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A Study on the Three Forms of *Sarcocheilichthys variegatus* in Lake Biwa

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Introduction

As seen in the international disputes related to raciation of Pacific salmon, raciation of fish seems to be a perpetual subject of discussion, not only with academic but also with industrial interests.

As to Japanese carp family, a very noteworthy article has lately been published by KAFUKU (1958), which successfully introduced the intestinal characters into raciation criteria and settled much of the racial discussion on the family. However, there still remains other category even in the same family, for which other new characteristics are required. And *Sarcocheilichthys variegastus* with three forms, *i. e.*, the Round headed, Long headed and Greasy, which are vaguely differentiated among fishermen, is an example.

In relation to taxonomical discrimination of these 3 intra-specific variations, only a few articles are citable, which have failed to reach beyond the superficial observation of fishermen. Especially, distinction between the Round- and the Long-headed has not been biologically established. It is the author's joy to be able to contribute to this problem in this small article.

Acknowledgements

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I) Samples and method

Of the three intra-specific variations, the Greasy is distinguishable from others by their peculiar coloration. AOKI (1957) and AOYAGI (1957) state the characteristic as follows :

"The Greasy, which is never found in other waters than Lake Biwa, in dotted with singular dark brown pigments all over the body surface."

The dinstinction of the other two from each other is far less informed and much more precarious. The above workers refer to them in the following brief and vague discription : "The Round-headed is rounder in head as the name implies, white in belly, and blue-black in back, while the Long-headed is longer in head, white in belly, and sharper in the tip of snout."

The author's experiment was started with samples assigned by the above criteria into the 3 groups roughly, on which techniques of comparative anatomy were applied to find rigid and reliable standard of discrimination.

Thus, their characteristics, were brought to light as shown in next chapter. Samples used were collected in Lake Biwa by professional fishermen. Tables 1 and 2 show that the samples are appropriate enough for the author's analysis.

Table 1. Size distribution of samples used

Standard length (cm)	3	4	5	6	7	8	9	10	11	12	13
Number	2	4	3	0	9	0	0	3	2	2	1

Table 2. Growth of *Sarcocheilichthys variegatus* according to the Report on Fisheries in Shiga Prefecture (1938)

Age	St. length (cm)
1	3-6 cm
2	9 cm
3	12-15 cm

II) Discrimination of the three variations (Plates I and II)

a. Body shape : The Greasy is conspicuous with body depth sharply increasing at the end of occiput.

b. Lips : In the Round-headed, upper lip is somewhat protruded and does not fit lower lip well. In both the Round- and the Long-headed, upper lip is a little cornificated, but more fleshy in the latter. In the Greasy, lateral lobes of lower lip are less prominent.

c. Barbels : Small barbels at the end of maxillaries are most rudimentary in the Greasy.

d. Black speckles at pectoral girdles : In the Greasy, no such speckles are observable, in contrast with the other two.

e. Furrows on branchiostegals :
Arrangement of the furrows running parallel with opercles are most complicated in the Greasy, and simplest in the Round-headed.

f. Copula of mandibles : Copula of both mandibles are smallest in the Round-headed, and largest in the Greasy.

g. Hind brain. : Rhomboid fossa is most distinct in the Round-headed, and is invisible from outside in the Greasy.
The Round-headed has also the most developed vagal and facial lobes, while the Greasy has not either visibly.

Ⅲ) Morphometric comparison among the three variations

With the samples reclassified on the basis of above criteria, morphometric difference was examined on various external characters. The following are those in which most conspicuous differentiation was detected :

a) Head length

Head length of the three variations is given in the following table, where H_R, H_L,

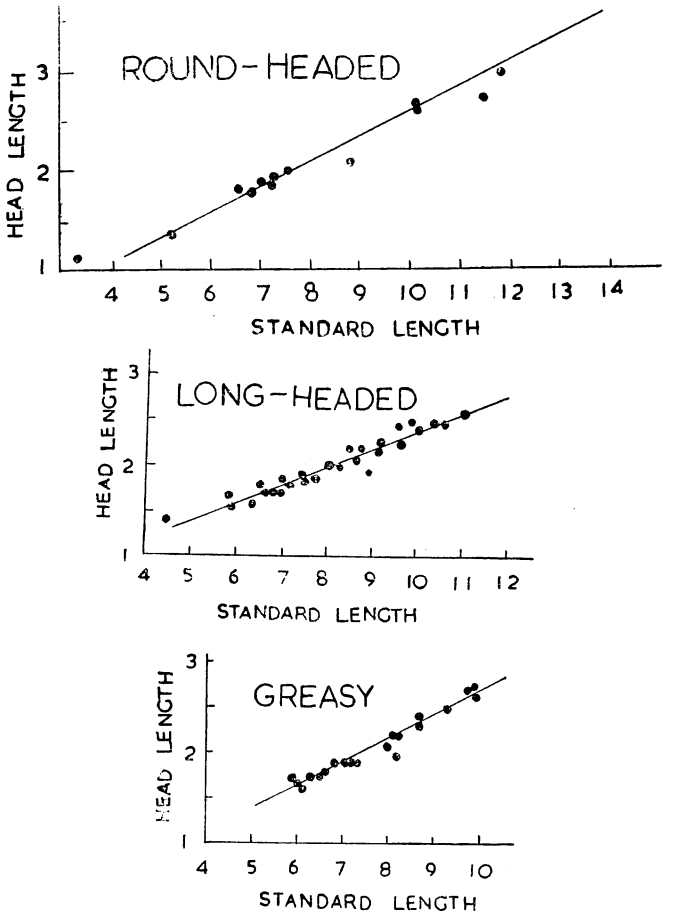


Fig. 1. Head and standard length relationship in the 3 variations.

H_G and S stand for head length of the Round-, Long-headed and Greasy, and standard length of body respectively (See Fig. 1).

		Standard body length of samples	
		Max.	Min.
Round-headed	$H_R = 0.221\,S + 0.1$	12.8 cm	4.3 cm
Long-headed	$H_L = 0.210\,S + 0.1$	11.0 cm	4.4 cm
Greasy	$H_G = 0.266\,S$	9.9 cm	5.9 cm

The difference in head length from each other, given by the above equations, is far beyond what would ordinarily be termed highly significant for $Pr \ll 0.01$.

It is to be noted that an inequality is deductive from the above equations, as $H_R < H_L < H_G$.

b) Relative position of anal fins

Relative position of anal fins determined by the following proportions (X), is another outstanding character with verifiable morphometric difference:

X=(length from the tip of snout to the back of the base of the first anal soft ray)/(length from the latter to distal end of vertical column).

The proportion for each variation is given by the following equations, where X_R, X_L, and X_G stand for the value for the Round-., Long-headed and Greasy:

$X_R = 3.08 \pm 0.18$ cm

$X_L = 3.15 \pm 0.16$ cm

$X_G = 3.34 \pm 0.18$ cm

(The difference among the above figures is proved statistically highly significant for Pr. $\ll 0.01$.)

An equation $X_R < X_L < X_G$ would be referred to later.

IV) Consideration in relation to their ecological inter-relation

According to EVANS ('31, '40), SATO ('41), UCHIHASHI (1953) and KAFUKU (unpublished), the species with barbels are bottom dwellers with developed vagal and facial lobes in hind brain, while those without barbels with both lobes under-developed are surface swimmers.

On other hand, KAFUKU (1957) drew the following conclusion from his extensive study carried out on carp family, both Japanese and American.

"The fish with anal fins closer to tail coincide with bottom dwellers while those with anal fins farther from tail, surface swimmers." The conclusion wrought out by the above workers may be applicable in relation to the objects of the author's study as follows: "The Round-headed with developed vagal and facial lobes in brain and anal fin closer to tail may select their ecological niche in bottom layer, while the Greasy with vagal and facial lobes invisible from outside, anal fins farther from tail and rudimentary barbels

Explanation of Plates

Heads and brains in three forms *Sarcocheilichthys variegatus*: from top to bottom the Round-headed, the Long-headed, and the Greasy. The all specimens examined are believed adult.

F-facial lobe, V-vagal lobe, R-rhomboid fossa.

Plate I

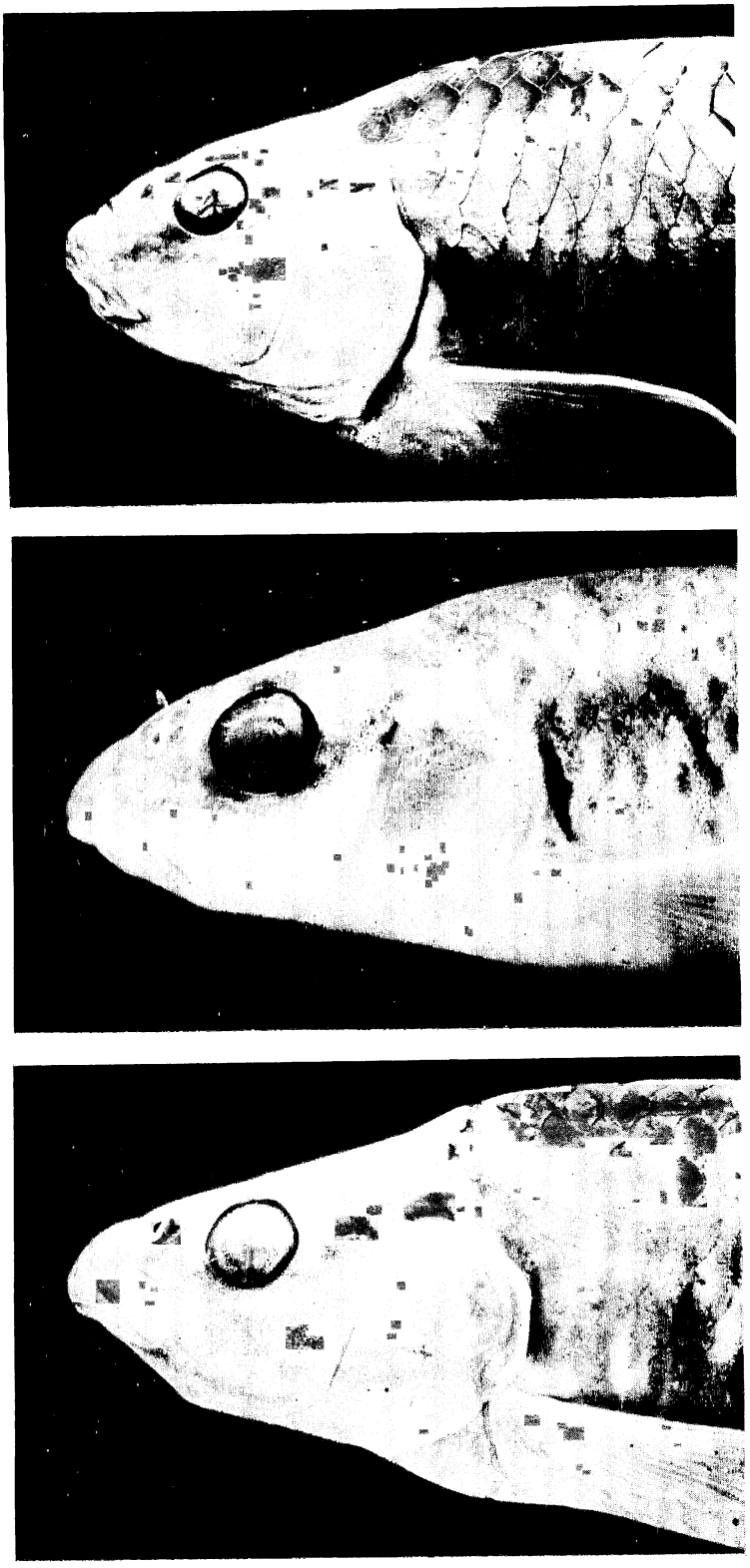
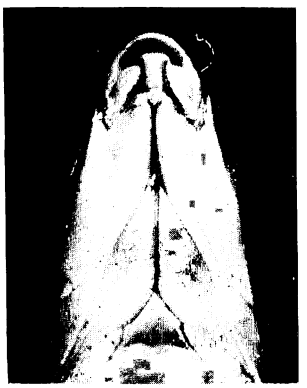
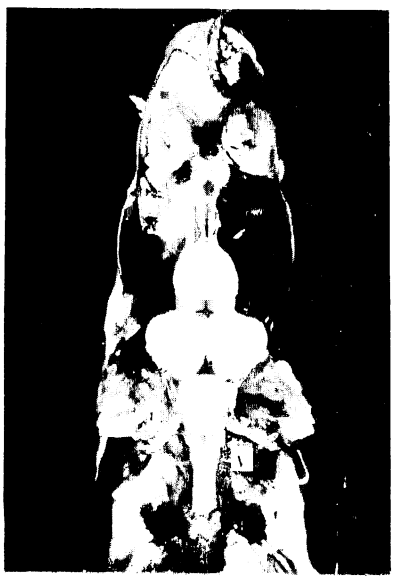


Plate II





probably prefer surface layer as their niche. The Long-headed would stand in between the two.

In the foregoing pages, the author has noted gradual variance among the characters of the three forms, Round- →Long-headed→Greasy or vice versa. This phenomenon reminds the author of the similar relation in the crucian carps (*Carassius carassius*) produced in Lake Biwa. Mr. KAFUKU and the present author (unpublished) notice that 3 endemic forms are found in this species of carp family, that among them Type A (Ganzo) are bottom dwellers, richest in the southern part of the Lake, that Type C (Gengoro) are surface swimmers, most abundant in the northern open part, and that Type B (Nigoro) stands in between the two.

According to "Report on Fisheries in Shiga Prefecture" (1938), the Greasy, supposed by the present author to be surface swimmers, are found most abundant in the northern open region, while the Round-headed, supposed by him to be bottom dwellers, are distributed richest in the southern region. The Long-headed are intermediate in the above character.

Synopsis

1) Three forms of *Sarcocheilichthys variegatus*, endemic species of Lake Biwa were established.

2) Their ecological features were discussed on their morphological characters, especially in relation to hinder brains and anal fin position.

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