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Relative abundance, sex ratio and population structure of the Japanese eel *Anguilla japonica* in the Tanshui River system of northern Taiwan

W.-N. TZENG*, P.-W. CHENG† AND F.-Y. LIN*

**Department of Zoology and †Institute of Fishery Sciences, College of Science, National Taiwan University, Taipei, 10617 Taiwan, Republic of China*

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From the Gong-Shy-Tyan (GST) Stream and the Tanshui River, Taiwan, eels ranged from 5·53 cm T.L. (elvers) to 72·5 cm T.L. *Anguilla japonica* accounted for 93–99%, *A. marmorata* 1–7% and *A. bicolor pacifica* less than 1% of all eels caught. Mean eel lengths increased from 10 cm T.L. at the downstream sites to 50 cm T.L. at the upstream sites. Females made up 92·8% of the sex-determined eels. Population density, averaged approximately 0·14 eel m^{-2} (2·42 g m^{-2}) and 0·25 eel m^{-2} (0·92 g m^{-2}) in downstream sites of the GST and Tanshui River, respectively, and decreased substantially with upstream distance. Eels were rarely found in the heavily polluted and dam constructed areas in the midstream site of the Tanshui River.

Key words: eel; *Anguilla japonica*; species composition; abundance; sex ratio; population structure; pollution; Tanshui River; Taiwan.

INTRODUCTION

Japanese eel, *Anguilla japonica* Temminck & Schlegel, is the most numerous species among the four anguillid eels in Taiwan (Tzeng, 1982, 1983*a*; Tzeng & Tabeta, 1983). Eels spawn in the middle Pacific Ocean, approximately 14–16° N, 134–143° E to the west of the Mariana Islands (Tsukamoto, 1992) during June–July (Tsukamoto, 1990; Tzeng, 1990), and are distributed south from the Philippines, through Taiwan, mainland China, Korea and north to Japan. Eels metamorphose at approximately 4–5 months old from leptocephalus to elver in the coastal waters during their migration from the ocean to the estuaries (Tzeng & Tsai, 1992). Elvers are caught in estuaries during their upstream migration and stocked in freshwater ponds for aquaculture (Tzeng, 1985). Due to the rapid development of the eel aquaculture industry in Taiwan, the supply of elvers is insufficient to meet the demand (Tzeng, 1983*b*, 1986).

A number of studies on the life history of the elver in Taiwanese estuaries have been conducted, including reports on age and birth date (Tabeta *et al.*, 1987; Tzeng, 1990; Umezawa & Tsukamoto, 1990), stock identification and larval migration (Tzeng & Tsai, 1992), immigration timing in relation to environmental cues (Tzeng, 1984*a*, 1985), and exploitation rates (Tzeng, 1984*b*). However, little is known concerning the ecology of the adult eel in the freshwater streams of Taiwan.

This paper attempts to clarify the population structure and distribution ecology of the Japanese eel in the freshwater streams of Taiwan, particularly species composition, distribution, population density and sex ratio.

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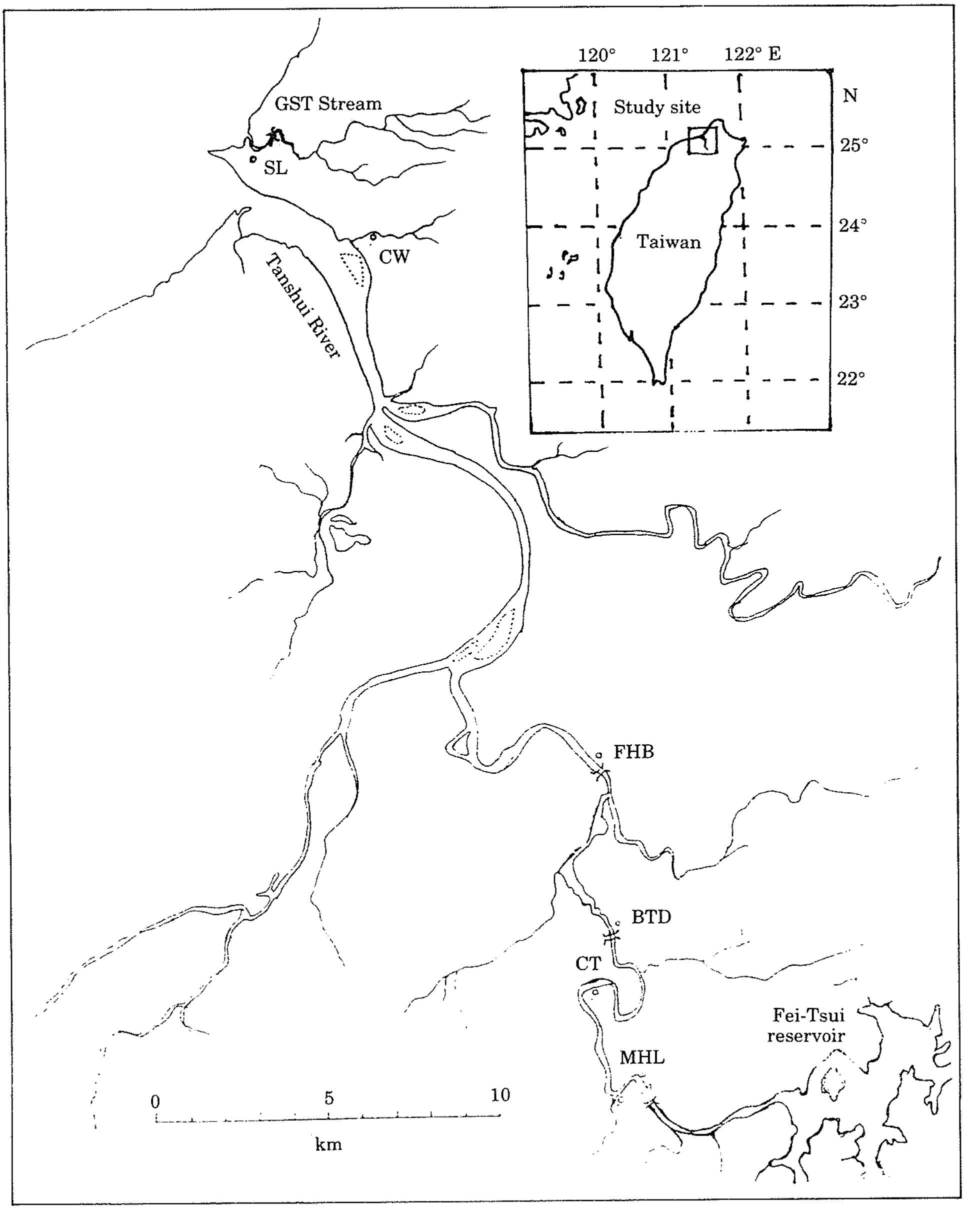

FIG. 1. Location of the sampling stations in the Gong-Shy-Tyan (GST) Stream and Tanshui River, North Taiwan. BTD, Bi-Tang dam; CT, Chin-Tang; CW, Chu-Wei; FHB, Fu-Ho bridge; MHL, Mei-Hua Lake; SL, Sha-Lung.

MATERIALS AND METHODS

STUDY SITE

Sampling was conducted in two streams in northern Taiwan (Fig. 1). The Gong-Shy-Tyan (GST) Stream is a small stream moderately polluted by domestic sewage, whose water level varies greatly with precipitation. Three stations for eel collection were selected in the GST at Sha-Lung. Station 1 was near the estuary, with a water depth less than 1 m, and scarcely affected by sea water. Station 2 was at the base of a small dam and was characterized by a diverse topography, with fast water movement during flood periods. A by-pass in the small dam allowed eels to migrate upstream. Station 3 was located above the small dam, approximately 100 m from Station 2, an area with slow water movement. All three stations were next to a wide rice field and the stream banks were covered with woody scrub and herbs.

The Tanshui River is the largest river in northern Taiwan, approximately 165 km long. The eels were collected in the down-, mid-, and upstream sites of the river at Chu-Wei, Fu-Ho bridge, Bi-Tang dam, Chin-Tang and Mei-Hua Lake (a corner pool), respectively (Fig. 1). As the river in the lower reaches was too wide and deep to collect eels with electrofishing apparatus, a tributary of the river at Chu-Wei was substituted. The midstream areas of the river were heavily polluted by domestic sewage and factory effluent at Fu-Ho bridge, and blocked by a water dam at Bi-Tang, both of which probably influence the upstream migration of the eels.

SAMPLING DESIGN

Eels were collected monthly using electrofishing apparatus in daylight from August 1991 through August 1993. The sampling time at each station was preset at approximately 30 min. Eels were separated from the rest of the catch and preserved in ice or 95% alcohol in the field. The eel made up a large proportion of the total catch, especially in downstream sites (Appendix Table I). Many environmental factors were monitored, but only water temperature, salinity, dissolved oxygen and pH are analysed in this paper.

The eels were identified and measured to the nearest 0·1 mm in total length (T.L.) and weighed to the nearest 1·0 g for the smaller ones, to the nearest 1·0 mm T.L. and 1·0 g for the larger ones. Sex was determined from a histological section of the gonad after Hematoxylin-Eosin staining.

DATA ANALYSIS

The density and biomass of the eels per unit area (m^2) were estimated. The total area swept at each station (A_j) was calculated as follows:

$$A_j = T_j \times a \qquad (1)$$

where (T_j) was the duration of the survey, and (a) was the mean area swept in unit time:

$$a = \frac{1}{n} \sum_{i=1}^{n} d_i \times w/t_i \qquad (2)$$

where, d_i was the distance surveyed in each station during time t_i, and w was the swept width of the electrofishing apparatus; (a) was estimated only at the initial period to reduce the labour.

Eels for otolith-aging and stomach content analysis were preserved in 95% alcohol. Body length shrinkage due to alcohol preservation was adjusted according to the following formula;

$$y = 1{\cdot}05x - 4{\cdot}26 \qquad (3)$$
$$(n = 19,\ r^2 = 0{\cdot}999)$$

where x was the total length (mm) of the eel after 72 h in 95% alcohol and y was the total length of the fresh eel preserved with ice (range: 86·4–211·7 mm T.L.).

In addition, the differences in abundance and biomass of eels collected between years, months and locations were compared by ANOVA (Sokal & Rohlf, 1969).

RESULTS

Water temperature was highest (31·9° C) in August 1992 and lowest (13·1° C) in January 1992 in GST Stream at Sha-Lung (Fig. 2). The trends of water

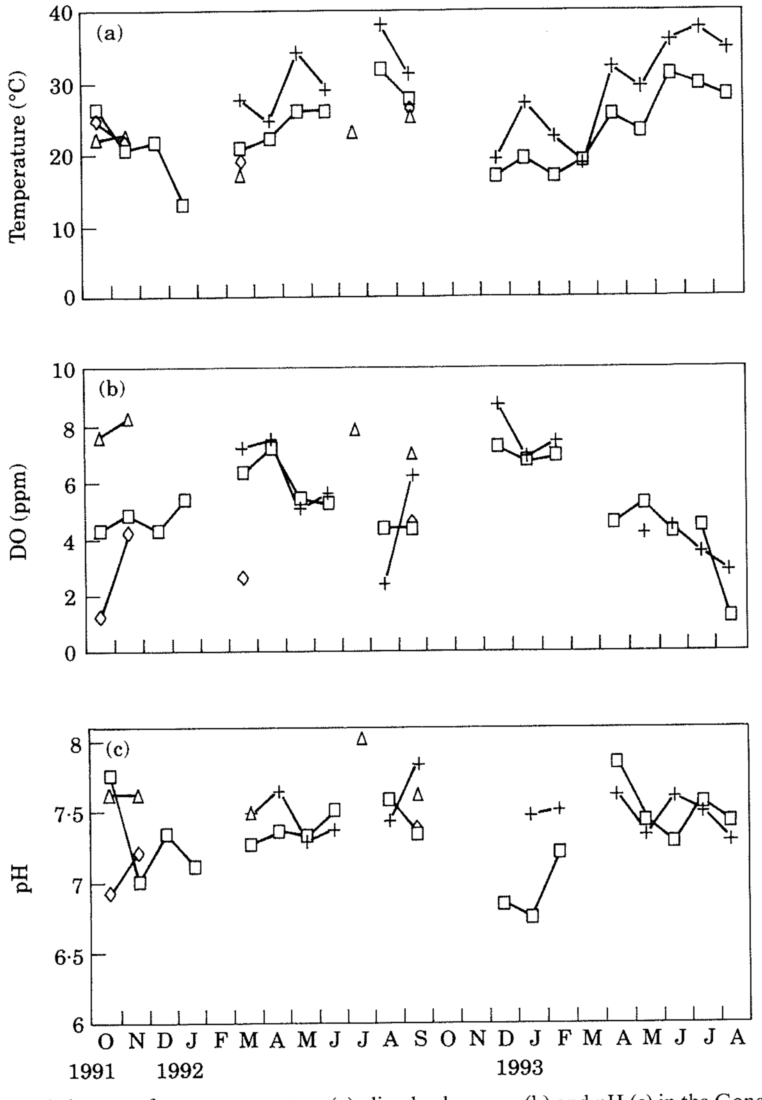

FIG. 2. Seasonal changes of water temperature (a), dissolved oxygen (b) and pH (c) in the Gong-Shy-Tyan Stream at Sha-Lung (□), and the down, middle and upper stream areas of Tanshui River at Chu-Wei (+), Fu-Ho bridge (◇) and Bi-Tang dam (△), October 1991–August 1993.

temperatures in the Tanshui River at Chu-Wei were similar to those of the GST Stream at Sha-Lung, but the temperature in the Chu-Wei was higher than that in the GST Stream because of thermal pollution from nearby factory effluents.

Dissolved oxygen (DO) also showed an obviously seasonal change in both GST Stream and Tanshui River, lower in summer-autumn and higher in winter-spring (Fig. 2). DO was related to the water current resulting from precipitation. DO was lower in Sha-Lung and Chu-Wei during the period from July to August 1993 because of very low precipitation and high temperatures. DO also varied with distance from the river mouth. At Fu-Ho bridge, DO decreased to 1·2 ppm in October and 2·4 ppm in August, indicating that the river around Fu-Ho bridge was heavily polluted. But DO increased at Bi-Tang dam, to approximately 8·0 ppm in the corresponding period, probably due to water overflow at the dam. Generally, the GST Stream and the Tanshui River at the midstream site were polluted as indicated by low DO.

pH in the GST Stream and in the Tanshui River at Chu-Wei ranged from 7·0–7·7 in most of the sampling period (Fig. 2), but was lower than 7·0 both in the Tanshui River around Fu-Ho bridge during March 1992 and in the GST Stream at Sha-Lung during January 1993. This also indicated that the river at the midstream site was heavily polluted.

SPECIES COMPOSITION

A total of 1531 eels was collected from the stations of the GST Stream and Tanshui River at downstream and upstream sites from August 1991 to August 1993 (Table I). Japanese eel, *Anguilla japonica*, was the most numerous species, making up 93–99% of the total number of anguillid eels. The other two species, *A. marmorata* Quoy & Gaimard (1–7%) and *A. bicolor pacifica* (Schmidt) (less than 1%), were very rare. *Anguilla japonica* is a temperate species, the other two are tropical species. Accordingly, eels in the rivers of northern Taiwan are mainly made up of the temperate species, *A. japonica*.

POPULATION DENSITY

The population density of the eels was significantly different between stations at downstream sites in the GST Stream and Tanshui River ($P<0{\cdot}0001$), but not significantly different in biomass ($P>0{\cdot}05$). The population density in mean (± S.D.) abundance of the eels dramatically decreased from $0{\cdot}14 \pm 0{\cdot}023$ eels m^{-2} at Station 1 to $0{\cdot}04 \pm 0{\cdot}008$ eels m^{-2} at Station 3 in the GST Stream. Overall mean (± S.D.) biomass of the eel was $1{\cdot}99 \pm 0{\cdot}211$ g m^{-2} (Table II).

Population density in abundance clearly increased during the period from December through April both at the Station 1 of the GST Stream and in the Tanshui River at Chu-Wei [Fig. 3(a)]. This increase followed the greatest immigration period, in both areas, of the elvers into the estuary (Tzeng, 1985). However, the seasonal change in biomass was not obvious [Fig. 3(b)].

SEX RATIO

The change in sex ratio of the eels in the freshwater streams of Taiwan was shown by fish length and habitat (Table III). The length–frequency distribution overlapped between sexually undifferentiated and differentiated fish. It was difficult to discriminate between males and females for a large proportion of the eels less than 30 cm T.L. The proportion of eels being sex-determined increased with fish length [Table III(a)]. Length–frequency distributions were similar between female and male eels, with their mean length being *c.* 40 cm T.L. (Fig. 4). However, most eels larger than 50 cm T.L. were female.

TABLE I. Number of anguillid eels collected in the Gong-Shy-Tyan Stream and Tanshui River, August 1991–August 1993

	Gong-Shy-Tyan Stream				Tanshui River							
					Downstream				Upstream			
	A.j.	*A.m.*	*A.b.*	Sum	*A.j.*	*A.m.*	*A.b.*	Sum	*A.j.*	*A.m.*	*A.b.*	Sum
1991												
Aug.	—	—	—	—	—	—	—	—	7	0	0	7
Sep.	5	0	0	5	—	—	—	—	14	1	1	16
Oct.	5	0	0	5	—	—	—	—	10	0	0	10
Nov.	14	0	0	14	—	—	—	—	—	—	—	—
Dec.	33	0	0	33	—	—	—	—	28	0	0	28
1992												
Jan.	40	1	1	42	—	—	—	—	17	0	0	17
Feb.	25	6	0	31	24	0	0	24	8	0	0	8
Mar.	29	11	0	40	22	0	0	22	25	0	0	25
Apr.	57	13	0	70	51	3	0	54	2	0	0	2
May	21	0	0	21	18	0	0	18	12	0	0	12
Jun.	22	1	0	23	11	0	0	11	7	0	0	7
Jul.	—	—	—	—	—	—	—	—	12	0	0	12
Aug.	24	0	0	24	15	0	0	15	1	0	0	1
Sep.	2	0	0	2	20	0	0	20	—	—	—	—
Oct.	—	—	—	—	—	—	—	—	—	—	—	—
Nov.	11	0	0	11	—	—	—	—	—	—	—	—
Dec.	25	0	0	25	8	0	0	8	—	—	—	—
1993												
Jan.	26	1	0	27	49	0	0	49	—	—	—	—
Feb.	10	8	0	18	29	8	0	37	—	—	—	—
Mar.	39	0	0	39	177	7	0	184	—	—	—	—
Apr.	17	1	0	18	45	0	0	45	—	—	—	—
May	22	2	0	24	37	3	0	40	—	—	—	—
Jun.	13	0	0	13	14	0	0	14	—	—	—	—
Jul.	181	3	0	184	113	0	0	113	—	—	—	—
Aug.	62	1	0	63	0	0	0	0	—	—	—	—
Total No.	683	48	1	732	633	21	0	654	143	1	1	145
%	93	7	<0·01		97	3	0		99	<0·01	<0·01	

A.j., *Anguilla japonica*; *A.m.*, *Anguilla marmorata*; *A.b.*, *Anguilla bicolor pacifica*.

To understand the sex ratio of the eels in the natural streams of Taiwan, eels collected from the Lu-Kang eel culture pond and Mei-Hua Lake were excluded in calculation of the overall sex ratio [Table III(b)] because the sex ratio has been reported to be different between eel culture ponds and natural streams (Egusa & Hirose, 1973). Female eels were extremely predominant, making up 92·8% of the total catch of the wild eel population from the GST Stream and Tanshui River [Table III(b)]. Male eels seemed to be more numerous in the LK eel culture pond, making up 80% of the catch; however sample size was small ($n=10$). The eels collected from Mei-Hua Lake, which was probably mixed with cultured eels, were slightly dominated by females (66·0%).

TABLE II. Mean (± S.D.) abundance (No. m^{-2}) and biomass (g m^{-2}) of the eel, *Anguilla japonica*, collected in the Gong-Shy-Tyan Stream and Tanshui River, Taiwan, Oct. 1991–Aug. 1993

	Gong-Shy-Tyan Stream			Tanshui River	Total
	St1	St2	St3		
Abundance	0·14 ± 0·023	0·07 ± 0·019	0·04 ± 0·008	0·25 ± 0·032	0·12 ± 0·010
Biomass	2·42 ± 0·068	1·87 ± 0·290	1·71 ± 0·403	1·92 ± 0·486	1·99 ± 0·211

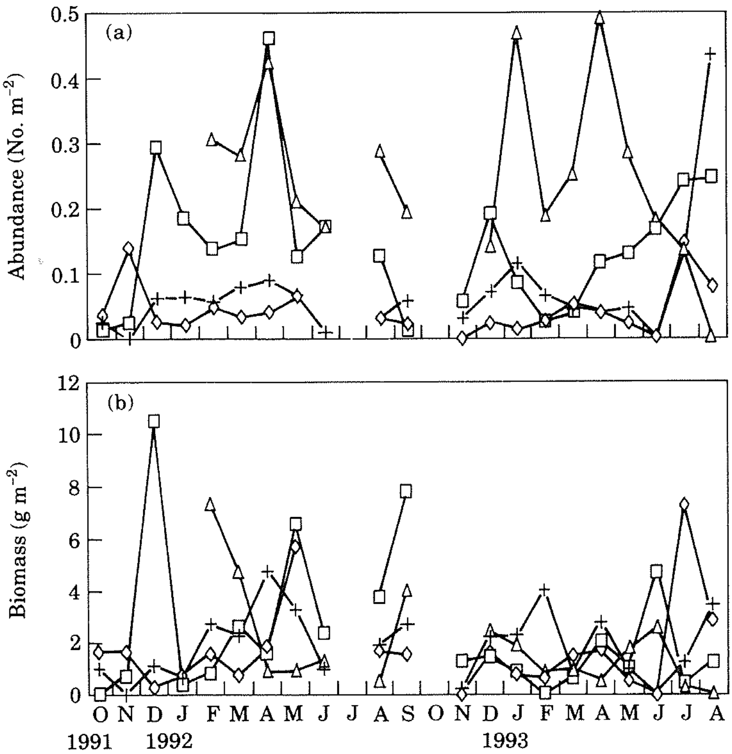

FIG. 3. Seasonal changes in abundance (a) and biomass (b) of the Japanese eel, *Anguilla japonica*, at the three stations of the Gong-Shy-Tyan Stream at Sha-Lung (□, St1; +, St2; ◇, St3) and a tributary of Tanshui River at Chu-Wei (△).

LENGTH–FREQUENCY DISTRIBUTION

Seasonal change

The size of Japanese eels caught in the GST Stream and the Tanshui River, ranged from 5·53 cm T.L. at elver stage to 72·5 cm T.L. at adult stage. The monthly length–frequency distributions indicated that the yearling eels, recruited into both the stream and the river beginning from approximately December through May, had a mean length of 5–10 cm T.L., and grew to 25–30 cm T.L. in the next year (Figs 5 and 6). The eels in the GST Stream and Tanshui River at

TABLE III. Sex ratio of the Japanese eel, *Anguilla japonica*, by fish length (a) and sampling location (b), caught in the Gong-Shy-Tyan Stream at Sha-Lung (SL), Tanshui River at Chu-Wei (CW), Mei-Hua Lake (MHL) and Lu-Kang (LK) eel culture pond

(a) By fish length

Total length (cm)	No. of eel examined	No. of eel sex-undetermined	Sex ratio (%)	
			Male	Female
<20	45	40	1 (20·00)	4 (80·00)
20 ~ 30	79	52	1 (3·70)	26 (96·30)
>30	80	15	5 (7·69)	60 (92·31)
Total*	204	107	7 (7·22)	90 (92·78)

(b) By location

Location	No. of eel examined	No. of eel sex-undetermined	Sex ratio (%)	
			Male	Female
SL	182	90	5 (5·43)	87 (94·57)
CW	22	17	2 (40·00)	3 (60·00)
MHL	56	3	18 (33·96)	35 (66·04)
LK	10	0	8 (80·00)	2 (20·00)
Total*	204	107	7 (7·22)	90 (92·78)

*MHL and LK are excluded.

Chu-Wei were composed mainly of 1- and 2-year-old fish. In contrast, the length–frequency distribution of eels caught from the upstream site of the Tanshui River at Mei-Hua Lake showed no marked seasonal change; the size of the eels was larger, approximately 50 cm T.L., indicating that they were approximately 3 years old or more (Fig. 7).

Comparison between stations

The size of eels in the GST Stream increased with distance from the river mouth. The mean lengths of the eel increased from 5–10 cm T.L. at Station 1 to 25–30 cm T.L. at Station 3 (Fig. 8). The mean lengths of eels at Stations 2 and 3 were 21·6 and 28·5 cm T.L., respectively, which were significantly greater than those at Station 1 (16·3 cm T.L.) ($P<0{\cdot}001$). The distribution of the length–frequency of the eels at Station 1 was positively skewed. The frequency dramatically increased at the 5–10 cm interval, indicating that a great number of elvers immigrated into Station 1 at a fixed size, and then gradually decreased, further indicating that the fish migrated upstream rapidly with growth [Fig. 8(a)]. In addition, a maturing eel of 72·5 cm T.L. was found at Station 1, which seemed to be a seaward migrating spawning eel. The length–frequency of the eels at Station 3 was close to a normal distribution

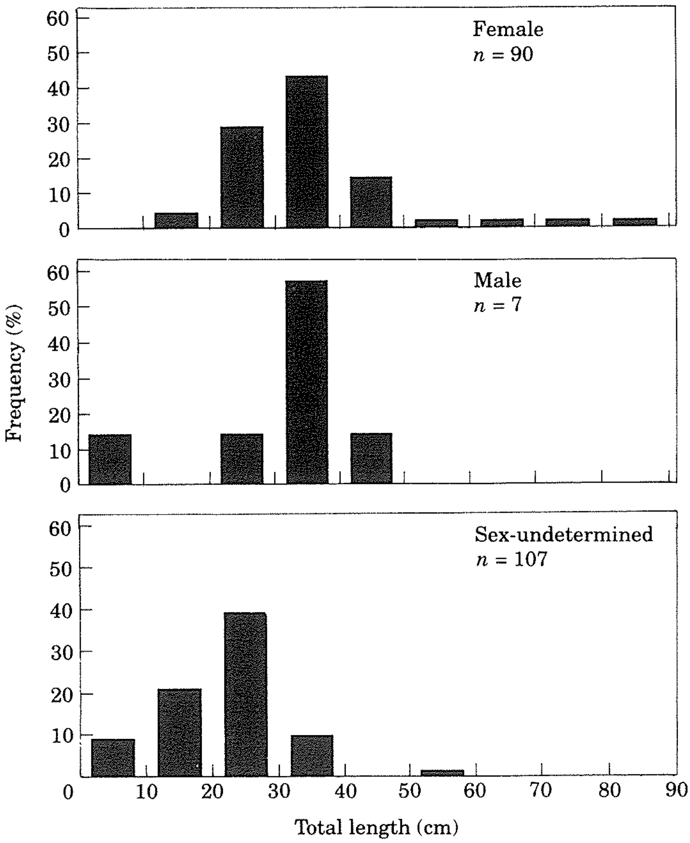

FIG. 4. Length–frequency distribution of female, male and sex-undetermined eels, *Anguilla japonica*, in natural populations in the freshwater streams of Taiwan. The samples from LK and MHL as Table II are excluded. *n*, Sample size.

[Fig. 8(c)], but that at Station 2 showed great dispersion, probably because of the diverse habitat [Fig. 8(b)].

Similarly, the mean lengths of the eels in the Tanshui River also increased with distance from the river mouth [Fig. 8(d)]. The length–frequency of eels at the downstream site of the river at Chu-Wei was similar to that at the first station of GST Stream. However, the length of the eels at the upstream site of the Tanshui River at Mei-Hua Lake was significantly greater ($P<0{\cdot}001$), mean of 45–50 cm T.L. [Fig. 8(e)]. This also indicated that the Japanese eel moved upstream with growth.

DISCUSSION

Four species of anguillid eels have been recorded in Taiwan (Tzeng, 1982, 1983*a*; Tzeng & Tabeta, 1983). *A. japonica* is a temperate species and the other three species, *A. marmorata*, *A. celebesensis* Kaup and *A. bicolor pacifica*, are tropical species (Tesch, 1977). The occurrence of the anguillid eels corresponds to their zoogeographical distribution documented in this area

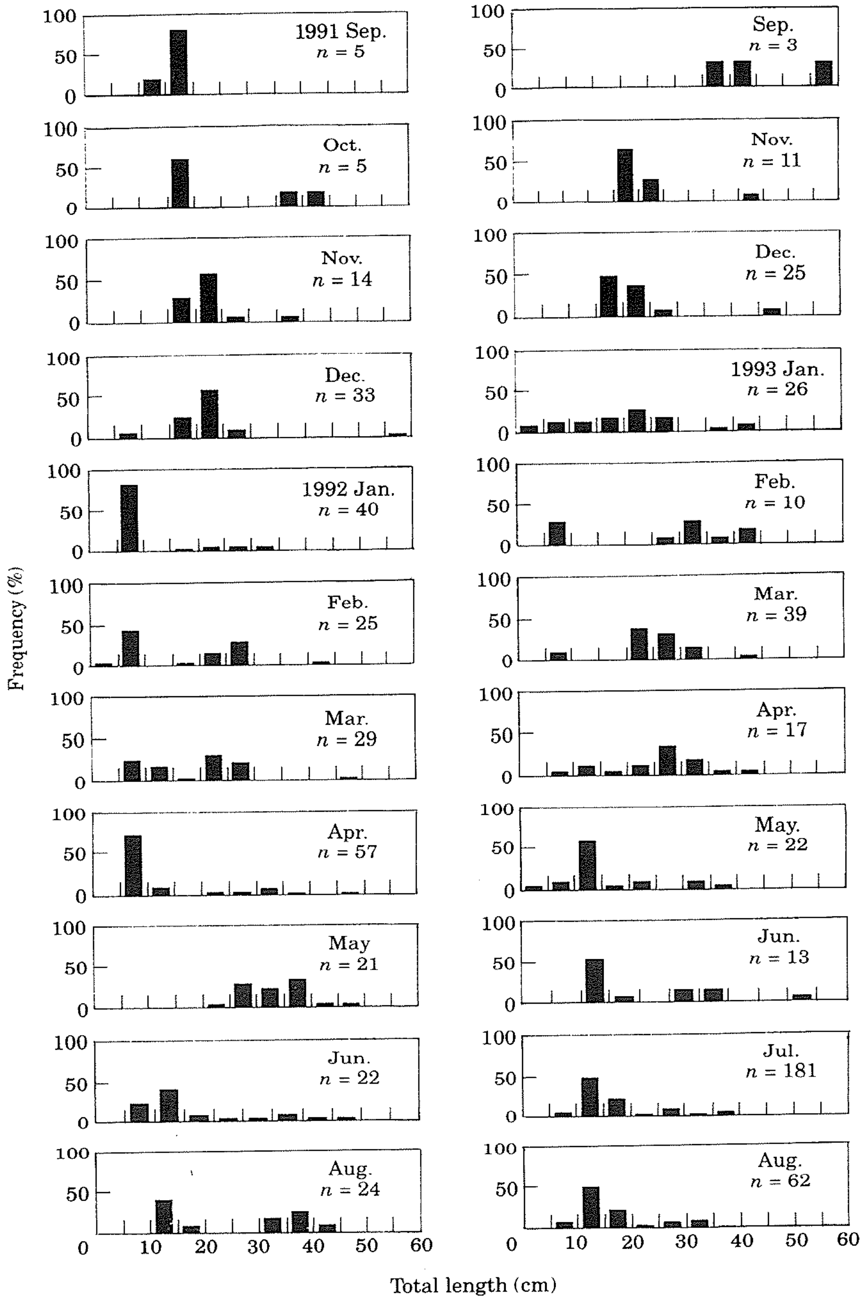

FIG. 5. Monthly length–frequency distributions of *Anguilla japonica* collected in the GST Stream from September 1991 through August 1993.

(Tesch, 1977; Tzeng, 1982; Tzeng & Tabeta, 1983). Taiwan is located in the subtropical zone, but *A. japonica*, the temperate species, is abundant in this area, making up 93–99% of the total anguillid eel catch (Table I). This finding

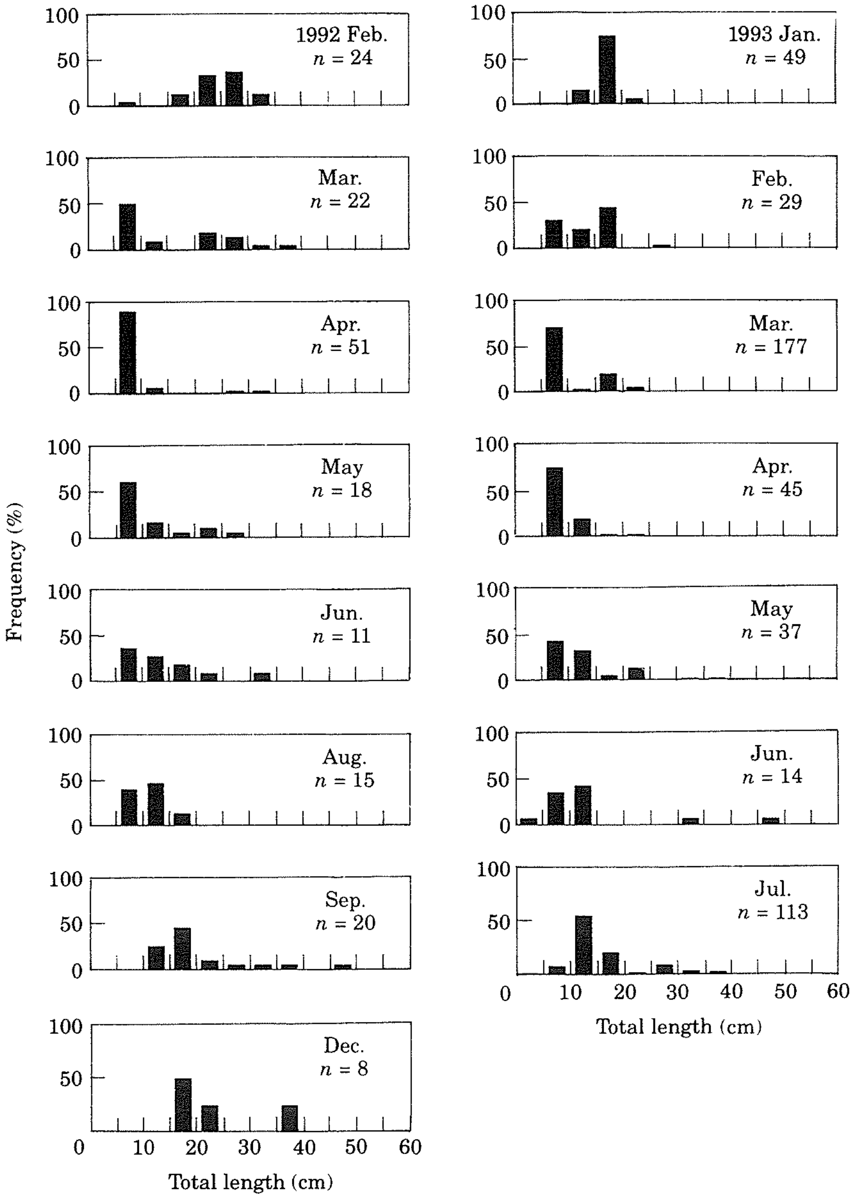

FIG. 6. Monthly length–frequency distributions of *Anguilla japonica* collected in the Tanshui River at Chu-Wei from February 1992 through July 1993.

contradicts the conventional concept that *A. marmorata* is predominant among the anguillid eels in the streams of Taiwan. Owing to the dramatic decrease in its population, *A. marmorata* was recently assigned endangered species status in Taiwan.

The population densities of the Japanese eel in the downstream sites of both the GST Stream and the Tanshui River were approximately 0·14 and 0·25 eel

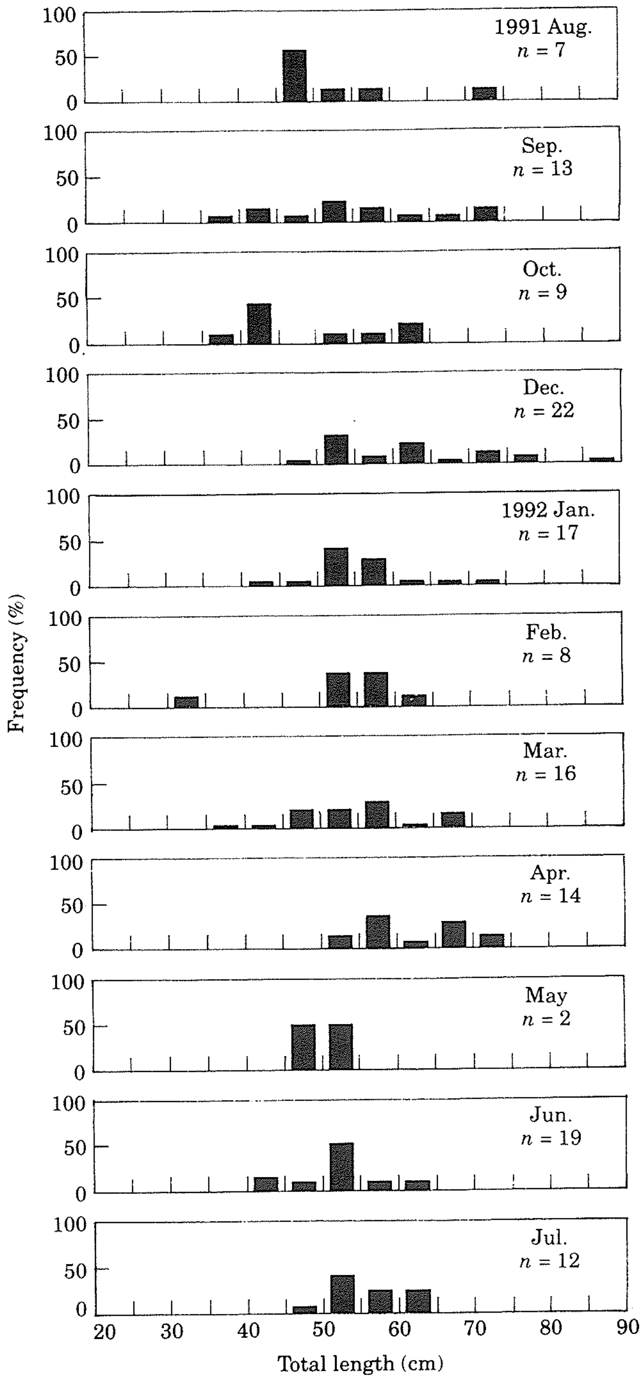

FIG. 7. Monthly length–frequency distributions of *Anguilla japonica* collected in the Mei-Hua Lake in the upstream of Tanshui River from August 1991 through July 1992.

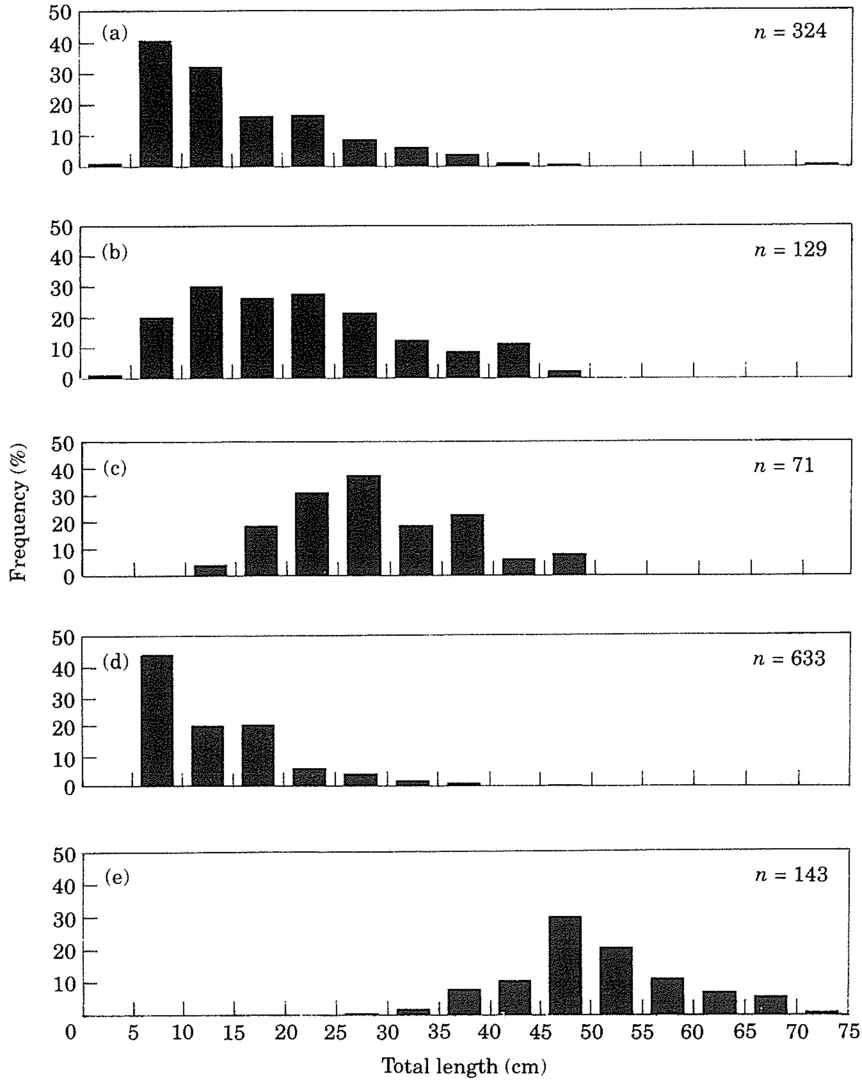

FIG. 8. Length–frequency distribution of *Anguilla japonica* caught in the three stations of Gong-Shy-Tyan Stream at Sha-Lung [(a)–(c)] and in the down- and upstream areas of Tanshui River at Chu-Wei (d) and Mei-Hua Lake (e), September 1991–August 1993. *n*, Sample size.

m^{-2}, respectively (Table III), which are greater than that of the European eel *A. anguilla* L. in the rivers of eastern England (0·005–0·0518 eel m^{-2}) (Barak & Mason, 1992) and in the River Severn, SW England (0·0015–0·0242 eel m^{-2}) (Aprahamian, 1986); but less than that in River Tweed, NE England (1·2–3·57 eel m^{-2}) (Hussein, 1981) and in a small Danish stream (1·012 eels m^{-2}) (Rasmussen & Therkildsen, 1979). On the other hand, due to the rapid development of the eel aquaculture industry in Taiwan, the elver was over-exploited before upstream migration (Tzeng, 1984*a*, *b*), and thus the population size of the Japanese eel in the stream decreased markedly.

In addition, the population density of the eel decreased dramatically with upstream distance (Table II). No eels were found at the midstream sites of the Tanshui River. The decrease in eel numbers in the upper Tanshui River was probably due to (1) pollution, e.g. the low DO in the midstream site at Fu-Ho bridge, (2) barriers, e.g. the dam construction at Bi-Tang, and (3) illegal fishing. These man-made habitat changes and overfishing have severely influenced the eel's survival in the stream. However, a few large eels were caught in Mei-Hua Lake at the upstream site of the Tanshui River. The eels in the upstream area were mixed with a population of cultured eels released by a local animal conservation group. These released eels were recognized easily by fishermen from their abnormal external features and colour pattern. We did not investigate how the natural Japanese eels could withstand pollution and overcome the dam barrier in the midstream to reach the upstream areas. However, it has been reported that the Australian eel, *A. australis australis* Richardson, elvers can climb vertically over a 20-m dam (Sloane, 1984). Accordingly, the natural eels in the Mei-Hua Lake are probably able to climb the Bi-Tang dam and move upstream during flood periods, when pollutants are diluted.

The mean total length of Japanese eels in the streams of Taiwan increased with distance from the river mouth (Fig. 8). This phenomenon was also found in Australian and European eels (Deelder, 1970; Jellyman, 1977; Aprahamian, 1986; Naismith & Knights, 1988). Barak & Mason (1992) also indicated that mean age of European eel differed with location, younger at downstream and older at upstream sites. In general, the growth of the eel was faster in females than males (Sinha & Jones, 1967; Vøllestad & Jonsson, 1986). In many instances, upstream eels were nearly all females, with the males predominant in the lower section of the river. These facts probably led to the mean size of the eels increasing with distance upstream. Unfortunately, because age and growth information was lacking and the males were few in the catch, we could not infer if the increase in mean size was correlated with growth and distribution differences between sexes.

Females made up 92·8% of the Japanese eel population in the natural freshwater streams of Taiwan [Table III(a)]. A similar higher proportion of females in natural population was also found in wild European eel populations in the Imsa River, Norway (Vøllestad & Jonsson, 1986). In contrast, the European eel stocked in intensive eel culture ponds was dominated by males, making up 75–90% (Egusa & Hirose, 1973; Egusa, 1979). This phenomenon was also found in the Japanese eel from the LK eel culture pond, although the sample size was small [Table III(b)]. The mechanism of sex-determination in the eel is not clear (Wiberg, 1983; Colombo *et al.*, 1984). A study on European eels suggested that elvers reaching the coast were asexual, dispersing in a random manner, and that sexual determination depended on the environment in which they grew (phenotypic determination). Overcrowding and poor feeding would give to rise to male eels and low population densities, while rich feeding would favour females (Parsons *et al.*, 1977; Vladykov & Liew, 1982). Our results seem to substantiate this case. Owing to overfishing, the population density of eels in the freshwater streams of Taiwan has decreased dramatically. Low population density has probably led to a preponderance of females in Taiwan streams [Table III(b)]. On the other hand, it was reported that because migratory tendencies are different between sexes, male eels generally live in estuaries and are scarce upriver, whereas females are found in fresh water and in progressively larger proportions further away from the sea (Bigelow & Schroeder, 1953; D'Ancona, 1959, 1960; Dolan & Power, 1977; Helfman *et al.*, 1984). However, the eel sampling stations in the GST Stream were near the estuary and the eels collected were mainly made up of sex-undifferentiated smaller individuals, whereas the sex-differentiated eels were mainly female (94·57%) (Table III). Our studies, therefore, could not support the hypothesis that males remained in the estuary and females migrated upriver.

In conclusion, the density of the Japanese eel population in freshwater streams of northern Taiwan decreased markedly, and is dominated by females.

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APPENDIX

Relative abundance (%) in number and weight of fish caught in the three stations of the Gong-Shy-Tyan Stream (GST) and Tanshui River at Chu-Wei (CW), Fu-Ho bridge (FHB), Bi-Tang dam (BTD), Chin-Tang (CT) and Mei-Hua Lake (MHL), Aug 1991–May 1993. (Wang & Tzeng unpublished data)

Family and species	GST Stream						Tanshui River									
	Station 1		Station 2		Station 3		CW		FHB		BTD		CT		MHL	
	No.	Weight	No.	Weight	No.	Weight	No.	Weight	No.	Weight	No.	Weight	No.	Weight	No.	Weight
Anguillidae																
Anguilla japonica Temminck & Schlegel	33·15	33·03	17·66	26·81	26·95	21·32	82·18	61·20	0	0	0	0	0·47	3·13	0·36	2·68
Anguilla marmorata Quoy & Gaimard	4·28	0·09	0·69	0·67	0	0	5·94	0·05	0	0	2·56	4·68	0	0	0·36	21·32
Anguilla bicolor pacifica Schmidt	0·28	0·01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Homalopteridae																
Hemimyzon formosanum (Boulenger)	0	0	0	0	0	0	0	0	0	0	0	0	0·47	0·07	0	0
Cyprinidae																
Abbottina brevirostris Günther	0	0	0	0	0	0	0	0	0	0	17·95	2·11	1·41	0·27	8·09	1·86
Acrossocheilus poradoxus (Günther)	0	0	0	0	0	0	0	0	0	0	0	0	15·49	12·52	18·75	25·13
Cyprinus carpio Temminck & Schlegel	0·14	5·36	0	0	0	0	0	0	0	0	0	0	0·47	42·57	0	0
Carassius auratus Linnaeus	1·10	5·58	1·15	4·26	1·20	2·04	0	0	0	0	0	0	0	0	0	0
Carassius cuvieri (Temminck & Schlegel)	0	0	0	0	0	0	0	0	0	0	2·56	1·74	0	0	0	0
Rhodeus ocellatus (Kner)	0·14	0·01	3·44	0·29	1·20	0·07	0	0	0	0	0	0	0	0	0	0
Pseudorasbora parva (Temminck & Schlegel)	0	0	0	0	0	0	0	0	0	0	5·13	0·25	0	0	0	0
Varicorhinus barbatulus (Pellegrin)	0	0	0	0	0	0	0	0	0	0	0	0	3·29	2·87	3·31	2·70
Zacco platypus (Temminck & Schlegel)	0	0	0	0	0	0	0	0	0	0	35·90	9·18	49·30	18·54	11·03	10·32
Zacco pachycephalus Günther	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3·68	2·57
Cobitididae																
Cobitis taenia Linnaeus	0	0	0	0	0	0	0	0	0	0	5·13	5·13	2·35	1·34	2·21	1·06
Misgurnus anguillicaudatus (Cantor)	0	0	0	0	0	0	0	0	0	0	0	0	0·47	0·54	0	0
Paramisgurnus dabryanus (Sauvage)	0	0	0	0	0	0	0	0	0	0	5·13	5·13	0	0	1·47	3·64
Crossostoma lacustre Steindachner	0	0	0	0	0	0	0	0	0	0	0	0	4·23	0·66	28·31	15·41
Clariidae																
Clarias fuscus (Lacépède)	0	0	0	0	0	0	0·33	0·13	0	0	0	0	0	0	0	0
Bagridae																
Leiocassis adiposalis (Oshima)	0	0	0	0	0	0	0	0	0	0	0	0	0·94	0·13	1·84	7·27
Plecoglossidae																
Plecoglossus altivelis (Temminck & Schlegel)	0	0	0·23	0·09	0	0	0	0	0	0	0	0	0	0	0	0

Poeciliidae																
Gambusia affinis (Baird & Girard)	1·93	0·06	1·61	0·05	4·19	0·04	1·32	0·05	0	0	2·56	0·07	0	0	0	0
Xiphophorus sp.	0·14	0·04	2·52	0·22	0·60	0·03	0	0	0	0	0	0	0	0	0	0
Synbranchidae																
Fluta alba (Zuiew)	0·14	0·11	0·69	1·08	1·80	1·29	0·33	0·85	1·33	<0·01	2·56	46·90	0	0	0	0
Kuhliidae																
Kuhlia marginata (Cuvier & Valenciennes)	1·80	0·23	3·44	0·26	1·20	0·05	0	0	0	0	0	0	0	0	0	0
Carangidae																
Caranx sexfasciatus Quoy & Gaimard	0	0	0·46	0·33	0	0	0	0	0	0	0	0	0	0	0	0
Lutjanidae																
Lutjanus argentimaculatus (Forsskål)	0	0	0·46	0·14	0	0	0	0	0	0	0	0	0	0	0	0
Gerreidae																
Gerres filamentosus Cuvier	0·14	0·02	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cichlidae																
Tilapia sp.	3·31	5·22	19·95	29·89	35·93	28·94	1·98	7·44	85·33	85·47	15·38	14·28	0	0	0	0
Mugilidae																
Mugil cephalus Linnaeus	0·28	<0·01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liza carinata (Cuvier & Valenciennes)	9·39	7·79	5·28	3·96	0	0	0	0	0	0	0	0	0	0	0	0
Liza macrolepis (Andrew & Smith)	30·80	26·09	33·49	16·30	1·80	1·34	1·98	0·62	0	0	0	0	0	0	0	0
Liza tade (Forsskål)	0·14	0·13	0·23	0·11	0	0	0	0	0	0	0	0	0	0	0	0
Rhyacichthyidae																
Rhyacichthys aspro (Kuhl & Van Hasselt)	0	0	0·46	0·06	0	0	0	0	0	0	0	0	0	0	0	0
Eleotridae																
Eleotris oxycephala Temminck & Schlegel	10·77	3·30	2·98	1·18	11·98	2·99	2·31	0·43	0	0	0·00	0	0	0	0	0
Gobiidae																
Rhinogobius brunneus (Temminck & Schlegel)	0·28	0·04	1·38	0·15	0	0	0	0	0	0	2·56	0·15	19·72	3·76	21·32	6·03
Rhinogobius giurinus Rutter	0·14	<0·01	0·23	0·01	0	0	0·33	0·11	0	0	0	0	0·94	0·48	0	0
Sicyopterus japonicus (Tanaka)	0	0	0	0	0·60	0·11	0	0	0	0	2·56	0·55	0	0	0	0
Awaous melanocephalus (Bleeker)	0·41	0·33	0·46	0·21	1·20	0·27	0·33	0·02	0	0	0	0	0	0	0	0
Channidae																
Channa gachua (Hamilton-Bouchanan)	0·97	9·49	2·75	12·87	10·18	40·60	2·97	28·73	13·33	14·53	0	0	0	0	0	0
Channa maculata (Lacépède)	0·14	3·06	0·46	1·04	1·20	0·91	0	0	0	0	0	0	0·47	12·21	0	0
Unidentified species	0·14	<0·01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No. of sample	16	16	16	16	15	15	11	11	5	5	3	3	4	4	3	3
No. of species	23		22		14		11		3		12		14		12	
No. of individuals	724		436		167		303		75		39		213		274	
Total weight (g)		13052		9588·8		7906·4		3639·8		6487·2		1077·5		2049		2745·1

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