Meristic and Morphometric Characters of Five Races of *Cyprinus carpio*

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Abstract Differences in meristic characters and body proportions in five races of the common carp, *Cyprinus carpio*, were studied to find racial characteristics. Individuals of each race were raised under different conditions: (1) in a pond fertilized with soy lees; (2) in running-water ponds with artificial feeding; or (3) in standing-water ponds with artificial feeding. Individuals of each race, even raised in different environments, are distinguishable in appearance. For the counts, the races were ranked on the basis of statistically significant differences on the mean found under nearly all these three conditions: mirror carp≈scaly German carp>Yamato carp≷asagi carp≷wild carp. For the proportional measurements, the rank was as follows: mirror carp≷scaly German carp>asagi carp≷Yamato carp≷wild carp. Domesticated European carp had higher meristic counts and greater measurements than domesticated Japanese carp in almost all the items examined, and wild carp had the lowest counts and smallest measurements in many items.

The common carp, *Cyprinus carpio* Linnaeus, has been domesticated longer than any other fish, and many races are now in existence. The analysis of how races of carp differ in meristic characters and in various body proportions will be not only interesting phylogenetically but also important as basic information for the genetic improvement of the species. For two Japanese kinds, the domesticated Yamato carp and the wild carp, such differences have been examined by Kobayashi (1950, 1953), Furukawa (1953, 1954), Tsuchiya (1954), and Kafuku (1966). Their data were based on specimens either raised under controlled environmental conditions or collected in the field. In the European carp, Schaperclaus (1961) compared some proportional and numerical characteristics of wild carp and several domesticated genotypes. Steffens (1964) made similar comparisons, adding some variations in environmental conditions. However, differences in such characteristics between Japanese and European races, or between domesticated Japanese races raised under various conditions, have not been studied.

Table 1. Number and mean sizes of carp specimens obtained from different environmental ponds. The ± values show 95% confidence limit on the mean.

Items and ponds	Mirror	Scaly German	Yamato	Asagi	Wild
Number of specimens					
Running-water ponds	20	44	34	19	15
Standing-water ponds	40	40	42	31	44
Fertilized pond	16	—	35	35	35
Body length (cm)					
Running-water ponds	15.4± 0.6	15.5± 0.5	16.4± 0.5	15.9± 1.2	12.4± 0.4
Standing-water ponds	22.7± 0.5	22.8± 0.5	23.7± 0.4	21.8± 0.5	17.9± 0.4
Fertilized pond	22.9± 1.1	—	23.7± 0.5	21.3± 0.6	22.5± 0.4
Body weight (g)					
Running-water ponds	120.9±12.3	117.2±14.8	116.5±10.3	112.2±30.6	47.7± 4.4
Standing-water ponds	392.9±24.8	390.0±20.0	328.5±15.7	314.0±19.4	148.9±10.2
Fertilized pond	407.7±45.0	—	340.5±21.6	294.5±20.7	277.6±11.8

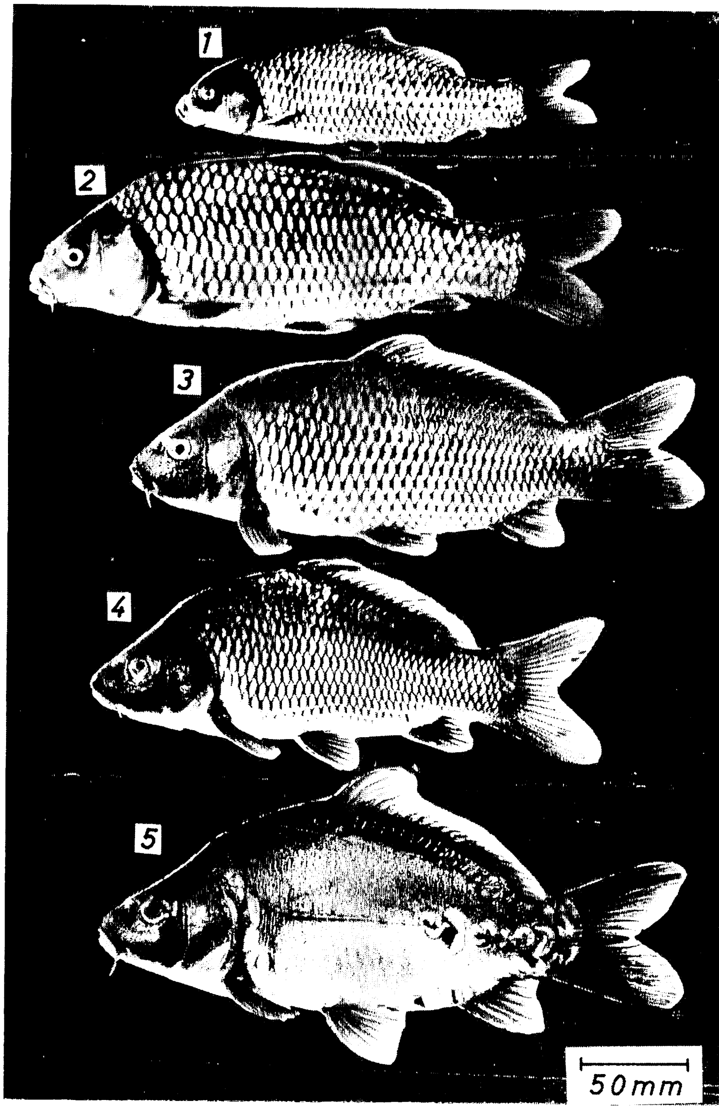

Fig. 1. Typical examples of the each race of carp cultivated in standing-water ponds with artificial feeding. 1: Wild carp. 2: Asagi carp. 3: Yamato Carp. 4: Scaly German carp. 5: Mirror carp.

We studied differences in various meristic characters and body proportions of three races of Japanese carp and two races of European carp raised under three different conditions to find racial characteristics.

Materials and methods

The carp studied were obtained from adults of the following races. Domesticated Japanese carp, both the Yamato and the asagi, were originally obtained from fish farms in Nagano Prefecture in 1966. The former race is more widely cultivated in Japan than the latter. Wild carp were originally collected from Lake Kasumigaura in 1966 and have been maintained in captivity since then. The domesticated European carp, both scaly and mirror types, were transplanted from Germany in 1968. In each race, fry were produced for this study from a single multiple spawn involving three females and four males.

Two-month-old fry of each race were

separated into three groups and each group was raised under different environmental conditions: (1) in a pond fertilized with soy lees; (2) in running-water ponds with artificial feeding; or (3) in standing-water ponds with artificial feeding. In pond 1, four races (mirror, Yamato, asagi, and Japanese wild) were raised together. The scaly German type was not used in this pond because it was felt to be hard to distinguish it from the Yamato carp. In ponds 2 and 3, each race was raised separately and given pelleted artificial carp feed. The amount of feed given daily was determined according to the body weight of the fish and the water temperature. Randomly selected specimens of two-year-old carp from each race were fixed with 10% formalin and used for morphological examination. Counts and measurements were generally made in accordance with the methods proposed by

Table 2. Mean counts and proportional measurements in the various races of carp cultivated in the three different environmental ponds. The ± values show 95% confidence limit on the mean.

Items and ponds	Mirror	Scaly German	Yamato	Asagi	Wild
Vertebrae					
Running-water ponds	35.0 ±0.7	35.2 ±0.3	33.8 ±0.3	33.4 ±0.3	32.3 ±0.4
Standing-water ponds	34.3 ±0.3	36.5 ±0.3	33.2 ±0.3	34.6 ±0.5	33.1 ±0.4
Fertilized pond	34.3 ±0.5	—	33.0 ±0.3	33.2 ±0.5	32.3 ±0.4
Scales along lateral line					
Running-water ponds	—	38.4 ±0.3	35.2 ±0.3	33.4 ±0.6	33.9 ±0.4
Standing-water ponds	—	37.2 ±0.4	35.7 ±0.4	33.2 ±0.6	34.5 ±0.3
Fertilized pond	—	—	35.7 ±0.3	33.6 ±0.5	34.3 ±0.3
Dorsal soft rays					
Running-water ponds	19.7 ±0.6	20.2 ±0.3	20.1 ±0.5	18.4 ±0.3	18.8 ±0.4
Standing-water ponds	19.9 ±0.3	20.6 ±0.4	20.4 ±0.3	18.8 ±0.3	18.8 ±0.3
Fertilized pond	19.8 ±0.2	—	20.1 ±0.2	18.6 ±0.2	18.5 ±0.3
Gill rakers on first arch					
Running-water ponds	29.1 ±0.6	28.2 ±0.6	25.2 ±0.5	26.5 ±0.6	22.6 ±0.8
Standing-water ponds	29.4 ±0.3	28.4 ±0.5	25.3 ±0.5	26.9 ±0.6	22.8 ±0.5
Fertilized pond	29.2 ±0.7	—	25.2 ±0.5	25.7 ±0.5	22.9 ±0.6
Body depth/Body length (%)					
Running-water ponds	36.4 ±0.7	36.7 ±0.5	32.2 ±0.4	32.6 ±0.6	27.2 ±0.4
Standing-water ponds	39.0 ±0.5	38.4 ±0.5	31.8 ±0.4	34.4 ±0.5	28.6 ±0.3
Fertilized pond	37.8 ±0.8	—	31.5 ±0.4	33.1 ±0.4	27.8 ±0.3
Body width/Body length (%)					
Running-water ponds	19.0 ±0.4	18.7 ±0.4	17.4 ±0.4	17.3 ±0.5	17.3 ±0.5
Standing-water ponds	19.7 ±0.2	18.8 ±0.4	16.7 ±0.3	19.2 ±0.4	17.6 ±0.2
Fertilized pond	19.1 ±0.5	—	17.0 ±0.3	19.5 ±0.3	17.8 ±0.2
Head length/Body length (%)					
Running-water ponds	31.6 ±0.5	29.6 ±0.3	28.7 ±0.3	29.1 ±0.5	28.0 ±0.3
Standing-water ponds	28.6 ±0.3	29.2 ±0.4	26.1 ±0.2	29.0 ±0.3	26.6 ±0.3
Fertilized pond	30.8 ±0.7	—	28.7 ±0.3	30.1 ±0.3	28.0 ±0.3
Intestinal length/Body length					
Running-water ponds	2.1 ±0.1	2.0 ±0.1	1.8 ±0.1	1.8 ±0.1	1.7 ±0.1
Standing-water ponds	2.2 ±0.1	1.9 ±0.1	1.7 ±0.1	1.8 ±0.1	1.7 ±0.0
Fertilized pond	2.5 ±0.1	—	2.1 ±0.1	2.4 ±0.1	1.8 ±0.1
Condition factor*					
Running-water ponds	3.26±0.13	3.04±0.07	2.61±0.07	2.55±0.11	2.46±0.07
Standing-water ponds	3.30±0.06	3.30±0.08	2.47±0.06	3.01±0.08	2.55±0.05
Fertilized pond	3.33±0.12	—	2.53±0.06	3.04±0.06	2.44±0.04

* $K=100\cdot W/L^3$, where K is condition factor, W body weight in gram and L body length in centimeter.

Matsubara (1955). The number and sizes of the specimens used are shown in Table 1.

Results

Specimens of each race, even raised in different environments, are distinguishable in appearance. Typical examples of each race from standing-water ponds are shown in Fig. 1. Of the carp we studied, the wild carp has the longest body; its back and sides are golden yellow, and the edges of the dorsal and caudal fins are more reddish than those of domesticated carp. The Yamato carp is not so long as the wild carp, and its back and sides are a dark yellowish brown. The asagi car has a somewhat deeper body than the Yamato; its back and sides are light blue. The scaly German carp has the deepest body among scaly carp; its back and sides are a somewhat golden yellow. The mirror carp is about as deep as the scaly German carp; none of the fish of this race have scales on the central part

Table 3. Ranking for the various races of carp in each environmental pond, on the basis of the statistically significant differences compared with t-test on the mean of the counts and the proportional measurements.

Items and ponds	Mirror	Scaly German	Yamato	Asagi	Wild
Vertebrae					
Running-water ponds	1	1	3	3	5
Standing-water ponds	2	1	4	2	4
Fertilized pond	1	—	2	2	4
Scales along lateral line					
Running-water ponds	—	1	2	3	3
Standing-water ponds	—	1	2	4	3
Fertilized pond	—	—	1	3	2
Dorsal soft rays					
Running-water ponds	1	1	1	4	4
Standing-water ponds	3	1	1	4	4
Fertilized pond	1	—	1	3	3
Gill rakers on first arch					
Running-water ponds	1	1	4	3	5
Standing-water ponds	1	2	4	3	5
Fertilized pond	1	—	3	2	4
Body depth/Body length (%)					
Running-water ponds	1	1	3	3	5
Standing-water ponds	1	1	4	3	5
Fertilized pond	1	—	3	2	4
Body width/Body length (%)					
Running-water ponds	1	1	3	3	3
Standing-water ponds	1	1	5	1	4
Fertilized pond	1	—	4	1	3
Head length/Body length (%)					
Running-water ponds	1	2	4	2	5
Standing-water ponds	3	1	5	1	4
Fertilized pond	1	—	3	1	4
Intestinal length/Body length					
Running-water ponds	1	1	3	3	5
Standing-water ponds	1	2	4	2	5
Fertilized pond	1	—	3	2	4
Condition factor					
Running-water ponds	1	2	3	3	5
Standing-water ponds	1	1	5	3	4
Fertilized pond	1	—	3	2	4

of the sides, although typical specimens have a few large, bright scales along the bases of the dorsal and caudal fins. Neither the line carp, in which the scales are confined to a prominent row along the lateral line and a row along the base of the dorsal fin, nor the leather carp, which is almost completely scaleless, is of the mirror-carp group.

Among the samples used for the present study, there were some differences in length; principally, specimens from running-water ponds were the smallest. A question arose as to whether the smallness of the samples induced observational error in the counts and measurements. All counts and measurements, however, were uncorrelated with the body length for each race from running-water ponds: $0.0141 < r < 0.4313$, $p > 0.05$, in the counts, and $0.0173 < r < 0.4451$, $p > 0.05$, in the measurements. This means that any apparent positive dependence of counts and measurements on the body length disappears and

Table 4. Ranking for three environmental ponds in each race, on the basis of statistically significant differences compared with t-test on the mean of the counts and proportional measurements.

Items and ponds	Mirror	Scaly German	Yamato	Asagi	Wild
Vertebrae					
Running-water ponds	1	2	1	2	2
Standing-water ponds	1	1	2	1	1
Fertilized pond	1	—	2	2	2
Scales along lateral line					
Running-water ponds	—	1	2	1	2
Standing-water ponds	—	2	1	1	1
Fertilized pond	—	—	1	1	1
Dorsal soft rays					
Running-water ponds	1	1	2	1	1
Standing-water ponds	1	1	1	1	1
Fertilized pond	1	—	2	1	1
Gill rakers on first arch					
Running-water ponds	1	1	1	1	1
Standing-water ponds	1	1	1	1	1
Fertilized pond	1	—	1	1	1
Body depth/Body length (%)					
Running-water ponds	2	2	1	2	3
Standing-water ponds	1	1	1	1	1
Fertilized pond	2	—	2	2	2
Body width/Body length (%)					
Running-water ponds	2	1	1	2	2
Standing-water ponds	1	1	2	1	1
Fertilized pond	2	—	1	1	1
Head length/Body length (%)					
Running-water ponds	1	1	1	2	1
Standing-water ponds	2	1	2	2	2
Fertilized pond	1	—	1	1	1
Intestinal length/Body length					
Running-water ponds	2	1	2	2	2
Standing-water ponds	2	1	2	2	2
Fertilized pond	1	—	1	1	1
Condition factor					
Running-water ponds	1	2	1	2	2
Standing-water ponds	1	1	2	1	1
Fertilized pond	1	—	2	1	2

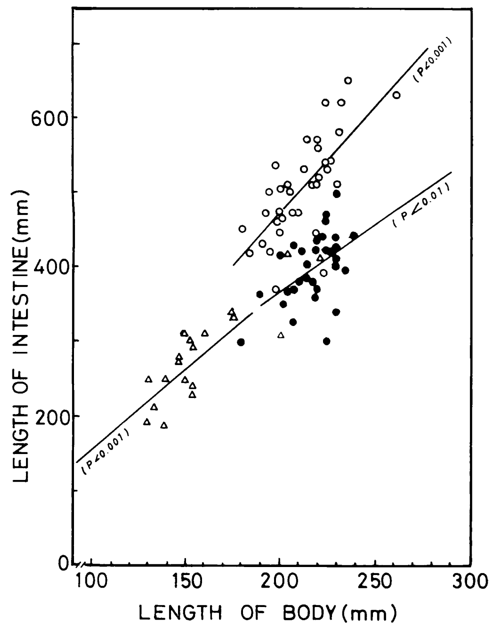

Fig. 2. Relation of the intestinal length to body length of the asagi carp cultivated in fertilized ponds (hollow circles), standing-water ponds (solid circles) and running-water ponds (hollow triangles).

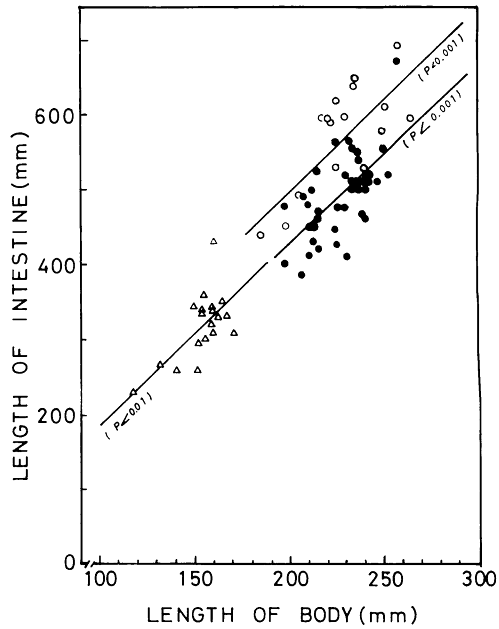

Fig. 3. Relation of the intestinal length to the body length of the mirror carp cultivated in fertilized ponds (hollow circles), standing-water ponds (solid circles) and running-water ponds (hollow triangles).

hence that the counts and the measurements were really comparable between races.

The mean counts and proportional measurements are summarized in Table 2, and the various races are ranked in Table 3 on the basis of statistically significant differences on t-test comparisons in the counts and measurements.

For the counts, the ranking was as follows under nearly all three environmental conditions: mirror carp≈scaly German carp> Yamato carp≷asagi carp≷wild carp. Thus, the two domesticated European carp had higher meristic counts than domesticated Japanese carp in almost all the items examined, and wild carp had the lowest counts in many items. The two European types did not differ significantly in most items. Of the two types of domesticated Japanese carp, the Yamato carp had higher counts than the asagi carp for most items except gill rakers and vertebrae.

On the other hand, for proportional measurements, the rank was as follows: mirror carp≷scaly German carp>asagi carp≷Yamato carp≷wild carp. This result closely resembles that for counts, but the positions of the Yamato and asagi carp are reversed.

In addition, differences in counts as related to the environment were examined in each race. Within most races there were no significant differences, as shown in Table 4. Although for some items in some races the differences under various conditions were significant, the differences in the mean counts for the three environments were much smaller than the differences for the various races in any single environment.

In proportional measurements, however, significant differences were found in many comparisons of carp of the same race in different conditions. An especially marked difference was in the ratio of the intestinal length to the body length, which was greatest in carp raised in the fertilized pond without artificial feeding (pond 1) than in either pond with artificial feeding, as shown in Table 4. This is also clear from Figs. 2 and 3 which show the regressive relation of the intestinal length to the body length in the asagi and the mirror carp raised under the three conditions. In general, however, differences in mean proportional measurements for carp of any one race in different conditions were much smaller than those for carp of the five races in the same conditions.

Discussion

The fact that domesticated carp have deeper bodies, longer intestines, and more gill rakers than wild carp has been demonstrated by many workers (Kobayashi, 1950, 1953; Furukawa, 1953, 1954; Tsuchiya, 1954; Schaperclaus, 1961; Steffens, 1964; Kafuku, 1966). In the present study, domesticated carp had not only more gill rakers but also more of nearly all the items counted than did wild carp, and domesticated European carp had higher counts than domesticated Japanese carp. This ranking of the races resembles that in growth rates and feed conversion efficiency, as reported by Suzuki et al. (1976, 1977). This relation holds in carp raised under all three environmental conditions. In addition, within a given race the counts for most items did not differ significantly with the various environmental conditions. The interracial differences in the counts, therefore, may be greatly affected by genetic factors. Schaperclaus (1961), who studied the heredity of scale formation in carp, reported that the occurrence of the factor n in both the mirror and scaly carp is responsible for their genetically-determined higher growth rate than that of the line and leather carp, which have the factor N. He found that the mirror and scaly carp have more gill rakers and pharyngeal teeth than do the line and leather carp. Superior growth and survival of the mirror and scaly carp to those of the line and leather carp were proven by Kirpichnikov (1961, 1962) and Wohlfarth et al. (1963). These results suggest that meristic counts are closely related to growth capacity. If this suggestion is correct, it would be an argument in favor of using counts as an indicator for the selection of carp with a genetically faster growth rate. However, in mean counts of dorsal soft rays only, the results of previous Japanese workers (cited above) were the reverse of our finding that the wild carp had fewer such rays than did domesticated Yamato carp. The difference in results may be due to a polymorphism of wild carp or to the presence in those previous workers' wild carp of some genetic factors of domesticated carp. The existence of a polymorphism seems to be demonstrated by the fact that those workers who used wild-carp samples from Lake Biwa or the rivers flowing into it (Kobayashi, 1950; Furukawa, 1953) found higher mean counts than those using wild carp from the Tone River (Tsuchiya, 1954; Kafuku, 1966), specimens from which had counts very close to those for the Yamato carp.

Our proportional measurements also produced the following ranking: domesticated European carp>domesticated Japanese carp> wild carp, for all three conditions. In most items, however, the difference in measurements was also significant for samples of any one race raised in different conditions. Chiba (1972) reported that Yamato carp cultivated in running-water ponds had a deeper body than those from standing-water ponds. These results may show that differences in the proportional measurements are affected by not only genetic but also environmental factors. In European carp, the experiments of both Schaperclaus (1958) and Stegman (1966) have shown that the plasticity of the body shape in response to environmental factors is very great and that the depth of the body is uncorrelated with its growth capacity. Therefore, selection for height/length ratio and other proportional characters seems to be a waste of time.

Based on ranks for counts and measurements of five races in the present study and ranks for growth rates of the same races reported earlier (Suzuki et al., 1976), we suppose that both domesticated Japanese and European carp originated from the wild carp, and European mirror and scaly carp have been more selectively domesticated than Japanese Yamato and asagi carp.

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コイ5品種の計数的および体形的差異

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食用ゴイの品種的特性を明らかにするために，日本産およびヨーロッパ産5品種の計数的および体形的差異を調査した．各品種の標本は，3種類の異なった環境下，すなわち (1) 施肥養殖，(2) 流水式給餌養殖，および (3) 止水式給餌養殖で飼育されたものが用いられた．計数的諸形質では，いずれの環境下においても，カガミゴイ≈ドイツ産ウロコゴイ＞ヤマトゴイ≧アサギゴイ≧野生ゴイの関係が，また体形的諸形質では，カガミゴイ≧ドイツ産ウロコゴイ＞アサギゴイ≧ヤマトゴイ≧野生ゴイの関係がみられた．すなわち，ヨーロッパ産養殖品種は日本産養殖品種よりも，ほとんどの計数的形質や体形的形質の数価が高く，野生種はそれが最も低かった．

(鈴木：519-04　三重県度会郡玉城町昼田 224　養殖研究所；山口：386　上田市小牧 1088　東海区水産研究所陸水部)