

# Comparative Studies of the Scales in Japanese Freshwater Fishes, with Special Reference to Phylogeny and Evolution

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## I. Introduction

It has been recognized for a long time that scales are of great significance in fish classification, but it is quite strange that fish systematists should have hitherto attached too much importance to scale number or size and neglected scale form and structure. Those who have ever engaged in this line of study might have realized what a convenient material scale character is to consider the affinity between fishes. We may, therefore, by studying the difference in scale character, correct the errors which some systematists committed in their classification of fishes, and by further consideration, may even imagine the affinity between fishes, and accordingly the relation of phylogeny or evolution, too. Needless to say, however, it is dangerous to discuss phylogeny by a single morphological character, while it is rather impossible, though easy to speak, to consider phylogeny after studying all characters, especially in smaller groups of animals, apart from larger groups of them (such as phyla and classes). Knowing these circumstances well, the author has studied in this paper the phylogeny of freshwater fishes, and that considerably in detail — in some cases the phylogenetic relation between species, subspecies or varieties, too — making scale character his keynote and taking into consideration as many other morphological characters as possible. He believes that scale character is the best material for studying the affinity between fishes, and that no other structure shows the phylogeny of fishes better than that, which the author emphasized in the Japanese Journal of Ichthyology (1951) and the Zoological Magazine (1951).

As a matter of fact, phylogenetic studies are so full of adventures that some scholars (*e. g.*, N. YATSU, in his Classification Table of Animals, 1938) regard the group Chaetognatha as a phylum which ranks at the lowest part of the Enterocoel stem, while others (*e. g.* T. KOMAI, in his Classification Table for the Course in Systematic Zoology, 1949), as a class in phylum Annelida belonging to the Teloblast stem, which is quite another stem. And then the animal group Endoprocta is regarded by some scholars (*e. g.*, N. YATSU) as an independent phylum, while by others (*e. g.*, T. KOMAI), as a class in Molluscoidea. Phylogeny is so difficult a problem to solve.

This study of the author's is limited within Order Teleostei in Subclass Teleostomi under Class Pisces in Vertebrata, and the relation between families, their origins, and the phylogenetic relation between subfamilies, and furthermore, the relation of affinity between genera, species, sometimes subspecies, or varieties being considered here, it may not be so serious a matter even if the study is not successful, and it may be considered of great value if successful. And the author believes that in this paper he could judge those relations quite calmly, with scale character as the ground and center of the judgment.

There are actually a great number of variations in scale character. Even in the same individual, scales are very different in form and structure, according to the portion of the body which they are attached to. In some extreme cases, it is not seldom that we find ctenoid scales in the center of the body side (c. b. s.), but cycloid scales on the breast and belly. Moreover, scales have their own characteristics respectively like plant-leaves, and no two identical ones can be found even in the same portion

of the body of the same individual; they are just like finger or sole pattern of man. But in spite of such variations in form and structure, when they are minutely observed, they are by no means mere disorder, but have the characteristics of the genus, species, or the race in the species, which the fish belongs to.

To avoid complexity, however, in the comparative study between fishes, scales in c. b. s. and on the side of caudal peduncle (s. c. p.) are used. According to the group of fishes, scales in c. b. s. are more suitable as in Salmonidae and Gobiidae, and scales on s. c. p., as in Cyprinidae. When the specimen of a fish is at hand, the author examined and compared the scales, taking them from as many portions as possible, and using as many of them as possible.

The greater part of the Japanese freshwater fishes are included in this study, as you will be seen in the following table (scaleless Petromyzontidae, Salangidae, Siluridae, Bagridae, Flutidae, Pleuronectidae, Cottidae, and *Leucopsarion petersi* in Gobiidae being excepted; Acipenseridae with ganoid scales, and Gasterosteidae with scutes studied by K., IKEDA, in 1933, being also excepted), and in addition to them, those closely related to them and found in the neighbouring islands of Japan, i. e., Formosa, Sakhalin, Kuriles, and in the neighbouring Continent, i. e. Corea, Manchuria and China, or further away in Central Asia, Europe and Hawaii, are also used, amounting to 23 families, 85 genera, or 161 species (or subspecies) of fishes.

To denote the two structures, which are the most important elements in scale sculpture, the technical terms Grooves (Radii), and Ridges (Circuli) are used, in accordance with the author's point of view in 1951 (Jap. Jour. Ichthyol., Vol. 1, No. 3).

As to the systematical studies covering the whole fish lepidology, there is an old one by T. D. A. COCKERELL, and a new excellent one on Cyprinidae by Y. T. CHU, while on Japanese Cyprinidae, Cobitidae, Plecoglossidae, etc., there is the author's and on Salmonidae, OHNO & ANDO's and M. OSHIMA's. The author referred not only to these papers, but also to as many papers as he could which have anything to do with scales, reinspectng the figures and photos shown in them and comparing them with those of his own collection, and borrowed from these papers only those impossible for him to collect, after carefully examining them.

The general system of classification of Pisces is chiefly based upon OKADA & MATSUBARA's "Key to the Fishes and Fish-like Animals in Japan", and as to the fishes of the Continent, MORI's Illustrated Encyclopedia of the Fauna of Japan, and MIYADI's Freshwater Fishes in Manchuria, were always referred to, the specimens of the group identified by its specialist being used, and when classifying them himself, the original papers of classification were referred to as much as possible, and above all, the books mentioned below were always kept at his elbow.

- KOBAYASI, H. 1935: The Japanese Freshwater Fishes, and their Parasites (in Japanese).  
Yōkendō, Tokyo.
- OKADA, Y. & NAKAMURA, M. 1948: The Japanese Freshwater Fishes (in Japanese). Nihon-shuppansha, Osaka.

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## II. Table of fishes used in this study

( ( ) Japanese species )  
( [ ] Exotic species )

Class PISCES

Subclass TELEOSTOMI

Order TELEOSTEI

I Suborder ISOSPONDYLI

[ 1 ] Family Engrauridae

Genus *Coilia*

( 1 ) *Coilia mystus* (LINNAEUS)

( 2 ) *Coilia ectenes* JORDAN et SEALE

[ 2 ] Family Dorosomatidae

Genus *Clupanodon*

( 3 ) *Clupanodon punctatus* (TEMMINCK et SCHLEGEL)

[ 3 ] Family Coregonidae

1) Genus *Coregonus*

[ 4 ] *Coregonus ussuriensis* BERG

[ 5 ] *Coregonus alvula* LINNAEUS

2) Genus *Brachymystax*

[ 6 ] *Brachymystax lenok* (PALLAS)

[ 4 ] Family Salmonidae

1) Genus *Oncorhynchus*

( 7 ) *Oncorhynchus nerka* (WALBAAUM)

( 8 ) *Oncorhynchus nerka adonis* (JORDAN et MCGREGOR)

( 9 ) *Oncorhynchus kawamurae* JORDAN et MCGREGOR

( 10 ) *Oncorhynchus gorbuscha* (WALBAUM)

( 11 ) *Oncorhynchus keta* (WALBAUM)

( 12 ) *Oncorhynchus kisutsch* (WALBAUM)

( 13 ) *Oncorhynchus tschawytcha* (WALBAUM)

( 14 ) *Oncorhynchus masou* (BREVOOT)

( 15 ) *Oncorhynchus masou macrostoma* (GÜNTHER)

( 16 ) *Oncorhynchus rhodurus* JORDAN et MCGREGOR

2) Genus *Salvelinus*

( 17 ) *Salvelinus fontinalis* (MITCHILL)

- (18) *Salvelinus leucomaenis* (PALLAS)
- (19) *Salvelinus pulvius* (HILGENDORF)
- [20] *Salvelinus malma* (WALBAUM)
- [21] *Salvelinus malma curiles* (PALLAS)
- (22) *Salvelinus miyabei* OSHIMA
- 3) Genus *Salmo*
  - (23) *Salmo shasta* JORDAN
- 4) Genus *Hucho*
  - (24) *Hucho perryi* (BREVOOT)
  - [25] *Hucho taimen* (PALLAS)
- [5] Family Plecoglossidae
  - Genus *Plecoglossus*
    - (26) *Plecoglossus altivelis* TEMMINCK et SCHLEGEL
- [6] Family Thymallidae
  - Genus *Thymallus*
    - [27] *Thymallus jaluensis* MORI
- [7] Family Osmeridae
  - 1) Genus *Osmerus*
    - (28) *Osmerus dentex* STEINDACHNER
  - 2) Genus *Spirinchus*
    - (29) *Spirinchus lanceolatus* (HIKIDA)
  - 3) Genus *Hypomesus*
    - (30) *Hypomesus olidus* (PALLAS)
- II Suborder CYPRINODONTES
  - [8] Family Cyprinodontidae
    - Genus *Aplocheilus*
      - (31) *Aplocheilus latipes* (TEMMINCK et SCHLEGEL)
  - [9] Family Poeciliidae
    - Genus *Gambusia*
      - (32) *Gambusia affinis* (BAIRD et GAIMARD)
- III Suborder EVENTHOGNATHI
  - [10] Family Cyprinidae
    - (a) Subfamily Acheilognathinae
      - 1) Genus *Pseudoperilampus*
        - (33) *Pseudoperilampus typus* BLEEKER
      - 2) Genus *Acanthorhodeus*
        - [34] *Acanthorhodeus guichenoti* (GÜNTHER)
        - [35] *Acanthorhodeus asmussi* (DYBOWSKY)
        - [36] *Acanthorhodeus chankaensis* (DYBOWSKY)
        - [37] *Acanthorhodeus gracilis* REGAN
        - [38] *Acanthorhodeus tokunagai* MORI
      - 3) Genus *Rhodeus*
        - (39) *Rhodeus ocellatus* (KNER)
        - [40] *Rhodeus sericeus* (PALLAS)
      - 4) Genus *Parachilognathus*

- (41) *Paracheilognathus rhombea* (TEMMINCK et SCHLEGEL)
- [42] *Paracheilognathus coreanus* (STEINDACHNER)
- (43) *Paracheilognathus tabira* JORDAN et THOMPSON
- 5) Genus *Acheilognathus*
  - (44) *Acheilognathus longipinnis* REGAN
  - (45) *Acheilognathus moriokae* JORDAN et THOMPSON
  - (46) *Acheilognathus intermedia* (TEMMINCK et SCHLEGEL)
  - (47) *Acheilognathus limbata* (TEMMINCK et SCHLEGEL)
  - (48) *Acheilognathus lanceolata* (TEMMINCK et SCHLEGEL)
  - (49) *Acheilognathus cyanostigma* JORDAN et FOWLER
  - [50] *Acheilognathus signifer* BERG
  - [51] *Acheilognathus himandegus* GÜNTHER
- 9) Genus *Tanakia*
  - (52) *Tanakia miobuta* (TANAKA)
- (b) Subfamily Gobioninae
  - 1) Genus *Gnathopogon*
    - (53) *Gnathopogon elongatus* (TEMMINCK et SCHLEGEL)
    - (54) *Gnathopogon elongatus suwae* JORDAN et HUBBS
    - (55) *Gnathopogon caerulascens* (SAUVAGE)
    - (56) *Gnathopogon biwae* (JORDAN et SNYDER)
    - (57) *Gnathopogon japonicus* (SAUVAGE)
    - (58) *Gnathopogon gracilis* (TEMMINCK et SCHLEGEL)
    - [59] *Gnathopogon tsuchigae* JORDAN et HUBBS
  - 2) Genus *Sarcocheilichthys*
    - (60) *Sarcocheilichthys variegatus* (TEMMINCK et SCHLEGEL)
    - [61] *Sarcocheilichthys sinensis* BLEEKER
    - [62] *Sarcocheilichthys morii* JORDAN et HUBBS
  - 3) Genus *Coreoleuciscus*
    - [63] *Coreoleuciscus splendidus* MORI
  - 4) Genus *Pungtungia*
    - (64) *Pungtungia hilgendorfi* (ISHIKAWA)
  - 5) Genus *Hemibarbus*
    - (65) *Hemibarbus barbatus* (TEMMINCK et SCHLEGEL)
    - (66) *Hemibarbus eristigma* JORDAN et HUBBS
    - [67] *Hemibarbus longirostris* (REGAN)
    - [68] *Hemibarbus labeo* (PALLAS)
  - 6) Genus *Belligobio*
    - [69] *Belligobio mylodon* (BERG)
  - 7) Genus *Pseudorasbora*
    - (70) *Pseudorasbora parva* (TEMMINCK et SCHLEGEL)
    - (71) *Pseudorasbora parva pumila* MIYADI
  - 8) Genus *Abbottina*
    - (72) *Abbottina psegma* JORDAN et FOWLER
    - [73] *Abbottina rivularis* (BASILEWSKY)

- 9) Genus *Pseudogobio*  
(74) *Pseudogobio esocinus* (TEMMINCK et SCHLEGEL)
- 10) Genus *Biwia*  
(75) *Biwia zezera* (ISHIKAWA)
- (c) Subfamily Leuciscinae
- 1) Genus *Zacco*  
(76) *Zacco platypus* (TEMMINCK et SCHLEGEL)  
(77) *Zacco temminckii* (TEMMINCK et SCHLEGEL)  
(78) *Zacco pachycephalus* (GÜNTHER)
- 2) Genus *Opsariichthys*  
(79) *Opsariichthys uncirostris* (TEMMINCK et SCHLEGEL)  
(80) *Opsariichthys bidens* GÜNTHER
- 3) Genus *Tribolodon*  
(81) *Tribolodon hakonensis* (GÜNTHER)
- 4) Genus *Phoxinus*  
(82) *Phoxinus steindachneri* SAUVAGE  
(83) *Phoxinus steindachneri yamamotoi* SAUVAGE  
(84) *Phoxinus lagowskii* (DYBOWSKY)  
(85) *Phoxinus percunurus* (PALLAS)  
(86) *Phoxinus percunurus sachalinensis* BERG  
(87) *Phoxinus semotilus* (JORDAN et STARKS)  
(88) *Phoxinus oxycephalus* (BLEEKER)
- 5) Genus *Leuciscus*  
(89) *Leuciscus waleckii* (DYBOWSKY)
- 6) Genus *Aphyocypris*  
(90) *Aphyocypris chinensis* GÜNTHER
- 7) Genus *Ctenopharyngodon*  
(91) *Ctenopharyngodon idellus* (CUVIER et VALENCIENNES)
- 8) Genus *Ischikauia*  
(92) *Ischikauia steenackeri* (SAUVAGE)
- 9) Genus *Hemigrammocypripis*  
(93) *Hemigrammocypripis rasborella* FOWLER
- (d) Subfamily Cyprininae
- 1) Genus *Carassius*  
(94) *Carassius carassius* LINNAEUS  
(95) *Carassius carassius* LINNAEUS var. "Tetugyo"  
(96) *Carassius carassius auratus* LINNAEUS. Goldfish
- 2) Genus *Cyprinus*  
(97) *Cyprinus carpio* LINNAEUS  
(98) *Cyprinus carpio* LINNAEUS × *Carassius carassius* LINNAEUS
- (e) Subfamily Hypophthalmichthynae
- 1) Genus *Hypophthalmichthys*  
(99) *Hypophthalmichthys molitrix* (CUVIER et VALENCIENNES)
- 2) Genus *Aristichthys*  
(100) *Aristichthys nobilis* (RICHARDSON)

## (II) Family Cobitidae

- 1) Genus *Leptobotia*
  - [101] *Leptobotia manchurica* BERG
- 2) Genus *Hymenophysa*
  - (102) *Hymenophysa curta* (TEMMINCK et SCHLEGEL)
- 3) Genus *Misgurnus*
  - (103) *Misgurnus fossilis anguillicaudatus* (CANTOR)
  - [104] *Misgurnus fossilis decemcirrosus* (BASILEWSKY)
  - [105] *Misgurnus fossilis fossilis* LINNAEUS
- 4) Genus *Lefua*
  - (106) *Lefua echigonia* JORDAN et RICHARDSON
  - (107) *Lefua nikkonis* (JORDAN et FOWLER)
  - (108) *Lefua costata* (KESSLER)
- 5) Genus *Cobitis*
  - (109) *Cobitis taenia* LINNAEUS
    - (i) *Cobitis taenia taenia* (LINNAEUS)
    - (ii) *Cobitis taenia striata* IKEDA
    - (iii) *Cobitis taenia biwae* JORDAN et SNYDER
  - (110) *Cobitis delicata* NIWA
  - [111] *Cobitis multifasciata* WAKIA et MORI
  - [112] *Cobitis rotundicauda* WAKIA et MORI
- 6) Genus *Nemachilus*
  - (113) *Nemachilus barbatulus toni* (DIBOWSKY)

## IV Suborder APODES

## [12] Family Anguillidae

Genus *Anguilla*

- (114) *Anguilla japonica* TEMMINCK et SCHLEGEL
- (115) *Anguilla mauritiana* BENNET

## V Suborder SYNENTOGNATHI

## [13] Family Hemirhamphidae

Genus *Hemirhamphus*

- (116) *Hemirhamphus kurumeus* (JORDAN et STARKS)

## VI Suborder Acanthopterygii

## (I) Percosoces

## [14] Mugilidae

1) Genus *Mugil*

- (117) *Mugil cephalus* LINNAEUS
- [118] *Mugil carinatus* CUVIER et VALENCIENNES

2) Genus *Liza*

- [119] *Liza parva* OSHIMA
- (120) *Liza haematocheila* (TEMMINCK et SCHLEGEL)

## (II) Labyrinthini

## [15] Ophicephalidae

Genus *Channa*

- (121) *Channa argus* (CANTOR)

- (122) *Channa maculata* (LACÉPEDE)  
 (123) *Channa asiatica* (LACÉPEDE)
- [16] Family Anabatidae  
 Genus *Macropodus*  
 (124) *Macropodus chinensis* (BLOCH)
- (III) *Percomorphi*  
*Scombroidei*
- [17] Family Leiognathidae  
 Genus *Leiognathus*  
 (125) *Leiognathus nuchalis* (TEMMINCK et SCHLEGEL)  
 Percoidei
- [18] Family Centrarchidae  
 Genus *Micropterus*  
 (126) *Micropterus salmoides* (LACÉPEDE)
- [19] Family Kuhlidae  
 Genus *Kuhlia*  
 (127) *Kuhlia marginata* (CUVIER et VALENCIENNES)
- [20] Family Cerranidae  
 (a) Subfamily Oligoninae  
 Genus *Lateolabrax*  
 (128) *Lateolabrax japonicus* (CUVIER et VALENCIENNES)  
 (b) Subfamily Epinephelinae  
 1) Genus *Coreoperca*  
 (129) *Coreoperca kawamebari* (TEMMINCK et SCHLEGEL)  
 (130) *Coreoperca herzi* HERZENSTEIN  
 2) Genus *Siniperca*  
 [131] *Siniperca shautsi* BASILEWSKY  
 [132] *Siniperca scherzeri* STEINDACHNER
- [21] Family Sparidae  
 Genus *Sparus*  
 (133) *Sparus swinhonis* GÜNTHER
- [22] Family Theraponidae  
 Genus *Therapon*  
 (134) *Therapon oxyrhynchus* (TEMMINCK et SCHLEGEL)  
 (135) *Therapon jarba* (FORSKAL)
- (IV) *Gobioidei*
- [23] Family Gobiidae  
 (a) Subfamily Eleotrinae  
 1) Genus *Mogurnda*  
 (136) *Mogurnda obscura* (TEMMINCK et SCHLEGEL)  
 2) Genus *Eleotris*  
 (137) *Eleotris oxycephala* TEMMINCK et SCHLEGEL  
 [138] *Eleotris swinhonis* GÜNTHER  
 (b) Subfamily Gobiinae  
 1) Genus *Gobius*

- (139) *Gobius similis* (GILL)  
 (140) *Gobius fusus* RUPPEL  
 (141) *Gobius gymnauchen* BLEEKER  
 (142) *Gobius giurinus* RUTTER  
 (143) *Gobius pflaumi* BLEEKER  
 [144] *Gobius candidianus* (REGAN)  
 [145] *Gobius formosanus* OSHIMA
- 2) Genus *Glossogobius*  
 (146) *Glossogobius biocellatus* (CUVIER et VALENCIENNES)  
 (147) *Glossogobius brunneus* (TEMMINCK et SCHLEGEL)
- 3) Genus *Chaenogobius*  
 (148) *Chaenogobius annularis urotaenia* (HILGENDORF)  
 (149) *Chaenogobius isaza* TANAKA
- 4) Genus *Acanthogobius*  
 (150) *Acanthogobius flavimanus* (TEMMINCK et SCHLEGEL)  
 (151) *Acanthogobius ommaturus* (RICHARDSON)  
 (152) *Acanthogobius lactipes* HILGENDORF
- 5) Genus *Tridentiger*  
 (153) *Tridentiger obscurus obscurus* (TEMMINCK et SCHLEGEL)  
 (154) *Tridentiger trigonocephalus* (GILL)
- 6) Genus *Pterogobius*  
 (155) *Pterogobius elapoides daimio* (JORDAN et SNYDER)
- 7) Genus *Chaeturiichthys*  
 (156) *Chaeturiichthys sciiistius* JORDAN et SNYDER  
 (157) *Chaeturiichthys hexanema* BLEEKER
- 8) Genus *Chasmichthys*  
 (158) *Chasmichthys dolichognathus* (HILGENDORF)
- (c) Subfamily Periophthalminae  
 Genus *Periophthalmus*  
 (159) *Periophthalmus cantonensis* (OSBECK)
- (d) Subfamily Sicyodiaphinae  
 Genus *Sicyopterys*  
 (160) *Sicyopterys japonica* TANAKA
- (e) Subfamily Trypaucheninae  
 Genus *Trypauchen*  
 (161) *Trypauchen vagina microcephalus* BLEEKER

(To be continued)