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Anguilliformes Leptocephali from the Tosa Bay and the Waters off Shikoku Island

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Abstract A total of 41 leptocephali was collected in the Kuroshio waters off Shikoku Island. They included 33 *Gnathophis nystromi nystromi* (JORDAN et SNYDER), one *Ariosoma* sp. 5, two *Ariosoma* sp. 7, one *Conger japonicus* BLEEKER, two *Congrinae* sp. 1, and two *Dysomma anguillare* BARNARD. Most of leptocephali collected (82.9% of a total catch) were occurred in the southern boundary of the Kuroshio Current. All the *Gnathophis* leptocephali were collected with the surface horizontal tow of High Speed Larva Net, and the other leptocephali were with step tow of Larva Net.

INTRODUCTION

Considerable biological informations on *Anguilla* leptocephali, particularly on their migration, have been accumulated since the early decade of this century (SCHMIDT 1923, 1925; TUCKER 1959; VLADYKOV 1964; SCHOTH and TESCH 1982; POWER and MCCLEAVE 1983; BOETIUS and HARDING 1985; KLECKNER and MCCLEAVE 1985; CASTONGUAY and MCCLEAVE 1987; TABETA *et al.* 1987; KAJIHARA 1988; KAJIHARA *et al.* 1988; TSUKAMOTO *et al.* 1989; UMEZAWA *et al.* 1989, etc.). However there is still little information on the biology of the other Anguilliformes leptocephali. KUBOTA (1961) reported on the growth and metamorphosis of Conger eel. CASTONGUAY and MCCLEAVE (1987) reported on the vertical migration of various species of leptocephali in the Sargasso Sea. HULET *et al.* (1972) and HULET (1978) reported the physiology and histology of Anguilliformes leptocephali. TANAKA *et al.* (1987) described otolith microstructure of *Conger* leptocephalus.

We had a chance to collect leptocephalus specimens during the research cruise (TS89-12) of R. V. Toyoshio Maru, Hiroshima University, conducted in the Tosa Bay and the adjacent Kuroshio waters between January 17 and Januaty 27, 1990. The final goal of our study is to obtain detailed informations concerning a whole life history of leptocephali including *Anguilla japonica* occurring in Japanese waters such as their age, growth, feeding, and migratory patterns. In this paper we preliminarily report the collection data and the

distribution of leptocephali collected during the research cruise.

MATERIALS AND METHODS

Three stations (St-1, 2, 3) and a series of 6 stations (St-K-1～6) transversely across the Kuroshio Current were placed in the Tosa Bay and its adjacent waters (Fig. 1). To deter-

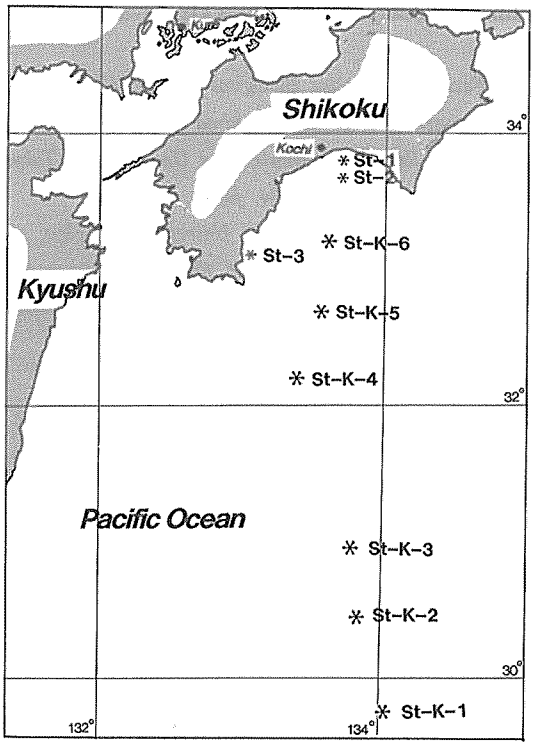

Fig. 1 Sampling stations in the present study. St-1,2 and St-3 were located at the mouth of the Monobe River and Shimanto River, respectively. St-K-1～6 were located in the Kuroshio Current.

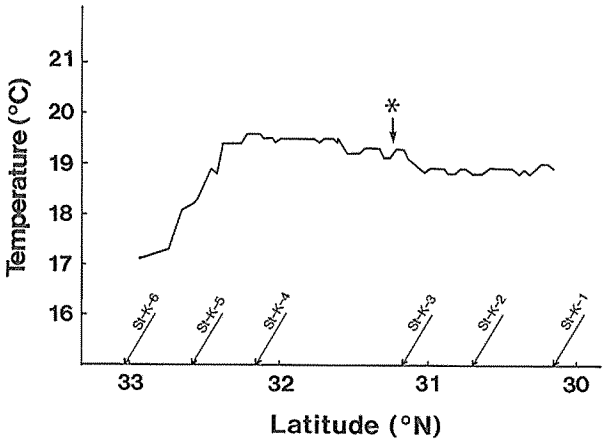

Fig. 2 Surface temperature in the area of the Kuroshio Current. An asterisk shows the location where the surface flow became weak. Southern area of it geostrophic flow was undetectable.

mine the location of the Kuroshio Current in advance to biological survey, the surface temperature was measured along the line crossing the Current from north to south. The temperature increased rapidly at 33°00′N and the maximum (19.6 ℃) appeared at 32°10′N (Fig. 2). Afterward the temperature slightly decreased and the surface flow became undetectable in the area south of 31°10′N. Therefore the Kuroshio Current was considered to flow in the south of 33°00′N. The area south of 31°10′N seemed to be the southern boundary of the current. Based on these data, we distributed the Stations-K in the area between 30°00′N and 33°00′N (Fig. 1).

Fish was collected by several consecutive oblique tows between bottom (wire length

Table 1. Collection data of Anguilliformes leptocephali.

Date	Station	Location		Time		Net-type	Towing method	Wire out (m)	Number of Leptocephali
		Latitude	Longitude	In	Out				
18 Jan 1990	St-1 (Day)	33°29′20	133°42′40	09 : 47	10 : 15	IKMT (6ft)	Oblique	75	0
		33°28′50	133°41′50	10 : 30	11 : 00	HS. Larva Net	Horizontal (surface)	—	0
	St-2 (Day)	33°22′20	133°41′46	12 : 41	13 : 25	IKMT (6ft)	Olique	300	0
	St-2 (Day)	33°20′47	133°41′39	13 : 28	13 : 58	HS. Larva Net	Horizontal (surface)	—	0
	St-1 (Night)	33°29′74	133°41′27	18 : 03	18 : 32	Larva Net	Oblique	70	0
	St-1 (Night)	33°27′73	133°41′83	18 : 49	19 : 21	Larva Net	Oblique	120	0
		33°26′87	133°42′63	19 : 29	19 : 52	HS. Larva Net	Horizontal (surface)	—	0
	St-2 (Night)	33°21′62	133°41′28	20 : 40	21 : 29	Larva Net	Oblique	300	0
		33°20′37	133°41′85	21 : 35	22 : 22	Larva Net	Step	190, 170, 150	0
19 Jan 1990	St-3 (Day)	32°57′89	133°04′69	13 : 55	14 : 29	Larva Net	Oblique	150	0
		32°57′74	133°06′97	14 : 38	19 : 08	HS. Larva Net	Horizontal (surface)	—	0
	St-3 (Night)	32°57′46	133°05′43	16 : 40	17 : 12	Larva Net	Oblique	150	0
		32°56′63	133°05′07	17 : 18	17 : 48	HS. Larva Net	Horizontal (surface)	—	0
	St-3 (Night)	32°57′58	133°05′02	20 : 10	20 : 42	Larva Net	Oblique	180	0
		32°57′10	133°08′09	20 : 50	21 : 20	HS. Larva Net	Horizontal (surface)	—	0
20 Jan 1990	St-K-1	30°09′74	134°02′90	18 : 20	19 : 51	Larva Net	Step	500, 400, 300 200, 100	2 (*Dysomma anguillare*: 1, *Ariosoma* sp. 7: 1)
		30°09′98	134°02′79	18 : 21	18 : 51	HS. Larva Net	Horizontal (surface)	—	6 (*Gnathophis nystromi nystromi*: 6)
	St-K-2	30°41′15	133°52′50	23 : 09	00 : 38	Larva Net	Step	500, 400, 300 200, 100	1 (*Ariosoma* sp. 7: 1)
		30°41′15	133°52′50	23 : 18	23 : 48	HS. Larva Net	Horizontal (surface)	—	19 (*G. nystromi nystromi*: 19)
21 Jan 1990	St-K-3	31°10′29	133°44′89	03 : 54	05 : 25	Larva Net	Step	500, 400, 300 200, 100	0
		31°10′40	133°44′85	03 : 58	04 : 28	HS. Larva Net	Horizontal (surface)	—	5 (*G. nystromi nystromi*: 5)
	St-K-4	32°09′71	133°22′56	18 : 22	19 : 49	Larva Net	Step	500, 400, 300 200, 100	2 (*D. anguillare*: 1, A. sp. 5: 1)
		32°09′96	133°25′47	18 : 27	18 : 57	HS. Larva Net	Horizontal (surface)	—	2 (*G. nystromi nystromi*: 2)
	St-K-5	32°35′48	133°22′08	22 : 15	23 : 37	Larva Net	Step	500, 400, 300 200, 100	0
		32°35′61	133′32′05	22 : 20	22 : 48	HS. Larva Net	Horizontal (surface)	—	1 (*G. nystromi nystromi*: 1)
22 Jan 1990	St-K-6	32°58′03	133°37′68	03 : 51	05 : 21	Larva Net	Step	500, 400, 300 200, 100	1 (*Conger japonicus*: 1)
		32°58′03	133°37′51	03 : 57	04 : 28	HS. Larva Net	Horizonal (surface)	—	2 (*Congrinae* sp. 1: 2)

70-300 m) and surface (wire length 20 m) with a Larva Net (mesh aperture 0.33 mm, mouth opening 1.33 m^2) for 30 min and horizontal surface tows with a High Speed Surface Larva Net (mesh aperture 2 mm, mouth opening 2.03 m^2) for 30 min by day and night at the stations in the Tosa Bay. A 6ft. Issacs-Kidd Midwater trawl (IKMT) was also used for oblique tows at stations 1 and 2 at night. At the stations in the Kuroshio waters sampling was conducted by step tow of wire lengths of 100, 200, 300, 400 and 500 m for 10 min each with the Larva Net and 30 min surface tow by the High Speed Surface Larva Net. The tows were conducted only by night at these six stations (Table 1).

Water temperature and salinity were measured with STD at every 1 m from the surface to 250 m deep at each station.

Leptocephali were preserved in 10% neutralized formalin and measured and counted following the methods described by JESPERSON (1942) and CASTLE (1963). Identification of the species was from MOCHIOKA (1988) and TABETA (1988).

RESULTS AND DISCUSSIONS

A total of 41 leptocephali were collected. All the specimens were taken at the stations in the Kuroshio waters (St-K-1~6) and none occurred in innermost stations of the Tosa Bay (St-1~3). They were belonged to the order Anguilliformes including Congridae and Dysommatidae (Table 1). The congrid leptocephali consisted of Gnathophis-type (33 specimens) and Ariosoma-type (6 specimens). All the Gnathophis-type specimens were identified as *Gnathophis nystromi nystromi* (JORDAN et SNYDER) (Fig. 3.1) from the number of myomere and the character of pigmentation. Ariosoma-type specimens were consisted of two *Ariosoma* sp. 5 (Fig. 3.2), one *Ariosoma* sp. 7 (Fig. 3.3), one *Conger japonicus* BLEEKER (Fig. 3.4), and two *Congrinae* sp. 1 (Fig. 3.5). Two Dysommatidae specimens were both identified as *Dysomma anguillare* BARNARD (Fig. 3.6). The data on total length, proportions, and number of myomeres of the specimens are shown in Table 2.

Only 6 leptocephali (14.6% of the total catch) were caught by the step tows using the Larva Net (Table 1). According to KAJIHARA *et al.* (1988) leptocephali are abundant between 50 and 80 m deep by night, which is coincide with the maximum distribution of biomass. In the present study scattering layer occurred at 80-100 m deep and the wire length of 500 m would be long enough for the Larva Net to reach the depth. Since the Larva Net used in this study was of smaller mouth opening (1.33 m^2) and small mesh size (0.33 mm) relative to the High Speed Surface Larva Net. Net avoidance would be more significant in the Larva Net than the other, which might produce the different catch between the two sampling methods.

G. nystromi nystromi was caught only by the surface tows by night, although the other leptocephali were caught by step tows. The vertical distribution pattern of leptocephali is known to vary among species, although most of them are found in the upper 100 m of the ocean at night (CASTONGUAY and MCCLEAVE, 1987). The distribution of *G. nystromi nystromi* might be restricted in the surface by night.

Thirty four specimens of the total catch (82.9%) was taken at the stations located in southern boundary of the Kuroshio Current (St-K-1, 2, 3). Many phyllosoma were also caught with leptocephali at St-K-2.

The surface water temperature of stations positive for leptocephali (St-K-1～6) ranged from 18.1 to 19.4°C. The vertical profile of temperature did not form a clear thermocline. The salinity ranged from 34.4 to 34.9‰ and almost constant vertically from surface to 250 m deep at the stations.

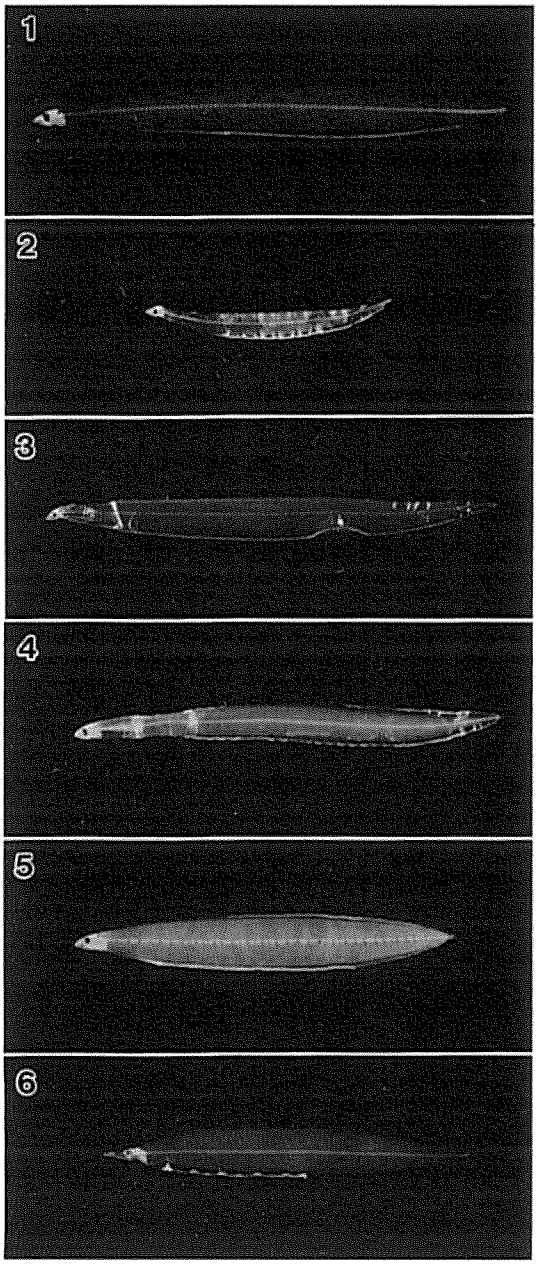

Fig. 3 Anguilliformes leptocephali collected in the present study. 1. *Gnathophis nystromi nystromi* (JORDAN et SNYDER), 87.0 mm TL. 2. *Ariosoma* sp. 5, 31.0 mm TL. 3. *Ariosoma* sp. 7, 83.0 mm TL. 4. *Conger japonicus* BLEEKER, 80.0 mm TL. 5. *Congrinae* sp. 1, 56.0 mm TL. 6. *Dysomma anguillare* BARNARD, 46.0 mm TL.

Table 2. Total lengh, proportions, and number of myomeres of Anguilliformes leptocephali collected in the present study.

Species	Number of fish	TL (mm)	SL/TL (%)	PD/TL (%)	PA/TL (%)	TM	GBM	PDM	PAM	VBV1st	VBVlast
Dysomma anguillare	2	38.0 ±8.00 (30.0~46.0)	97.2 ±0.58	56.7	55.8 ±2.54	129.0 ±1.00 (126~132)	13.0 ±1.00	48.0	58.5 ±0.50	12.0 ±1.00	55.5 ±0.50
Ariosoma sp. 5	1	31.0	98.4	—	95.2	119	23	—	104	22	59
Ariosoma sp. 7	2	80.5 ±2.50 (78.0~83.0)	99.4 ±0.02	97.3 ±0.10	97.2 ±0.40	147.0 ±2.00 (145~149)	24.5 ±2.00	138.5 ±1.50	138.5 ±2.50	23.0 ±1.00	74.0 ±1.00
Congrinae sp. 1	2	52.6 ±3.40 (49.2~56.0)	98.4 ±1.81	39.9 ±0.27	69.6 ±3.58	117.0 ±1.00 (116~118)	20.5 ±0.50	40.0 ±1.00	75.0 ±0.00	13.5 ±0.50	55.0 ±0.00
Conger japonicus	1	80.0	98.1	62.5	90.0	141	37	74	119	14	51
Gnathophis nystromi nystromi	33	60.1 ±11.6 (35.0~92.5)	97.8 ±0.33	72.2 ±3.71	89.5 ±1.85	123.4 ±2.05 (119~128)	39.9 ±1.74	71.4 ±3.67	100.3 ±2.36	11.1 ±0.964	41.4 ±1.62

TL, total length; SL, standard length; PD, predorsal length; PA, predorsal length; PA, preanal length; TM, total myomere; GBM, pre-gall-bladder length; PDM, predorsal myomere; PAM, preanal myomere; VBV, vertical blood vessels at myomere level.
Values are mean±S. D., and numbers in parentheses represent the range of values.

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REFERENCES

BOETIUS, J. and E. F. HARDING, 1985, A re-examination of Johannes Schmidt's Atlantic eel investigations. *Dana,* 4:129-162.

CASTLE, P. H. J., 1963, Anguillid leptocephali in the southwest Pacific. Zool. Publ. Vic. Univ. Wellington, 33:1-14.

CASSTONGUAY, M. and J. D. MCCLEAVE, 1987, Vertical distribution, diel and ontogenetic vertical migrations and net avoidance of leptocephali of *Anguilla* and other common species in the Sargasso Sea. *J. Plankton Res.,*9(1):195-214.

HULET, W. H., 1978, Structure and functional development of the eel leptocephalus *Ariosoma balearicum* (DE LA ROCHE, 1809). *Phil. Trans. R. Soc. London, Ser. B,* 282:107-138.

HULET, W. H., J. FISHER, and B. J. RIETBERG, 1972, Electrolyte composition of Anguilliform leptocephali from the straits of Florida. *Bull. Mar. Sci.,* 22:432-448.

JESPERSON, P., 1942, Indo-Pacific leptocephalids of the genus *Anguilla*: Systematic and biological studies. *Dana Rep.,* 22:1-128.

KAJIHARA, T., 1988, Distribution of *Anguilla japonica* leptocephali in western pacific during September 1986. *Nippon Suisan Gakkaishi,* 54(6):929-933.

KAJIHARA, T., K. TSUKAMOTO, T. OTAKE, N. MOCHIOKA, H. HASUMOTO, M. OYA and O. TABETA, 1988, Sampling leptocephali with reference to the diel vertical migration and the gears. *Nippon Suisan Gak-*

kaishi, 54(6):941-946.

KLECKENER, R. C. and J. D. MCCLEAVE, 1985, Spacial and temporal distribution of American eel larvae in relation to north Atlantic Ocean current systems. *Dana,* 4:67-92.

KUBOTA, S., 1961, Studies on the ecology, growth and metamorphosis in Conger eel, *Conger myriaster* (BREVOORT). *J. Fac. Fish. Pref. Univ. Mie,* 5(2):190-370. (In Japanese.)

MOCHIOKA, N., 1988, Congridae. Pages 44-54 in M. OKIYAMA, ed. An atlas of the early stage fishes in Japan. Tokai Univ. Press, Tokyo. (In Japanese.)

POWER, J. H. and J. D. MCCLEAVE, 1983, Simulation of the north Atlantic Ocean drift of *Anguilla* leptocephali. *Fish. Bull.,* 81(3):483-500.

SCHMIDT, J., 1923, The breeding places of the eel. *Phil. Trans. R. Soc.,* 211:179-208.

SCHMIDT, J., 1925, The breeding places of the eel. *Ann. Rep. Smithonian Inst.,* 1924:279-316.

TABETA, O., 1988, Dysommatidae. Pages 42-44 in M. OKIYAMA, ed. An atlas of the early stage fishes in Japan. Tokai Univ. Press, Tokyo. (In Japanese.)

TABETA, O., K. TANAKA, J. YAMADA, and WANN-NIAN TZENG, 1987, Aspects of the early life history of the Japanese eel *Anguilla japonica* determined from otolith microstructure. *Nippon Suisan Gakkaishi,* 53(10):1727-1734.

TANAKA, K., O. TABETA, N. MOCHIOKA, J. YAMADA, and S. KAKUDA, 1987, Otolith microstructure and ecology of the conger eel (*Conger myriaster*) larvae collected in the Seto Inland sea, Japan. *Nippon Suisan Gakkaishi,* 53(4):543-549.

TSUKAMOTO K., A. UMEZAWA, O. TABETA, N. MOCHIOKA and T. KAJIHARA, 1989, Age and birth date of *Anguilla japonica* leptocephali collected in Western North Pacific in September 1986. *Nippon Suisan Gakkaishi,* 55(6):1023-1028.

UMEZAWA, A., K. TSUKAMOTO, O. TABETA and H. YAMAKAWA, 1989, Daily growth increments in the larval otolith of the Japanese eel, *Anguilla japonica. Japan. J. Ichthyol.,* 35(4):440-444.

VLADYKOV, V. D., 1964, Quest for the true breeding area of the American eel (*Anguilla rostrata* LE SUEUR). *J. Fish Res. Bd. Can.,* 21:1523-1530.

土佐湾及び四国沖黒潮流域で採集されたウナギ目魚類レプトケファルス幼生の分布

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土佐湾及び四国沖黒潮流域で，1990年1月にウナギ目魚類レプトケファルス幼生の採集を行った。採集は丸稚ネット（口径 1.3 m, 網口面積 1.33 m^2, 目合 0.33 mm)による傾斜曳あるいはステップ曳と高速稚魚ネット（網口面積 2.03 m^2, 目合 2.0 mm）による表層曳で行われた。計41尾のレプトケファルス幼生が黒潮流域で採れた。その内訳はギンアナゴ *Gnathophis nystromi nystromi* (JORDAN et SNYDER) (33尾)，ニラミアナゴ属 sp. 5 *Ariosoma* sp. 5（1尾)，ニラミアナゴ属 sp. 7 *Ariosoma* sp. 7（2尾)，クロアナゴ *Conger japonicus* BLEEKER（1尾)，クロアナゴ亜科 sp. 1 *Congrinae* sp. 1（2尾)，メクラアナゴ *Dysomma anguillare* BARNARD（2尾）であった。全個体の82.9%（34尾）が黒潮南外側域に分布していた。またギンアナゴは全個体が表層曳で，それ以外は全てステップ曳（ワイヤー長；500, 400, 300, 200, 100 m）で採集された。