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Three New Species of the Cyprinid Genus *Schizothorax* from Lake Rara, Northwestern Nepal

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Abstract *Schizothorax raraensis*, *S. macrophthalmus* and *S. nepalensis* are described as new species of the Schizothoracinae, Cyprinidae, from Lake Rara, northwestern Nepal. *S. raraensis* and *S. macrophthalmus* are distinguished from other species of the genus *Schizothorax* by the combination of the following characters: the position of ventral and dorsal fins, length of the dorsal, length of the barbel, head length and interorbital width. In addition to these differences, the latter species was characterized by the snout length and eye diameter. *S. nepalensis* was characterized by the non-sharp horny sheath and the length of barbels.

The food habits of the three species were different from each other. Reproductive isolation was observed between *S. raraensis* and *S. macrophthalmus*.

In spite of an intensive survey in many river systems in Nepal, these species were found only in Lake Rara. Therefore, these species are considered endemic to Lake Rara. It seems that sympatric speciation in Lake Rara has been brought about by the more diverse environment.

Fishes belonging to the subfamily Schizothoracinae are widely distributed in mountain streams and lakes around the Himalayan, Karakorum and Hindukush Ranges, the Tibet Plateau and Central Asia.

In this paper, the genus *Schizothorax* was defined by the three rows of pharyngeal teeth and two pairs of barbels, characters unique among the species of the Schizothoracinae. A discussion about the nomenclature of the genus *Schizothorax*, based on comparative osteology will be published elsewhere.

In the course of collecting fishes in Nepal from 1977 to 1983, a number of specimens which are referable to *Schizothorax* were collected from many river systems. Though several kinds of *Schizothorax* (including species assigned to *Oreinus* and *Schizothoraichthys*) have been reported from Nepal (Günther, 1861; Day, 1877; Regan, 1907; DeWitt, 1960; Datta, 1961; Shrestha, 1978, 1981), three species of *Schizothorax* from Lake Rara are different from the species that have been described from Nepal and other areas. Descriptions of these three new species are given here with data on food habits and reproductive ecology.

Lake Rara is a Himalayan lake located about 30 km north-northwest of Jumla, western Nepal. The lake is 2,990 m above sea level and 10.2 km^2 in surface area. Many small streams flow into Lake Rara, though the only outlet is Khater Khola. Khater Khola forms a very deep gorge at about 7 km downstream from the outlet and

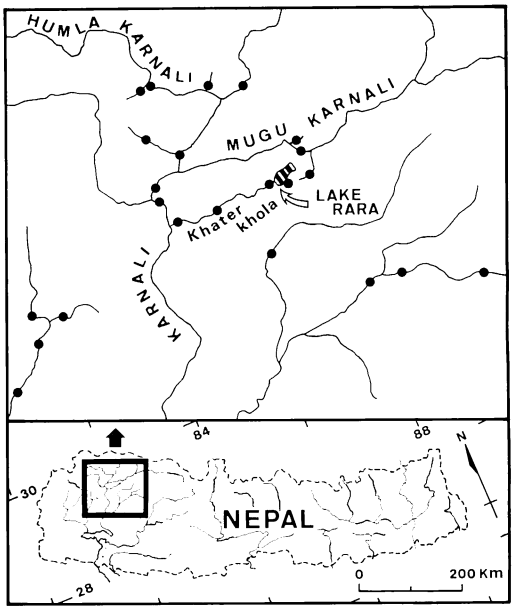

Fig. 1. Maps showing the location of Lake Rara and the sampling points around the Lake Rara. Black dots indicate the sampling points.

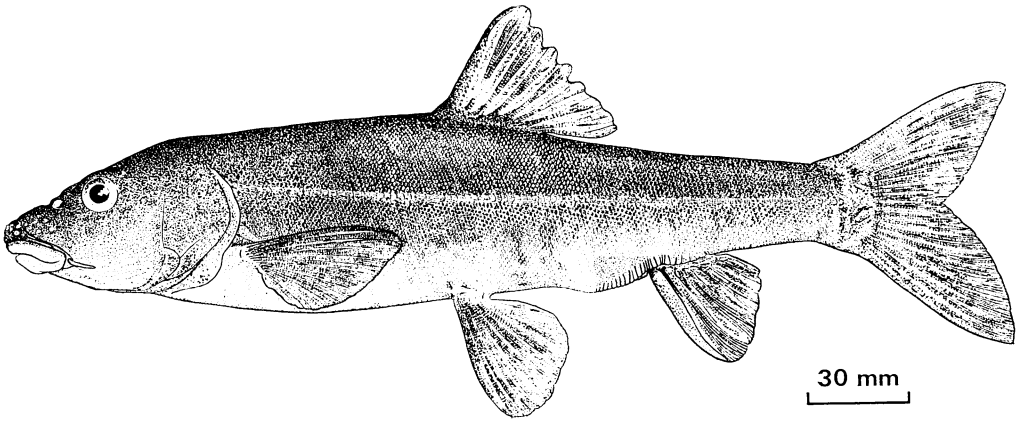

Fig. 2. *Schizothorax raraensis* sp. nov., holotype, NSMT-P 22184, male, 245 mm SL, collected from Lake Rara, northwestern Nepal. Drawn by A. Terashima.

then flows into the Karnali River 26 km westward of Lake Rara (Fig. 1). Field surveys in Lake Rara were performed twice in 1979, the first survey was from April 28 to May 3 and the second was from May 17 to May 21.

Materials and methods

Specimens described in this paper were collected from Lake Rara from May 17 to 21, 1979, by cast net and fishing with rod and line. The descriptions of *S. raraensis*, *S. macrophthalmus* and *S. nepalensis* are based on 81, 61 and 3 type specimens, respectively. The abbreviations prefixed to the catalogue numbers of the specimens are: OHBS-PH: Otsu Hydrobiological Station, Kyoto University; NSMT-P: Department of Zoology, National Science Museum, Tokyo; NHMTU-PN: Natural History Museum, Tribhuvan University, Kathmandu, Nepal; IHAS: Institute of Hydrobiology Academia Sinica, Wuhan, China; F: Zoological Survey of India, Calcutta; GCM (NH): Department of Zoology, Government College, Lahore, Pakistan.

Comparative materials. *Schizothorax kozlovi*, IHAS 7716281, 586542, two specimens, 142–170 mm in standard length (SL), Guizhou, China; *Schizothorax macropogon*, IHAS TS-016, TS-026, two specimens, 250–314 mm SL, Tibet, China; *Schizothorax progastus*, F 5327/1, 1511/412057, two specimens, 137–147 mm SL, Satreji River, India; *Schizothorax skarduensis*, GCM (NH) No. 15-F (Holotype), 274 mm SL, GCM (NH) No. 16-F (Paratype) 356 mm SL, Indus River at Skardu, Pakistan.

Counts and measurements were made in accordance with Hubbs and Lagler (1958). Some counts employed in this study require explanation as follows; scale counts for transverse series below the lateral line were counted from the pelvic fin on the left side not containing the free axillary scale. Counts for vertebrae were taken from radiographs and the Weberian apparatus was counted as four. Head length excludes the opercular membrane from the measurement. Sex was determined by dissection. Females were identified by the presence of an ovary and eggs, males were identified by large testis.

Analysis of intestine contents followed the methods reviewed by Hynes (1950). It was carried out on the contents from the esophagus to the second corner of the intestine in *S. raraensis*, and from the esophagus to the first corner of the intestine in *S. macrophthalmus* and *S. nepalensis*. The contents in *S. raraensis* and *S. macrophthalmus* were examined using the occurrence method, because it was difficult to measure the volume or weight of fragments of aquatic insects and aquatic plants (macrophytes). For *S. nepalensis*, the number method was used. The average cell number of sessile algae was counted under a microscope.

Schizothorax raraensis sp. nov.
(Figs. 2, 3A, 4A, 5A)

Holotype. NSMT-P 22184, male, 245 mm SL, May 18, 1979, Lake Rara, northwestern Nepal, 29°32′N, 82°5′E; collected by Akira Terashima.

Paratypes. A total of 80 specimens were designated as paratypes, May 18–20, 1979, same locality as holotype, Males: OHBS-PH 00011–00077, 00130–00131, 69 specimens, 130–209 mm SL, NHMTU-PN

Table 1. Counts for meristic characters and their frequencies and means of *Schizothorax raraensis* sp. nov., *Schizothorax macrophthalmus* sp. nov. and *Schizothorax nepalensis* sp. nov. Means ($\bar{x}$) are calculated from both holo- and paratypes. Numerals in parentheses indicate number of specimens. Coiling types of intestine are represented in Fig. 6.

	S. raraensis			*S. macrophthalmus*			*S. nepalensis*		
	Holo-type	Paratypes	$\bar{x}$	Holo-type	Paratypes	$\bar{x}$	Holo-type	Paratypes	$\bar{x}$
Principal dorsal fin rays	9	7 (3), 8 (26), 9 (51)	8.71	8	8 (36), 9 (24)	8.39	8	8 (1), 9 (1)	8.33
Principal anal fin rays	6	6 (79)	6.00	6	5 (2), 6 (58)	5.97	6	6 (2)	6.00
Total pectoral fin rays	18	14 (1), 16 (9), 17 (26), 18 (35), 19 (5), 20 (3)	17.54	16	16 (14), 17 (31), 18 (12), 19 (3)	17.05	16	16 (1), 18 (1)	16.67
Total pelvic fin rays	10	9 (5), 10 (66), 11 (9)	10.05	10	9 (9), 10 (47), 11 (4)	9.92	10	9 (1), 10 (1)	9.67
Gill rakers (outside)	14	11 (5), 12 (19), 13 (23), 14 (17), 15 (6)	13.01	21	17 (3), 18 (10), 19 (12), 20 (14), 21 (8), 22 (3), 23 (2)	19.62	18	17 (1), 20 (1)	18.33
Gill rakers (inside)	16	13 (1), 14 (9), 15 (23), 16 (16), 17 (14), 18 (6), 19 (1), 20 (1)	15.63	26	22 (2), 23 (5), 24 (9), 25 (12), 26 (8), 27 (9), 28 (4), 29 (3)	25.49	21	24 (1), 28 (1)	24.33
Vertebrae	47	46 (1), 47 (24), 48 (24), 49 (8)	47.67	46	45 (2), 46 (9), 47 (25), 48 (13), 49 (3)	47.09	48	45 (1), 47 (1)	46.67
Principal caudal fin rays	19	18 (1), 19 (63), 20 (3)	19.03	19	18 (6), 19 (53), 20 (1)	18.92	18	19 (2)	18.67
Lateral-line scales	100	91 (3), 92 (9), 93 (9), 94 (3), 95 (5), 96 (12), 97 (3), 98 (6), 99 (4), 100 (4), 101 (5)	95.73	95	91 (2), 92 (3), 93 (6), 94 (6), 95 (5), 96 (11), 97 (9), 98 (3), 99 (3), 100 (4), 101 (1), 102 (1), 103 (2)	96.12	93	93 (1), 99 (1)	95.00
Scales in transverse series above lateral line	27	25 (4), 26 (4), 27 (12), 28 (9), 29 (10), 30 (10), 31 (2)	28.61	30	26 (1), 27 (3), 28 (7), 29 (14), 30 (10), 31 (8), 32 (3), 33 (6)	29.83	30	29 (2)	29.33
Scales in transverse series below lateral line	25	19 (5), 20 (10), 21 (11), 22 (8), 23 (7), 24 (7), 25 (7)	21.98	23	18 (2), 19 (2), 20 (3), 21 (18), 22 (8), 23 (7), 24 (6), 25 (2)	21.76	21	20 (1), 21 (1)	20.67
Coiling type of intestine		b (1), c (13), d (25), e (29)		c	a (2), b (15), c (20), d (12), e (1)		d	d (1), e (1)	

16B 0205, 16B-0211–16B-0213, 4 specimens, 156–233 mm SL, NSMT-P 22184–22188, 5 specimens, 141–248 mm SL. Females: OHBS-PH 00078, 1 specimen, 190 mm SL, NHMTU-PH 16B-0204, 1 specimen, 167 mm SL, NSMT-P 22189, 1 specimen, 164 mm SL; all the paratypes were collected by Akira Terashima.

OHBS-PH 00073–00079, 5 specimens, 162–187 mm SL, were kept in the Fisheries Development Section of the Department of Agriculture, Ministry of Food, Agriculture and Irrigation of Nepal, Kathmandu, Nepal. OHBS-PH 00130–00131, 2 specimens, 173–175 mm SL, were kept in the Institute of Hydrobiology, Academia Sinica, Wuhan, China.

Diagnosis. A species of *Schizothorax* distinguishable from other members of the genus by a combination of the following characters: ventral view of the margin of lower jaw horseshoe in shape; tip of the lower jaw fleshy; scales on the breast; origin of dorsal fin slightly behind the middle of the body, and in advance of insertion of pelvic fin; number of scales above and below lateral line, above 25–31, below 19–25; length of barbels, rostral 3.3% , maxillary 3.6% of SL; number of gillrakers, outside 11–15, inside 13–20; head length 27.5% of SL; length of dorsal fin 16.5% of SL.

Description. Counts for fin rays, scales, gillrakers, vertebrae and coiling type of the intestine are listed in Table 1; proportional measurements are given in Table 2.

Body moderately elongate, somewhat compressed; greatest depth at origin of dorsal fin; caudal peduncle compressed. Dorsal profile almost straight from tip of snout to nape, from nape to caudal fin somewhat arched; ventral profile slightly curved. Head long. Snout subtriangular. Mouth somewhat oblique and protractile, upper lip a little prominent, lower labial folds on right side and left side deeply incised, lower labial fold in the central part of smaller specimens not incised, lower lip not papillate, the margins of the mandibles slightly hard (Fig. 3A). Barbels four, two rostral, two maxillary; maxillary barbels slightly longer than rostral barbels. Nostrils nearer to eye than to tip of snout. Eye moderate, diameter in small speci-

Table 2. Proportional measurements expressed as percentage of standard length in *Schizothorax raraensis* sp. nov., *Schizothorax macrophthalmus* sp. nov., and *Schizothorax nepalensis* sp. nov. Means ($\bar{x}$) are calculated from both holo- and paratypes.

	S. raraensis			*S. macrophthalmus*			*S. nepalensis*		
	Holotype	Paratypes (n=80) Range	$\bar{x}$	Holotype	Paratypes (n=60) Range	$\bar{x}$	Holotype	Paratypes (n=2) Range	$\bar{x}$
Standard length (mm)	245	130–248		122	104–156		78.9	97.2–107	
Head length	26.9	25.2–29.1	27.5	24.1	23.0–25.4	24.4	25.0	23.6–25.0	24.5
Head depth	17.7	15.3–18.7	17.4	16.4	15.5–17.8	16.6	17.5	16.4–17.7	17.2
Head width	15.1	13.6–15.9	14.6	13.3	12.2–15.0	13.6	13.7	13.3–13.7	13.6
Snout length	11.1	10.1–12.2	11.0	8.6	8.0– 9.1	8.6	10.1	8.8– 9.4	9.4
Eye diameter	4.3	4.3– 5.9	5.2	6.2	5.2– 6.6	5.8	5.8	5.5– 5.6	5.6
Interorbital width	10.5	9.1–10.7	9.9	9.4	8.6–10.6	9.6	9.8	9.0– 9.2	9.3
Length of rostral barbel	2.9	2.5– 4.0	3.3	2.0	1.4– 2.8	2.0	1.7	2.0	1.9
Length of maxillary barbel	3.6	2.7– 4.5	3.6	2.5	2.0– 3.4	2.7	1.9	2.4– 2.8	2.4
Body depth	20.4	18.3–24.0	20.7	21.0	18.4–23.5	20.9	22.3	20.6–22.0	21.6
Body width	14.8	10.1–16.6	12.8	12.2	10.4–16.6	12.8	13.6	11.7–13.0	12.8
Length of caudal peduncle	17.1	16.1–19.1	17.8	17.4	15.8–19.0	17.7	17.7	16.3–17.3	17.1
Depth of caudal peduncle	9.6	8.3–10.1	9.5	9.0	8.6–10.2	9.6	10.4	9.5– 9.9	9.3
Predorsal length	53.3	50.8–56.0	53.2	52.3	48.3–54.0	52.1	49.8	49.0–51.4	50.1
Prepelvic length	55.4	54.0–57.8	55.8	53.7	51.3–55.8	53.7	52.6	52.4–55.9	53.6
Preanal length	77.6	74.3–78.4	76.2	77.0	74.0–78.8	76.7	75.4	75.4–79.0	76.6
Length of dorsal base	12.5	10.8–14.1	12.2	11.6	10.1–12.9	11.8	12.8	10.6–12.9	12.1
Length of dorsal fin	16.3	15.1–17.8	16.5	17.2	16.4–18.8	17.4	20.7	20.6–22.1	21.1
Length of pectoral fin	18.8	16.9–20.6	18.5	17.7	17.3–19.8	18.5	16.9	17.0–17.2	17.0
Length of pelvic fin	16.1	14.3–17.1	15.7	15.2	14.5–17.8	16.0	15.2	15.5–16.2	15.6

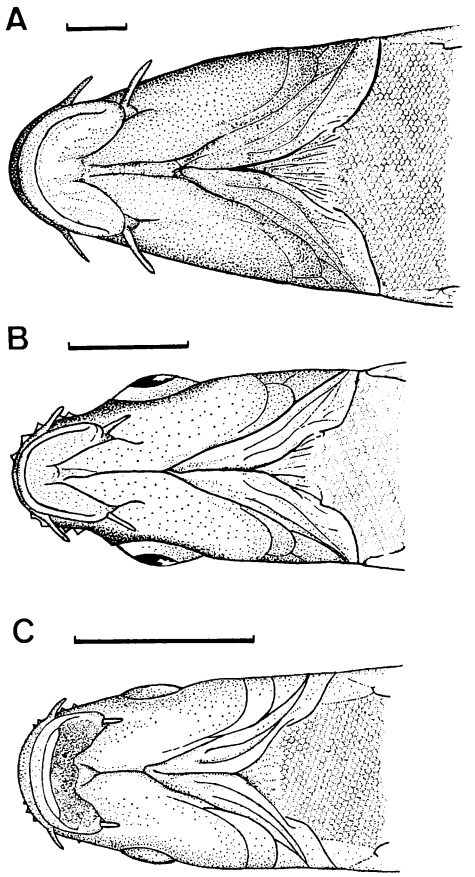

Fig. 3. Ventral views of head of three new species from Lake Rara. A, *S. raraensis* sp. nov., holotype. B, *S. macrophthalmus* sp. nov., holotype. C, *S. nepalensis* sp. nov. holotype. Bars indicate 10 mm.

mens larger than in large specimens, average 4.8% of SL (201–248 mm SL), 5.2% (130–197 mm SL). Interorbital space flat. Gillrakers small, short, thick; those on outside coarsely set; those on inside slightly close set (Fig. 4A). Pharyngeal teeth (from 7 specimens) three or four rows, 2, 3, 5–5, 3, 2 (OHBS-PH 00015, 00033, 00076), 2, 3, 5–4, 3, 2 (OHBS-PH 00011, 00038), 1, 2, 3, 5–5, 3, 2, 1 (OHBS-PH 00012), 1, 2, 3, 4–4, 3, 2, 1 (NHMTU-PN 16B-0213); the first tooth in main row (according to Zhu (1935)) small, conical, with a round tip, lacking in some specimens; the second tooth in main row large, subconical, with a pointed tip; remaining three teeth in main row well developed, little hooked; smaller teeth in outer rows subconical, forming a spoon-like hook, grinding surface oblique.

Lateral line complete, running in middle of flank and caudal peduncle; sensory tubes simple. Scales of flank and breast minute. Scales on the basal sheath of anal fin large, those of female larger than male (Fig. 5A). Thick epidermis covers minute scales on breast. Dorsal fin small; simple soft ray osseous; principal simple ray elongate and strong, serrated with about 13 denticles along its hind margin; origin of dorsal slightly posterior to mid-point of body, in advance of insertion of pelvic fin. Fin membranes of dorsal slightly notched between rays in large specimens. Anal fin with a basal scaly sheath, simple soft ray osseous; principal simple ray prolonged. Anal laid flat, not reaching caudal fin in males, reaching caudal fin in females

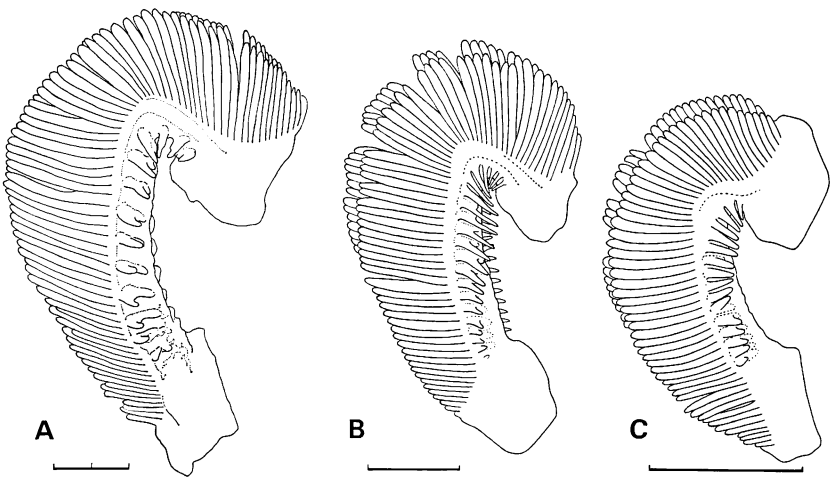

Fig. 4. Lateral views of outside of first gill from right side. A, *S. raraensis* sp. nov., OHBS-PH 00015. B, *S. macrophthalmus* sp. nov., OHBS-PH 00122. C, *S. nepalensis* sp. nov., OHBS-PH 00125. Bars indicate 5 mm.

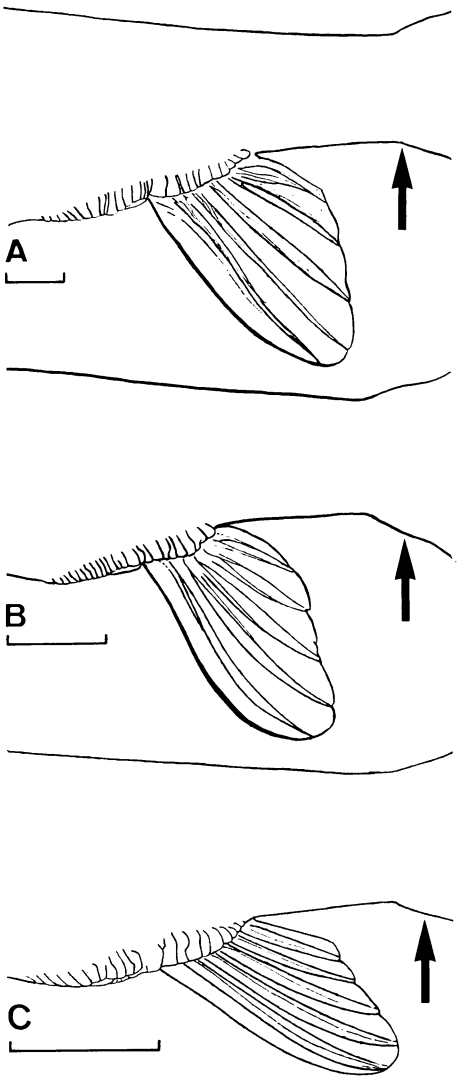

Fig. 5. The position of the anal laid flat of female of the three new species from Lake Rara. A, *S. raraensis* sp. nov., OHBS-PH 00078. B, *S. macrophthalmus* sp. nov., OHBS-PH 00123. C, *S. nepalensis* sp. nov., OHBS-PH 00125. Bars indicate 10 mm.

(Fig. 5A), length of anal fin, males 14.7%, females 20.2% of SL. Pectoral fin slightly pointed, rays branched except uppermost one. Pelvic fin with a free axillary scale, rays branched except outermost one. Caudal fin forked; each lobe obtusely pointed, upper of which shorter than lower. Nuptial organ remarkable in snout part of male, not present in snout part of female.

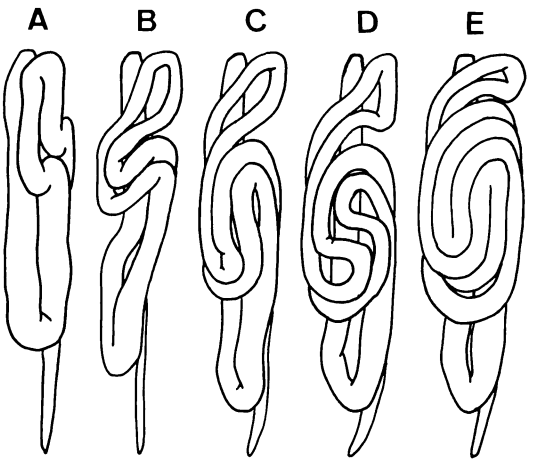

Fig. 6. Ventral views of the coiling type of intestine. Alphabets represent the coiling types.

Coiling type of intestine simple, types B, C (Fig. 6) not found in specimens larger than 190 mm SL, peritoneum black.

Coloration: In life, top of head and back of body black, ventral surface of body blackish, membranes of all fins blackish. In formalin, top of head and back of body grayish dark brown, ventral surface of body brown. Black marks on body in some specimens. No differences in coloration between males and females.

Sexual dimorphism. Sexual dimorphism was found in the following characters: position of anal laid flat, presence of nuptial organ, size of basal sheath scale. The details of these characters were given in each description. Females grow larger than males.

Food habits. Many fragments of chironomid larvae and other aquatic insects were identified from the intestine of many specimens (Table 3). The occurrence frequency of fishes which fed on chironomid and other aquatic insect larvae was 80%. Aquatic plants (macrophytes) were identified from one third of the specimens examined. However, there were no more than two or three fragments in each specimen. Small amounts of sand were also found in six specimens. Most of the intestine contents were composed of larvae of aquatic insects.

Sucking up the bottom sand and mud was a frequently observed feeding habit at the shoreline. Sand in the intestines should probably be

considered as being incidentally ingested during the search for insect larvae.

Intestine contents suggest that the main food of this species is aquatic insects living in or on the sand or mud. A large number of parasites (Caryophyllaeidae) were observed from the esophagus to near the first corner of the intestine.

Reproductive ecology. Spawing behavior was observed from dawn to noon during the second field survey, May 18–21, 1979, though none was observed during the first survey, April 28–May 3, 1979. This suggests that spawning starts around the middle of May.

The spawning site was on a sand bottom at depths of 5–6 m, 4–5 m from shore near the inlet of a small stream. Spawning groups included some large females and many males. After the female rubbed its belly against the bottom, many males crowded there. The diameter of eggs in the ovary was about 2.0 mm. Eggs taken from the ovaries numbered 1,710 (OHBS-PH 00078).

Adult females are larger than males. The maximum size of a male and a female specimen-were 248 mm, 540 mm SL, respectively.

Etymology. The name *raraensis* refers to Lake Rara, where all specimens of the species were collected.

Remarks. Three and four rows of pharyngeal teeth were observed in *S. raraensis*. The number of rows of pharyngeal teeth is one of the most important key characters in genera of the Schizothoracinae. The monotypic genera *Tetrostichodon* and *Paraschizothorax* were proposed for fishes that have the four rows of pharyngeal teeth in the Schizothoracinae (Cao, 1964; Zhang et al, 1964). However, the type species of these two genera represented the same species *S. occonori*.

Schizothoracinae having four rows of pharyngeal teeth have been collected from some mountain streams in Nepal, namely the Marsyandi River, Nishi Khola, Bagmati Khola and Raswa Khola, and in Lake Rara. However, the number of individuals that have four rows was much fewer than those having three rows even in one population. All the morphological characters except the dental formula were the same in the other specimens that have three rows of pharyngeal teeth. Therefore, the Schizothoracinae with pharyngeal teeth in four rows are regarded as a variation.

S. raraensis is similar to *S. progastus* from India and *S. kozlovi* from China. However, *S. progastus* differs from *S. raraensis* in the following characters: the pelvic and dorsal fins situated more anteriorly, prepelvic length 48.9% of SL, predorsal length 49.6% of SL; long dorsal length (23.8% of SL); short head length (22.8% of SL); narrow interorbital width (7.4% of SL).

Table 3. Food contents in intestine of *Shizothorax raraensis* sp. nov., *S. macrophthalmus* sp. nov. and *S. nepalensis* sp. nov.

	S. raraensis	*S. macrophthalmus*	*S. nepalensis*
Method of analysis	O*	O*	N**
Number of individuals examined	15	12	3
Chironomidae larvae	53.3	33.3	
Other aquatic insects larvae	66.7	33.3	
Gammaridae	6.7		
Aquatic plants (macrophytes)	33.3		
Sand	40.0		
Diaptomidae		100.0	
Cydorinae		16.7	
Synedra spp.			58.0
Gomphonema spp.			17.5
Cocconeis sp.			1.6
Cymbella sp.			0.5
Navicula sp.			0.3
Oscillatoria sp.			22.2
Others		16.7	

O*, occurence method; N**, number method.

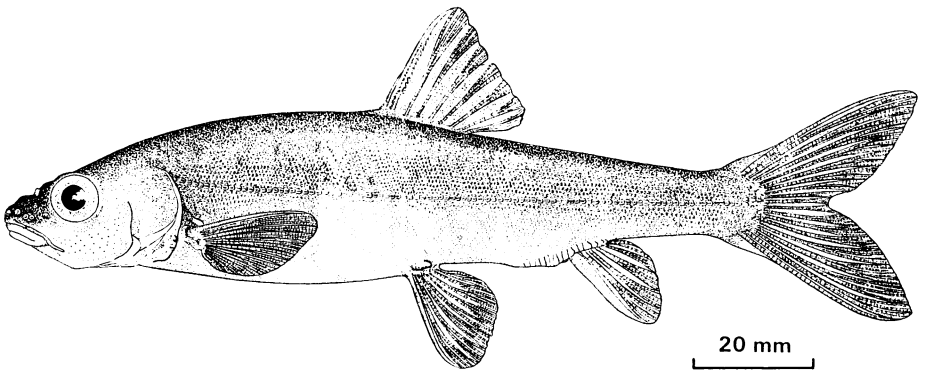

Fig. 7. *Schizothorax macrophthalmus* sp. nov., holotype, NSMT-P 22190, male, 122 mm SL, collected from Lake Rara, northwestern Nepal. Drawn by A. Terashima.

S. kozlovi differs from *S. raraensis* in that it has long barbels (rostral 8.0% of SL, maxillary 8.2% of SL).

Shrestha (1978) examined one specimen of a fish from Lake Rara, and stated that it resembled *Schizothoraichthys esocinus*. However, judging from the description of the species, it seems to correspond to *Schizothorax raraensis*.

Schizothorax macrophthalmus sp. nov.
(Figs. 3B, 4B, 5B, 7)

Holotype. NSMT-P 22190, male, 122 mm SL, May 19, 1979, Lake Rara, northwestern Nepal, 29°32′N, 82°5′E, collected by Akira Terashima.

Paratypes. A total 60 specimens were designated as paratypes, May 18–20, 1979, same locality as holotype; Males: OHBS-PH 00079–00114, 00132, 36 specimens, 103-138 mm SL, NHMTU-PN 16B-0206–16B-0208, 16B-0210, 4 specimens, 104–125 mm SL, NSMT-P 22190–22194, 5 specimens, 109–133 mm SL, Females: OHBS-PH 00115–00124, 00133, 11 specimens, 127–156 mm SL, NHMTU-PN 16B-0209, 1 specimen, 141 mm SL, NSMT-P 22195–22197, 3 specimens, 131–148 mm SL; all the paratypes were collected by Akira Terashima.

OHBS-PH 00113–00115, 3 specimens, 108–141 mm SL were kept in the Fisheries Development Section of the Department of Agriculture, Ministry of Food, Agriculture and Irrigation of Nepal, Katmandu, Nepal. OHBS-PH 00132–00133, 2 specimens, 118–147 mm SL were kept in the Institute of Hydrobiology, Academia Sinica, Wuhan, China.

Diagnosis. This species of *Schizothorax* is distinguishable from other members of the genus by a combination of the following characters: ventral view of the margin of lower jaw horseshoe in shape; tip of the lower jaw fleshy; scales on the breast clearly evident; origin of dorsal fin slightly posterior to mid-point of body, in advance of insertion of pelvic fin; number of scales above and below lateral line, above 26–33, below 18–25; number of gillrakers, outside 17–23, inside 22–29; length of dorsal fin 17.4% of SL; length of barbels, rostral 2.0%, maxillary 2.7% of SL; head length 24.5% of SL; eye diameter 5.8% of SL; snout length 8.6% of SL.

Description. Counts for fin rays, scales, gillrakers, vertebrae and coiling type of intestine are listed in Table 1; proportional measurements are given in Table 2.

Body moderately elongate, somewhat compressed; greatest depth at origin of dorsal fin; caudal peduncle compressed. Dorsal profile arched; ventral profile less curved. Head moderately long. Snout sub-triangular. Mouth oblique, upper lip a little prominent. Lower labial folds on right side and left side are deeply incised, lower labial fold in the central part of small specimens is not incised, lower lip not papillate (Fig. 3B). Retroarticular projects downward. Barbels four, two rostral, two maxillaries; maxillary barbels slightly longer than rostral barbels. Nostrils nearer to eye than tip of snout. Eye large; interorbital space moderately wide. Gillrakers; those on outside slender, thin, lying close together; those on inside small, thin, slightly close set (Fig. 4B). Pharyngeal teeth (from 5 specimens) three rowed, 2, 3, 5–5, 3, 2 (OHBS-PH 00082), 2, 3, 4–5, 3, 2 (OHBS-PH 00117, 00123), 2, 3, 5–4, 3, 2 (OHBS-PH 00093, 00114); the first tooth in main row small, conical, with a rounded tip,

lacking in some specimens, the second tooth in main row large, subconical, slightly hooked; remaining three teeth in main row well developed, forming a spoonlike hook; smaller teeth on outer rows subconical, forming a spoon-like hook.

Lateral line complete, running in middle of flank and caudal peduncle; sensory tubes simple. Scales of flank and breast minute. Scales on the basal sheath of anal fin large, those of female larger than male (Fig. 5B); thick epidermis covers minute scales on breast. Dorsal fin small; simple soft ray osseous; principal simple ray elongate and strong, serrated with about 15 denticles along its hind margin; origin of dorsal slightly posterior to mid-point of body, anterior to insertion of pelvic. Anal fin with a basal scaly sheath; simple soft ray osseous; principal simple ray prolonged. Anal laid flat not reaching caudal fin in males, reaching caudal fin in females (Fig. 5B); length of anal fin, males 15.6%, females 21.2% of SL. Pectoral fin rays branched except the uppermost one. Pelvic fin with a free axillary scale, rays branched except the outermost one. Caudal fin forked, each lobe obtusely pointed. Nuptial organ remarkable in snout of male, not present in snout of female.

Coiling type of intestine very simple, type A (Fig. 6) not observed in specimens larger than 120 mm SL, type E (Fig. 6) not observed in specimens smaller than 130 mm SL, peritoneum black.

Coloration: In life, top of head and back of body dark brown, ventral surface of body silver. In formalin, top of head and back of body grayish brown, ventral surface light brown. There are no differences in coloration between males and females.

Sexual dimorphism. Sexual dimorphism was found in the following characters; position of anal laid flat, presence of nuptial organ, size of basal sheath scale. The details of these characters were given in each description. Females grow larger than males.

Food habits. Diaptomid copepods occurred in all specimens and occupied most of the intestinal contents measured in volume (Table 3). On the other hand, Chydorinae occurred rarely in both frequency and number. Aquatic insect larvae occurred in a few specimens, but their fragments were scarce. It seems that these aquatic insects were eaten when *S. macrophthalmus* came to the littoral zone for spawning. The intestinal contents suggest that the main food source of this species is the zooplankton such as Diaptomidae which live in the pelagic zone.

Reproductive ecology. The spawning behavior was observed from dawn to noon during the second field survey, May 18–21, 1979, though it was not observed in the first survey, April 28–May 3, 1979. This suggests that spawning starts around the middle of May. The spawning site was along the beach line at depths about 3–5 cm near the inlet of a small stream. The spawning school was observed along the beach line and also in the small streams that flow into the lake from May to September, 1983 (Dr. H. Tabata, personal communication). From these observations, this species may spawn from the middle of May to the end of September, and the spawning site seems to be by beaches and in streams.

The spawning school of 20–30 individuals move along the beach. It scatters the demersal eggs among the gravel in the course of movement. The average diameter of eggs in the ovary was 2.4 mm. The spawned eggs were covered with jelly-like material. The average number of eggs from both ovaries from seven specimens was 1,406. The adult size of females is larger than that of males. The maximum size of a male and a female specimen were 138 mm, 156 mm SL, respectively.

Etymology. The name *macrophthalmus* is derived from the Latin macro, meaning large, and ophthalm, meaning eye, referring to the fact that the species has large eyes.

Remarks. This species is small in size as compared with the other species in *Schizothorax*. The present species is related to *S. progastus* from India. However, *S. progastus* differs from *S. macrophthalmus* in the following characters: the pelvic and dorsal fins situated more anteriorly, prepelvic length 48.9%, predorsal length 49.6% of SL, respectively; long dorsal fin (103% of HL, 23.8% of SL); small eye diameter (4.6% of SL); long snout length (9.3% of SL). The sizes of large type specimens of *S. macrophthalmus* are similar to those of smaller type specimens of *S. raraensis*, however, the two species are easily distinguishable. Though the characters of both species have been described, the differences in the characters between *S. macrophthalmus* (131–156 mm SL, n=14) and *S. raraensis* (130–

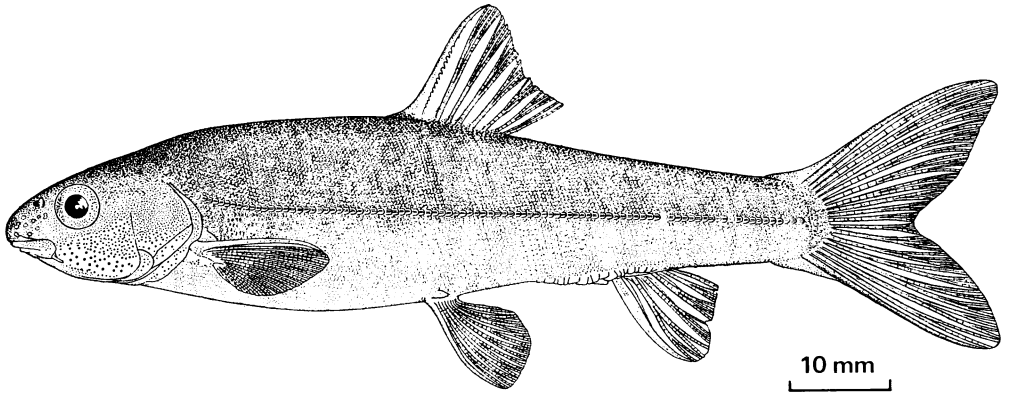

Fig. 8. *Schizothorax nepalensis* sp. nov., holotype, NSMT-P 22198, male, 78.9 mm SL, collected from Lake Rara, northwestern Nepal. Drawn by A. Terashima.

165 mm SL, n=30) are as follows. *S. macrophthalmus* differs from *S. raraensis* in having a short head length, 24.0% of SL (27.7% of SL in *S. raraensis*), a short snout length, 8.6% of SL, 35.4% of head length (HL), (10.9% of SL, 39.4% of HL). Retroarticular of *S. macrophthalmus* projects more downward than in *S. raraensis*. Therefore, the head depth at the center of eye in *S. macrophthalmus* is higher than that in *S. raraensis*, its ratio in *S. macrophthalmus* is 13.3% of SL, 54.8% of HL, whereas in *S. raraensis* it is 12.6% of SL, 46.9% of HL. The mouth of *S. macrophthalmus* is more oblique than that of *S. raraensis*. As a whole, the shape of head of *S. raraensis* is more slender than that of *S. macrophthalmus*.

Schizothorax nepalensis sp. nov.
(Figs. 3C, 4C, 5C, 8)

Holotype. NSMT-P 22198, male, 78.9 mm SL, May 19, 1979, Lake Rara, northwestern Nepal, 29°32′N, 82°5′E; collected by Akira Terashima.

Paratypes. A total of 2 specimens were designated as paratypes, May 18–20, 1979, same locality as holotype. Females, OHBS-PH 00125, 00126, 97–107 mm SL, paratypes were collected by Akira Terashima.

Diagnosis. This species of *Schizothorax* is distinguishable from other members of the genus by a combination of the following characters: ventral view of the margin of lower jaw represents a nearly straight line with both ends curved backward; the tip of the lower jaw covered with non-sharp horny sheath; scales on the breast; length of dorsal fin 21.1% of SL; length of barbels, rostral 1.9%, maxillary 2.4% of SL.

Description. Counts for fin rays, scales, gillrakers, vertebrae and coiling type of intestine are listed in Table 1, proportional measurements are given in Table 2.

Body moderately elongate, somewhat compressed; greatest depth at origin of dorsal fin; caudal peduncle compressed. Dorsal profile somewhat arched; ventral profile less curved. Head moderately long. Snout somewhat round. Mouth almost horizontal, upper lip a little prominent, lower labial folds on right side and left side are deeply incised, lower labial fold in the central part is shallow incised, lower lip papillate, anterior margin of lower mandible covered with horny sheath, edge of horny sheath not sharp (Fig. 3C). Barbels four, two rostral, two maxillary, maxillary barbels slightly longer than rostral barbels. Nostrils nearer to eye than to tip of snout. Eye somewhat large; interorbital somewhat round. Gillrakers; those on outside slender, lying close together; those on inside small, slightly close set (Fig. 4C). Pharyngeal teeth (from 2 specimens) three rowed, 2, 3, 4–5, 3, 2 (OHBS-PH 00125), 2, 3, 5–5, 3, 2 (OHBS-PH 00126); the first tooth in main row small, conical, with a rounded tip, lacking on left side of the specimen (OHBS-PH 00125); remaining four teeth in main row well developed, forming a spoon-like hook; smaller teeth in outer row subconical, forming a spoon-like hook.

Lateral line complete, running in middle of flank and caudal peduncle; sensory tubes simple. Scales of flank and breast minute. Scales on the

basal sheath of anal fin large, those of femaels are larger than those of males (Fig. 5C). Dorsal fin small; simple rays osseous; simple soft ray osseous, principal simple ray elongate and strong, serrated with about 15 denticles along its hind margin; origin of dorsal slightly anterior to midpoint of body, in front of insertion of pelvic. Anal fin with a basal scaly sheath, simple soft ray osseous; principal simple ray prolonged. Anal laid flat, not reaching caudal fin in males, reaching caudal fin in females (Fig. 5C), length of anal fin, males 15.9%, females 18.5% of SL. Pectoral fin rays branched except uppermost one. Pelvic fin with a free axillary scale, rays branched except outermost one. Caudal fin forked; each lobe obtusely pointed. Nuptial organ remarkable in snout of male, not present in snout of female.

Coiling type of intestine simple, peritoneum black.

Coloration: In life, top of head and back of body dark brown, ventral surface of body silver. In formalin, top of head and back of body grayish brown, ventral surface light brown. There are no differences in coloration between males and females.

Sexual dimorphism. Sexual dimorphism was found in the following characters: position of anal laid flat, presence of nuptial organ, size of basal sheath scale. The details of these characters were given in each description.

Food habits. The intestinal contents contained mostly diatoms, such as *Synedra* spp., *Gomphonema* spp., *Cocconeis* sp., *Cymbella* sp. and *Navicula* sp. *Oscillatoria* sp., a bluegreen alga, was also abundant in the intestine. Most of these algal species were sessile algae. The intestinal contents suggest that this species is a sessile algal feeder.

Reproductive ecology. Spawning behavior could not be observed during the investigation period (April 28–May 3 and May 18–21, 1979). The testis from one specimen (NSMT-P 22198) was immature. Many fine eggs were observed in the ovary and the size of ovary was very small in females (OHBS-PH 00125, 00126).

Etymology. Named *nepalensis*, referring to the distribution of the species in a Himalayan lake in Nepal-Himalaya region.

Remarks. In the genus *Schizothorax*, *S. nepalensis* is characterized by having a dull horny sheath on the margin of the lower jaw. The same characteristic is known from the following two species; *S. macropogon* in Tibet, and *S. skarduensis* in east Karakorum, Pakistan. The ventral view of the lower jaw and the morphology of the dull horny sheath of *S. macropogon* are similar to those of *S. nepalensis*. However, *S. macropogon* differs from *S. nepalensis* in having long barbels (rostral 15.2% of SL, maxillary 16.3% of SL). The ventral view of the lower jaw of *S. skarduensis* is horseshoe in shape and there are many striae on the surface of the horny sheath. Also, it has long barbels (rostral 7.2% of SL, maxillary 5.8% of SL).

Discussion

In the course of field surveys, collection of fishes were carried out in many river systems in Nepal. Fishes of the genus *Schizothorax* were collected from the upper and middle parts of mountain streams. Particularly in the upper part, including the streams around Lake Rara, the genus *Schizothorax* was dominant. In spite of intensive surveys in many streams of Nepal, *S. raraensis*, *S. macrophthalmus* and *S. nepalensis* were found only in Lake Rara and near the outlet of Khater Khola. From these facts, *S. raraensis*, *S. macrophthalmus* and *S. nepalensis* are considered to be the endemic species in Lake Rara.

Hagen (1969) suggested that Lake Rara was made from the ancient Mugu Karnali River and the Khater Khola from Lake Rara was the ancient Mugu Karnali River course. According to him, an eastern tributary of Humla Karnali River captured the ancient Mugu Karnali River from the west. The formation age of Lake Rara has not been determined. However, Lake Rara is estimated as the depression lake that was formed hundreds of thousand years ago (K. Arita, personal communication).

From the geohistory of Lake Rara and the present fish fauna around there, it seems reasonable to conclude that the ancestral species of endemic Rara species were probably derived from the ancient Mugu Karnali River.

The hydrological environment for aquatic organisms considerably changed when Lake Rara was formed. Therefore, it seems that aquatic organisms were seriously affected by the formation of the lake. Especially, some of hydrological environments such as still water and deep pelagic zone are quite different from the

environments of the mountain streams.

Some morphological characters of endemic Rara species were smaller than those of *Schizothorax* spp., which have fleshy lips and are distributed in the mountain streams of Nepal. The length of the caudal peduncle was 17.1–17.8% of SL in Lake Rara (19–20% in the Nepalese mountain streams); depth of the caudal peduncle was 9.3–9.6% of SL (10–12%); length of the dorsal fin was 16.5–21.1% of SL (22–24%). These characteristic common features to all the endemic species of Lake Rara may be related to the decreasing of capacity for locomotion found among stream dwelling species.

The food habits of endemic Rara species are different from each other, namely insectivorous *S. raraensis*, planktivorous *S. macrophthalmus* and herbivorous *S. nepalensis* (Table 3). The mouths of *S. raraensis* and *S. macrophthalmus* were somewhat oblique in both species. This shape seems to be advantageous to take the larvae of aquatic insects and zooplankters. The mouth of *S. nepalensis* was almost horizontal and it seems to be suitable to scrape sessile algae (Fig. 3). The shape and the space of gillrakers were different in each species. The gillrakers of *S. raraensis* were spaced at wide intervals. Their morphology seems to be effective for taking aquatic insects that live in or on the sand. On the other hand, the closely set gillrakers in *S. macrophthalmus* and *S. nepalensis* seem to be advantageous to fillter the fine organisms (Fig. 4). The coiling type of intestine of *S. macrophthalmus* was more simple than those of the other two species. These facts suggest that food segregation among the three species has been established.

The food habits of insectivorous species like *S. raraensis* and herbivorous species like *S. nepalensis* are similar to those of *Schizothorax* spp. which live in the Nepalese mountain streams. However, *S. macrophthalmus* is considered to be planktivorous, due to the fact that Diaptomidae are found abundantly in the intestine. Planktivorous *Schizothorax* like *S. macrophthalmus* were not found in the Nepalese mountain streams. Some planktivorous Schizothoracinae (e.g., *Gymnocypris scoliostomus, Herzensteinia microcephalus, Schizothorax microstomus* and *Schizothorax taliensis*) were reported from some lakes in China (Zhang and Wang, 1962; Cao 1964; Wu and Chen 1979; Chen et al; 1982). Though the surface area of Lake Rara is comparatively small, *S. macrophthalmus* is considered to have evolved as a result of adaptations to feed on zooplankton like Diaptomidae, which live in the pelagic zone (Okino, unpublished).

Judging from the food habits, the main habitats of *S. raraensis* and *S. nepalensis* seem to be the littoral zone of Lake Rara where aquatic insects and sessile algae are abundant. On the other hand, the main habitat of *S. macrophthalmus* is regarded as the pelagic zone.

The spawning behavior of *S. raraensis* and *S. macrophthalmus* was observed during the second field survey. However, the spawning places of two species were distinctly separated. *S. raraensis* spawned in relatively deep water (5–6 m), while the spawning site of *S. macrophthalmus* was along the beach line at depth of about 3–5 cm and in the small streams that flow into the lake. Agressive behavior between the spawning *S. raraensis* and *S. macrophthalmus* was not observed. Judging from the immature gonad condition of *S. nepalensis*, it seems that its spawning starts later than other two species. The differences among the spawning places and spawning seasons of *S. raraensis, S. macrophthalmus* and *S. nepalensis* suggest reproductive isolation.

The three endemic fishes from Lake Rara were different not only in morphological structure but also ecologically, as demonstrated by food habits and reproductive ecology. It seems that these differences are results of adaptations to diversity of their respective environments, since becoming isolated in Lake Rara. A new ranid frog was recently described from Lake Rara (Dubois and Matsui, 1983). These aquatic organisms in Lake Rara appear to have evolved there. The endemic Rara fishes are regarded as another example of sympatric speciation that is well known from such lakes as Lake Biwa, Lake Baikal and the east African lakes.

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ララ湖（西北ネパール）から得られた *Schizothorax* 属（コイ科）の3新種

寺島　彰

西北ネパールの高山湖，ララ湖（標高2,990m）から *S. raraensis*, *S. macrophthalmus*, *S. nepalensis* の3新種を記載した．前2種は，腹鰭，背鰭の位置，背鰭長，頭長，ひげの長さ，両眼間隔，吻長，眼径の諸形質の組み合わせによって，同属他種と区別出来る．また，*S. nepalensis* は，下顎前縁を被う角質鞘が鋭利でないこと，ひげの長さによって同属他種と区別出来る．これら3種は形態的に異なるだけでなく，食性や産卵生態にも各々特徴が認められた．また，ララ湖周辺の渓流を含むネパール内の魚類相調査の結果，これら3種はララ湖の固有種であると思われる．ララ湖は河川

争奪によって，古ムグカルナリ川の流路に出来たとされていることから，その形成時に3種の祖先種が渓流より隔離され，その後静水環境下において，同所的に種分化を起こしたものと思われる．

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