The Journal of the Korean Society of Oceanography
Vol. 32, No. 4, pp. 202-207, December 1997

Dynamics of Fish Larvae in the Han River Estuary and Kyunggi Bay, Korea

GYUNG SOO PARK AND KYUNG NAM HAN*
National Fisheries Research and Development Institute, West Sea Fisheries Research Institute, Incheon 400-201, Korea
**Department of Oceanography, Inha University, Incheon 402-751, Korea*

Species composition and abundance of fish larvae were studied from May 1988 through August 1989 in the Han River Estuary and adjacent Kyunggi Bay, Korea. Of 23 taxa identified, *Coilia nasus, Ilisha elongata*, and Cyprinidae spp. were dominated. Maximum density (3,577/1,000m^3) occurred in August 1988 and minimum (3/1,000m^3) in February 1989. Oligo- or mesohaline species dominated during ebb tides while polyhaline species during flood tides. Correspondence analysis revealed that three distinctive species groups; oligohaline species, *Coilia nasus, Ilisha elongata* and Cyprinidae spp., which dominated at both channels of Kwanghwa Island (stations 1, 2), mesohaline species, *Sardinella zunasi* and Gobiidae spp., at the mouth of Yeomha Channel (station 3), and polyhaline species, *Engraulis japonicus* and *Syngnathus schlegeli*, in the middle of Kyunggi Bay (station 4). *Coilia nasus* was the most abundant species and reported first time in the study area. Given the species composition and density of fish larvae, the Han River Estuary is considered to be a major spawning and nursery ground for brackish water species such as *Coilia nasus, Ilisha elongata* and some Cyprinidae spp.

INTRODUCTION

Han River is the largest river in South Korea, with 470 km long, and passes through metropolitan Seoul. Han River Estuary, connected to Kyunggi Bay, is a broad shallow system with an average depth of 10 m, and a very important area as a spawning and nursery ground for brackish water fishes (Park, 1990).

Environmental conditions change greatly within short time periods, even within one hour, due to the various input sources of freshwater and tidal action in Kyunggi Bay, and also large input of the domestic sewage and industrial waste in the vicinity of Seoul and Inchon (Kim, 1990).

The large scale-dredging and underwater dam construction during the Han River Development Project from 1982 through 1986, which resulted in elevating water level and slowing water flow, may have a significant impact on the estuarine ecosystem.

Water quality and plankton survey in the Han River Estuary has been limited due to the restriction of public access to this military area. A few studies have examined the ichthyoplankton populations of Kyunggi Bay adjacent to the Han River Estuary (Yoo *et al.*, 1987).

This paper investigates dynamics of fish larvae and related environmental conditions in the Han River Estuary.

MATERIALS AND METHODS

Sampling stations are located in the both channels of Kwanghwa Island (stations 1, 2), southern end of the Island (station 3), and in middle of the Kyunggi Bay (station 4) (Fig. 1). Allocation of the stations was designed to collect samples with a salinity gradient from the Han River Estuary to the middle of Kyunggi Bay. Samples were collected five times from May 1988 through August 1989, with four time moorings (8-13 hrs.) and one survey through stations in October 1988.

Water temperature and salinity were measured with STD, and dissolved oxygen with DO meter (YSI Model 57). DCM-II and DRCM-II were used to measure current velocities and directions.

Fish larvae were collected using Bongo Net (mesh size 505 μm, frame diameter 60 cm, length 2 m). The net was towed for 5-10 minutes at the speed of 3-4 knots. The samples were preserved in 10% buffered formaldehyde. The volume of water filtered by the net was estimated using a flowmeter

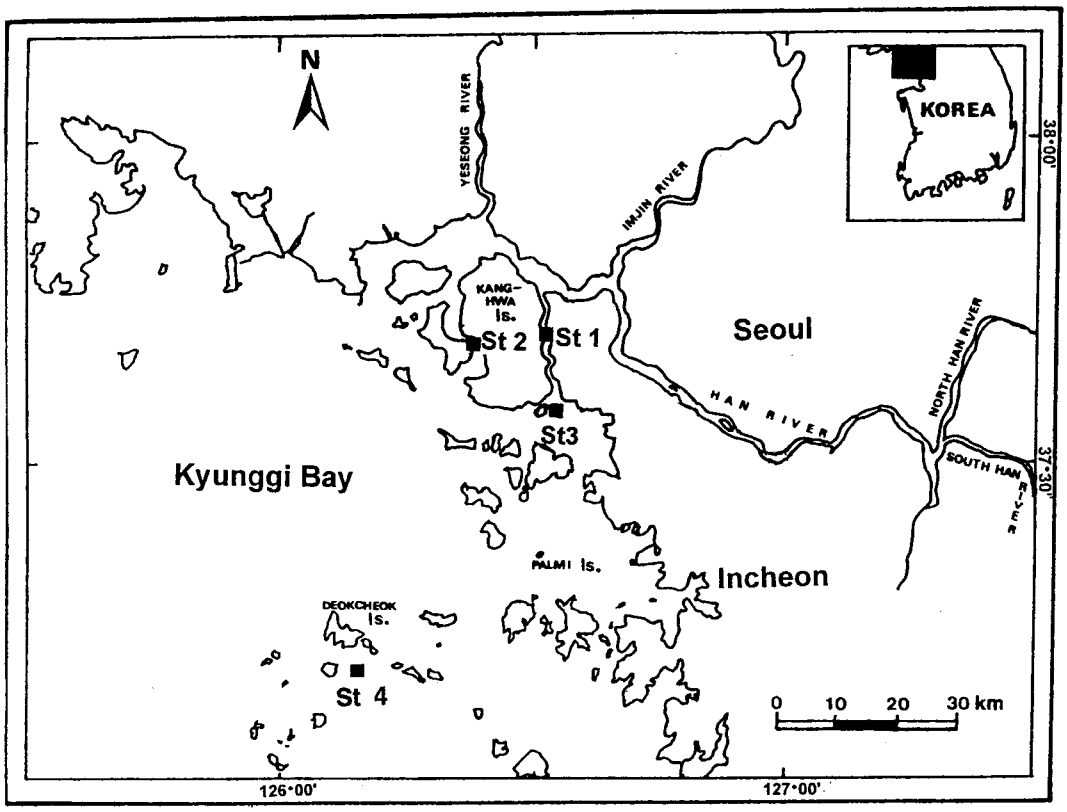

Fig. 1. Sampling locations in the Han River Estuary and Kyunggi Bay.

(General Oceanics) mounted in the mouth of the net. Identifications referred to Cha *et al.* (1987), Chyung (1986), Kim *et al.* (1986), Lindberg and Krasyukova (1971), Lindberg and Legeza (1969), Matsubara (1979), Okiyama (1988) and Russel (1976). The taxonomy and systematics of fish larvae followed Masuda *et al.* (1984).

Species diversity index (Shannon and Weaver, 1963) was calculated to compare the diversity of fish larval community between stations. Correspondence analysis by Curtis and McIntosh (1951) was performed to examine the ecological interrelationships between sampling sites and fish larval species in the Han River Estuary and adjacent Kyunggi Bay. The computer programs in "Statistical Ecology" by Ludwig and Reynolds (1988) were used for all statistical analyses.

RESULTS

Environmental conditions

Water temperature: Surface water temperature ranged from 2.7 (February 1988) to 26.7°C (August 1988), and showed typical seasonal pattern of temperate zone; highest in summer (August) and lowest in winter (February). Surface water temperature varied slightly between the sampling sites. Thirteen hour observation at station 3 in August 1988 revealed that water temperature in freshwater was slightly higher than that in seawater. Maximum water temperature within one tidal cycle was detected one hour after low tide. Details of water temperature in this study area can be found on Park (1990).

Salinity: Salinity varied greatly with seasons and tides (Table 1). It ranged from 4.91 to 27.59‰ between seasons and 1.30 to 7.95‰ between tides from the whole sampling period. In August 1988, a salinity gradient of >25‰ existed in surface water between station 1 (5.10‰) and station 4 (30.44‰). Maximum salinity usually occurred at high tide and minimum at one hour after low tide (Fig. 2). From these observations, station 1 and 2 were oligohaline, stations 3 mesohaline, and station 4 polyhaline in August 1988. However, all the stations were meso- or ploy haline during the other sampling months.

Dissolved oxygen: The highest values were in February 1989 with 12.6 mg/l and lowest in August 1988 with 5.2 mg/l (Table 1). The variation of DO values between tides was 3.3 mg/l at station 3, with

Table 1. Variation of salinity (‰) and dissolved oxygen (mg/l) at each station during the sampling months

dates	stations	salinity mean (range)	DO mean (range)
May 1988	1	22.83 (20.85-26.50)	8.28 (7.14- 9.89)
	2	25.85 (25.00-27.55)	7.90 (6.95- 8.28)
	3	27.83 (26.13-30.00)	5.61 (4.28- 6.71)
Aug. 1988	1	5.10 (2.83- 8.20)	5.23 (5.04- 6.01)
	2	14.25 (9.90-18.40)	6.00 (5.10- 7.01)
	3	23.20 (14.25-28.97)	7.31 (5.52- 8.85)
Oct. 1988	1	21.70	8.42
	2	24.25	8.66
	3	23.97	8.99
Feb. 1989	1	27.55 (24.25-30.00)	12.57 (11.85-12.66)
	2	27.83 (25.85-29.90)	12.45 (12.00-12.66)
	3	30.85 (27.55-32.55)	10.74 (10.43-11.52)
Aug. 1989	1	9.25 (4.90-16.50)	5.61 (4.09- 7.00)
	2	16.60 (12.55-19.25)	not measured
	3	18.97 (10.00-27.27)	6.83 (4.99- 7.33)

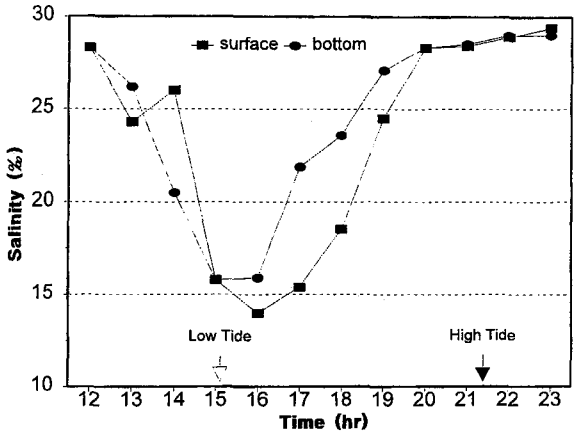

Fig. 2. Changes of salinity with time at station 3 in August 1988.

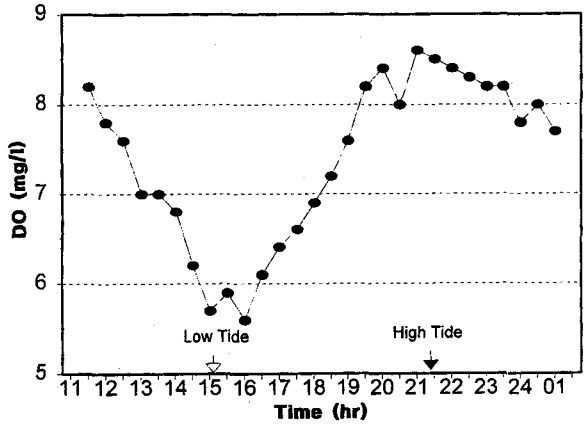

Fig. 3. Changes of dissolved oxygen (surface) with time at station 3 in August 1988.

low values during ebbing and high values during flooding in August 1988 (Fig. 3)

Current: All the stations showed bi-directional currents depending on the tidal cycle. During rainy seasons (usually summer in this area), ebb tides were greatly accelerated due to the large input of freshwater from the Han River and the other major tributaries, with a maximum of 178 cm/sec. Flooding tides were, however, diminished by the down flowing freshwater from the tributaries. Mean velocity at each station in August 1988 was 102.2, 124.9 and 105.0 cm/sec for stations 1, 2, and 3, respectively. All the stations showed ebb tide dominated bi-directional flow, with stronger north-south component than east-west component. Details can be found on Park (1990) and Kim (1990).

Species composition and abundance

A total of 23 taxa was identified during the whole sampling period (Table 2). There was a clear seasonal pattern of abundance and number of species. High numbers of taxa occurred in August 1988 (18 taxa) and 1989 (13 taxa). For the other seasons, the number of species ranged from 2 (February 1989) to 6 (October 1988). Species composition and density in May and August 1988 are given in Table 3. In

Table 2. Species composition and density of fish larvae as a mean of three stations from May 1988 through August 1989

unit: inds/1,000m^3

Species name	1988 May	1988 Aug.	1989 Oct.	1989 Feb.	1989 Aug.
Coilia nasus		1,070			89
Ilisha elongata		705			1
Sardinella zunasi		610			27
Gobiidae spp.	5	362	10	5	36
Cyprinidae spp.		382			1
Collichthys sp.		181			38
Thryssa kammalensis		190	1		19
Myoxocephalus sp.	73				
Enedrias fangi	34			2	
Argyrosomus argentatus		19			
Repomucenus sp.		13	1		1
Engraulis japonicus		11	1		2
Cynoglossus sp.		3	1		6
Larimichthys crocea					6
Nibea albiflora		3			
Ctenotrypauchen vagina			1		2
Syngnathus schlegeli		2			
Pampus echinogaster		1			1
Gymnapogon sp.		2			
Platycephalus indicus		1			
Hippocampus aterrimus		1			
Anguilla japonica	1				
Microcephalus gilli		1			
Total	113	3,557	15	7	229

Table 3. Species composition and density of fish larvae in May and August 1988 in the Han River Estuary and Kyunggi Bay

May 1988			unit: inds/1,000m^3	
Species name	St.1	St.2	St.3	
Myoxocephalus sp.	146	54		
Enedrias fangi	16	85	6	
Gobiidae spp.	6	7	3	
Anguilla japonica		3		
Total	168	149	9	

August 1988			unit: inds/1,000 m^3	
Species name	St.1	St.2	St.3	St.4
Coilia nasus	94	3,117		
Ilisha elongata	1,011	1,106		
Sardinella zunasi	5		1,824	1
Cyprinidae spp.	1,113	34		
Gobiidae spp.	46	145	894	1
Thryssa kammalensis		207	363	
Collichthys sp.	98	404	40	
Engraulis japonicus		14	19	250
Repomucenus sp.		5	35	65
Argyrosomus argentatus		2	54	3
Syngnathus schlegeli			7	28
Cynoglossus sp.			8	7
Nibea albiflora			8	
Gymnapogon sp.			5	
Pampus echinogaster		2		
Platycephalus indicus		1	1	
Hippocampus aterrimus			1	1
Microcephalus gilli		1		
Total	2,367	5,040	3,295	356

May 1988, *Myoxocephalus* sp. and *Enedrias fangi* dominated at station 1 and 2, and their abundances ranged from 0 to 146/1,000m^3. *Myoxocephalus* sp. occurred only at station 1 and 2 but *Enedrias fangi* was found throughout the stations. *Coilia nasus, Ilisha elongata, Sardinella zunasi* and Cyprinidae spp. dominated in August 1988, with a maximum of 3,117/1,000m^3 for *C. nasus* at station 2, 1,824/1,000m^3 for *S. zunasi* at station 3, 1,106/1,000m^3 for *I. elongata* at station 2, and 1,113/1,000m^3 for Cyprinidae spp. at station 1. In October 1988, 6 taxa were found, with low abundance ranged from 1 to 10/1,000m^3. In February 1989, only 2 taxa (Gobiidae spp. and *E. fangi*) were observed, with 5 and 2/1000 m^3 respectively. There was a significant correlation between water temperatures and abundances ($r=0.75$, $p<0.05$).

Species diversity indices for each station in August 1988 were 1.07, 1.13, 1.18 and 0.93 for station 1, 2, 3, and 4, respectively. Station 3 had the highest diversity due to its location in the estuarine system. The station is located in the transitional area between oligo- or mesohaline Yeomha Channel and polyhaline Kyunggi Bay. Accordingly, various oligo-, meso- and polyhaline species can be introduced to the station with tidal currents. On the other hand, *Coilia nasus, Ilisha elongata* and Cyprinidae spp. predominated at stations 1 and 2, comprising over 90% of the total abundance, and this resulted in low species diversity at these oligohaline stations. At station 4, a typical polyhaline station with very small temporal salinity changes, *Engraulis japonicus, Repomucenus* sp. and *Syngnathus schlegeli* predominated (>95%) and only 8 species were found, resulting in low species diversity.

Changes of species composition and abundance with tides

Changes in the number of species and density with tidal cycles are given in Fig. 4. While flooding, total abundance declined but the number of species

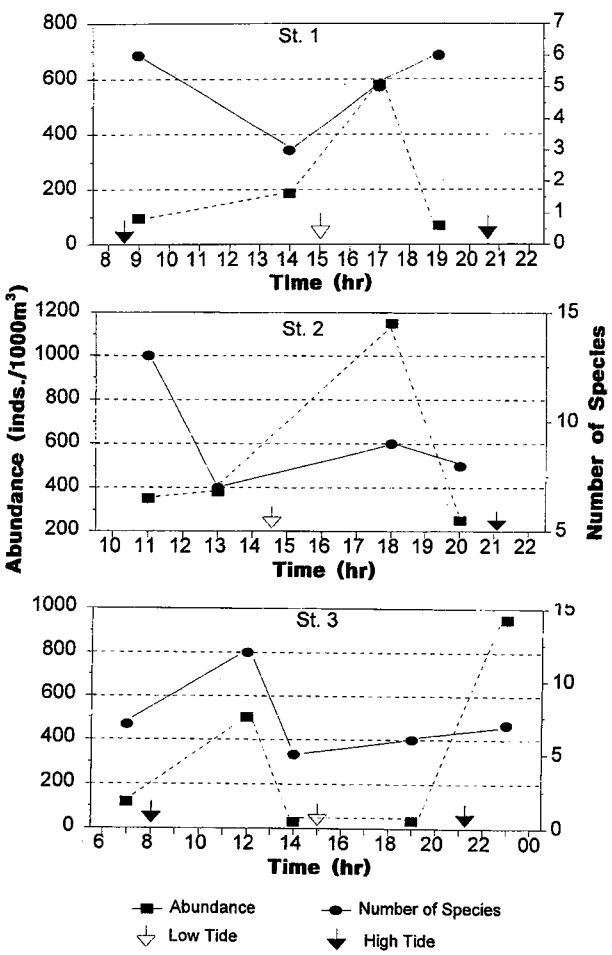

Fig. 4. Changes in fish larval abundance and number of species with time in the Han River Estuary in August 1988.

increased at station 1 and 2. However, at station 3 both density and number of species increased during flooding. At station 1 and 2, oligo- or mesohaline species, *Coilia nasus*, Cyprinidae spp. and *Ilisha elongata*, dominated during ebb tides, but they were absent near high tides. On the other hand, polyhaline species such as *Engraulis japonicus* and *Syngnathus schlegeli* were introduced with flood tides into the station 1 and 2, but their abundances were not high enough to cover the loss of oligo- or mesohaline species by flooding at these oligohaline stations. These resulted in high number of species but low density during flood tides at stations 1 and 2. At station 3, these patterns were different from the other two stations. Even it located in the same stream with station 1, with only 15 km away from the station 1, dominant species at station 1 were not found at station 3, even with strong ebb tides reaching up to 178 cm/sec. This resulted in the decrease of density and number of species during ebbing. While flooding, many polyhaline species such as *Engraulis japonicus, Repomucenus* sp. and *Syngnathus schlegeli* recruited to the station. Oligo- and mesohaline species, *Coilia nasus, Ilisha elongata*, and Cyprinidae spp., were found only at station 1 and 2. From these results, station 3 (near Seo Island) seems to be the southern boundary for the distribution of these oligohaline species in the Han River Estuary.

Community structure of fish larvae

Correspondence analysis revealed three distinctive groups of species and stations (Fig. 5). Stations 1 and 2 had similar eigenvalues, indicating similar species composition and density between the stations, but station 3 and 4 were different from stations 1 and 2. These were due to the different species composition and abundance with salinity gradients.

Species group I was primarily composed of the species dominated at stations 1 and 2 such as *Coilia nasus*, Cyprinidae spp. and *Ilisha elongata*, species group II dominated at station 3 such as *Sardinella zunasi* and Gobiidae spp., and species group III dominated at station 4 such as *Engraulis japonicus, Repomucenus* sp. and *Syngnathus schlegeli*. These patterns indicated the distribution of fish larvae in the Han River Estuary was primarily affected by salinity.

DISCUSSION

A total of 23 taxa were identified with highest density in August and lowest in February. The dominant species was *Coilia nasus, Ilisha elongata*, Cyprinidae spp. and *Sardinella zunasi* in August. From the other sampling months, densities were less than 100/1,000m^3 dominated by *Myoxocephalus* sp., *Enedrias fangi* and Gobiidae spp.

In the Han River Estuary, clear seasonal patterns of density were observed and there was a significant correlation between water temperature and abundance. In other temperate estuaries and coastal waters, similar seasonal patterns have been reported; Port Phillip Bay, Victoria (Jenkins, 1986) and the Yellow Sea (Cha, 1987; Han, 1987; Hur and Yoo, 1984; Kim, 1981). However, there is a practical difficulty in comparing the actual abundance of fish larvae from these studies due to the use of different

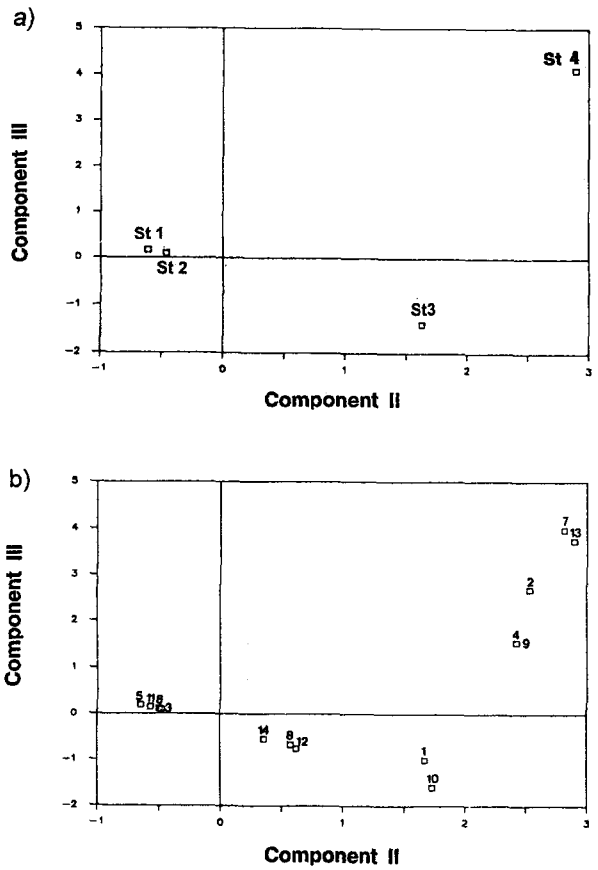

Fig. 5. a) Ordination of four stations in the Han River Estuary and Kyunggi Bay in August 1988 by correspondence analysis b) Ordination of 14 fish larval species in the Han River Estuary and Kyunggi Bay in August 1988 by correspondence analysis.

mesh sizes and sampling methods.

In addition to seasonal changes of water temperature, higher magnitude of other environmental changes in this estuarine system may make significant contribution to the seasonal changes of abundance. For instance, salinity variation between seasons reached to up to 25‰ at station 1. This should be a significant stress to the estuarine organisms (McLusky, 1981).

The fish larvae of the Han River Estuary were highly dominated by *Coilia nasus*, which made up 80% of the total density in summer. Ichthyoplankton of this species is reported first time in the estuary of Kyunggi Bay. This species has been identified with *C. mystus* and *C. ectenes*, which are synonyms of *C. nasus* (Yoon and Kim, 1996). In other rivers of Korea, the species has been reported in Nakdong River (Ju and Jeon, 1977), Seomjin River (Kim and Lee, 1984) and Yongsan River Estuary (Park *et al.*, 1988). During the other seasons, density and number of species were very low, but *Enedrias fangi* and some Gobiidae spp. dominated during winter months.

Distribution of fish larvae was clearly discriminated depending on the salinity regimes. Oligohaline species such as *C. nasus, I. elongata* and Cyprinidae spp. were found only at station 1 and 2, but never found at the other stations, even with strong ebb tidal current (max. 178 cm/sec). It seems likely that these species reside bottom and banks of the channels where the current velocities are relatively slow (Kim, 1990).

Given the species composition, abundance and distribution patterns of fish larvae, the Han River Estuary is considered to be a major spawning and nursery ground in summer for some oligohaline species.

ACKNOWLEDGMENTS

I gratefully acknowledge the assistance of Dr. Jong Mahn Kim for the identification of fish larvae, and Dr. Yong Chul Lee for his critical review of this manuscript. This study was supported by Ministry of Education.

REFERENCES

Cha, S.S., 1987. A study on the fish larvae community in the mid east coastal waters of the Yellow Sea. Ph.D. thesis, Seoul National University, 144pp.

Cha, S.S., J.M. Yoo, J.M. Kim and H.T. Huh, 1987. Key for the identification of fish larvae in the mid-east coastal waters of the Yellow Sea. *J. Ocean. Soc. Kor.*, **22**(4): 236-245.

Chyung, M.K., 1986. The Fishes of Korea. Il Ji Sa Publishing Co., Seoul. 727pp.

Curtis, J.T. and R.P. McIntosh, 1951. Correspondence analysis. In: Statistical Ecology, edited by J.A. Ludwig and J.F. Reynolds, John Wiley and Sons, New York.

Han, K.N., 1987. An ecological study on the ichthyoplankton in the south-western coastal waters of Korea, Yellow Sea. M.S. thesis, Inha University, 58pp.

Hur, S.B. and J.M. Yoo, 1984. Distribution of fish eggs and larvae in the western waters of Korea. *Bull. Kor. Fish. Soc.*, **17**(6): 536-542.

Jenkins, G.P., 1986. Composition, seasonality and distribution of fish larvae in Port Phillip Bay, Victoria. *Aust. J. Freshw. Res.*, **37**: 507-520.

Ju, I.Y. and S.R. Jeon, 1977. Studies on the fish fauna from the Nakdong River, 1. Areas of Sangju and Andong. *Kor. J. Limnol.* **10**(3-4): 19-28.

Kim, I.S. and W.O. Lee, 1984. Effects of stream modification in the Seomjin River on the fish communities of the Dongjin River in Korea. *Bull. Kor. Fish. Soc.* **17**(6): 549-556.

Kim, J.M., J.M. Yoo, J.K. Myoung and J.Y. Lim, 1986. Guide to the Early Stages of Marine Fishes in Korean Waters. KORDI Report, BSPE 00060-98-3, 369pp.

Kim, Y.T., 1990. Physical characteristics of Han River Estuary and Kyunggi Bay. M.S. thesis, Inha University, 67pp.

Kim, Y.U., 1981. Fish Eggs and Larvae of the Coastal Waters in Korea. Nat'l. Fisheries Univ. of Pusan. 109pp.

Lindberg, G.U and M.I. Legeza, 1969. Fishes of the Japan Sea and Adjacent Areas of the Sea of Okhotsk and the Yellow Sea. Part 2. Translated from Russian, Israel Program for Scientific Translations, Jerusalem. 389pp.

Lindberg, G.U. and Z.V. Krasyukova, 1971. Fishes of the Japan Sea and Adjacent Areas of the Sea of Okhotsk and the Yellow Sea. Part 3. Translated from Russian, Israel Program for Scientific Translations, Jerusalem. 498pp.

Ludwig, J.A. and J.F. Reynolds, 1988. Statistical Ecology - A Primer on Methods and Computing. John Wiley and Sons, New York. 337pp.

Masuda, H., K. Amaoka, C. Araga, T. Uyeno and T. Yoshino, 1984. The Fishes of the Japanese Archipelago. Tokai Univ. Press, Tokyo. 437pp.

Matsubara, K., 1979. Fish Morphology and Hierarchy, Ishizaki-Shoten. Tokyo. 1605pp.

McLusky, D.S., 1981. The Estuarine Ecosystem. John Wiley and Sons, New York and Toronto. 150pp.

Okiyama, M., 1988. An Atlas of the Early Stage Fishes in Japan. Tokai University Press. Tokyo. 1154pp.

Park, G.S., 1990. A study on the fish community in the lower Han River and Han River Estuary. M.S. thesis, Inha University, 63pp.

Park, Y.J., S.K. Kim, and J.A. Lee, 1988. Ecological survey on the marine environments in the Yongsan River Estuary before and after the enclosure of a dam. *Bull. Nat. Res. Dev. Agency.* **42**: 1-32.

Russell, F.S., 1976. The Eggs and Planktonic Stages of British Marine Fishes. Academic Press. 524pp.

Shannon, C.E. and W. Weaver, 1963. The Mathematical Theory of Communication. University of Illinois Press, Urbana. 117pp.

Yoo, J.M., J.M. Kim, H.T. Hur and S.S. Cha, 1987. Distribution of fish larvae in Kyonggi Bay. *Ocean Research.* **9**(1-2): 15-23.

Yoon, C.H. and I.S. Kim, 1996. Taxonomic study of the Family Engraulidae (Pisces: Clupeiformes) from Korea. *Kor. J. Ichthyol.* **8**(2): 33-46.