossus altivelis altivelis* larvae captured per haul at each station.

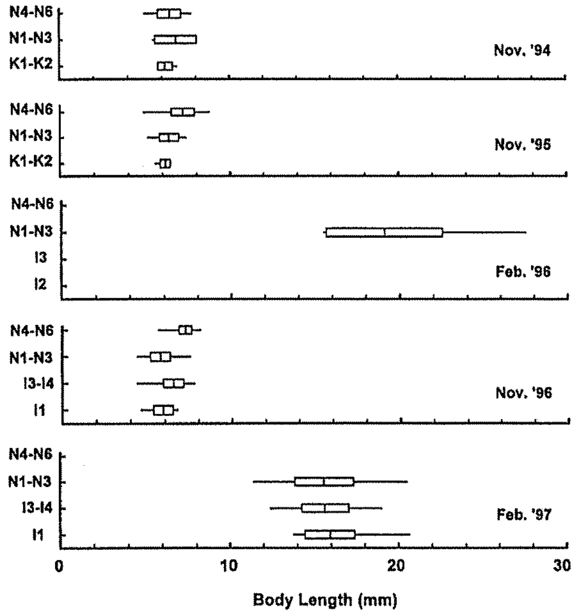

Fig. 11. Body lengths of *Plecoglossus altivelis altivelis* larvae. Horizontal bars indicate ranges, vertical bars means and rectangles means ± standard deviation.

Table 7. Range, Mean and Standard Deviation (SD) of Body Length (mm) of Catadromous *Plecoglossus altivelis altivelis* Larvae at the Upper Nagara River Stations in November

	1995		1996		
	N4	N6	N4	N5	N6
Range	4.88-8.75	5.50-7.50	5.88-8.13	5.75-8.00	5.63-7.88
Mean	7.77	6.64	7.33	7.24	7.08
SD	0.45	0.34	0.38	0.35	0.38

100 larvae measured at each station.

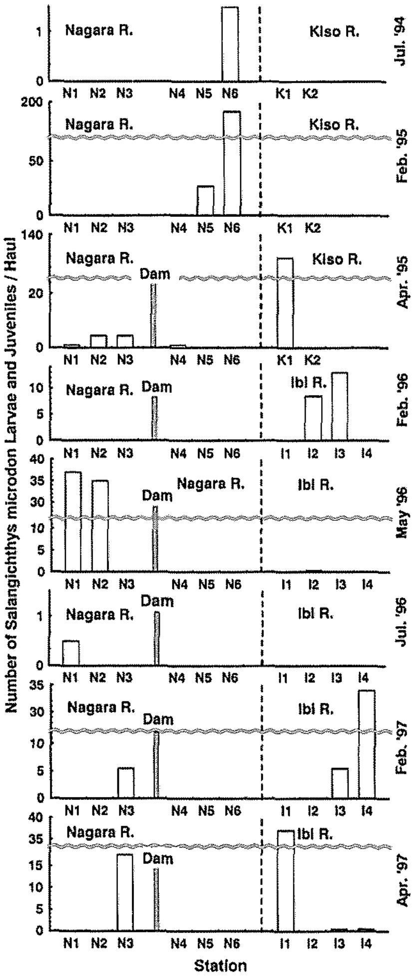

Fig. 12. Number of *Salangichthys microdon* larvae and juveniles captured per haul at each station.

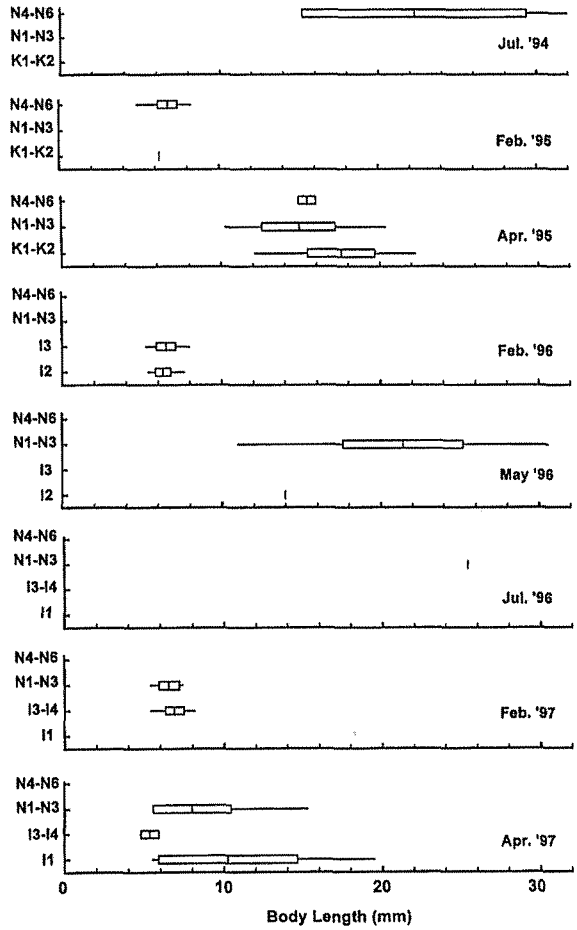

Fig. 13. Body lengths of *Salangichthys microdon* larvae and juveniles. Horizontal bars indicate ranges, vertical bars means and rectangles means ± standard deviation.

stations showed wide ranges in body length (flexion larvae 8.4-9.9 mm BL, a single postflexion larva 12.5 mm BL and juveniles 15.1-16.5 mm BL; Figs. 16, 17).

Gobiid larvae and juveniles.

A total of 6,103 gobiid larvae and juveniles were collected in the lower reaches of the Nagara, Ibi and Kiso Rivers. Approximately 80 % were identified as *Tridentiger bifasciatus, Chaenogobius urotaenia* complex, *Acanthogobius flavimanus* and *A. latipes*, the remainder being unidentifiable and sorted into 4 forms, Gobiidae NA, NB, NC and NK. Of the gobiid larvae and juveniles, excluding badly damaged specimens, *A. flavimanus* was the greatest numerically, accounting for 79.9% of the gobiid catch.

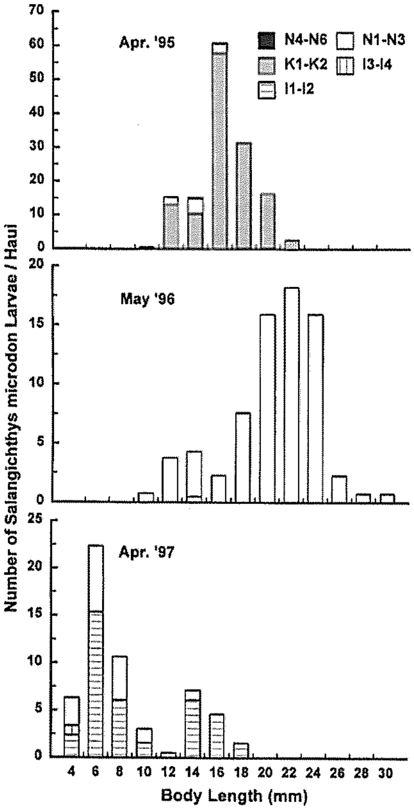

Fig. 14. Size composition of *Salangichthys microdon* larvae and juveniles collected in April 1995, May 1996 and April 1997.

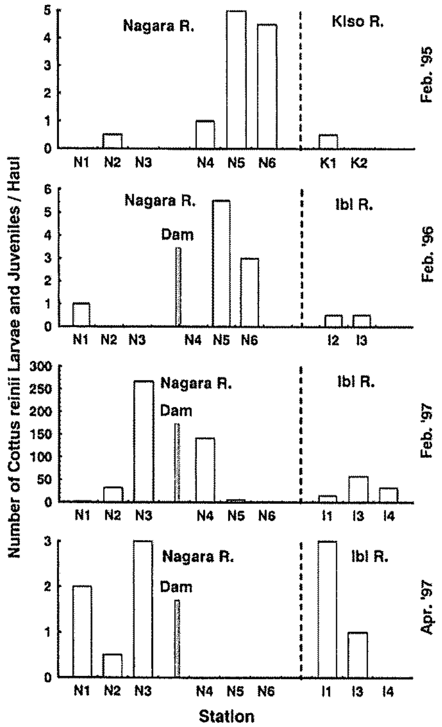

Fig. 15. Number of *Cottus reinii* larvae and juveniles captured per haul at each station.

Gobiidae NA accounted for 15.6%, and Gobiidae NB and *C. urotaenia* complex 1.9 and 1.7%, respectively. The remainder comprised less than 1%.

Morphological characteristics and ecological aspects of the unidentifiable gobiids were as follows:

Gobiidae NA—Body elongated, ca. 26 myomeres, poorly pigmented; dorsum lacking melanophores; dorsal surface of gas bladder heavily pigmented; a single large branched melanophore present on ventral midline of tail (Fig. 18A). Yolksac to flexion larvae were collected at all stations, mainly in summer. The larvae occurred at both the upper and lower stations in the Nagara River after the dam gates were closed.

Gobiidae NB—Body elongated, ca. 26 myomeres; a single large branched melanophore present on dorsal midline of tail; a series of melanophores on dorsal surface of visceral cavity continuous with those along ventral midline of tail, forming a single black line (Fig. 18B). Preflexion and flexion larvae were collected from spring to autumn (peak in summer) at all stations, except I2 and I3. The larvae occurred at both the upper and the lower stations in the Nagara River after the dam gates were closed.

Gobiidae NC—Body elongated, ca. 26 myomeres; a small melanophore present on dorsal midline of tail; melanophores on dorsal surface of visceral cavity well separated from each other; a single well

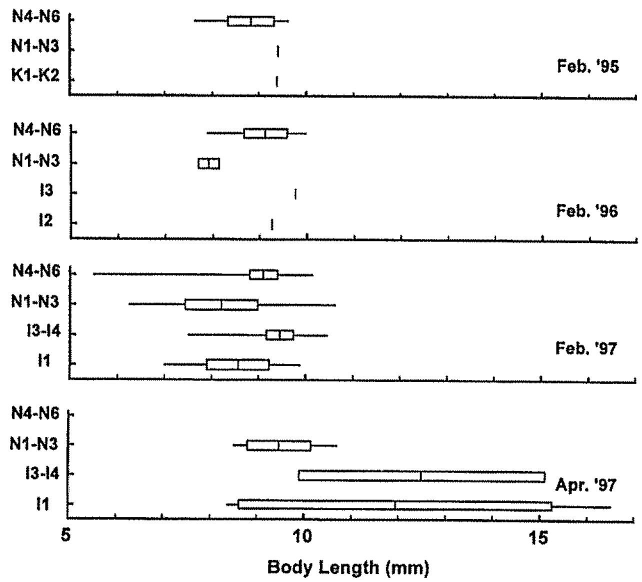

Fig. 16. Body lengths of *Cottus reinii* larvae and juveniles. Horizontal bars indicate ranges, vertical bars means and rectangles means ± standard deviation.

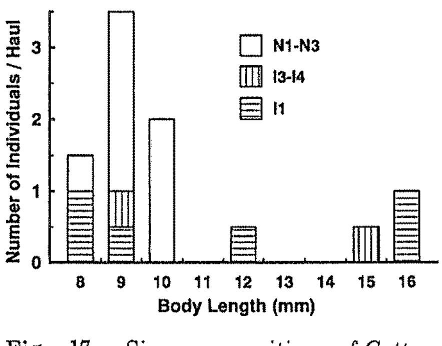

Fig. 17. Size composition of *Cottus reinii* larvae and juveniles collected in April 1997.

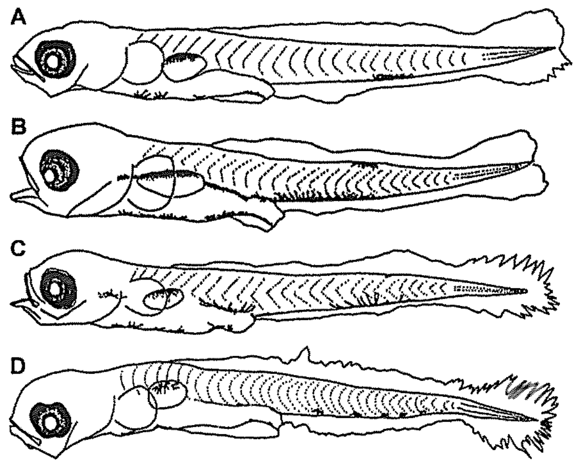

Fig. 18. Four forms of unidentifiable gobiid larvae. A–Gobiidae NA, FRLM 24163, preflexion larva, 3.5 mm BL, 2 July 1994, St. N4. B–Gobiidae NB, FRLM 24164, preflexion larva, 3.2 mm BL, 2 July 1994, St. N4. C–Gobiidae NC, FRLM 24165, preflexion larva, 3.1 mm BL, 5 August 1996, St. K2. D–Gobiidae NK, FRLM 24166, preflexion larva, 5.7 mm BL, 15 February 1997, St. I1.

branched melanophore on ventral midline of tail (Fig. 18C). Preflexion larvae were collected in summer at the upper stations in the Nagara (N4-N6) and Kiso (K2) Rivers.

Gobiidae NK – Body elongated, ca. 30 myomeres; dorsal midline lacking melanophores; 6 melanophores on ventral midline of tail (Fig. 18D). A total of 4 preflexion larvae were collected in summer and winter at station I1.

Discussion

Characteristics of the larval and juvenile fish fauna in the lower reaches of the Nagara River

The larval and juvenile fishes collected at the Nagara River stations consisted mainly brackish water species e. g. *Salangichthys microdon*, diadromous migratory species e. g. *Plecoglossus altivelis altivelis* and *Cottus reini*, and many coastal marine species e. g. *Sardinella zunasi*, *Konosirus punctatus*, *Engraulis japonicus* (Engraulidae), *Omobranchus elegans* (Blenniidae) and *Acanthogobius flavimanus*. Marine fishes were collected mainly at the lower stations, N1-N3, even when the dam gates were open, although a few *E. japonicus* larvae were taken at station N4 (6.5 km from the river mouth) and *Sardinella zunasi* and *Kareius bicoloratus* (Pleuronectidae) larvae at N5 (10.0 km). After the dam gates were closed, no marine fish larvae or juveniles occurred at the upper Nagara River stations. Therefore, it was clear that marine fish larvae and juveniles were usually restricted to within ca. 5 km above the river mouth, rarely occurring beyond that even when the dam gates were open. Although most of the marine fish eggs were taken from stations N1 and N2, *Sardinella zunasi* eggs occurred at station N4 when the gates were open.

Amongst the larvae collected during this study, *P. a. altivelis* were the greatest numerically, accounting for 42.6 % of the total catch. *Acanthogobius flavimanus* comprised 26.0 % of the total catch, and *Cottus reinii*, *Salangichthys microdon*, Gobiidae NA and *Sardinella zunasi* 7.4, 6.1, 5.1 and 3.1 %, respectively. The remaining species comprised less than 2 % by number. Because of the different methods and gear used, it is difficult to compare the present results in detail with those of previous workers. However, *P. a. altivelis* and gobiid larvae were also found to be dominant in the Shimanto River estuary, Shikoku, Japan.[8]

The species composition of the larval and juvenile fishes in the lower reaches of the Nagara River changed both seasonally and spatially (Fig. 5). Seasonal changes were periodic, each season being characterized by a particular faunal complement at each station (Table 6) : *Sardinella zunasi*, *O. elegans* and other marine fish larvae and juveniles at the lower stations (N1-N3), and Gobiidae NA at the upper stations (N4-N6), in summer; *E. japonicus* and *Repomucenus* sp (p). at the lower stations and *P. a. altivelis* at almost all stations, in autumn; *Chaenogobius urotaenia* complex and *A. flavimanus* at the lower stations and *Cottus reinii* at mainly the upper stations, in winter; *Salangichthys microdon* and *A. flavimanus* at the lower stations and Gobiidae NA, NB and *Chaenogobius urotaenia* complex at the upper stations, in spring. Spatial changes in the larval and juvenile fish faunas appeared to be complex (Fig. 9), such faunas changing abruptly between stations N2 and N3 or between N3 and N4, in the summer seasons. However, because migratory larvae were distributed widely in the estuary, the larval fish fauna gradually changed spatially during the other seasons, even after the dam gates had been closed.

Influence of the Nagara River estuary dam on the larval and juvenile fish assemblage in the lower Nagara River estuary

In the lower Nagara River estuary (below the dam), larvae of *Sardinella zunasi*, *Engraulis japonicus*, *Pholis nebulosa* (Pholididae), *Repomucenus* sp(p). and *Acanthogobius flamivanus* were dominant both before and after the dam gates were closed. Large numbers of *S. zunasi*, *Konosirus punctatus* and *Triacanthus biaculeatus* eggs were also caught in this area. Therefore, the lower estuary plays an important role as a spawning and nursery ground for the above species. Neither numbers of species nor numbers of larval and juvenile individual changed after the dam gates were closed (Figs. 6, 7). The diversity indices also did not change after the gates were closed (Fig. 8). A field survey by Amaoka et al . [19] on marine fish eggs and larvae in the innermost part of Ise Bay and around the Nagara River mouth from June to October 1967, reported that *S. zunasi* and *K. punctatus* eggs and *S. zunasi* larvae were dominant in summer, and *E. japonicus* and *Repomucenus* sp (p). larvae in autumn. Their results were closely comparable to those given here. Consequently, closing of the gates of the Nagara River estuary dam does not appear to have markedly affected larvae of the above marine species.

Influence of the Nagara River estuary dam on the larval and juvenile fish assemblage in the upper Nagara River estuary

The larval fish fauna in the upper Nagara River estuary (above the dam) was generally rather poor, even when the dam gates were open. The indices of diversity for the upper Nagara River stations were lower than for the lower stream stations (Fig. 8). After the gates were closed, the upper estuary became a backwater with even fewer larval and juvenile fishes, owing to the inability of, for example, *Sardinella zunasi*, *Engraulis japonicus* and *Salangichthys microdon* to move upstream beyond the dam. The index of diversity at station N4 clearly decreased just after the gates were closed. Conversely, the overall number of individuals increased, owing to an increase in numbers of gobiid and *Plecoglossus altivelis altivelis* larvae. Therefore, the larval fish assemblage in the upper Nagara River estuary was strongly affected, with a drop in species diversity, by the closing of the dam gates.

Larval stages of *Plecoglossus altivelis altivelis* and influence of the Nagara River estuary dam

Preflexion larvae of *Plecoglossus altivelis altivelis* occurred in autumn, the species being dominant at both lower and upper Nagara River stations. However the larvae were not distributed uniformly in the estuary, the greater quantity usually being collected at the upper stations in November. In November 1994, when the dam gates were open, a relatively large number of larvae were collected at the uppermost station (N6), but very few at the other stations. During the November 1994 collection, water salinity was found to have decreased markedly at station N6, especially in the bottom layer. An ecological study of larval *P. a. altivelis* around an estuary dam in the Takahashi River, Okayama Prefecture, western Honshu, Japan, by Senta [20] reported a high density of larvae just above the salinity front, with a decreased density below. Therefore, the high density of *P. a. altivelis* larvae at station N6 was likely due to the formation of a salinity front between stations N5 and N6. To explain this phenomenon, Senta [20] suggested that the salinity front functioned both as a physiological and physical barrier for the larvae. After the gates of the Nagara River estuary dam were closed, a large number of larvae were collected in the dam backwater in November 1995 and 1996 (Fig. 10). Undoubtedly the estuary dam had become a considerable barrier for the larvae. Such an accumulation of *P. a. altivelis* larvae has also been found in the backwater of the estuary dam in the Tone River, Chiba Prefecture, eastern Honshu, Japan.[21] At the lower Nagara River stations, only a small number of *P. a. altivelis* larvae were collected, larval mortality perhaps increasing markedly as they were conveyed across the dam with overflowing water, due to physiological and physical shock.[22, 23] Senta[20] also suggested that the larvae could easily migrate and disperse below the salinity front, there being no further physiological or physical barriers; subsequently, larval density would decrease with such dispersion.

The body lengths of the catadromous larvae collected during this study were similar to those given by Tsukamoto (6.1-8.8 mm and 4.6-8.5 mm BL for the Nagara and Kiso Rivers, respectively).[21] In November 1994, although the mean body lengths of specimens from the upper and lower Nagara stations were similar (Fig. 11), the comparison is tenuous since only 3 individuals were collected at the lower Nagara River stations. In November 1995 and 1996, more than 10 specimens were collected at each of the upper and lower Nagara River stations, and at the Kiso (1995) and Ibi River (1996) stations. Those collected at the upper Nagara River stations in November 1995 and 1996 were considerably larger than those at the lower stations, a situation paralleled by specimens from the upper and lower Ibi River stations. However, the difference in the mean body length between the upper and lower Nagara River stations was considerably greater than that seen in the Ibi River collections. Therefore, the greater mean body length of the larvae from the upper Nagara River stations may have resulted from their longer period of residency in the dam backwater. Because the mean body lengths of specimens from station N4 were significantly greater than those from N6 in both 1995 and 1996, the larvae apparently grew while remaining in the backwater (Table 7). Tsukamoto[21] estimated the daily growth rate of *P. a. altivelis* larvae as ca. 0.14 mm BL/day. Applying this rate suggests that the larvae spent ca. 8 days in the backwater in 1995 or ca. 1.8 days in 1996. Because the mean body lengths at the lower stations (N 1 - N 3) were apparently less than that at the upper stations, the larger larvae may quickly migrate to sea, whereas smaller larvae remain in the estuary.

In February 1996 and 1997, the body lengths of the flexion and postflexion larvae collected at the lower Nagara River and Ibi River stations, agreed approximately with data obtained from the Kumano River estuary, central Honshu, Japan[24] and the Shimanto River estuary.[25] Accordingly, there was no apparent influence of the dam on the life stages and development of the larvae in the lower part of the Nagara River estuary. Although larvae occurred at the lower Nagara River stations, none were collected in the dam backwater in February 1996 and 1997 (Fig. 10). The large numbers of larvae in the backwater during the previous November had thus completely disappeared, there being no evidence that the larvae could overwinter in the dam backwater.

Larval and juvenile stages of *Salangichthys microdon* and influence of the Nagara River estuary dam

In the present survey, preflexion larval to juvenile stages of *Salangichthys microdon* were collected in the lower reaches of the Nagara, Kiso and Ibi Rivers, from February to July. Because spawning shoals of adults were caught commercially in the same areas in January and February, it is likely that the species lives in brackish water for most of its life, not migrating diadromously.[26, 27]

The incubation period of *S. microdon* has been estimated as 14 days at 14-19 ℃,[28] and ca. 20 days at 10℃ or 10 days at 15℃,[29] the yolk disappearing entirely 12[28] or 7-15[30] days after hatching. In the present study, preflexion larvae of *S. microdon* were first apparent on 25 February 1995, 10 February 1996 and 15 February 1997. Consequently, initial spawning seems to occur from mid-January to early February at the study site, although the species spawns twice or more per year (estimated from the polymodal distribution of body length composition in April or May; Fig. 14). Preflexion larvae were absent in April 1995 and May 1996, but present in April 1997. Thus, spawning continued to late March or early April in 1997. The spawning period of the species is generally considered to be from February to April and from March to May in western and eastern Japan, respectively.[31] Saruwatari and Okiyama[26] reported larvae first appearing in March or April in Lake Hinuma, Ibaraki Prefecture, eastern Honshu, Japan, and Kuwamura[27] estimated that spawning occurred from early March to early May in the Yura River estuary, Kyoto Prefecture, central Honshu, Japan. Therefore, spawning in the Nagara, Ibi and Kiso Rivers began slightly earlier than in the other areas.

Before the gates of the Nagara River estuary dam were closed, 2 juveniles were taken at the uppermost station (N6) in July 1994. Numerous preflexion larvae were collected at the same station, but none at the lower Nagara River stations, in February 1995. Subsequently, flexion and postflexion larvae were obtained at the lower Nagara River stations and Kiso River station K1. Accordingly, the life history of *S. microdon* in the Nagara River estuary before closure of the dam gates is likely to have been as follows: parental fish spawned in the upper part of the estuary, preflexion larvae mainly residing in the same area. Subsequently, larvae extended their range to the lower part of the estuary with growth, resulting in their wide distribution throughout the estuary. However after the dam gates were closed, neither larvae nor juveniles were collected at the upper Nagara River stations (Fig. 12).

Eight *S. microdon* eggs were taken with fragments of decayed plant material, which had been deposited on the riverbed, at station I2 in February 1996, when the net just touched the bottom. Because the eggs were adhered to the plant fragments, it was clear that such had been done purposely, although Senta[32] reported the spawning substratum of the species to be sand, spawning not occurring on a muddy bottom. Because the lower part of the Nagara River estuary has been extensively dredged, there being no macroscopic plant sediments on the riverbed or sandbanks, it can be considered that the spawning ground for *S. microdon* in the Nagara River estuary disappeared completely after the dam gates were closed. The larvae taken at the lower Nagara River stations possibly originated in the Ibi River. Kawashima et al.[31] stated that *S. microdon* was distributed in Lakes Kasumigaura, Ibaraki Prefecture, and Hachirogata, Akita Prefecture, northern Honshu, Japan, after the lakes had been converted from brackish to fresh water. Therefore, the absence of *S. microdon* from the backwater of the Nagara River estuary dam indicates that the closing of the dam gates had deprived the species of its spawning and larval nursery grounds.

Larval and juvenile stages of *Cottus reinii* and influence of the Nagara River estuary dam

Several specimens of catadromous *Cottus reinii* larvae were collected in February 1995 and 1996. However, numerous larvae were taken in February 1997, and several larvae and juveniles in April. Data from the February 1997 survey showed that large numbers of the larvae had been collected at both the upper and lower Nagara River stations. Larval accumulation in the backwater, which had been observed for *Plecoglossus altivelis altivelis*, was not apparent (Fig. 15). Although anadromous juveniles were collected at the Ibi River stations in April, they were not taken in the Nagara River, despite many settled juveniles being observed at the lock gate-type fishway at the dam. This indicates that although the catadromous larvae were apparently not effected by the dam, the anadromous juveniles may be more or less influenced as they pass across the latter.

Comments on the unidentifiable gobiid larvae.

Gobiidae NA, NB and NC occurred mainly in summer, the NA and NB forms being collected at both the upper and lower Nagara River stations after the dam gates were closed, and the NC form being restricted to the upper stations. Their morphological and ecological characteristics suggest that the NA and NB forms perhaps represented diadromous species of *Tridentiger* or *Rhinogobius*, and the NC form a freshwater species of either genus.

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長良川河口域に出現する魚卵・仔稚魚

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1994年7月から1997年4月までの期間に，長良川下流域の6定点（長良川河口堰上流3定点，下流3定点），木曽川下流域の2定点，および揖斐川下流域の4定点で，各季節に1回，丸稚ネットによる魚卵・仔稚魚の採集を行い，この水域の魚卵・仔稚魚相を明らかにし，さらに長良川河口堰がこの水域に生息する仔稚魚の生活に及ぼした影響を考察した。なお，河口堰は本研究開始前の1994年5月から試験運用が始まったが，1995年2月までの調査時には堰は開放されていた。しかし，1995年4月以降の調査時には堰は閉鎖されていた。

本研究で，11分類群4,771粒の魚卵と27科37種17,848個体の仔稚魚を採集した。魚卵はほとんどがサッパやコノシロ，ギマなどの沿岸性海産魚のものであった。仔稚魚は汽水性魚類であるシラウオ，アユやウツセミカジカなどの両側回遊性魚類，およびサッパやコノシロ，カタクチイワシ，ナベカ，マハゼなどの沿岸性海産魚類で構成されていた。河口堰下流域ではサッパやカタクチイワシ，ギンポ，ネズッポ属，マハゼなどが優占種で，この水域はこれらの産卵場や成育場として機能していると考えられた。河口堰運用後も堰下流域の魚卵・仔稚魚相に大きな変化はなく，これらに対する河口堰の影響はほとんどないものと考えられた。河口堰上流域は堰運用以前でも下流域に比較して仔稚魚の種数は少なかった。河口堰運用後はサッパやカタクチイワシ，シラウオが分布しなくなり，多様度も低下して仔稚魚相はさらに貧弱なものになった。アユ降河仔魚は11月に長良川下流域全体に分布し，優占種となっていた。河口堰運用後は堰上流に形成された湛水域に大量に蓄積するようになり，正常な降河回遊が行えないものと考えられた。シラウオは河口堰運用以前では長良川下流域に広く分布し，周年この水域で生活していたものと考えられた。主な産卵場は河口堰上流にあると考えられ，仔魚も主として堰上流域に分布していた。しかし，河口堰運用後は堰上流域では全く出現せず，河口堰によって長良川におけるシラウオの産卵場および成育場は壊滅したと考えられた。ウツセミカジカ降河仔魚は河口堰下流域でも多数出現し，河口堰の影響は少ないと考えられた。しかし，溯河稚魚は揖斐川では採集されたものの，河口堰上流の長良川では採集されず，長良川河口堰はウツセミカジカ溯河稚魚には障害物となっている可能性が考えられた。