

First Record of the Short-Finned Eel *Anguilla bicolor pacifica* Elvers from Taiwan

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Forty-two elvers of the short-finned eel *Anguilla bicolor pacifica* SCHMIDT were found among 1,915 anguillid elvers caught from the estuaries in southern and northern Taiwan during November 1980–April 1981. The pigmentation, body measurements and vertebral counts were examined. The short distance of ano-dorsal length and lower counts of ano-dorsal vertebrae distinguish them from elvers of *A. japonica* and *A. marmorata*, two other species commonly found in Taiwan. This first record from Taiwan extends the northernmost distribution of this subspecies.

Eighteen species and subspecies of freshwater eels are recognized around the world. Two are found in the northern Atlantic region and the rest in the tropical and temperate Indo-Pacific region. Based on the ano-dorsal length as a percentage of total length, they can be classified into long-finned and short-finned eels. Thirteen species and subspecies belong to the first category and the remainders to the second one.¹⁻³⁾

Only two species of long-finned eel *Anguilla japonica* TEMMINCK & SCHLEGEL and *A. marmorata* QUOY & GAIMARD, have been reported in Taiwan.⁴⁻⁶⁾ Since November 1980, a number of short-finned elvers were collected by one of the authors in the estuaries of Taiwan while conducting ecological investigation of elvers. The purpose of this study is to identify these short-finned elvers.

Materials and Methods

The elvers were caught by dip nets at night by local fishermen in the estuaries during winter months in Taiwan. The fishermen classified these elvers into white- and black-types according to the pigmentation on the tail. The white-type was sold for eel culture, but the black-type has not been cultured in Taiwan. A total of 1,915 elvers was purchased for species identification from the local fishermen who collected them in the estuaries of River Shin-Ting, River Shuang and River Gong-Shy-Tyan, Taipei Prefecture and River Tungkang, Pintung Prefecture (Fig. 1) from

November 1980 to April 1981. The elvers were fixed in 10% formalin solution. The short-finned eel elvers were sorted out easily because of their short ano-dorsal length³⁾ and specific caudal pigmentation.⁷⁾

The number of short-finned elvers used for various measurements and counts is shown in Table 1. The pigmentation stages were determined following the methods described by STRUBBERG⁸⁾ and BERTIN.³⁾ Six morphometric characters as shown in Fig. 2, i.e. total length, standard length, predorsal length, preanal length,

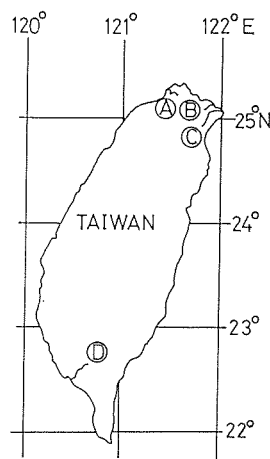


Fig. 1. Map showing the rivers from which samples were collected. A, River Gong-Shy-Tyan; B, River ShihTing; C, River Shung; D, River Tungkang.

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Table 1. Number of anguillid elvers used in this study. Numerals in the parentheses indicate the number of short-finned elvers found and measured

	No. of anguillid elvers (short-finned elvers)
Specimens collected	1,915 (42)
Specimens studied	
Developmental stage	1,239 (42)
Body measurement	1,182 (38)
Vertebral counts	433 (17)

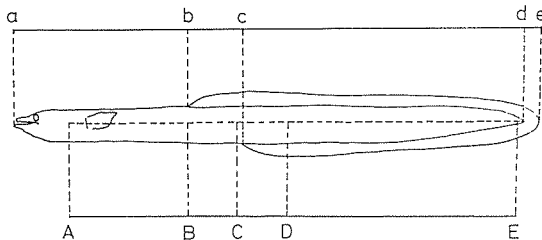


Fig. 2. Diagram showing body measurements and vertebral counts of the elvers. a-b, predorsal length; a-c, preanal l.; a-d, standard l.; a-e, total l.; A-B, predorsal vertebrae; A-C, preanal v.; B-C, ano-dorsal v.; A-D, abdominal v.; D-E, caudal v.; A-E, total v.; B & C, the vertebrae cut by the vertical lines through origin of dorsal fin and anus, respectively.

ano-dorsal length and body depth (at dorsal origin) were measured. The sectional counts of vertebrae were made after alizarin treatment⁽⁶⁾ (Fig. 2).

Results

A total of 42 short-finned eel elvers was found in the rivers of northern and southern Taiwan: 28 specimens from River Shin-Ting, 7 from River Shuang, 2 from River Gong-Shy-Tyan and 5 from River Tungking (Fig. 1).

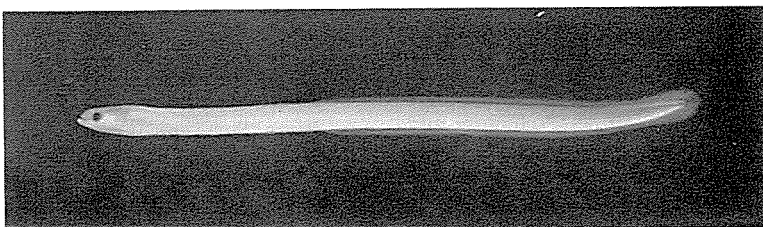


Fig. 3. Photograph of the short-finned elver *Anguilla bicolor pacifica* found on Nov. 29, 1980 at River Tungking, Pingtung Prefecture, Taiwan, 47.2 mm TL.

Table 2. Body measurements of the short-finned elver (the same specimen as shown in Fig. 3)

Total length	47.2 mm
Body length	46.1 mm
Predorsal length	17.7 mm
Preanal length*	18.2 mm
Ano-dorsal length	0.5 mm
Head length	5.4 mm
Eye diameter	0.8 mm
Snout length	0.9 mm
Upper jaw length	1.3 mm
Lower jaw length	1.5 mm
Body height at dorsal fin origin	2.3 mm
Pectoral fin length	1.3 mm

* From the tip of lower jaw to the anus.

Description of the Short-finned Eel Elver

Characteristics of the elvers were described from a specimen 47.2 mm TL collected from River Tungking, Pingtung Prefecture, on November 29, 1980 (Fig. 3). The detailed body measurements are given in Table 2. In live specimen, the body is transparent; the visceral organs and vertebrae are clearly visible; slender, and cylindrical. The ano-dorsal length is very short, occupying ca 1.0% of the total length. This is the most marked external feature for the elver.

Pigmentation stage is VIA 2³⁾: there are no preanal ventro-lateral pigments. The pattern of the smaller melanophore spots on the caudal fin is conspicuous and very much like that of *Anguilla bicolor pacifica* SCHMIDT described by TABETA *et al.*⁽⁷⁾

Size Composition and Pigmentation Stage

Of the 42 short-finned eel elvers found among the 1,915 elvers, four had deformed external features due to formalin fixation. The total lengths of the remaining 38 short-finned eel elvers ranged from 44.0 to 64.0 mm (Fig. 4). The mode and mean were located between 46.0 and 48.0 mm. In general, the total length of the elvers fell near the mean, but two large elvers had lengths falling between 62.0 and 64.0 mm.

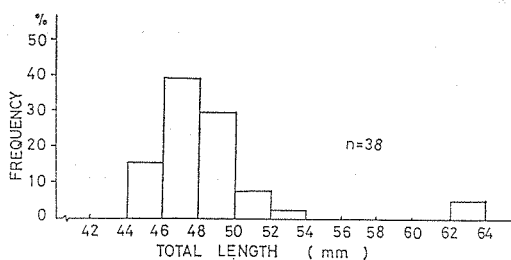


Fig. 4. Length frequency distribution of the elvers of *A. bicolor pacifica* caught in the rivers of Taiwan.

Table 3. Development of subepidermal pigment in the elvers of *A. bicolor pacifica* caught in the rivers of Taiwan. Developmental stages were determined according to BERTIN⁸⁾

Stage	No. of specimen	%
VA	0	
VB	3	7.14
VIA 1	5	11.90
VIA 2	25	59.52
VIA 3	7	16.68
VIA 4	2	4.76
VIB	0	
Total	42	100.00

The pigmentation stages of the elvers ranged from VB to VIA 4 (Table 3). Sixty percent of the total elvers were at the VIA 2 stage. Larvae at stage VB, which refers to the developmental stages from the end of metamorphosis in the leptocephalus to the beginning of pigmentation, are called glass eels; larvae beyond this stage are called elvers.⁹⁾

Morphometric Characters and Vertebral Counts

Figs. 5 and 6 indicate that the short-finned eel elvers can be easily distinguished from *A. japonica* and *A. marmorata* by using body proportions, especially predorsal length/total length and ano-dorsal length/total length. Predorsal length as a

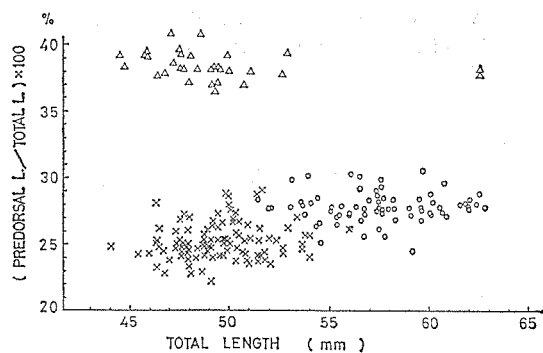


Fig. 5. Relationship between the total length and the percentages of predorsal length to total length in the elvers of *A. bicolor pacifica* (Δ), *A. japonica* (\circ) and *A. marmorata* (\times) caught in the rivers of Taiwan.

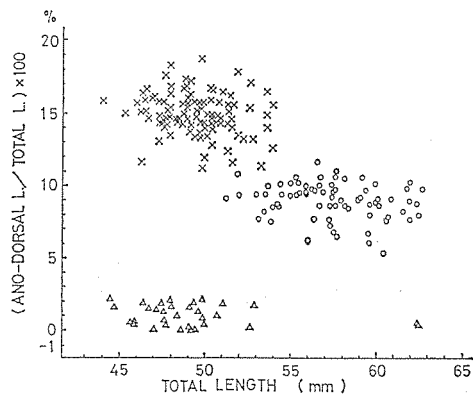


Fig. 6. Relationship between the total length and the percentages of ano-dorsal length to total length in the elvers of *A. bicolor pacifica* (Δ), *A. japonica* (\circ) and *A. marmorata* (\times) caught in the rivers of Taiwan.

percentage of total length was 36.5–40.9% (mean 38.0%) in the short-finned eel elvers, 24.5–30.5% (27.8%) in *A. japonica*, and 22.2–29.1% (25.3%) in *A. marmorata*. The origin of the dorsal fin of the short-finned eel elvers was also very different from that of the other two species. In addition,

Table 4. Vertebral count of the short-finned elvers *A. bicolor pacifica* caught in the rivers of Taiwan

No. of specimen	Total v.	Predorsal v.	Preanal v.	Ano-dorsal v.	Abdominal v.	Caudal v.
17	107–110* ¹	34–38	35–38	0–2	41–44	63–66
	107.88 ± 0.93* ²	35.88 ± 1.22	36.59 ± 1.00	0.71 ± 0.69	42.94 ± 0.83	64.88 ± 0.86

*¹ Range of vertebrae.

*² Mean ± S.D.

Table 5. Comparison of the number of total vertebrae in the elvers of *A. bicolor pacifica*, *A. japonica* and *A. marmorata* caught in the rivers of Taiwan

No. of vertebrae	Species		
	<i>A. japonica</i>	<i>A. marmorata</i>	<i>A. bicolor pacifica</i>
103		1	
104		75	
105		102	
106		57	
107		19	7
108		2	6
109			3
110			1
111			
112			
113			
114	14		
115	31		
116	60		
117	40		
118	14		
119	1		
Total	160	256	17
Mean	116.08	105.09	107.88

Table 6. Comparison of the number of predorsal vertebrae of *A. bicolor pacifica* with that of *A. japonica* and *A. marmorata* caught in the rivers of Taiwan

No. of vertebrae	Species		
	<i>A. japonica</i>	<i>A. marmorata</i>	<i>A. bicolor pacifica</i>
18		1	
19		48	
20		92	
21		103	
22		10	
23			
24	1		
25	2		
26	18		
27	42		
28	69		
29	26		
30			
31			
32			
33			
34			3
35			3
36			5
37			5
38			1
Total	158	254	17
Mean	27.61	20.29	35.88

Table 7. Comparison of the number of ano-dorsal vertebrae in the elvers of *A. bicolor pacifica*, *A. japonica* and *A. marmorata* caught in the rivers of Taiwan

No of vertebrae	Species		
	<i>A. japonica</i>	<i>A. marmorata</i>	<i>A. bicolor pacifica</i>
0			7
1			8
2			2
3			
4			
5			
6			
7			
8	11		
9	66		
10	71		
11	10		
12			
13		3	
14		44	
15		120	
16		80	
17		6	
Total	158	253	17
Mean	9.51	15.67	0.71

ano-dorsal length as a percentage of total length was 0–2.1% (1.1%) in the short-finned eel elvers, 5.3–11.7% (9.0%) in *A. japonica*, and 11.2–18.7% (15.0%) in *A. marmorata*. The origin of the anal fin in relation to the origin of the dorsal fin also differed markedly in the short- and long-finned elvers.

Counts of total and sectional number of vertebrae of seventeen short-finned eel elvers (Table 4) disclosed that the former ranged from 107 to 110 in the short-finned elvers. Furthermore, the small number of ano-dorsal vertebrae was one of the most marked characteristics for the short-finned eel elvers. Comparison showed that the total number of vertebrae of the short-finned eel elvers (107–110) was completely separated from that of *A. japonica* (114–119) but partially overlapped that of *A. marmorata* (103–108) (Table 5). A t-test showed a significant difference from the latter species ($t=11.80$, $p<0.01$). Furthermore, it was found that the predorsal and ano-dorsal vertebral counts were the most valid in distinguishing the short-finned eel elvers from *A. japonica* and *A. marmorata* (Tables 6 and 7) when compared with other sectional vertebral counts: number of preanal, abdominal and caudal

Table 8. Comparison of total number of vertebrae in short-finned eels^{1,6)}

Species	Total number of vertebrae		Sources
	Range	Mean	
<i>Anguilla obscura</i>	101-107	104.03	EGE ¹⁾
<i>A. bicolor pacifica</i>	103-111	107.15	EGE ¹⁾
	107-112	109.38	TABETA <i>et al.</i> ⁶⁾
<i>A. bicolor bicolor</i>	106-115	109.53	EGE ¹⁾
	106-110	108.67	TABETA <i>et al.</i> ⁶⁾
<i>A. australis schmidti</i>	108-115	111.70	EGE ¹⁾
	110-116	112.70	TABETA <i>et al.</i> ⁶⁾
<i>A. australis australis</i>	106-116	112.04	EGE ¹⁾
The present species	107-110	107.88	The present study

vertebrae. The number of predorsal vertebrae ranged from 34 to 38 (35.9) in the short-finned eel elvers, 24-29 (27.6) in *A. japonica*, and 18-22 (20.3) in *A. marmorata*. It was clear that the number of predorsal vertebrae of these three species was completely different from each other. In addition, the number of ano-dorsal vertebrae ranged from 0-2 (0.7) in the short-finned eel elvers, 8-11 (9.5) in *A. japonica*, and 13-17 (15.7) in *A. marmorata*. Thus, the count of the ano-dorsal vertebrae of these three species was also an excellent character for distinguishing one species from another.

Discussion

By comparison of morphometric characters and vertebral counts, we concluded that the short-finned eel elvers from Taiwan are completely different from *A. japonica* and *A. marmorata*. Because there are no additional information about the short-finned eel elvers from Taiwan, we are providing a description of these short-finned eel elvers.

There are five species and subspecies of short-finned eels around the world. The vertebral counts and geographical distribution are considered valid for species identification. The total number of vertebrae in the elvers of the five short-finned species and subspecies were investigated by EGE¹⁾ and TABETA *et al.*⁶⁾ (Table 8). The mean number of vertebrae of these three species group listed in increasing order is *A. obscura* (104.0), *A. bicolor* (107.2, 109.4), and *A. australis* (111.7, 112.7). The mean number of vertebrae of the short-finned eel elvers examined is 107.9 which falls closest to that of *A. bicolor*.

Geographical distributions of three short-finned eel species group¹⁾ are as follows: *A. obscura* is a western equatorial and southern Pacific species

and distributed mainly in New Guinea, Fiji and Tahiti. *A. australis australis* and *A. australis schmidti* are southern Pacific species, the former distributed mainly in southeastern Australia, whereas the latter mainly in New Zealand. *A. bicolor bicolor* is Indian Ocean species and distributed mainly along the coast of East Africa, Malagasy, Indian Hinterland, Burma, Sumatra, Java and North-west Australia. *A. bicolor pacifica*, the only short-finned eel in the equatorial zone of the western Pacific, is distributed from the east coast of Borneo and the northern parts of New Guinea to Luzon in the Philippines where it occurs in abundance.^{1,7,10-12)} From the zoogeographical point of view, therefore, the short-finned eel elvers from Taiwan are most likely to be *A. bicolor pacifica* which migrated from the waters of Luzon. This interpretation appears reasonable because both Luzon Island and Taiwan are located in the same current system of Kuroshio.¹³⁾ Both vertebral counts and zoogeographical evidence are congruous.

Occasionally, exotic eels derived from the imported elvers for eel culture escape into native rivers in Japan.¹⁴⁾ Although elvers are frequently imported into Taiwan for eel culture because of poor catch of elvers, the short-finned eel elvers we caught were not considered to be from such a source. There are no eel-culture ponds adjacent to the rivers from which our specimens were collected. Besides, as mentioned above, the developmental stages of the short-finned eel elvers were VB - VIA 4 with most elvers at the VIA 2 stage, which occurs soon after the upstream migration. If they had indeed escaped from eel-culture ponds, then their developmental stages would be expected to be advanced. Therefore, we are sure that the elvers *A. bicolor pacifica* found in Taiwan are native in origin. The elvers of *A. bicolor pacifica* were found not only in 1980-

1981, but also in 1970 when they were collected by the faculties in the Tungkang Marine Laboratory, Taiwan Fisheries Research Institute. In addition, there are two specimens of adult short-finned eels preserved in the Museum of the Department of Zoology, National Taiwan University. The smaller of the two (Reference No. NTUM 00304; total length 30.0 cm) was collected by Liuke LEE at Lo-Tung, I-Lan Prefecture in 1943, whereas the larger specimen (No. NTUM 00324; total length 99.5 cm) was collected by N. SASAKISENDAI in Taipei Prefecture in 1954. These two specimens were identified by C. F. YEH as *Anguilla australis* RICH.¹⁵⁾ As mentioned previously, *A. australis* is a southern Pacific species. Because eel culture in Taiwan was not prevailing until 1966, it is highly unlikely that these two specimens were imported from a foreign country. In addition, eels are generally not cultured to size as large as 99.5 cm. Therefore, we concluded that these two adult short-finned eels must be native ones. They may be *A. bicolor pacifica* which were misidentified as *A. australis*. Unfortunately, we could not examine the number of vertebrae because these two specimens had been preserved in formalin solution for a long time and were decalcified.

Acknowledgments

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