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Hybridization Experiment between *Carassius carassius* ♀ and *Gnathopogon elongatus elongatus* ♂

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Abstract Hybrids from an intergeneric cross between *Carassius carassius* ♀×*Gnathopogon elongatus elongatus* ♂ were analyzed morphologically and karyologically and compared with the parental species. These hybrids possessed a mosaic of character expressions, but could be generally classified in two types similar to either *C. carassius* or *G. elongatus elongatus*. The karyotype was composed of two genomes of the *Carassius* parent and one of the *Gnathopogon* parent for the *Carassius*-type hybrids, and one genome of the *Carassius* parent and two genomes of the *Gnathopogon* parent for the *Gnathopogon*-type hybrids.

Hybridization experiments have been carried out by many investigators with salmonid, cyprinid, cobitidid and gasterosteid fishes. With cyprinid fishes, Suzuki (1962, 1963a–e, 1964, 1965a, b, 1966, 1968) performed experimental hybridizations among several species. However, these studies dealt almost exclusively with survival analysis, viability and morphological analysis, and with only a few species as parents. They have also taken little interest to chromosome morphology.

This paper, constituting the fifth in a series (Kasama and Kobayasi, 1987, 1988, 1989a, b) of articles dealing with investigation on morphological and karyological analyses of various artificial hybrids among the Cyprinida, examines intergeneric hybrids between *Carassius carassius* (Linnaeus) ♀ and *Gnathopogon elongatus elongatus* (Temminck et Schlegel) ♂.

Materials and methods

Fishes used in this study were *C. carassius* collected in Holland and *G. elongatus elongatus* from Lake Biwa. They had bred in our laboratory, and the second generation in each species was used as parental species. Artificial fertilization was performed as in the foregoing experiment (Kasama and Kobayasi, 1987). Hybrids used for morphological and karyological studies were about three and a half years old.

Methods for making most meristic counts and morphometric measurements were from Matsubara (1955) and Hubbs and Lagler (1970). Measurements were read from a dial caliper to 0.1 mm. We added two measures not typically taken on cyprinid fishes. "Pectoral fin origin to ventral fin origin" is the distance from the uppermost base of the pectoral fin to the uppermost base of the ventral fin. "Ventral fin origin to anal fin origin" is the distance from the uppermost point of the base of the ventral fin to the anterior basis of the anal fin. All meristic and morphometric characters and other aspects of the body analyzed here were chosen on the basis of marked and consistent differences between the parental species. The hybrid index computed following Hubbs and Kuronuma (1942) and Hubbs et al. (1943) was used to compare hybrid character states to the parental species. The mean of each character value was set at 0.0 for *C. carassius* and 100.0 for *G. elongatus elongatus*. A hybrid index of 50.0 for any character would indicate exact intermediacy of the hybrid between the parental species for that character. Scales at the region between the anterior base of the dorsal fin and the lateral line were plucked out, and examined after staining with alizarin red S. Pharyngeal bones were cleared in 1% KOH and stained with alizarin red S to examine their morphological features. The terminology for the scales and the pharyngeal bones followed that of Chu (1935). Vertebrae were counted from radiographs and included the four Weberian ossicles and the urostylar vertebra. The gonads fixed in dioxan-Bouin's solution were sectioned 6 μm by the usual paraffin method and stained with Delafield's hematoxylin and eosin. Chromo-

some study was carried out using cells from the primary culture of the scale epithelium. The cells were fixed in Carnoy's fluid, flame-dried on slides and stained with Giemsa.

Results

Development and viability. About 51% of 1,654 eggs produced from *C. carassius* ♀×*G. elongatus elongatus* ♂ developed into embryos up to the gastrular stage. Embryo mortality was high at this stage. Almost all surviving embryos hatched 80 to 98 hours after fertilization, and 44% of the eggs produced larvae. But 40% of the larvae suffered from edema, bent bodies and circulatory disorder and died 1 to 5 days after hatching. The survivors seemed to develop normally, but many could not feed and died within 10 days after hatching. Many larvae that did feed died with the lapse of time, over a period of a year, 62 hybrids were raised up to the young stage but most of them died at this stage due to malnutrition caused by digestive system disorders. Hybrids reared to the adult-like stage totaled 13.

Morphological characters. The hybrids were distinguished into two types on the basis of 11 characters (Table 1). Eleven were of the *Carassius*-type (Fig. 1b) similar to *C. carassius* (Fig. 1a) and the remaining two were of the *Gnathopogon*-type (Fig. 1c) similar to *G. elongatus elongatus* (Fig. 1d).

The *Carassius*-type hybrids: The body side was light and a golden copper-red, and each fin was dark red. At the adult-like stage, the dark spot at the base of the caudal fin characteristic of *C. carassius* was absent. The nine hybrids had barbels that were tubercular and minute which could not be seen by the naked eye. The two hybrids lacked barbels. The ratio of body depth/standard length approached exact intermediacy. But the outline from breast to belly was somewhat straight, similar to *G. elongatus elongatus*. The ratio of caudal peduncle length/caudal peduncle depth was closer to that of *C. carassius*. The ratios of pectoral fin origin to ventral fin origin/ventral fin origin to anal fin origin and dorsal fin base length/longest dorsal fin ray length were intermediate. The outline of the dorsal fin was round, similar to that of *C. carassius*. The number of dorsal fin rays approached intermediacy. The dorsal fin of the hybrids had the serrated ray characteristic of *C. carassius*, but the ventral fin lacked it. The numbers of lateral line scales and scales below the lateral line were closer to those of *C. carassius*. The number of scales above the lateral line was seven, which was the typical number for *C. carassius*. The aspect of the scales was very similar to that of *C. carassius*. The basal margin was wavy, but there were fewer waves than in *C. carassius*. The radial grooves were few and all round, resembling

Table 1. Comparison of meristic and morphometric characters of *Carassius carassius* ♀×*Gnathopogon*

Character	*C. carassius*		
	$\bar{x}$	r	N
Body depth/standard length	0.404	0.401–0.413	20
Caudal peduncle length/caudal peduncle depth	0.992	0.879–1.137	20
Pectoral fin origin to ventral fin origin/ventral fin origin to anal fin origin	1.009	0.938–1.055	20
Dorsal fin base length/longest dorsal fin ray length	2.344	2.243–2.446	20
Dorsal fin rays	18.8	18.0–21.0	20
Lateral line scales	31.8	31.0–33.0	20
Scales above lateral line	7.0	7.0	20
Scales below lateral line	5.7	5.0–6.0	20
Gill-rakers	28.4	28.0–30.0	20
Pharyngeal teeth formula:			18
outer row on left side	0.0	0.0	
inner row on left side	4.0	4.0	
inner row on right side	4.0	4.0	
outer row on right side	0.0	0.0	
Vertebrae	31.8	29.0–33.0	20

those of *C. carassius*. The focus was situated at the central part of the scale. The number of gill-rakers was closer to that of *C. carassius* than of *G. elongatus elongatus*. The length of the gill-rakers in relation to the gill-filaments was much longer than that of *G. elongatus elongatus*. The gill arch curved gently and its corner was indistinct, similar to that of *C. carassius*. The number of pharyngeal teeth was four, which was the typical number for *C. carassius*. The aspect of the pharyngeal bones was more similar to that of *C. carassius* than of G. *elongatus elongatus*, although the curves of pharyngeal arches were somewhat steeper than in *C. carassius*. The tooth platform was shorter and the anterior process had much the same length as the posterior process, indicating *C. carassius* character. The number of vertebrae was much closer to that of *C. carassius*. The gas-bladder was similar to that of *C. carassius* in shape. Its anterior chamber was relatively large and the posterior one had a round terminus. The intestine was simpler in its coiling than that of *C. carassius* and was closer to that of *G. elongatus elongatus* rather than to intermediacy. Anatomical observation showed the gonads to be extremely underdeveloped in the spawning season and hidden by fat tissues. Microscopic examination disclosed that two hybrids were female and the others were neuter. The ovaries were abnormal and had somewhat large cells corresponding to oogonium. No oocytes were found and typical oogenesis was not noticed.

The *Gnathopogon*-type hybrids: The body side was yellowish silver and each fin was yellow. This coloration was very similar to that of *G. elongatus elongatus* although somewhat darker. The lateral band was present but more indistinct than that of *G. elongatus elongatus*. Barbels were short but visible to the naked eye in the two hybrids. The ratios of body depth/standard length and caudal peduncle length/caudal peduncle depth were closer to those of *G. elongatus elongatus* than to intermediacy. The ratios of pectoral fin origin to ventral fin origin/ventral fin origin to anal fin origin and dorsal fin base length/longest dorsal-fin ray length were much closer to those of *G. elongatus elongatus*. The number of dorsal fin rays was closer to that of *G. elongatus elongatus* than of *C. carassius*, and both dorsal and ventral fins lacked serrated rays, resembling *G. elongatus elongatus*. The number of lateral line scales was closer to *G. elongatus elongatus* than to intermediacy. The number of scales above the lateral line was seven, the typical number for *C. carassius*. The number of scales below the lateral line approached exact intermediacy. The aspect of the scales was very similar to that of *G. elongatus elongatus*. The basal margin gently swelled out in the middle and the radial grooves extended

elongatus elongatus ♂ with parental species. $\bar{x}$, mean; r, range; N, sample size; I, index value.

Carassius-type hybrid				*Gnathopogon*-type hybrid				*G. elongatus elongatus*		
$\bar{x}$	r	N	I	$\bar{x}$	r	N	I	$\bar{x}$	r	N
0.342	0.313–0.364	11	39.4	0.284	0.284	2	76.4	0.247	0.218–0.288	20
1.190	1.115–1.136	11	36.8	1.453	1.416–1.491	2	85.8	1.529	1.303–1.792	20
1.091	1.016–1.155	11	48.8	1.245	1.232–1.259	2	100.0	1.177	1.089–1.270	20
1.522	1.472–1.602	11	50.1	0.778	0.746–0.811	2	95.4	0.704	0.638–0.828	20
14.3	13.0–15.0	11	41.6	11.0	10.0–12.0	2	72.2	8.0	8.0	20
33.6	33.0–34.0	11	34.6	36.0	36.0	2	80.7	37.0	35.0–39.0	20
7.0	7.0	11	0.0	7.0	7.0	2	0.0	5.6	5.0–6.0	20
5.1	5.0–6.0	11	37.5	5.0	5.0	2	43.7	4.1	4.0–5.0	20
20.0	18.0–22.0	11	44.6	12.0	12.0	2	87.2	9.6	8.0–12.0	20
		10	0.0			2	29.1			17
0.0	0.0			0.0	0.0			3.0	3.0	
4.0	4.0			4.5	4.0–5.0			5.0	5.0	
4.0	4.0			4.5	4.0–5.0			5.0	5.0	
0.0	0.0			0.5	0.0–1.0			3.0	3.0	
32.3	30.0–34.0	11	13.8	34.5	33.0–36.0	2	75.0	35.4	35.0–37.0	20
Hybrid index=31.5				Hybrid index=67.7						

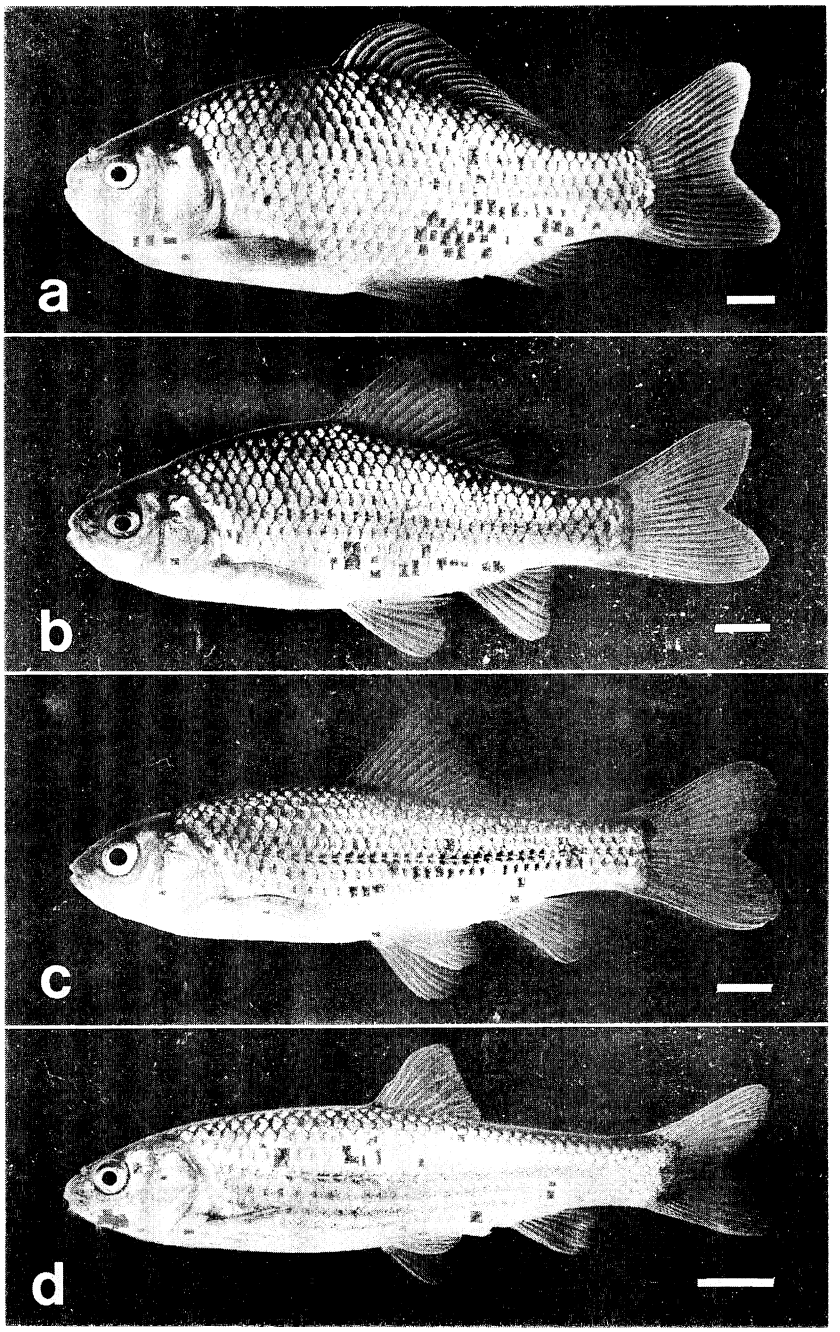

Fig. 1. Hybrid and parental species. *Carassius carassius* (a), *Carassius*-type (b) and *Gnathopogon*-type (c) of *C. carassius* ♀×*Gnathopogon elongatus elongatus* ♂ hybrid, and *G. elongatus elongatus* (d). Bars equal 10 mm.

only to the apical area as in *G. elongatus elongatus*, although there were fewer grooves. The focus was situated by the basal margin. The number of gill-rakers was closer to that of *G. elongatus elongatus* than to intermediacy. The length of the gill-rakers in relation of the gill-filaments was

shorter than that of *C. carassius*, and more similar to that of *G. elongatus elongatus*. The gill arch angled acutely and its corner was distinct, similar to that of *G. elongatus elongatus*. The number of pharyngeal teeth was closer to that of *C. carassius* than of *G. elongatus elongatus*. The aspect of the pharyngeal bones was more similar to that of *G. elongatus elongatus*, but the tooth platform was somewhat shorter than this species, as in *C. carassius*. The number of vertebrae was closer to that of *G. elongatus elongatus* than of *C. carassius*. The gas-bladder was similar to that of *G. elongatus elongatus* in shape although somewhat more roundish. The intestine was very simple in its coiling, closer to *G. elongatus elongatus*. The anatomical appearance of the gonads was similar to the *Carassius*-type in one hybrid and more developed in the other. Microscopic examination showed two hybrids to be female. The ovaries had many oogoniums and a few previtellogenic oocytes, and no vitellogenic oocytes were found (Fig. 2).

Fig. 2. Cross section of ovaries from *Gnathopogon*-type of *Carassius carassius* ♀×*Gnathopogon elongatus elongatus* ♂ hybid. Bar equals 100 μm.

Karyotypes. The chromosome number of the hybrids was 125 for *Carassius*-type (Fig. 3a) and 100 for *Gnathopogon*-type (Fig. 3b) hybrids. It was 2n=100 for *C. carassius* and 2n=48 for *G. elongatus elongatus*. The karyotype of *C. carassius* contained 20 metacentrics, 40 submetacentrics and 40 acrocentrics, and that of *G. elongatus elongatus* involved 12 metacentrics, 32 submetacentrics and 6 acrocentrics. These results from the parental species agreed with those reported by Kobayasi et al. (1970) and Ojima et al. (1972). In the *Carassius*-type hybrids, the chromosomes were distinguished into 26 metacentrics, 56 submetacentrics and 43 acrocentrics, from which 25 chromosomes, i. e. 6 metacentrics, 16 submentacentrics and 3 acrocentrics, were chosen out as a genome belonging to *G. elongatus elongatus* on the basis of the karyotype. The other 100 chromosomes consisted of 50 pairs of homologous chromosomes, 10 pairs of metacentrics, 20 pairs of submetacentrics and 20 pairs of acrocentrics. The 5th chromosome pair in the acrocentric group showed a satellite on the short arm. These 100 chromosomes were identical to the karyotype of *C. carassius* in both number and morphology and could belong to two genomes of this species.

In the *Gnathopogon*-type hybrids, the chromosomes were distinguished into 22 metacentrics, 52 submetacentrics and 26 acrocentrics. in which 50 chromosomes, i. e. 10 metacentrics, 20 submetacentrics and 20 acrocentrics, were chosen out as a genome belonging to *C. carassius* on the basis of the karyotype. The other 50 chromosomes consisted of 25 pairs of homologous chromosomes, 6 pairs of metacentrics, 16 submetacetrics and 3 pairs of acrocentrics. These 50 chromosomes were identical to the karyotype of *G. elongatus elongatus* in both number and morphology and could belong to two genomes of this species.

Discussion

The phenotype of the hybrids was distinctly distinguished into two types, with the hybrid index for these two types being not intermediate but closer to either *C. carassius* or *G. elongatus elongstus*. The karyotype of the *Carassius*-type incorporated two genomes of *C. carassius* and one of *G. elongatus elongatus*, while that of the *Gnathopogon*-type combined one genome of *C.*

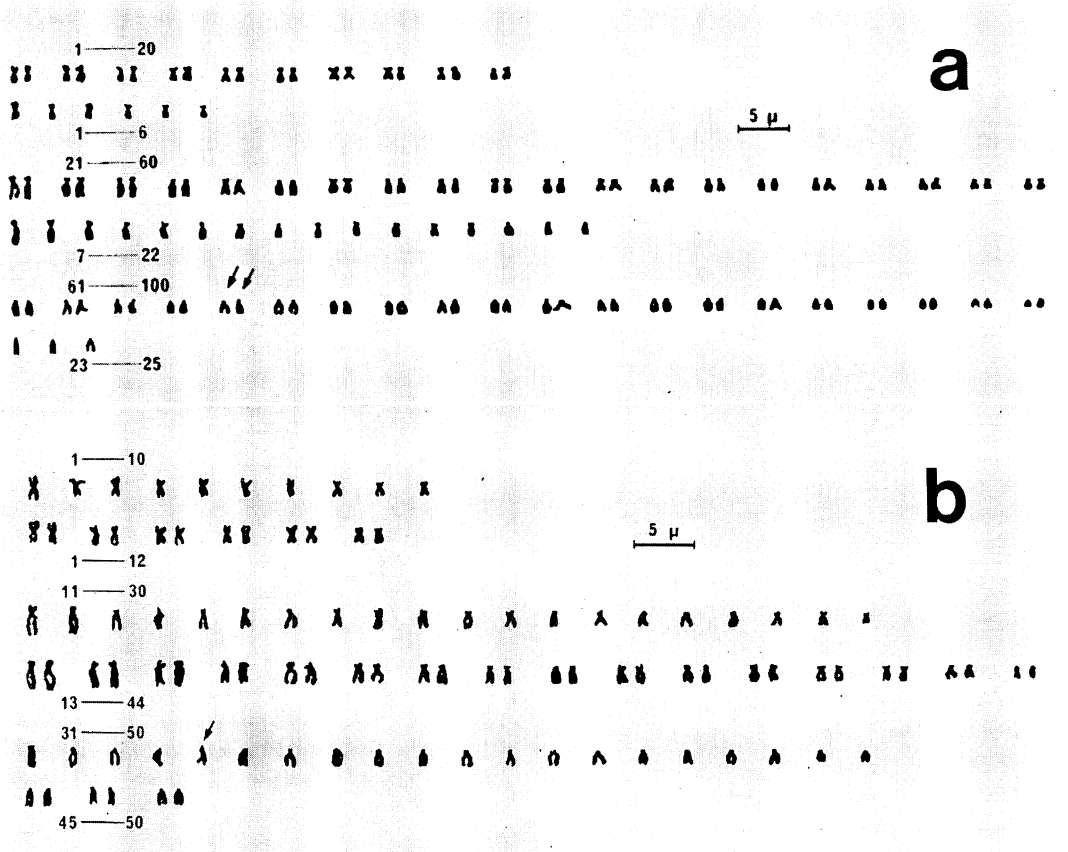

Fig. 3. Karyotype of *Carassius carassius* ♀ × *Gnathopogon elongatus elongatus* ♂ hybrid. *Carassius*-type (a) and *Gnathopogon*-type (b). Arrows show chromosomes with satellites.

carassius and two of *G. elongatus elongatus*. These data confirm that the tendency to resemble either *C. carassius* or *G. elongatus elongatus* in most of the characters resulted from unbalanced inheritance from the parental species. Kasama and Kobayasi (1989b) reported that intergeneric hybrids between *C. carassius* ♀ and *Ctenopharyngodon idellus* (Valenciennes) ♂ were similar to *Ct. idellus*, and their karyotypes incorporated two genomes of *C. carassius* and one of *Ct. idellus*. In the present report, we show for the first time that two types were both morphologically and karyologically confirmed in the sister hybrids.

Suzuki (1963d) reported that intergeneric hybrids between *C. auratus auratus* (Linnaeus) ♀ and *G. elongatus elongatus* ♂ were similar to *C. auratus auratus*. But our study suggests that his hybrids may have been more similar to *G. elongatus elongatus* rather than *C. auratus auratus*, on the basis of the presence of barbels in all hybrids and the aspect of scales. He noted that one hybrid had a tri-lobed caudal fin of the *Carassius*-type, but no further mention was made of this hybrid. He hypothesized that the similarity of the hybrids may have resulted from the relatively greater gap in the phylogenetical relationship between *C. auratus auratus* and *G. elongatus elongatus* compared with the other intergeneric *Gnathopogon* hybrids, which were typically intermediate. The caudal fin for the hybrids between the tri-lobed fin type and the di-lobed fin type is known to be of the di-lobed type (Matsui, 1950). Therefore the present data suggest that one tri-lobed fin hybrid had a karyotype incorporating two genomes of *C. auratus auratus* and one of *G. elongatus elongatus*, while the other hybrids had karyotypes incorporating one genome of *C. auratus auratus* and two of *G.*

elongatus elongatus. Our findings support caution against discussing the interrelationship among parental species of various hybrids on the basis of morphological analysis only.

Kobayasi and Hashida (1977) and Kobayasi and Nakano (1976) noted that some back-cross hybrids of F_1 fishes between *C. auratus langsdorfii* Temminck et Schlegel ♀ and *Cyprinus carpio* Linnaeus ♂ or between *C. auratus* subsp. ♀ and *C. carassius* ♂ had karyotypes consisting of two genomes of the maternal species and one of the paternal species. Fishes belonging to the genus *Carassius* seem to produce offspring by a specific fertilization mechanism in intergeneric or interspecific crosses, and further study of this is needed.

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Literature cited

Chu, Y. T. 1935. Comparative studies on the scales and on the pharyngeal and their teeth in Chinese cyprinids, with particular reference to taxonomy and evolution. Biol. Bull. St. John's Univ. (Shanghai), 2: 1–225, 30 pls.

Hubbs, C. L. and K. Kuronuma, 1942. Hybridization in nature between two genera of flounders in Japan. Rap. Mich. Acad. Sci. (Arts and Lett.), 27: 267–306.

Hubbs, C. L. and K. F. Lagler. 1970. Fishes of the Great Lake region. Univ. of Michigan Press, Ann Anbor, Michigan, xv+213 pp,. 44 pls., 1 map.

Hubbs, C. L., L. C. Hubbs and R. E. Johnson. 1943. Hybridization in nature between species of catostomid fishes. Contr. Lab. Vert. Biol. Univ. Mich., 22: 1–77.

Kasama, M. and H. Kobayasi. 1987. Hybridization experiments in Cyprinida (I). Cross between *Gnathopogon elongatus elongatus* and *Pseudorasbora parva*. Japan Women's Univ. J., 34: 107–112.

Kasama, M. and H. Kobayasi. 1988. Hybridization experiments in Cyprinida (III). Cross between *Gnathopogon elongatus elongatus* and *Sarcochilichthys biwaensis*. Japan Women's Univ. J., 35: 119–124.

Kasama, M. and H. Kobayasi. 1989a. Hybridization experiments in Cyprinida (IV). Cross between *Gnathopogon elongatus elongatus* and *Squalidus gracilis*. Japan Women's Univ. J., 36: 101–106.

Kasama, M. and H. Kobayasi, 1989b. Hybridization experiment between crucian carp *Carassius carassius* ♀ and grass carp *Ctenopharyngodon idellus* ♂. Hybridization experiments in Cyprinida (II). Nippon Suisan Gakkaishi, 55(6): 1001–1006.

Kobayasi, H. and M. Hashida. 1977. Morphological and cytological studies in back-cross hybrids of F_1 fishes between the kinbuna (*Carassius auratus* subsp.) ♀ and the crucian carp (*Carassius carassius*) ♂. Japan Women's Univ. J., 24: 121–133. (In Japanese with English summary.)

Kobayasi, H. and K. Nakano. 1976. Morphological and cytological studies in back-cross hybrids of F_1 fishes between the ginbuna (*Carassius auratus langsdorfii*) ♀ and the carp (*Cyprinus carpio*) ♂. Japan Women's Univ. J., 23: 113–122. (In Japanese with English summary.)

Kobayasi, H., Y. Kawashima and N. Takeuchi. 1970. Comparative chromosome studies in the genus *Carassius*, especially with a finding of polyploidy in the ginbuna (*C. auratus langsdorfii*). Japan. J. Ichthyol., 17(4): 153–159. (In Japanese with English summary.)

Matsubara, K. 1955. Fish morphology and hierarchy. Part I. Ishizaki Shoten, Tokyo, xi+789 pp. (In Japanese.)

Matsui, Y. 1950. On Japanese carp *Cyprinus carpio*, funa *Carassius carassius* and the hybrids between these species. Pages 152–188 *in* The topics in mordern biology. Zoushindo, Tokyo, 589 pp. (In Japanese.)

Ojima, Y., M. Hayashi and K. Ueno. 1972. Cytogenetic studies in lower vertebrates X. Karyotype and DNA studies in 15 species of Japanese Cyprinidae. Japan. J. Genet., 47(6): 431–440.

Suzuki, R. 1962. Hybridization experiments in cyprinid fishes I. *Gnathopogon elongatus elongatus* ♀× *Pseudorasbora parva* ♂ and the reciprocal. Bull. Japan. Soc. Sci. Fish., 28(10): 992–997.

Suzuki, R. 1963a. Hybridization experiments in cyprinid fishes II. Reciprocal crosses between *Pseudogobio esocinus* and *Gnathopogon elongatus elongatus*. Japan. J. Genet., 38(2): 89–96.

Suzuki, R. 1963b. Hybridization experiments in cyprinid fishes III. Reciprocal crosses between *Pseudorasbora parva* and *Gnathopogon elongatus elongatus*. Bull. Japan. Soc. Sci. Fish., 29(5): 421–423.

Suzuki, R. 1963c. Hybridization experiments in cyprinid fishes IV. Reciprocal crosses between *Biwia zezera* and *Gnathopogon elongatus elongatus*. Bull. Japan. Soc. Sci. Fish., 29(7): 655–657.

Suzuki, R. 1963d. Hybridization experiments in cyprinid fishes V. Reciprocal crosses between *Carassius carassius auratus* and *Gnathopogon elongatus elongatus*. Annot. Zool. Japan., 36(4): 203–207.

Suzuki, R. 1963e. Hybridization experiments in cyprinid fishes VI. Reciprocal crosses between

Gnathopogon elongatus elongatus and *Gnathopogon japonicus*. Japan. J. Ichthyol., 10(2/6): 39–42.

Suzuki, R. 1964. Hybridization experiments in cyprinid fishes VII. Reciprocal crosses between *Pseudogobio esocinus* and *Biwia zezera*. Japan. J. Ichthyol., 12(1/2): 18–22.

Suzuki, R. 1965a. Hybridization experiments in cyprinid fishes VIII. Two kinds of reciprocal crosses, *Pseudogobio esocinus*×*Pseudorasbora parva* and *Biwia zezera*×*Pseudorasbora parva*. Japan. J. Ichthyol., 13(1/3): 64–68.

Suzuki, R. 1965b. Hybridization experiments in cyprinid fishes IX. *Gnathopogon japonicus* ♀×*Biwia zezera* ♂ and reciprocal crosses between *Pseudorasbora parva pumila* and *Biwia zezera*. Bull. Freshw. Fish. Res. Lab., 14(2): 91–95.

Suzuki, R. 1966. Hybridization experiments in cyprinid fishes X. *Gnathopogon japonicus* ♀×*Pseudogobio esocinus* ♂. Bull. Freshw. Fish. Res. Lab., 16(1): 65–69.

Suzuki, R. 1968. Hybridization experiments in cyprinid fishes XI. Survival rate of F_1 hybrids with special reference to the closeness of taxonomical position of combined fishes. Bull. Freshw. Fish. Res. Lab., 18(2): 113–155.

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ヨーロッパブナ雌とタモロコ雄の間の交雑実験

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ヨーロッパブナ *Carassius carassius* 雌とタモロコ *Gnathopogon elongatus elongatus* 雄との間で人工的に交雑を試みた．この交雑における発生率，孵化率はそれぞれ 51%，44% で，生き残った雑種のうち 13 個体が，ほぼ成魚形にまで成長した．これらの雑種を孵化後 3 年 6 ケ月経過したところで形態学的，核学的に分析し，両親種との比較を行なった．その結果，雑種の形態は雌魚に似たヨーロッパブナ型，雄魚に似たタモロコ型の 2 型に分けられた．また核型はヨーロッパブナ型では雌魚由来の 2 ゲノムと雄魚由来の 1 ゲノムの合体したもので，一方タモロコ型では雌魚由来の 1 ゲノムと雄魚由来の 2 ゲノムの合体したものであった．従って雑種の形態の 2 型は，核型に含まれる 3 ゲノムに左右されていることがわかった．

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