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The Sectional Counts of Vertebrae in the Anguillid Elvers

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Abstract The numbers of predorsal, ano-dorsal, preanal, abdominal, caudal, and total vertebrae in and shortly after the elver stage of 9 species and subspecies of eels from the various areas in the world were counted. The numbers of vertebrae in such sections are useful for the specific identification when the ranges of variations do not overlap between the respective species. A key to the species was given based on the sectional counts of vertebrae. Moreover, the graphic representations of the correlation between the number of vertebrae in respective sections facilitate the identification of most species.

Although Ege (1939) reported the number of vertebrae of 19 species and subspecies of eels around the world, he counted only prehemal and total vertebrae. The present authors examined the numbers of the predorsal, anodorsal, and preanal vertebrae, as well as those of abdominal, caudal, and total. It was found that such sectional counts of vertebrae are more useful in identifying the species than count of total vertebrae only. The correlation between each of the sectional counts and the total number of vertebrae is represented in a graphic form to facilitate the specific identification.

Materials and methods

The materials examined in the present investigation are about 230 specimens obtained from the various areas in Asia, Europe, Canada, and New Zealand (Table 1). The samples are in and shortly after the elver stage. Among the samples, there exist distinct differences in development of pigmentation, as indicated in Table 1 according to the definition given by Bertin (1956) and Egusa (1972). Besides these samples, the young eels from Borneo were also examined. Following observation and measurements on the external morphology of the preserved specimens, the elvers were stained with alizarin, and predorsal, ano-dorsal, preanal, abdominal, caudal, and total vertebrae were counted (Fig. 1). In some specimens the vertebral number was counted from X-ray photographs. The number of ano-dorsal vertebrae is defined as the number of vertebral centra between verticals through the anus and origin

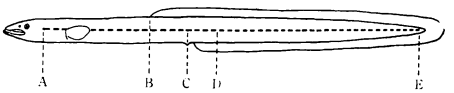

Fig. 1. Diagram showing measurement of total length, and sectional counts of vertebrae. A～B, predorsal vertebrae; B～C, anodorsal vertebrae; A～C, preanal vertebrae; A～D, abdominal vertebrae; D～E, caudal vertebrae; A～E, total vertebrae.

of the dorsal fin, excluding the centra which were cut by the verticals, as was defined by Jespersen (1942) in the anguillid leptocephali. The centra which were cut by the verticals through origin of the dorsal fin and the anus are also excluded in counting the number of predorsal and preanal vertebrae, respectively. The first vertebral centrum with closed hemal arch or hemal spine is defined as the first caudal vertebra (Ege, 1939). The terminal and preterminal centra, which are known to fuse in young stage (Bertin, 1956), are counted as one vertebra, even though they are not yet fused in the elver stage.

Observation

The vertebral characters in the samples examined are shown in Table 2. More than 20 nominal species of eels have been reported from the world by many investigators (Ege, 1939; Bertin, 1956; Matsui, 1972). In identifying our samples, however, we followed mainly the classification given by Ege (1939), who recognized 16 valid species, of which three species were divided into two subspecies. Taking the geographical distribution into consideration, the

Table 1. Locality, number of specimens, date, length and developmental stage based on pigmentation of materials examined. Developmental stage followed Bertin (1956) and Egusa (1972).

Locality	No. of specimens	Date	TL (mm) (x)	Developmental stage
Japan: Shizuoka Pref.	35	Mar. 1968	55～62 (59.0)	IIa
Yamaguchi	20	Apr. 1972	55～78 (65.9)	IIa
Fukuoka	10	May 1967	60～83 (72.8)	IVa
Kagoshima	3	Jan. 1967	58, 68, 99	Vc
Taiwan: East coast (Ta-shi R.)	10	Feb. 1970	54～89 (71.4)	III
England: Inverness (Scotland)	30	Apr. 1972	66～77 (71.7)	VIA
Italy: Pisa (West Italy)	20	Jan. 1973	61～68 (63.5)	VB & VIAI
France: Bay of Biscay	20	Feb. 1973	61～73 (66.6)	VIA
Philippines: Aparri	10	Sep. 1970	45～53 (50.8)	IVB
(Luzon I.)	35	Mar. 1972	48～57 (52.6)	IVB
	4	Sep. 1972	48～51 (49.6)	IVB
Canada: New Brunswick	11	Sep. 1972	57～71 (63.4)	VIB
New Zealand	13	Feb. 1970	56～65 (59.9)	IV
Malaysia: Sabah (Borneo)	10	Sep. 1970	46～51 (49.2)	IV
	2	Apr. 1973	78, 185	
Indonesia: Padang (Sumatra)	6	Sep. 1973	52～58 (54.4)	VIB

samples examined were identified as follows.

Japanese eels From the numbers of predorsal, ano-dorsal, caudal, and total vertebrae, the samples are divided into two groups. The group with large number of vertebrae can be identified as *Anguilla japonica* Temminck et Schlegel, and another, with small number of vertebrae, as *A. marmorata* Quoy et Gaimard (three specimens from Kagoshima Prefecture).

Taiwanese eel *A. japonica* and *A. marmorata* are known to be distributed in Taiwan. The present specimens, however, can be referred to *A. japonica* from the vertebral characters.

European eel The elvers from England, France, and Italy are included in one group and clearly show the characters of *A. anguilla* Linnaeus.

Philippine eels The present samples were divided into two groups by the difference of the number of predorsal and ano-dorsal vertebrae. According to Ege (1939), three species are known to be distributed in the Philippines: one is a short finned eel (*A. bicolor pacifica* Schmidt) and two others are long finned eels (*A. marmorata* and *A. celebesensis* Kaup). In addition to these three eels, Tabeta et al. (1975) recorded recently *A. japonica* from Luzon Island, the Philippines. The group with fewer vertebrae is identified as *A. marmorata*. Another group belongs to the long finned species in having more than 8 ano-dorsal vertebrae. This fact, together with the caudal pigmentation of the specimens as described by Ege (1939), suggests that it is identified as *A. celebesensis*.

Canadian eel The present specimens from the Atlantic area of Canada are referable to *A. rostrata* (Le Sueur) from the geographical distribution.

New Zealand eel In New Zealand, one short finned eel, *A. australis schmidti* Phillipps and one long finned eel, *A. dieffenbachi* Gray are known to be distributed. The examined specimens are apparently referable to a short finned eel, *A. australis schmidti* in having the ano-dorsal distance less than 2.0% of the total length.

Malaysian (Borneo) eels As for the number of predorsal and ano-dorsal vertebrae, the present specimens are divided into 3 groups. Ege (1939) described two species from Borneo, *A. bicolor pacifica* and *A. borneensis* Popta. Recently, Inger and Chin (1962) revealed that *A. marmorata* was also commonly found in the inland waters of North Borneo. Among three groups of elvers, the first group with the ano-dorsal distance less than 1.5% of the total length is identified as a short finned species, *A. bicolor pacifica*, and the second, as *A. marmorata* in having the fewer vertebrae. Finally, the third group can be referred to *A. borneensis* from both the vertebral characters and the

Table 2. Sectional counts of vertebrae in each sample.

Locality	No. of specimens	Predorsal Range ($\bar{x}$, s)	Ano-dorsal Range ($\bar{x}$, s)	Preanal Range ($\bar{x}$, s)	Abdominal Range ($\bar{x}$, s)	Caudal Range ($\bar{x}$, s)	Total Range ($\bar{x}$, s)	Species	Groups
Japan	35	25~31 (27.66, 1.47)	7~10 (8.46, 1.01)	34~38 (36.09, 1.12)	43~45 (43.71, 0.67)	68~75 (72.69, 1.62)	112~119 (116.37, 1.54)	*A. japonica*	A
	20	26~31 (27.89, 1.37)	9, 10 (8.63, 1.01)	35~39 (36.53, 0.90)	43~45 (43.74, 0.65)	70~75 (72.94, 1.13)	115~119 (116.63, 1.12)		
	10	26~30 (27.60, 1.26)	8, 9 (8.60, 0.52)	35~38 (36.20, 0.92)	42~44 (43.10, 0.74)	72~75 (73.20, 1.03)	115~118 (116.30, 1.16)		
	3	19, 20, 20	15, 15, 15	34, 35, 35	44, 44, 44	61, 61, 62	105, 105, 106	*A. marmorata*	B
Taiwan	10	27~29 (28.00, 0.71)	8~10 (8.77, 0.83)	35~38 (36.78, 1.09)	43~45 (43.70, 0.67)	69~74 (72.10, 1.45)	113~118 (115.80, 1.62)	*A. japonica*	C
England	30	25~29 (26.55, 1.12)	10~13 (11.86, 0.95)	37~40 (38.41, 0.90)	43~46 (44.48, 0.95)	67~75 (70.55, 1.70)	112~119 (115.03, 1.88)	*A. anguilla*	D
Italy	20	24~28 (25.90, 1.17)	11~13 (12.10, 0.85)	37~40 (38.00, 1.03)	44~45 (44.43, 0.51)	67~71 (69.00, 1.36)	112~116 (113.60, 1.31)		
France	20	24~28 (26.15, 1.31)	11~14 (12.15, 0.99)	37~41 (38.30, 0.92)	44~47 (45.25, 0.96)	66~71 (69.55, 1.54)	112~117 (114.70, 1.27)		
Philippines	7	19~22 (20.50, 1.07)	14, 15 (14.70, 0.93)	33~37 (35.50, 1.20)	41~43 (41.75, 0.70)	62~66 (63.50, 1.30)	104~107 (105.25, 1.04)	*A. marmorata*	E
	1	19	17	36	42	64	106		
	28	23~25 (24.15, 0.59)	8~11 (9.95, 1.00)	33~35 (34.10, 0.85)	39~42 (40.80, 0.83)	63~67 (64.55, 1.43)	103~108 (105.20, 1.50)	*A. celebesensis*	F
	10	23~25 (23.88, 0.78)	8~11 (9.67, 1.22)	31~36 (33.56, 1.67)	39~42 (40.90, 0.99)	62~67 (64.60, 1.51)	103~108 (105.50, 1.65)		
	3	23, 23, 24	10, 10, 10	33, 33, 33	39, 41, 41	64, 65, 65	104, 105, 106		
Canada	11	27~30 (28.91, 1.04)	6~ 9 (7.27, 0.79)	35~38 (36.18, 0.98)	41~44 (42.73, 1.01)	63~68 (65.09, 1.51)	104~110 (107.82, 1.99)	*A. rostrata*	G
New Zealand	13	36~40 (37.56, 1.20)	0~ 2 (1.00, 0.82)	37~40 (38.54, 0.78)	45~47 (46.08, 0.76)	64~69 (66.77, 1.36)	110~116 (112.70, 1.73)	*A. australis schmidti*	H
Malaysia	8	34~40 (36.75, 2.05)	−1~ 1 (0.13, 0.64)	34~39 (36.88, 1.73)	44, 45 (44.25, 0.46)	63~67 (65.13, 1.36)	107~112 (109.38, 1.60)	*A. bicolor pacifica*	I
	2	20, 20	15, 15	35, 35	40, 41	66, 68	107, 108	*A. marmorata*	J
	2	24, 25	10, 11	34, 35	40, 40	62, 63	102, 103	*A. borneensis*	K
Indonesia	6	35~38 (36.00, 1.26)	0~ 2 (0.50, 0.84)	35~38 (36.50, 1.05)	41~43 (42.17, 0.75)	63~68 (66.50, 1.87)	106~110 (108.67, 1.51)	*A. bicolor bicolor*	L

geographical distribution. It may be very defficult to distinguish *A. borneensis* from *A. celebesensis* from the vertebral characters alone. In the adult stage, however, the former has a uniform color, whereas the latter has the peculiarly variegated markings on the side of the body. In identifying the present elvers of *A. borneensis*, we are positively supported by the facts that the recent investigation by Inger and Chin (1962) did not recorded *A. celebesensis* in Borneo, and that the vertebral characters of young *A. borneensis* (Table 3) which were sent to the authors from Mr. Chin, well correspond to those of the examined elvers.

Indonesian (Sumatra) eel In Sumatra, *A. marmorata, A. nebulosa nebulosa* McClelland, and *A. bicolor bicolor* McClelland are known to be distributed. Among these three forms, *A. bicolor bicolor* belongs to the short finned eel. The examined samples with the ano-dorsal distance less than 1.5% of the total length are included in one group referable to *A. bicolor bicolor*.

Discussion

The sectional counts of vertebrae in 9 species and subspecies of eels from the various areas of the world were made clear. The numbers of abdominal and total vertebrae of each species mentioned above fit well to those of adults shown by Ege (1939). For further comparison between species the range and mean of the predorsal and ano-dorsal counts of vertebrae for each species are shown in Figs. 2 and 3. As only 2 elvers of *A. borneensis* are available, additional data on the sectional counts of vertebrae of young specimens as shown in Table 3 are utilized for the species. Fig. 2 shows that these species can be divided into three groups with regard to the number of predorsal vertebrae: *A. marmorata* (less than 22), three short finned eels (more than 34), and other eels (23～31). An inverted order can be drawn from the number of ano-dorsal vertebrae (Fig. 3): three short finned eels (less than 2),

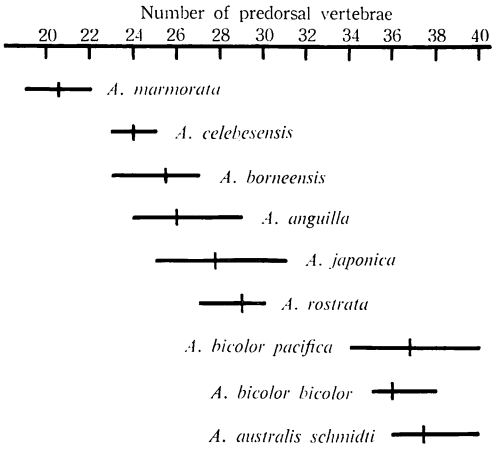

Fig. 2. Range and mean of number of predorsal vertebrae in each species.

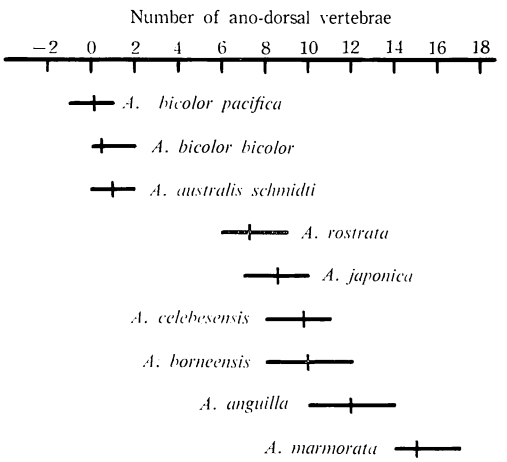

Fig. 3. Range and mean of number of ano-dorsal vertebrae in each species.

Table 3. Sectional counts of vertebrae in young *A. borneensis* from Borneo, Malaysia. TL, total length (mm); PD, predorsal; AD, ano-dorsal; PA, preanal; AB, abdominal; TV, total vertebrae.

No.	TL	PD	AD	PA	AB	CD	TV	Locality, date
1	283	25	10	35	40	63	103	
2	252	24	11	35	40	61	101	Sungei Matukungan
3	226	24	11	34	40	61	101	Jun. 28, 1961
4	157	24	11	35	41	64	105	
5	204	24	11	35	41	62	103	Kinabatagan
6	183	27	8	35	41	62	103	May 2, 1956

A. marmorata (more than 14), and other eels (6～14). A key to the elvers of these 9 species and subspecies is given below based on Table 2, Figs. 2 and 3, and additional data (Tabeta et al., in press):

a_1 Ano-dorsal vertebrae more than 6
- b_1 Total vertebrae more than 112
  - c_1 Ano-dorsal vertebrae 7～10 (mean 9) ..... *A. japonica*
  - c_2 Ano-dorsal vertebrae 10～14 (mean 12) ..... *A. anguilla*
- b_2 Total vertebrae less than 111
  - d_1 Ano-dorsal vertebrae 13～17 (mean 15) ..... *A. marmorata*
  - d_2 Ano-dorsal vertebrae 6～12
    - e_1 Predorsal vertebrae 26～30 (mean 29) ..... *A. rostrata*
    - e_2 Predorsal vertebrae 22～27... *A. celebesensis, A. borneensis*

a_2 Ano-dorsal vertebrae less than 2 ..... *A. bicolor pacifica, A. bicolor bicolor, A. australis schmidti*

As seen from the Table 2, and Figs. 2 and 3, the range of sectional counts of vertebrae overlaps considerably each other among some species. The authors made the graphic representation of correlation between predorsal and total, ano-dorsal and total, and predorsal and ano-dorsal counts of vertebrae as well as caudal and abdominal vertebrae in each species (Figs. 4～7), which facilitate the identification of the species except for *A. celebesensis* and *A. borneensis*. Although most specimens of *A. anguilla* had more ano-dorsal vertebrae than *A. japonica*, 5% of the former specimens and 15% of the latter specimens had 10 ano-dorsal vertebrae (Figs. 3 and 8). In the specimens having 10 ano-dorsal vertebrae, therefore, it is necessary to differentiate the two species by pigmentation (Bertin, 1956; Egusa, 1972). In this paper, the authors dealt with only 9 out of 19 known species and subspecies of eels. Further observation on more specimens and also on other species are needed.

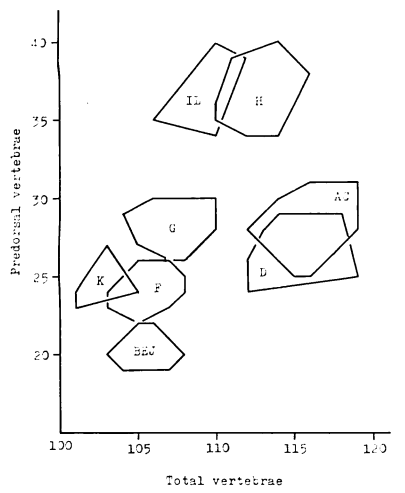

Fig. 4. Relationship between total and predorsal vertebrae in each species. AC, *A. japonica*; BEJ, *A. marmorata*; D, *A. anguilla*; F, *A. celebesensis*; G, *A. rostrata*; H, *A. australis schmidti*; IL, *A. bicolor*; K, *A. borneensis*.

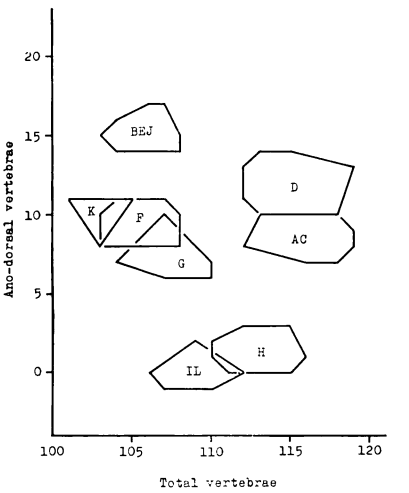

Fig. 5. Relationship between total and ano-dorsal vertebrae in each species. Abbreviations are same as those in Fig. 4.

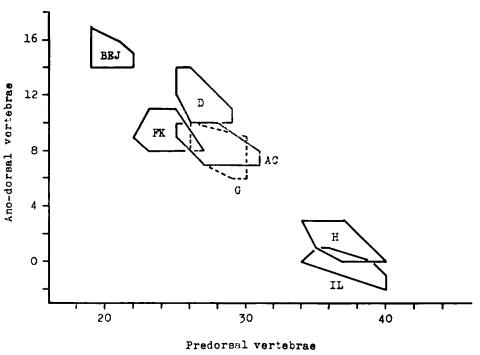

Fig. 6. Relationship between predorsal and ano-dorsal vertebrae in each species. Abbreviations are same as those in Fig. 4.

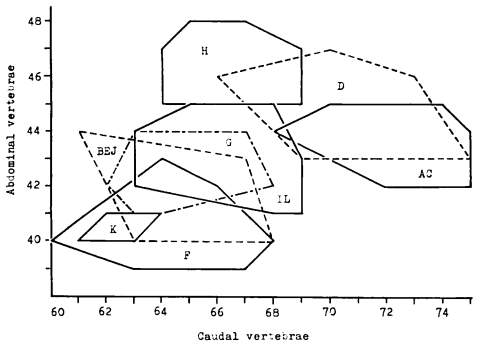

Fig. 7. Relationship between caudal and abdominal vertebrae in each species. Each polygon is modified on the data of Ege (1939). Abbreviations are same as those in Fig. 4.

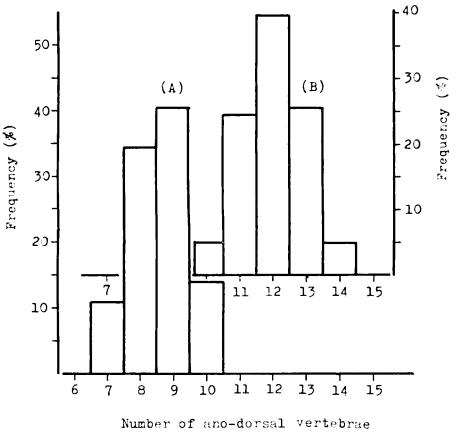

Fig. 8. Frequency distribution of number of ano-dorsal vertebrae in *A. japonica* (A) and *A. anguilla* (B).

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シラスウナギ類の脊椎骨数構成について

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日本，台湾，フィリピン，ボルネオ，スマトラ，ニュージーランド，カナダ，イギリス，フランス，イタリアの各地から得られたシラスウナギ類について，背鰭前脊椎骨数，肛門-背鰭起部間脊椎骨数，肛門前脊椎骨数，腹椎数，尾椎数，総脊椎骨数を計数し，9種，亜種の脊椎骨数構成を明らかにした．これらの構成の特徴はシラス期における種の識別に役立つことが示された．

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