Bull. Natn. Sci. Mus., Tokyo, Ser. A, 7 (2), June 22, 1981

Chromosomes of Six Species of Percoid Fishes from Japan

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The suborder Percoidei is the largest among 12 suborders of perciform fishes. It contains 72 families, 595 genera and about 3935 species (NELSON, 1976). This suborder is considered to be the most basic in the order Perciformes. However, interrelationships of percoid fishes are so complicated that construction of their phylogenetic tree is very difficult.

Although there are so many families in the suborder Percoidei, karyological studies on percoid fishes are very poor except on some families such as Centrarchidae, Percidae, Chaetodontidae, Cichlidae and Pomacentridae (VASILIEV, 1980).

As we observed chromosomes of six species of percoid fishes from Japan, i. e., two species of the family Kuhliidae, one species each of the family Gerreidae, the family Leiognathidae, the family Chaetodontidae and the family Embiotocidae, we describe their karyotypes and discuss relationships between karyotypes and morphological characters in some percoid families.

Method of chromosome preparation is the same as that of ARAI (1973). Classification of chromosomes is adopted from LEVAN *et al.* (1964). Metacentrics and submetacentrics are described as two-arm chromosomes, subtelocentrics and acrocentrics as one-arm chromosomes. The definition of the new arm number (NAN) is referred to ARAI and NAGAIWA (1976).

All the specimens used for the experiments are deposited in the fish collection of the Department of Zoology, National Science Museum, Tokyo.

Kuhlia taeniura (CUVIER) "Gin-yugoi"

(Figs. 1 A, C)

Seven specimens of the family Kuhliidae (Nos. E·99·1, E·99·15, E·99·17, E·99·18, A·4·14, A·4·15 and A·4·20), 27.0, to 56.0 mm in total length, were collected at Amatsu-kominato, Awa, Chiba Prefecture. Some morphological characters of material fish are shown in Table 1.

As shown in Table 2, the diploid chromosome number of this species is 48. The karyotype comprises a pair of submetacentric and 23 pairs of acrocentric chromosomes. One-arm chromosomes are comparable in appearance and show a gradation in size which makes it impossible to arrange them in size groups. The arm number is 50.

Kuhlia boninensis (FOWLER) "Togenaga-yugoi"

(Figs. 1 B, D)

Two specimens of kuhliid fish (Nos. E·97·1 and E·97·2), 201.3 and 200.5 mm in total length, were caught by Messrs. SATO and SAKAI at Urauchi River, Iriomote Island, southern Ryukyus (Table 1).

The diploid chromosome number is 48 (Table 2). As shown in Fig. 1D, the karyotype comprises a pair of submetacentric and 23 pairs of acrocentric chromosomes. The arm number is 50. The karyotype of this species is very similar to that of *Kuhlia taeniura*.

Table 1. Characters of six species of material fishes.

Species	No. of fish	S. L. (mm)	Dorsal	Anal	VN
Kuhliidae					
Kuhlia taeniura	7	21.4– 43.7	X, 10–11	III, 11–12	10+16
K. boninensis	2	159.0–160.3	X, 11	III, 11	10+15
Gerreidae					
Gerres oyena	5	54.5– 83.0	IX, 10	III, 7	10+14
Leiognathidae					
Leiognathus nuchalis	7	50.0– 85.1	VIII, 16–17	III, 14	10+14
Chaetodontidae					
Heniochus acuminatus	1	47.1	XI, 26	III, 18	10+14
Embiotocidae					
Neoditrema ransonneti	1	103.6	VI, 21	III, 26	15+21

Table 2. Frequency distributions of diploid chromosome counts in six species of material fishes.

Species	2n 42	43	44	45	46	47	48	49	50	51	52	Total
Kuhliidae												
Kuhlia taeniura			3	5	7	13	51	2				81
K. boninensis	3	1	3	3	4	12	56	1				83
Gerreidae												
Gerres oyena				3	4	3	11	1				22
Leiognathidae												
Leiognathus nuchalis				3	7	10	43	9	1	2	1	76
Chaetodontidae												
Heniochus acuminatus					1	1	5					7
Embiotocidae												
Neoditrema ransonneti							3					3

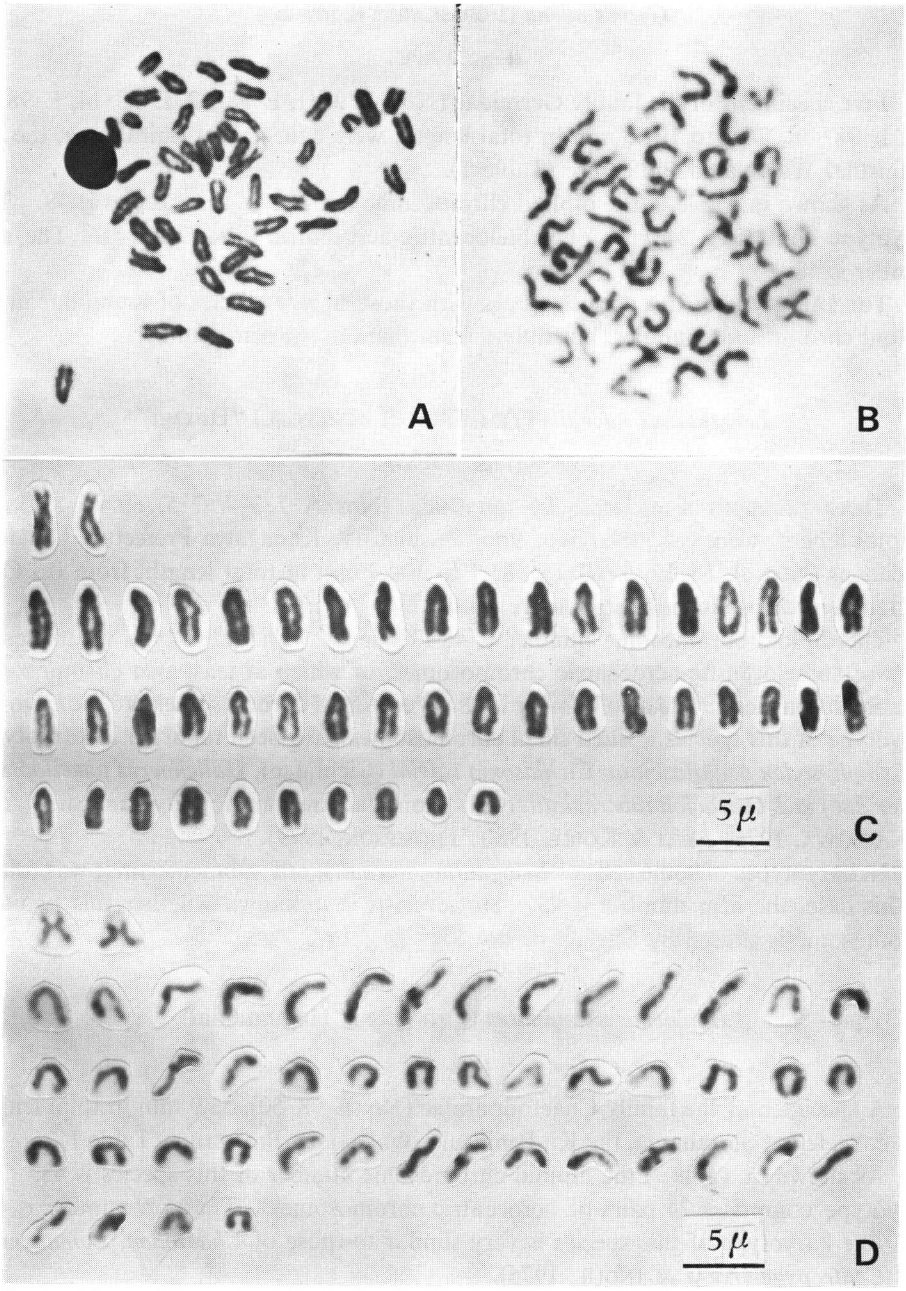

Fig. 1. Photomicrographs of mitotic metaphase chromosomes and karyotypes from gill epithelial cells of two species of kuhliids. —— A, *Kuhlia taeniura* (No. A·4·20), 2n=48, ×1,340; B, *K. boninensis* (No. E·97·2), 2n=48, ×2,340; C, *Kuhlia taeniura*, from Fig. A, NF=50, ×1,910; D, *K. boninensis*, from Fig. B, NF=50, ×2,340.

Gerres oyena (FORSSKÅL) "Kuro-sagi"

(Figs. 2 A, C)

Five specimens of the family Gerreidae (Nos. E·98·1, E·98·12, E·98·14, E·98·15 and E·98·49), 70.0 to 102.3 mm in total length, were collected at Shirahama, the Kii Peninsula, Wakayama Prefecture (Table 1).

As shown in Table 2, the diploid chromosome number of this species is 48. The karyotype comprises 24 pairs of subtelocentric-acrocentric chromosomes. The arm number is 48.

The karyotype of this species agrees with those of two species of Kuhliidae in the diploid chromosome number, but differs from them in the arm number.

Leiognathus nuchalis (TEMMINCK et SCHLEGEL) "Hiiragi"

(Figs. 2 B, D)

Three specimens of the family Leiognathidae (Nos. A·7·3–A·7·5), 60.4 to 89.5 mm in total length, were caught at Kotsubo, Zushi City, Kanagawa Prefecture and four specimens (Nos. A·13·12–A·13·15), 87.7 to 100.9 mm in total length, from Itô City, the Izu Peninsula, Shizuoka Prefecture (Table 1).

The diploid chromosome number is 48 (Table 2). The karyotype comprises 24 pairs of subtelocentric-acrocentric chromosomes, of which at least two chromosomes are subtelocentrics. The arm number is 48. Very small chromosomes are found in the karyotype of this species. Such small chromosomes have been reported in karyotypes of *Symphysodon aequifasciata*, *Cichlasoma salvini* (Cichlidae), *Halichoeres poecilopterus* (Labridae) and *Ostracion tuberculatus* (Ostraciontidae) in acanthopterygian fishes (ARAI & NAGAIWA, 1976; ARAI & KOIKE, 1980; THOMPSON, 1979).

In karyotypes of some cells of *Leiognathus nuchalis*, one submetacentric was found. In this case, the arm number is 49. However, it is unknown whether this two-arm chromosome is caused by artefact or not.

Heniochus acuminatus (LINNAEUS) "Hatatate-dai"

(Fig. 3)

A specimen of the family Chaetodontidae (No. E·98·50), 53.9 mm in total length, was collected at Shirahama, the Kii Peninsula, Wakayama Prefecture (Table 1).

As shown in Table 2, the diploid chromosome number of this species is 48. The karyotype comprises 24 pairs of acrocentric chromosomes. The arm number is 48.

The karyotype of this species is very similar to those of *Chaetodon*, *Pomacanthus* and *Centropyge* (ARAI & INOUE, 1976).

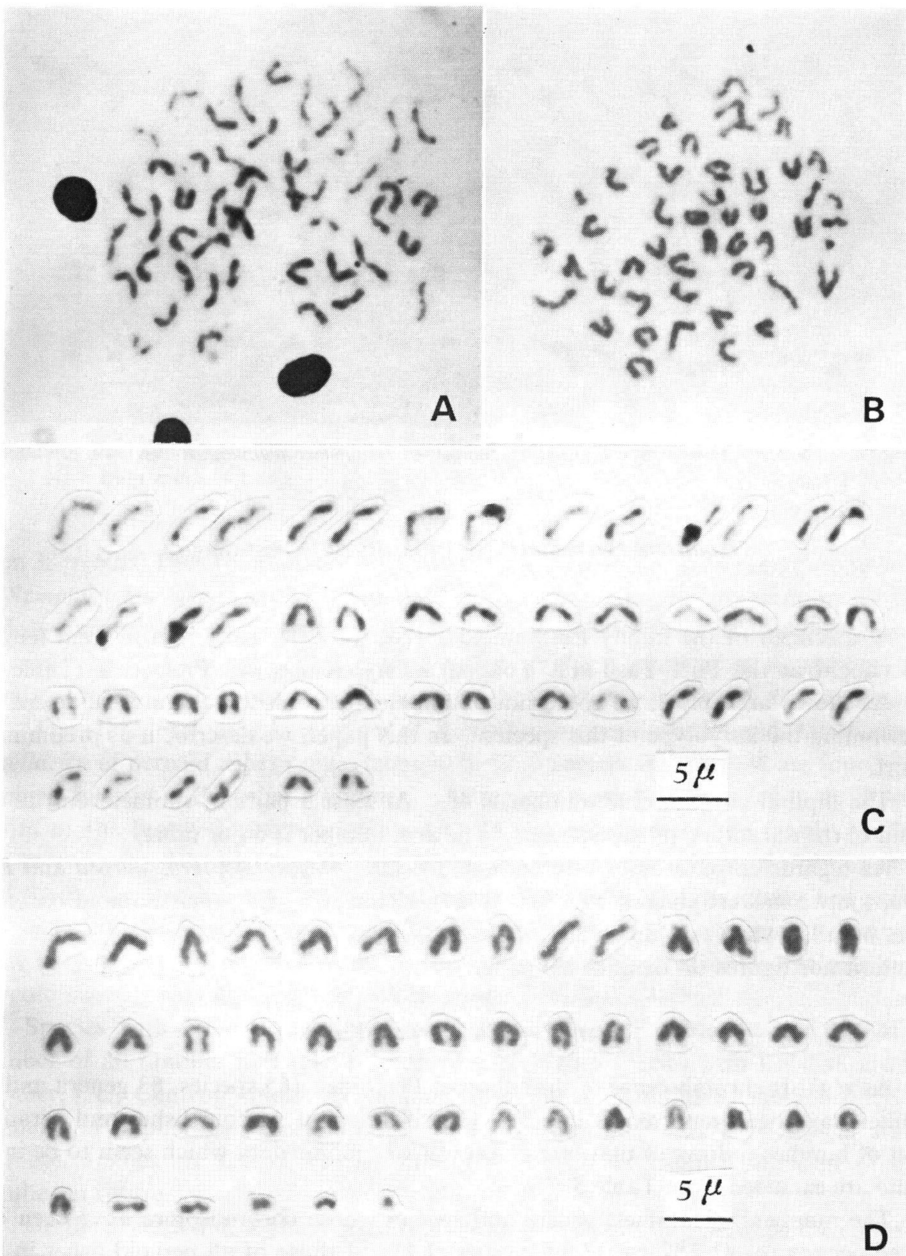

Fig. 2. Photomicrographs of mitotic metaphase chromosomes and karyotypes from gill epithelial cells of a gerreid and a leiognathid. —— A, *Gerres oyena* (No. E·98·12), 2n=48, ×1,550; B, *Leiognathus nuchalis* (No. A·13·15), 2n=48, ×1,610; C, *Gerres oyena*, from Fig. A, NF=48, ×1,810; D, *Leiognathus nuchalis*, from Fig. B, NF=48, ×1,830.

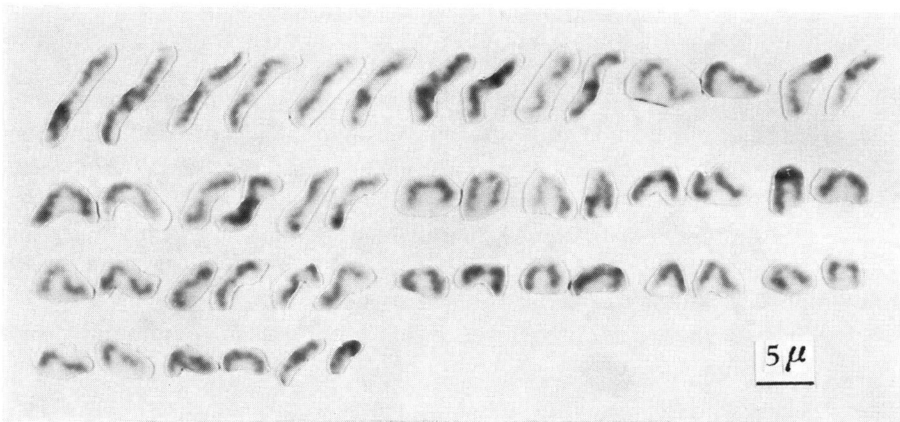

Fig. 3. The karyotype from the gill epithelial cell of *Heniochus acuminatus*. 2n=48, NF=48, ×1,750.

Neoditrema ransonneti STEINDACHNER "Oki-tanago"

(Fig. 4)

A specimen of the family Embiotocidae (No. A·7·1), 127.7 mm in total length, was caught at the Port Yasu-ura, Yokosuka City, Kanagawa Prefecture (Table 1).

As shown in Table 2, we could not obtain clear chromosome figures sufficient for determining the karyotype of this species. In this paper, we describe it as preliminary report.

The diploid chromosome number is 48. At least 3 pairs of submetacentrics are found in the karyotype of this species. The arm number is 54 or more.

As regards chromosomes of embiotocid fishes, *Amphigonopterus aurora* and *Embiotoca jacksoni* were studied by CHEN (1967). However, only their haploid chromosome number was listed up in table (CHEN, 1967, p. 204) and there were neither description nor figures on them in his paper.

Karyotypes of Percoid Fishes

As regards chromosomes of the suborder Percoidei, 165 species, 83 genera and 30 families have been reported (Table 3). Classification of percoid fishes and arrangement of families follows to that of NELSON (1976). Some data which seem to be inaccurate are excluded from Table 3.

The numbers of families, genera and species whose chromosomes have been observed occupy ca. 41.7%, ca. 13.9% and ca. 4.2% of those of all percoid fishes in the world, respectively. Freshwater fishes are studied more than marine fishes, i. e., the total number of species of Centrarchidae, Percidae and Cichlidae is 96, which occupies 60% of all the percoid fishes whose chromosomes have been studied.

As shown in Table 3, the diploid chromosome numbers of percoid fishes range

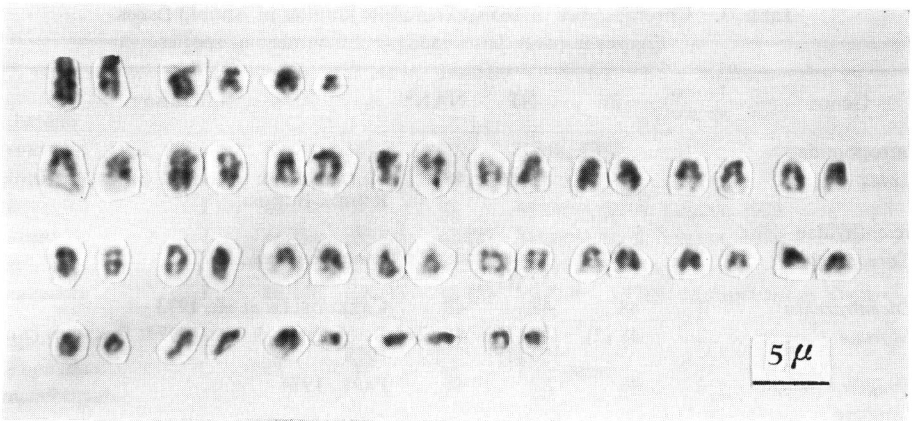

Fig. 4. The karyotype from the gill epithelial cell of *Neoditrema ransonneti*. 2n=48, NF=54 or more, ×1,830.

from 38 to 60. The arm number (NF) ranges from 42 to 118. However, chromosomes of *Symphysodon aequifasciata* (Cichlidae) is very characteristic in exceptionally large diploid chromosome number (2n=60) and arm number (NF=118) among those of percoid fishes. Although 2n of *Apistogramma borellii* (Cichlidae) is 38, the new arm number (NAN) of this species is 46 and 2n of the other two species of *Apistogramma* is 46. Therefore, excluding karyotypes of *Symphysodon aequifasciata* and *Apistogramma borellii*, 2n of percoid fishes ranges from 40 to 52. Species with 2n=48 are found in 26 families, but not in the other 4 families. As regards these 4 families, 44 to 46 chromosomes of the family Emmelichthyidae and 44 chromosomes of the family Mullidae can be considered to be formed from 48 chromosomes, i. e., NAN of *Spicara smaris* and *Parupeneus spilurus* is 48. Descriptions on chromosomes of the family Apogonidae (2n=46) and the family Echeneidae (2n=42) are so short that we cannot discuss on their karyotypes. These facts seem to show that the diploid chromosome number of percoid fishes is very conservative and that their basic 2n is 48.

Species with NF=48 distribute in 17 families which occupy ca. 56.7% of the number of all families in Table 3. Families having no species with FN=48 are 9 in number, i. e., Centropomidae, Serranidae, Plesiopidae, Kuhliidae, Emmelichthyidae, Mullidae, Pempheridae, Oplegnathidae and Embiotocidae. As karyological studies of these families are scanty, species with NF=48 will be found from some of these families in future.

On the other hand, we have tried to find out the relationship between the comparative morphology and karyotypes, and to determine the polarity (Maslin, 1952) of morphological characters.

As regards percoid fishes, karyological studies are too poor to discuss the polarity of osteological characters. Nevertheless, we try to discuss it on three families whose chromosomes have been studied comparatively well.

Table 3. Chromosomes of 165 species of 30 families in percoid fishes. Figures in parentheses indicate the number of species.

Genus	No. of species	2n	NF	NAN*	Literature
Centropomidae					
Lates	1	48	52–56	48	NATARAJAN & SUBRAHMANYAM, 1974; KUHDA-BUKHSH, 1979
Percichthyidae					
Coreoperca	2	48 (2)	50 (1) 52 (1)	48 (2)	UENO & OJIMA, 1977
Dicentrarchus	1	48	48	48	CATAUDELLA *et al.*, 1973
Morone	2	48 (2)	48 (1) 50 (1)	48 (2)	BENIRSCHKE & HSU, 1973; RACHLIN *et al.*, 1978
Siniperca	1	48	52	48	PARK, 1974
Serranidae					
Epinephelus	1	48	50	48	NATARAJAN & SUBRAHMANYAM, 1974
Plesiopidae					
Plesiops	1	48	50	48	ARAI *et al.*, 1976
Theraponidae					
Therapon	2	48 (2)		48 (2)	SUBRAHMANYAM & NATARAJAN, 1970
Kuhliidae					
Kuhlia	2	48 (2)	50 (2)	48 (2)	This paper
Centrarchidae					
Acantharchus	1	48	48	48	ROBERTS, 1964
Ambloplites	1	48	48	48	ROBERTS, 1964
Centrarchus	1	48	48	48	ROBERTS, 1964
Chaenobryttus	1	48	48	48	ROBERTS, 1964
Elassoma	1	48	50	48	ROBERTS, 1964
Enneacanthus	3	48 (3)	48 (3)	48 (3)	ROBERTS, 1964
Lepomis	8	48 (7) 46 (1)	48 (8)	48 (8)	ROBERTS, 1964; OHNO *et al.*, 1968; BENIRSCHKE & HSU, 1971
Micropterus	4	46 (4)	48 (4)	48 (4)	ROBERTS, 1964; BENIRSCHKE & HSU, 1971; THOMPSON *et al.*, 1978
Pomoxis	2	48 (2)	48 (2)	48 (2)	ROBERTS, 1964
Apogonidae					
Apogon	3	46 (3)	52 (1)	48?(1)	RISHI, 1973; MUROFUSHI *et al.*, 1980
Percidae					
Ammocrypta	1	48	92	48	GOLD *et al.*, 1979
Etheostoma	8	48 (8)	50 (1) 52–54(6) 56 (1)	48 (8)	ROSS, 1973; DANZMANN, 1979; GOLD *et al.*, 1979
Gymnocephalus	1	48		48	NYGREN *et al.*, 1968
Perca	2	48 (2)	48 (1)	48 (2)	NYGREN *et al.*, 1968; BENIRSCHKE & HSU, 1973; DANZMANN, 1979
Percina	4	48 (4)	80 (1) 92 (2) 94 (1)	48 (4)	DANZMANN, 1979; GOLD *et al.*, 1979
Stizostedion	2	48 (2)	48 (1)	48 (2)	NYGREN *et al.*, 1968; DANZMANN, 1979
Sillaginidae					
Sillago	1	48			RISHI, 1973

* Data of NAN are estimated from description and figures in literature cited.

Table 3 (continued).

Genus	No. of spicies	2n	NF	NAN*	Literature
Echeneidae					
Remora	1	42			RISHI, 1973
Carangidae					
Alectis	1	48	48	48	MUROFUSHI & YOSIDA, 1979
Caranx	2	48 (2)	48 (2)	48 (2)	MUROFUSHI & YOSIDA, 1979
Seriola	1	48	50	48	IDA *et al.*, 1978
Trachurus	2	48 (2)	{58 (1) {66 (1)	48 (2)	VASILIEV, 1978a; MUROFUSHI & YOSIDA, 1979
Leiognathidae					
Leiognathus	1	48	48	48	This paper
Emmelichthyidae					
Spicara	1	44–45	60	48	VASILIEV, 1978b
Lutjanidae					
Lutjanus	1	48	48	48	CHOUDHURY *et al.*, 1979
Gerreidae					
Gerres	1	48	48	48	This paper
Pomadasyidae					
Haemulon	1	48	48	48	REGAN *et al.*, 1968
Sparidae					
Archosargus	1	48	53	48	LAW *et al.*, 1978
Chrysophrys	1	48	48	48	NISHIKAWA & KARASAWA, 1972
Diplodus	1	48	54	48	VASILIEV, 1978a
Sciaenidae					
Bairdiella	1	48			WHARTON *et al.*, 1977
Cynoscion	1	48			RAMIREZ, 1980
Sciaena	1	48	48	48	VASILIEV, 1978a
Mullidae					
Parupeneus	1	44	60	48	ARAI & KOIKE, 1979
Monodactylidae					
Monodactylus	1	48	48	48	NATARAJAN & SUBRAHMANYAM, 1974
Pempheridae					
Pempheris	1	48	50	48	ARAI & KOIKE, 1979
Kyphosidae					
Girella	1	48	48	48	NISHIKAWA & KARASAWA, 1972
Microcanthus	1	48	50	48	ARAI & INOUE, 1975
Ephippidae					
Platax	1	48	48	48	ARAI *et al.*, 1976
Scatophagidae					
Scatophagus	1	48	{48 (♀) {49 (♂)	48	KHUDA-BUKHSH & MANNA, 1974; CHOUDHURY *et al.*, 1979
Chaetodontidae					
Centropyge	1	48	48	48	ARAI & INOUE, 1975
Chaetodon	5	48 (5)	48 (5)	48 (5)	ARAI & INOUE, 1975
Heniochus	1	48	48	48	This paper
Megaprotodon	2	48 (2)	50 (2)	48 (2)	ARAI & INOUE, 1975
Pomacanthus	1	48	48	48	ARAI & INOUE, 1975

Table 3 (continued).

Genus	No. of species	2n	NF	NAN*	Literature
Oplegnathidae					
Oplegnathus	1	48	50	48	NISHIKAWA & KARASAWA, 1972
Embiotocidae					
Amphigonopterus	1	48			CHEN, 1967
Embiotoca	1	48			CHEN, 1967
Neoditrema	1	48	54≦	48	This paper
Cichlidae					
Acarichthys	1	48	54	48	THOMPSON, 1979
Aequidens	2	44 (1) 48 (1)	54 (1) 70 (1)	48 (1) 46 (1)	THOMPSON, 1979
Apistogramma	3	38 (1) 46 (2)	60 (1) 70 (2)	46 (3)	THOMPSON, 1979
Astronotus	1	48	54	48	THOMPSON, 1979
Cichla	1	48	48	48	THOMPSON, 1979
Cichlasoma	20	48 (18) 50 (1) 52 (1)	52 (2) 54 (12) 56 (5) 80 (1)	48 (19) 50 ?(1)	THOMPSON, 1979
Crenicara	1	46	58	46	THOMPSON, 1979
Crenicichla	5	48 (5)	52 (1) 54 (3)	48 (5)	OYHENART-PERERA *et al.*, 1975; THOMPSON, 1979
Etroplus	2	46 (1) 48 (1)	48 (1) 64 (1)		NATARAJAN & SUBRAHMANYAM, 1974; THOMPSON, 1979
Geophagus	3	48 (3)	52 (3)	48 (3)	THOMPSON, 1979
Haplochromis	2	40 (1) 44 (1)	56 (1) 54 (1)	46 (1) 46 ?(1)	THOMPSON, 1976; KORNFIELD *et al.*, 1979
Herotilapia	1	48	54	48	THOMPSON, 1979
Nannocara	1	44	62	46	THOMPSON, 1979
Neetroplus	1	48	56	48	THOMPSON, 1979
Pseudotropheus	1	46	56	48	THOMPSON, 1976
Pterophyllum	1	48	52	48	THOMPSON, 1979
Sarotherodon	5	44 (5)	44 (1) 54 (2) 62 (1)	46 (4)	KORNFIELD *et al.*, 1979; ARAI & KOIKE, 1980
Symphysodon	1	60	118		THOMPSON, 1979
Tilapia	4	44 (2) 42 (1) 40 (1)	44 (1) 46 (1) 52 (1) 54 (1)	46 (3) 46? (1)	THOMPSON, 1976; MICHELE & TAKAHASHI, 1977; KORNFIELD *et al.*, 1979
Tristramella	2	44 (2)	50 (2)		KORNFIELD *et al.*, 1979
Uaru	1	46	54	48	THOMPSON, 1979
Pomacentridae					
Abudefduf	4	48 (4)	48 (1) 50 (1) 52 (2)	48 (4)	ARAI & INOUE, 1976
Amphiprion	3	48 (3)	78 (1) 84 (2)	48 (3)	ARAI & INOUE, 1976; ARAI *et al.*, 1976
Dascyllus	1	47	48	48	ARAI & INOUE, 1976
Pomacentrus	1	48	48	48	ARAI & INOUE, 1976

Table 4. Karyotypes and some morphological characters of neotropical cichlids.

Species	Karyotype			Structure of neurocranium			Jaw apparatus		Caudal skeleton	
	NAN	2n	NF	Height of SOC*	Crest formed by SOC, F*	Apophysis of PS*	Jaw size	Height of articular process	PHYP*	Neural spine of second preural
Pterophyllum scalare	48	48	52	High	SOC & F	Present	Inter.**	Inter.	Reduced	Fine
Uaru amphiacanthoides	48	46	54	High	SOC & F	Present	Large	Inter.	Reduced	Blade shape
Geophagus jurupari	48	48	52	Inter.	SOC & F	Present	Inter.	Inter.	Developed	Blade shape
Cichlasoma nigrofasciatum	48	48	52	Inter.	SOC & F	Present	Inter.	Inter.	Reduced	Blade shape
Astronotus ocellatus	48	48	54	Low	SOC	Present	Inter.	Low	Reduced	Blade shape
Crenicichla saxatilis	48	48	52	Low	SOC	Absent	Large	Low	Absent	Blade shape
Nannocara anomala	46	44	62	Low	SOC	Absent	Small	Low	Absent	Pointed
Apistogramma agassizi	46	46	70	Low	SOC	Absent	Small	Low	Absent	Pointed

* SOC, Supraoccipital; F, Frontal; PS, Parasphenoid; PHYP, Parhypurapophysis.
** Intermediate.

CENTRARCHIDAE. NF of *Elassoma zonatum* is 50, whereas that of the other genera is 48. *Elassoma* is characteristic in no suborbital bones except the lachrymal, no lateral line on body and 5 branchiostegals. In other genera, both of suborbitals and lateral line on body are present, and the number of branchiostegals is 6. These facts seem to show that the polarity of the number of branchiostegals is from 6 to 5, and that the polarity of suborbitals and lateral line is from presence to absence.

PERCIDAE. NF of *Perca flavescens* and *Stizostedion vitreum vitreum* is 48, whereas those of other genera are 50 or more. Characteristics common to only both of *Perca* and *Stizostedion* are presence of one predorsal bone and 7 or 8 branchiostegals; absence of predorsal bones and presence of 5 or 6 branchiostegals in other genera. These facts seem to support that the polarity of the number of branchiostegals and predorsals is from being large to small.

CICHLIDAE. Karyotypes of 43 species of neotropical cichlid fishes have been reported (OYHENART-PERERA *et al.*, 1975; MICHELE & TAKAHASHI, 1977; THOMPSON, 1976, 1979). On the other hand, NEWSOME (1971) and CICHOCKI (1976) studied osteology of 46 species of neotropical cichlids. Although karyotypes and osteology of many neotropical cichlid species have been reported as described above, the number of species whose karyotypes and osteology both have been studied is only eight. Table 4 shows karyotypes and some morphological characters of 8 genera and 8 species of neotropical cichlids. Data of comparative anatomy are adopted from NEWSOME (1971) and CICHOCKI (1976).

From the viewpoint of fish phylogeny, NAN is the most important among 2n, NF and NAN, as discussed by ARAI and NAGAIWA (1976). NAN of neotropical cichlid fishes are 48 and 46 excepting that of *symphysodon aequifasciata* whose NAN could not be estimated. NAN of *Apistogramma* and *Nannocara* is 46 which is considered to be more specialized than NAN=48. Therefore, when the polarity of morphological characters is analized by NAN, polarities of 7 characters seem to be determined as follows (Table 4).

1) Low supraoccipital crest is more specialized than high or intermediate one. 2) Crest formed by only supraoccipital is more specialized than that formed by frontal and supraoccipital. 3) Apophysis of parasphenoid is from presence to absence. 4) Small jaw is more specialized than large or intermediate jaw. 5) Low articular process is more specialized than high or intermediate one. 6) Hypurapophysis on hypural one is from presence to absence. 7) Pointed neural spine of second preural is more specialized than blade-shape one.

Acknowledgments

We wish to express our gratitudes to Mr. Masayoshi HAYASHI, Yokosuka City Museum, Messers. Yukio SAWADA and Harumi SAKAI, Hokkaido University, Mr. Akihiko YATSU, Tokyo University of Fisheries, Dr. Keiichi MATSUURA, National Science Museum, Tokyo, and Mr. Mitsuaki SATO for collecting material fishes and

their assistance in the experiments.

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