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Notes on the Intestinal Convolution of the Fishes of the Pomacentridae (Perciformes)

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Abstract The re-examination on the intestinal convolution of pomacentrid fishes including 10 genera and 32 species were carried out as the first step in the anatomical comparison of the two taxonomic groups, the pomacentrids and cichlids. The results obtained are shown as follows: 1) The observation on a substantial number of specimens in *Chromis notatus* revealed that the species has a specific intestinal type only with few individual variations, convincing the specificity of intestinal type in this group of fish; 2) In the fishes of *Abudefduf vaigiensis* and *Actinicola percula*, the specific intestinal type is completed at 6.1 cm (S. L.) in the former and 4.6 cm in the latter; 3) Four distinct intestinal types are found among the pomacentrids examined; 4) These four types, though different in the complexity of coiling, are somewhat similar to those of the cichlids.

Introduction

A certain regulation of intestinal types was found on the fishes genus *Tilapia* and other cichlids (Fukusho, 1967). Aoyagi (1941) examined the digestive system of the pomacentrids considering its close relation to the cichlids, and paid special attention to the intestinal convolution as a specific and diagnostic character. But his expression of intestinal types seemed to exhibit a little lack of uniformity, and it would seem appropriate to re-examine the character, adopting the same procedures taken as in the study of cichlids by Fukusho (1967). Also it is intended to compare the pomacentrids and cichlids from various viewpoints. The present study was carried out as the first step in the series of studies on this particular group of fish. The present paper deals with the examination on the character of intestine in 32 species (Table 1) referred to the Family Pomacentridae which are found in Japanese water.

Material and Methods

Material. Most of the pomacentrids examined in this study originated from the specimens collected by the Amami Island Expedition of Misaki Marine Biological Institute, Kyoto University, in 1958, and some specimens collected in Yoron Island in Ryukyu Islands as well as Okinawa-jima. The material of the pomacentrid *Chromis notatus* was obtained at the fish market of Maizuru, Kyoto Prefecture. Other specimens of the pomacentrids were, supplied from the Himeji City Aquarium in Hyogo Prefecture.

Experiment procedure. The intestine with stomach removed from the body cavity was observed and sketched by using binocular dissecting microscope, the observations being made on dorsal, left and right side of the organ, and schematic drawing of intestinal convolution from oesophagus to anus was made. The mode of intestinal convolution or coiling was studied on the ventral side of the organ as stressed by Kafuku (1952, 1958), who found the true character of the organ in its ventral side, instead of dorsal or lateral side as adopted by former workers as Aoyagi (1941), Suyehiro (1942) and others. In the present study on the intestine of pomacentrid fishes, the terms right, left, upward or downward mean those directions observed on the

Table 1. List of pomacentrid fishes studied and the types of intestine diagnosed for each species. The sources of specimens are indicated by: YN, Yoron Id.; MIKU, Misaki Marine Biological Station, Kyoto University; FAKU, Okinawan specimens, deposited at Dept. of Fisheries, Kyoto University; HA, Himeji City Aquarium.

Species	S.L. (cm)	Specimen	Intestinal type
Amphiprion xanthurus	5.9	YN	B
A. frenatus	8.6	YN	B
A. laticlavius	9.8	HA	B
A. perideraion	3.8	MIKU-2860	B
Actinicola percula	5.6	YN	B
Chromis isharae	10.2	MIKU-2483	B
C. dimidiatus	3.1	FAKU-41261	B
C. caeruleus	6.0	FAKU-41213	A
Siphonochromis lepidostethicus	9.2	MIKU-2322	C
Tetradrachmum aruanum	4.9	FAKU-41254	C
Parapomacentrus nigricans	7.9	MIKU-2452	D
P. aureus	6.1	MIKU-3117	B
P. marginatus	7.2	MIKU-2795	D
Pomacentrus dorsalis	5.5	MIKU-2807	B
P. caudovittatus	6.0	MIKU-2770	B
P. flavicauda	5.4	MIKU-3114	B
P. nagasakiensis	4.6	MIKU-3135	B
P. moluccensis	4.3	MIKU-3070	C
P. fumeus	3.4	FAKU-41260	B
Cheiloprion labiatus	4.4	FAKU-41259	B
Abudefduf vaigiensis	12.6	MIKU-2789	B
A. leucozonus	7.3	MIKU-2792	B
A. sordidus	6.6	MIKU-2793	B
A. sexfasciatus	2.4	MIKU-2778	B
Chrysiptera albofasciata albofasciata	5.4	MIKU-2810	B
C. xanthura cochinensis	8.2	MIKU-2769	B
C. hollisi	6.6	MIKU-2755	B
C. uniocellata	4.1	MIKU-3140	B
C. zonata	5.0	MIKU-3146	B
C. glauca	4.5	MIKU-3147	C
C. rex	4.6	MIKU-3059	C

ventral side of the organ. The pattern of convolution of intestine, which supplied the basis to diagnose the differentiation of the organ, was described by stating the way it is laid out and pointing out the positions where the intestine makes turning or bending. These positions were desingnated by numbers 1 to 10 in the order from oesophagus to anus (see Figs. 1 and 2); the curvature of the organ in an arch or a circle was denoted by the term "loop" followed by same numbers as above, for instance, the loop 3–4–5 meaning the arch or circle formed between 3 and 5 passing 4. Diagramatic drawings, illustrated in the present article, may be of help to show the true picture of intestinal convolution, which otherwise could hardly be diagnosed.

Results

Consistency of the Intestinal Convolution Observed in *Chromis notatus*

To evaluate the character, the individual variation within the species was examined in *C. notatus*, a species with wide geographical distribution in the shore waters throughout Japan. The total of 346 specimens measuring 6.4 to 10.3 cm in standard length and

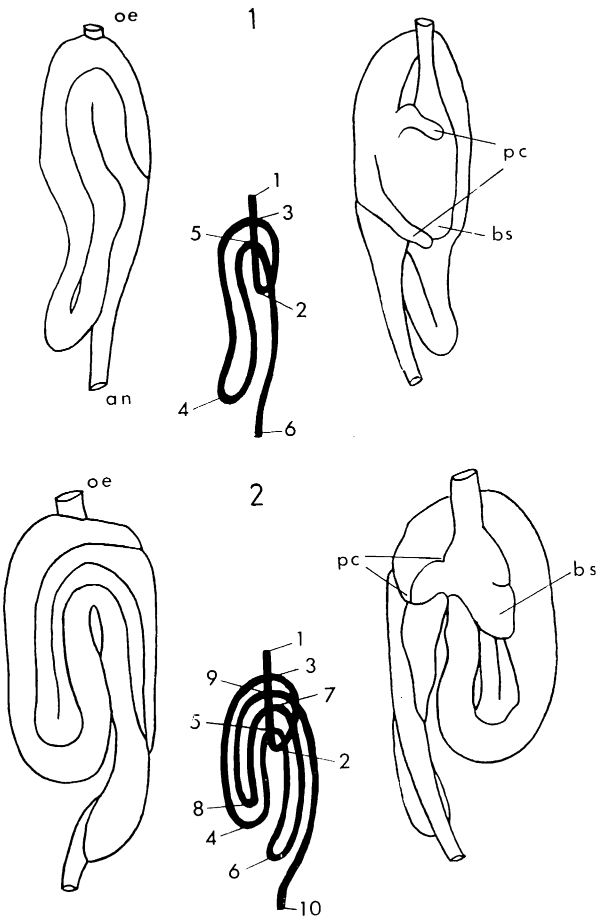

Fig. 1. Two types, A and B of intestinal convolution. 1, Type A, represented by *Chromis caeruleus* (6.0 cm in S.L.) showing ventral (left) and dorsal view (right), and diagramatic presentation of ventral view (middle); 2, Type B seen in *Chromis notatus* (9.1 cm) presented same as other species. oe, oesophagus; an, anus; pc, pyloric caecum; bs, blind sac.

collected at Maizuru fish market were studied. Among those, 340 had the organ categorized under Type B (Fig. 1, 2), two individuals Type A (Fig. 1, 1), and other four fell on the intermediate category of these two types. All of the 10 specimens (2.9 to 10.0 cm) came from Amami Islands showed the Type B convolution in their intestine. The examination of *C. notatus*, it is believed, shows that the type of intestinal convolution is a highly consistent character among the species of pomacentrid fishes.

Development and Establishment of Specified Pattern of Intestinal Convolution

The ontogenetical study of the intestine has been made on a limited number of fish (Yoshizaki, 1957, 1958; Yamane, 1964; and others), but the pomacentrid fishes have been so far left blank in this respect. However, for the evaluation and biological interpretation of the convolution pattern of the intestine it was felt necessary to trace the development of the pattern along with the growth of the fish and to find out the growth stage of the fish completing the specified type of convolution. In the present study the two species, *Abudefduf vaigiensis* and *Actinicola percula* were selected partly because

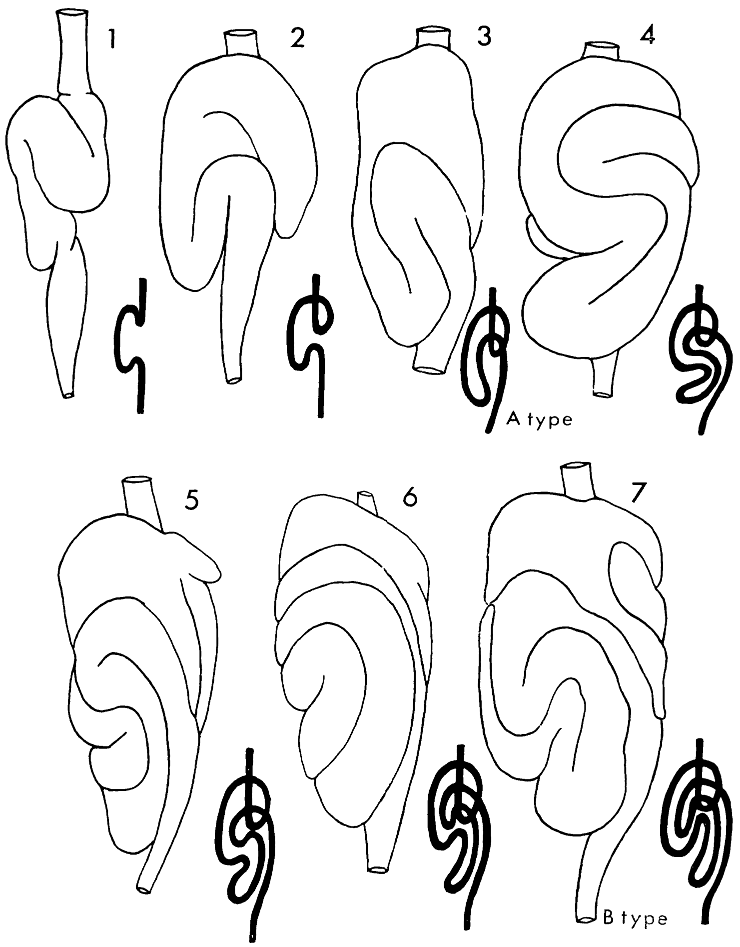

Fig. 2. Change of intestinal convolution in *Abudefduf vaigiensis* (Type B) with growth of fish tracing the recapitulation from Type A to B. Numerical order 1 to 7 indicates the size of fish measuring in standard length 1.3, 1.4, 1.4, 3.4, 3.9 and 6.1 cm respectively.

of their size, attained and the easiness to obtain the specimens in series. In the first species *A. vaigiensis* of which a series of specimens ranging from 1.3 to 3.6 cm in standard length was tested, the formulation of the convolution was traced in seven arbitrary stages (Fig. 2) starting from the first stage (1.3 cm) where the intestine is a single tube with a simple convolution in the middle to the last stage (6.1 cm) when the convolution is completed pattern it was of highly interest to find that the organ developed to the final completed Type B through a stage (1.4 cm) where the convolution was shaped Type A. Similar change of the pattern was also demonstrated in a series of specimens of *A. percula* (2.5 to 4.6 cm), in which the final completed pattern of Type B was reached in the fish 4.6 cm long.

Four Types of Intestinal Convolution

The present study on the pattern of intestinal convolution attempted on 32 species found it most justifiable as far as macroscopical examination is concerned to recognize four types of intestinal convolution. These types, designated as A, B, C and D, are believed to be an established character possessed by each species, and are diagnosed below together with il-

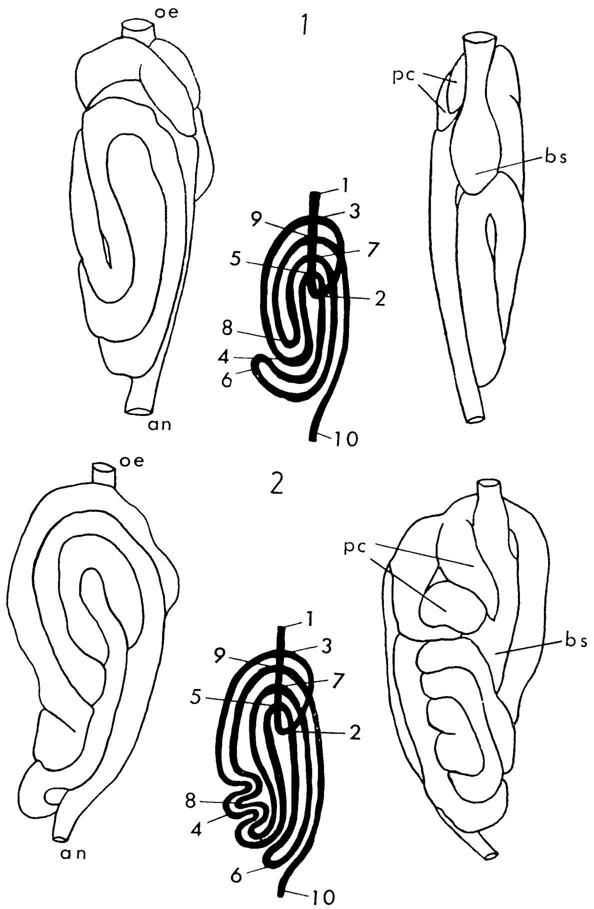

Fig. 3. Two types, C and D intestinal convolution illustrated in the same way as in Fig. 1, 1, Type C observed in *Chrysiptera glauca* (4.5 cm in S.L.); 2, Type D in *Parapomacentrus marginatus* (6.2 cm).

lustrations (Figs. 1 and 3).

Type A (Fig. 1, 1). This is the most simplified convolution, and found only in *Chromis caeruleus* among 32 species treated. It is diagnosed: the intestine from oesophagus runs straight downward to the position 2, where it turns forward on the position 3, it goes down in a concave to the position 4; the intestine there makes an acute bend upward and goes up alongside the loop 3–4: the intestine again makes an acute turning at the position 5, then proceeds downward in a weak curve on the right of the axis of oesophagus, and reaches the anus at position 6.

Type B (Fig. 1, 2). The present type of intestine is found in 25 species or 80% of the species examined. The convolution in this type is traced in a similar pattern as in the Type A up to the position 4, but the intestine at this position turns forward again instead of opening to the anus there: the intestine, then, forms a loop passing the positions 7, 8, and 9, which is enclosed in the loop 3–4–5, and goes down outside the curve 6–7 to the anus (position 10).

Type C (Fig. 3, 1). The Type C of convolution is demonstrated by *Chrysiptera glanca* and other four species or 16% of the species examined. The pattern is very close to that in Type B, from which it is distinguished by the turning at the position 6. The turning extends laterally beyond the axis oesophagus and directs slightly upward.

Type D (Fig. 3, 2). The Type D is represented by the two species, *Parapomacentrus marginatus* and *P. nigricans*. The present type appears to be a replica of the Type B, but it differs from the latter by the two meandering made at the positions both 4 and 8.

The species of the pomacentrids and their intestinal types thus far examined are shown in Table 1. It appears certain, as seen in the table, that the type of convolution of the intestine carries no significance as a character to define species and genera in the pomacentrid fishes.

The other characters associated with digestive tract were found less differentiated than in the pattern of intestinal convolution. The pyloric caeca, attached around the terminal end of the stomach to intestine, are counted two, in *Chromis caeruleus*, and three in the rest of the species examined. The size or extent of development of organ depends more or less on species and individuals. The stomach of the pomacentrid fishes is well developed morphologically, and the organ in all the species exhibits either Y-shape or incomplete Y-shape in the terms used Suyehiro (1942), thus retaining no specificity.

Discussion

Some workers on fishes (Aoyagi, 1941; Berner, 1949; Yoshizaki, 1957, 1958; Watanabe, 1958; Ochiai, 1966; Kafuku, 1966 a, b, c; for example) used the morphology of the intestine as a diagnostic character in taxonomic studies of fish. It is generally held that the intestinal type, as well as gill raker number, dentition and body height, well reflects the feeding habits. Also, the character of the intestine especially has been highly valued as the criterion to deliberate the process of speciation or raciation of fishes within a limited taxonomic group. In corollary the character has served in the discussion of phylogenetic relationships not only in the field of ichthyology, but also the calyptrate muscoid flies (Hori, 1962), the scarabaeoids (Umetani, 1961), the drosophilids (Okada, 1954), and the hemipterids (Goodchild, 1966).

By the examination on the 346 fishes of *Chromis notatus* caught at the two different localities, it is believed that the species of pomacentrid fishes has a specified intestinal type. And, some irregularities found in some individuals (1.7%) are considered as a phenomenon of deformity which is experienced quite often in other characters.

Aoyagi (1941) reported that the intestine of the pomacentrids is well modified in each species and showed the shape of the alimentary canal viewed on the left side claiming that the form of the alimentary canal provides a criterion for the identification of the species. But, the present observations made on ventral side of the organ reveal that there are only four intestinal types among 32 species of the pomacentrids examined in the present study. Subsequently, it is assured the intestinal type of the these fishes bearing no specific significance.

The biological interpretation on these types of intestine may not be given at present due to the lack of the informations on their modes of life, such as habitats, feeding habits and other conditions. The only fact virtually found is that the types of the intestinal convolution in the species of the pomacentrids develop with no relation to other characters such as scalation, dentition, meristic characters, depth of body, etc., which serve as criteria in the separation of species and genera. In these particular group of the percoid fishes, the modification of the intestinal convolution is believed to have evolved in a diverse way, when the orthogenetical development of the organ in the cyprinids (Kafuku, 1952, 1958) is drawn to the attention.

The derivation of the pomacentrids was said to be the cichlids (Jordan and Snyder, 1902). On the contrary, there is another opinion that the ancestral forms of the cichlids were tropical and coral fishes including the pomacentrid (Nichols and Griscom, 1915). Supporting the hypothesis that the ancestral forms of the

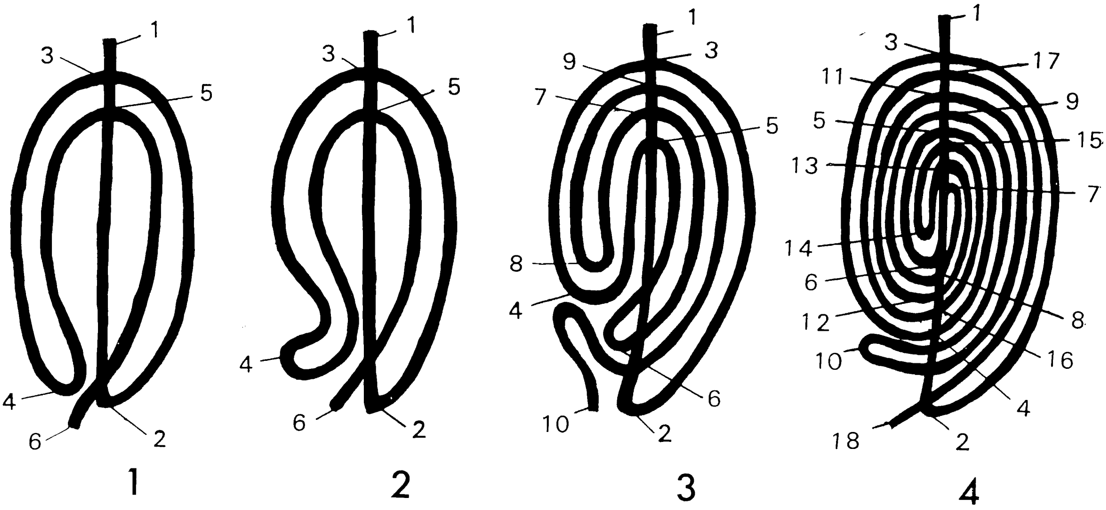

Fig. 4. Intestinal types found in cichlids. 1, South and Central American cichlids, *Aequidens pulcher* and others; 2, South American cichlids *Symphysodon discus* and *Cichlasoma severum*; 3, Indian cichlid *Etroplus maculatus*; 4, African cichlid *Tilapia mossambica*. Numerals to denote the bending and other features are same as those in Fig. 1, 2. After Fukusho (1967).

cichlids are the pomacentrids, Matsubara (1955, 1963) postulated the close phylogenetic relationships because of their peculiality such as possession of single nostril on each side, fuzed lower pharyngeal bone, and lateral lines in two parts, and he arranged the Cichlidae with the Japanese family name "Kawasuzume (meaning the freshwater pomacentrids)" beside the Pomacentridae under the Suborder Pomacentrina. This classification is somewhat different from that of Lagler, et al. (1962) and Greenwood, et al. (1966). Fukusho (1967) dealing with seven species of *Tilapia* and other several species of the cichlid fishes, ascertained the basic pattern of their intestinal convolution (Fig. 4). By the present investigation, it was ascertained that the pomacentrids is basically similar to the cichlids in the mode of intestinal convolution (compare Fig. 4 and Figs. 1, 2), as well as in other characters referred above, although they are different in the complexity of coiling and in their ontogenetical change. In view of comparative morphology, the results of present study may offer a fact here to advance the concepts of a close relationship between the cichlids and pomacentrids.

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スズメダイ科魚類の腸型について 福所邦彦

Pomacentridae および Cichlidae の両科は極めて近縁の分類群といわれており，この2分類群の形態上の比較の第一歩として消化系，とくに消化管の腹腔内走向（腸型）について調べた．その結果広い分布を示す *Chromis notatus* 356 尾の腸型は，種固有の腸型をそなえることが判明したので，ついで邦産スズメダイ科魚類 10 属 32 種について調査したところ腸型に 4 型 (Type) があり，それぞれの種がいずれかの型に属することを認めた．これらの腸型は分類形質としてはなお問題があるが，その構造の様式において近縁の cichlids のそれと基本的に類似していることがわかった．

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