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Seasonal, Sexual and Individual Variations in Gonad Weight and Secondary Sexual Characters of the Dark Chub, *Zacco temmincki*

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Abstract The relationships among body length, gonad and body weights and secondary sexual characters of the dark chub, *Zacco temmincki*, were analyzed with reference to their variations. Both condition factor and gonosomatic index (GSI) greatly increased in the pre-mating season. Body size was positively correlated with GSI value for females, except in post-spawning periods, but negatively correlated or uncorrelated for males. Individual variation (CV) of both condition factor and GSI value also increased in the pre-mating and mating seasons. Breeding color and pearl organs on the head developed in both sexes all the year round, and most conspicuously in males in the mating season. Pearl organs on the anal fin only developed in males in the mating season. The development of these secondary sexual characters neither necessarily indicated sexual maturation nor a high potential for reproduction, but was greatly associated with large body size. Breeding color was believed to function as a signal showing the development of pearl organs and body size, pearl organs on the head as a weapon in conspecific aggressive encounters and pearl organs on the anal fin as a tool for burying eggs in spawning behavior.

The development of reproductive characters, such as gonad and secondary sexual characters, has long been employed as an index of sexual maturation in fishes, e.g., the gonosomatic index (GSI) is frequently used to determine the reproductive state of fishes (e.g., Nikolsky, 1963; Mann, 1973; Heins and Clemmer, 1976; Lagler et al., 1977; Burns and Flores, 1981; de Vlaming et al., 1982). Histological and endocrinologic analyses have produced more accurate information on the mechanism of maturation (e.g., Hoar, 1969; de Vlaming, 1972; Tricas and Hiramoto, 1989), but the function of reproductive characters, except for the simple assumption that they serve in mating activities, usually remains unclarified due to a lack of direct observations of mating behavior.

Recent ecological approaches emphasize the importance of individual variations in behavior and morphology, since they reflect different strategies, or are formed by ontogenetic, environmental and social conditions according to some ecological rules (Dunbar, 1982; Magurran, 1986; Katano, 1987; Clark and Ehlinger, 1987; Ehlinger and Wilson, 1988). From this point of view, it is necessary to clarify variations in the development of reproductive characters for each season, sex and individual in relation to the mating period and behavior of the fish. For instance, the GSI value for ripe individuals has been traditionally used as an index of reproductive effort for a population or a species (Mann, 1980; Deacon and Keast, 1987; Saitoh, 1990), but now individual variation in gonad weight is also important, since it indicates the difference in potential reproductive ability of each individual for producing or fertilizing eggs. Increasing evidence shows that there are large individual differences in reproductive success for both males and females (Clutton-Brock, 1988). However, little information has been published on the relationships between mating system and behavior of a fish species, and the pattern and variation in the development of gonad and secondary sexual characters.

The dark chub, *Zacco temmincki* (Temminck et Schlegel) is a small cyprinid fish that inhabits rivers and lakes of eastern Asia. The reproductive behavior of the fish has been reported in detail by Katano (1983, in press), and the development of secondary sexual characters was qualitatively described by Okada (1934) and Nakamura (1969), but a quantitative analysis of gonad and secondary sexual characters has not been conducted. The body size and age of maturity of *Z. temmincki* are not known,

although Nakamura (1969) suggested that the fish commonly matures at the age of two. The objectives of this paper are to analyse the relationships between reproductive characters statistically with relevance to their seasonal, sexual and individual variations, and to discuss the functions of reproductive characters in the mating activities of the fish.

Materials and methods

Sampling was conducted in the Kiyotaki River near Nakagawa (35°04′N, 135°41′E), Kyoto City, Japan, in 1984. A total of 346 fish was captured in a transparent columnar baited trap five times from April 8 to November 3. Before samples were preserved in buffered 10% formalin, the standard length was measured to the nearest 1 mm and body weight to the nearest 0.01 g. The development of secondary sexual characters was also recorded and classified into several stages on the basis of breeding color, maximum major axis of pearl organs and appearance of pearl organs on the anal fin. The release of sperm or eggs was checked by slight abdominal pressure.

After samples were preserved in formalin, the body and gonad weights were also measured to the nearest 1 mg. The preserved body weight showed a high correlation with the fresh body weight ($r=0.998$, $P<0.001$). Age of the fish was not examined. The condition factor (K) was calculated using $K=1{,}000W/L^3$, where L is the standard length and W is the fresh body weight. Since gonad weight was significantly correlated with body weight in each sample ($P<0.01$), the gonosomatic index (GSI) was calculated as the percentage gonadal weight of the total body weight of preserved samples. For the calculation of the coefficient of variation (CV), samples were divided into two groups, more than and less than 9 cm long.

All statistical tests were two-tailed. Categories were combined when necessary for Fisher's exact probability test, or to achieve expected frequencies of ≥5 in chi-squared tests.

Results

Sex ratio, body length and weight. The sex ratio of 346 specimens collected was 1 : 0.89, male:female, not differing significantly from 1 : 1 ($\chi^2=1.2$, df=1, $P>0.2$). Body lengths ranged from 5.3 to 15.7 cm for males, and from 4.6 to 12.3 cm for females. The body weight ranged from 2.6 to 64.9 g for males and from 1.6 to 38.2 g for females. Males were significantly larger than females (ANOVA, length: $F_{1,344}=9.7$, $P<0.01$; weight: $F_{1,344}=10.5$, $P<0.01$). The correlation between body length and weight was tested as $W=aL^b$ and was significant at the 0.1% confidence level in each sample (Table 1).

Condition factor and GSI value. Seasonal changes in condition factor and gonosomatic index (GSI) are shown in Fig. 1. Condition factors ranged from 13.5 to 20.9 for males, and from 11.1 to 21.9 for females. Gonosomatic index values ranged from 0.18 to 9.10 for males, and from 0.80 to 15.15 for females.

Seasonal changes in both condition factor and GSI were similar between males and females. Condition factor increased from April to July, then decreased to August, with no further change to November (ANOVA, 5% confidence level for both males and females in any two successive sampling times). Gonosomatic index also increased from April to July, and then decreased to November (ANOVA, 5% confidence level).

Individuals which readily released sperm or eggs under slight abdominal pressure were termed "ripe." The appearance of ripe individuals was limited to the period from May to August. Although only one male (2.9%) released sperm in May, almost all males became ripe in July (95.2%) and August (90.9%). Although no female released eggs in May, several females became ripe in July (12.1%) and August (9.7%). The minimum standard length of ripe individuals was 6.4 cm for males and 6.9 cm for females.

Ripe males tended to be larger than unripe ones

Table 1. Body length-weight regression coefficients of *Zacco temmincki* calculated from $W=aL^b$ where W=body weight (g) and L=standard length (cm). *$P<0.001$.

Sex	Date	*n*	Regression coefficients a	Regression coefficients b	*r*
Male	Apr. 8	26	0.0111	3.15	0.997*
	May 19	35	0.0184	2.98	0.994*
	Jul. 1	42	0.0219	2.93	0.997*
	Aug. 11	44	0.0207	2.92	0.997*
	Nov. 3	36	0.0187	2.96	0.998*
Female	Apr. 8	33	0.0110	3.18	0.986*
	May 19	32	0.0085	3.34	0.992*
	Jul. 1	33	0.0155	3.10	0.992*
	Aug. 11	31	0.0260	2.82	0.991*
	Nov. 3	34	0.0160	3.05	0.996*

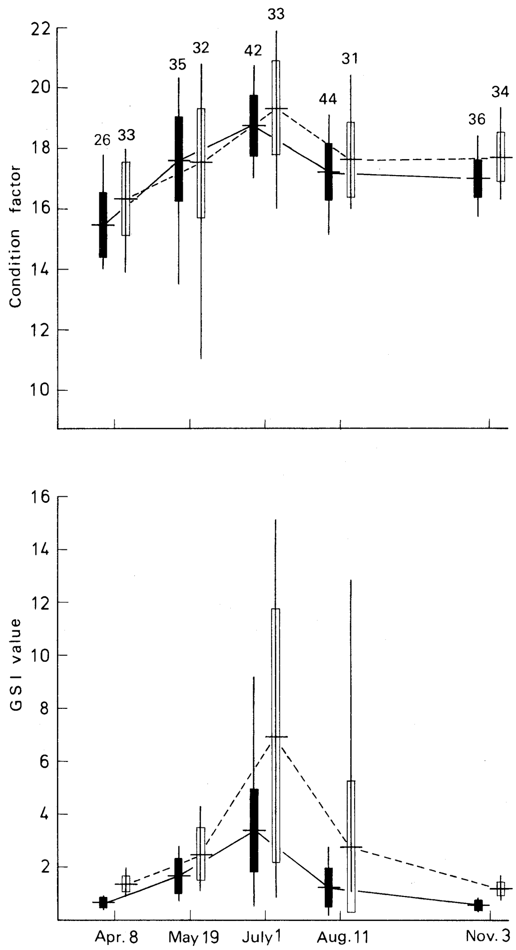

Fig. 1. Seasonal changes in condition factor and gonosomatic index (GSI) for each sex of *Zacco temmincki*. Numerals indicate sample sizes, vertical lines ranges, horizontal bars means and rectangles standard deviations. Solid rectangles and lines show males, while open rectangles and broken lines females.

(ANOVA, July: $F_{1,40}=5.1$, $P<0.05$; August: $F_{1,42}=11.2$, $P<0.01$). The condition factors in July and August, and GSI values in August did not differ significantly between ripe and unripe males (ANOVA, $P>0.05$), but the GSI value in July for ripe males tended to be larger than that for unripe ones. Body lengths did not differ between ripe and unripe females (ANOVA, $P>0.40$), but condition factors and GSI values for ripe females were significantly greater than those for unripe ones (ANOVA, condition factor: July, $F_{1,31}=12.8$, $P<0.01$; August, $F_{1,29}=12.5$, $P<0.01$; GSI: July, $F_{1,31}=5.0$, $P<0.05$; August, $F_{1,29}=138.0$, $P<0.001$).

Seasonal changes in the correlations between body length, condition factor and GSI value are shown in Table 2. Body length was positively correlated with condition factor for males in April, and for females in May, but negatively for both sexes in August. The body length for males showed a negative correlation with GSI value in April, August and November, but showed a positive and strong correlation from April to July for females. Condition factor also showed a positive correlation with GSI value for males in May and August, and for females from May to August.

The gonosomatic index value was analyzed on the basis of both body length and condition factor on three occasions (Table 3). Body length was the most contributive factor in GSI values for females in April and July, while condition factor was most contributive for males in August.

In order to clarify seasonal changes in individual variation in condition factor and GSI value, the coefficient of variation (CV) is shown for each sex, sampling time and fish size (Fig. 2).

The coefficient of variation of condition factors ranged from 3.2 to 6.3% for small males, from 4.2 to 9.1% for large males, from 4.3 to 11.4% for small females, and from 4.5 to 8.5% for large females. In both cases CV tended to be small in November in the post-mating period.

The coefficient of variation of GSI values ranged from 18.0 to 64.0% for small males, from 18.4 to 50.9% for large males, from 12.3 to 130.2% for small females, and from 8.2 to 71.0% for large females. In both cases CV tended to be large during the mating period, differing between smaller and larger individuals. The coefficient of variation for smaller males peaked in July and then decreased in August, while CV for larger males peaked in August. The coefficient of variation for both smaller and larger females peaked in August, the value for smaller females being greater than that for larger ones in the mating period.

Secondary sexual characters. Breeding color and pearl organs appeared conspicuously as secondary sexual characters. The developmental stages of these characters are given in Table 4.

Breeding color was red and appeared mainly in the lower parts of the body. At the first stage, breeding color appears as a small light mark, but then develops into more darkened lines. At the final stage, almost all parts of the underside of the head are a dark red color. The minimum length of the fish that

developed breeding color was 6.1 cm for males and 6.2 cm for females.

Pearl organs whose base was circular or ellipsoidal appeared mainly on the head and the anal fin, as reported by Okada (1934) and Nakamura (1969). The maximum major axis of the base of pearl organs on the head was classified into three stages (Table 4). The minimum length of the fish that developed pearl organs was 5.3 cm for males and 6.1 cm for females.

The development of pearl organs on the anal fin was classified into four stages. At stage 4, pearl organs develop in almost all parts of the anal fin, occasionally extending on to the base of the anal fin. The surface of the anal fin is abraded and white in color, and the edge jagged at this stage.

The relationships between the development of three types of secondary sexual character are shown in Table 5. The development of breeding color was associated with large pearl organ size ($\chi^2=96.5$, df$=1$, $P<0.001$, stages 2 and 3 are combined for both

Table 2. Correlation coefficients (r) between body length (L), condition factor (K) and gonosomatic index (GSI) in each sample and sex of *Zacco temmincki*. Sample size is given in parentheses. $^*P<0.05$; $^{**}P<0.01$; $^{***}P<0.001$.

Variables	Apr. 8		May 19		Jul. 1	
	Male (26)	Female (33)	Male (35)	Female (32)	Male (42)	Female (33)
L–K	0.522**	0.276	−0.052	0.649***	−0.274	0.246
L–GSI	−0.536**	0.577***	−0.083	0.623***	−0.139	0.706***
K–GSI	−0.293	−0.147	0.364*	0.500**	0.005	0.701**

Variables	Aug. 11		Nov. 3	
	Male (44)	Female (31)	Male (36)	Female (34)
L–K	−0.314*	−0.418*	−0.195	0.184
L–GSI	−0.351*	−0.058	−0.546***	−0.196
K–GSI	0.366*	0.486**	0.037	−0.033

Table 3. The multiple regression equation of gonosomatic index (GSI) against body length (L) and condition factor (K) of *Zacco temmincki*. *F*-level to enter variables in equations was 2.0. $^*P<0.05$; $^{**}P<0.001$.

Date	Sex	Most contributive variable	Second-most contributive variable	R^2	Total F	Regression equation
Apr. 8	Female	L	K	0.434	$F_{2,30}=11.51^{**}$	GSI=0.151L−0.077K+1.189
Jul. 1	Female	L	K	0.795	$F_{2,30}=58.01^{**}$	GSI=1.476L+1.696K−39.451
Aug. 11	Male	K	L	0.195	$F_{2,41}=4.98^{*}$	GSI=−0.096L+0.230K−1.799

Table 4. Developmental stages of secondary sexual characters in *Zacco temmincki*.

Character	Stage	Description
Breeding color	1	no or partial light appearance
	2	appearance in lines on the jaw and the belly
	3	overall dark appearance on the jaw (more than 70% of the jaw) and the belly
Pearl organ on the head (Maximum major axis of the base)	1	shorter than 0.1 mm
	2	between 0.1 and 1.0 mm
	3	longer than 1.0 mm
Anal fin (appearance of pearl organs)	1	no appearance
	2	partial appearance
	3	overall appearance (more than 70% of the anal fin)
	4	overall appearance; the anal fin is partially rubbed and white in color

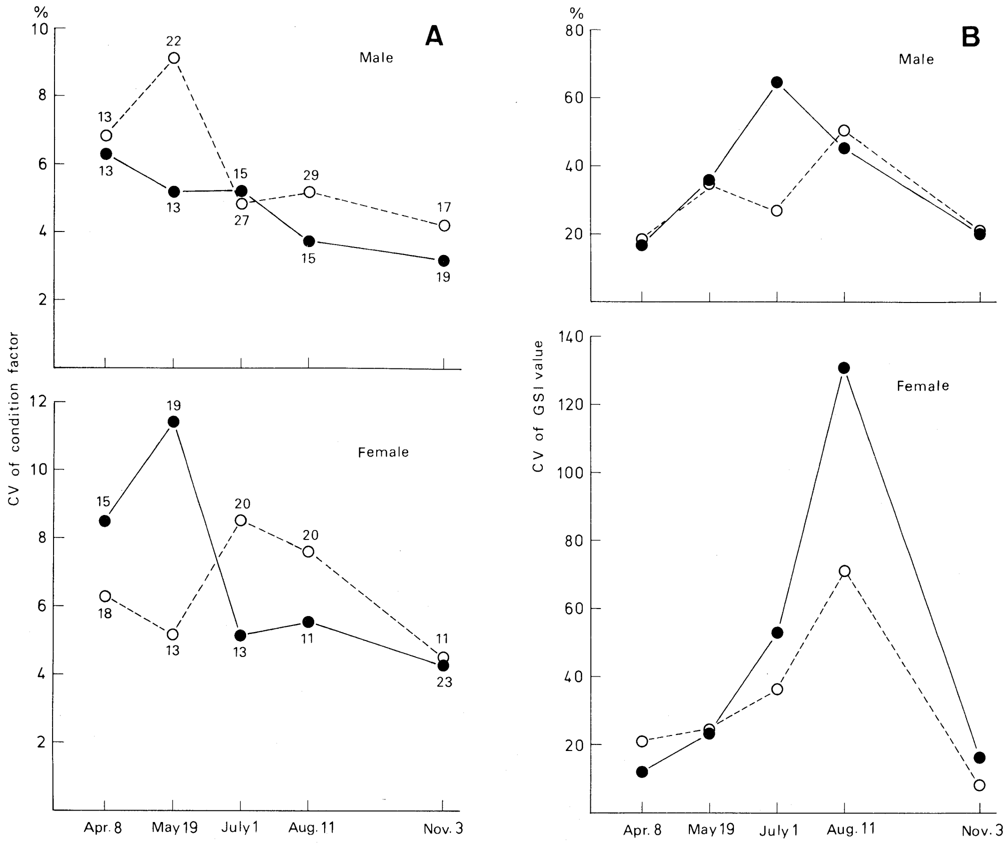

Fig. 2. Seasonal changes in the coefficient of variation (CV) in condition factor (A) and gonosomatic index (GSI) (B) for each sex of *Zacco temmincki*. Solid circles and lines indicate individuals smaller than 9.0 cm long, while open circles and broken lines individuals larger than 9.0 cm long. Sample numbers are shown beside the points in A.

characters) and the development of pearl organs on the anal fin ($\chi^2=66.3$, df=1, $P<0.001$, stages 2–4 are combined for both characters). All individuals with anal fin pearl organ development at stage 4 also developed stage 3 breeding color. Large pearl organ size was also associated with the development of pearl organs on the anal fin ($\chi^2=73.3$, df=1, $P<0.001$, stages 2–4 are combined for both characters). All individuals with stage 1 of pearl organ size also developed stage 1 of anal fin pearl organ development.

The development of secondary sexual characters in each sex and sample is shown in Table 6. All three characters developed in males to a more marked degree than in females (stages 2–4 in each character are combined in chi-squared test. breeding color: $\chi^2=49.5$, df=1, $P<0.001$; pearl organ size: $\chi^2=121.9$, df=1, $P<0.001$; anal fin: $\chi^2=76.8$, df=1, $P<0.001$), and stage 3 of breeding color and pearl organ size, and the development of pearl organs on the anal fin were limited to males. All characters developed most markedly in July or August, in the mating period of the fish. The development of pearl organs on the anal fin was limited to the period from May to August, but other characters remained in non-mating periods.

Ripe males in July and August developed breeding color (Fisher's exact probability test, $P=0.003$, stages 2 and 3 are combined), and pearl organs on the head ($P=0.0001$, stages 2 and 3 are combined) and the anal fin ($P=0.001$, stages 2–4 are combined), more markedly than unripe males. Neither breeding color ($P=1.000$) nor pearl organ size ($P=0.354$) differed between ripe and unripe females in July and August.

Body length, condition factor and GSI value were

compared between individuals with stage 1 and stages 2–4 of secondary sexual characters (Table 7). A large male body size was associated with the development of any of the above secondary sexual characters. A large female body size was associated with the development of breeding color from April to August, and large pearl organ size in July. High condition factor in females was associated with the development of breeding color from April to July, and with large pearl organ size in August. However high condition factor was associated with small pearl organ size in males in August. A large GSI value was associated with the development of breeding color and large pearl organ size for females in May and July. However large GSI values for males showed different correlations with the development of secondary sexual characters; positively with pearl organ size and anal fin development in July, and negatively with breeding color and pearl organ size in April.

Discussion

In the study area, daily direct observations of spawning of *Zacco temmincki* were conducted in 1982 and 1983 (Katano, in press). In 1982 spawning occurred from June 1 to August 12, and in 1983 spawning was initiated from June 2 although the end of the mating period was not investigated. Therefore, April 8 and May 19, when sampling was conducted, corresponded to the pre-mating period, July 1 and August 11 to the middle and end of the mating period, respectively, and November 3 to the post-mating period. The gonad weight of both males and females increased from April to July, indicating that gonad development progressed during the pre-mating period. Condition factor for both sexes also increased from April to July, but then decreased. During winter the fish hide in caves and crevices between large boulders and commonly grow from April to September (Miyadi et al., 1976). These results together show that the fish actively performed foraging activities during the pre-mating period.

The relationship between body length, condition factor and GSI value differed greatly between males and females. Female body size was positively and strongly correlated with the GSI value except in the post-mating period, as shown for other fish species (e.g., Heins et al., 1980; Mann, 1980; Mann and Mills, 1985). Male body size has also been reported to show a positive correlation with the GSI value in the cuatro ojos, *Anableps dowi* (Burns and Flores, 1981), but in the case of *Z. temmincki*, male body size was uncorrelated or negatively correlated with the GSI value. The sex ratio of *Z. temmincki* was almost 1 : 1. However, since females were not synchronized in their spawning and no female choice of partner was evident, the mating system of the fish was a form of male dominance polygyny where only large and dominant males could obtain females, while smaller males did not participate in spawning or performed sneaking behavior; dashing towards a spawning pair to release sperm or eat eggs (Katano, 1983, in press). At the sites where spawning was very frequent, very dominant males performed spawning behavior several hundred times per day during several successive days. These males tended to become exhausted and disappear from spawning grounds after frequent reproductive activities (Katano, in press). It was also notable that some dominant males performed spawning activities over two successive years. These results together suggest poor development of testis in some large males which frequently performed spawning behavior in the previous mating year.

Individual variation in condition factor for both sexes was the lowest in November, but increased in the pre-mating and mating periods. This result shows that some individuals became significantly

Table 5. Relationships between the development of three types of secondary sexual character in *Zacco temmincki*. Data are shown as percentages of the total sample ($N=346$).

	Stage	Pearl organ size 1	2	3
Breeding color	1	33.8	11.3	0.0
	2	12.1	26.9	6.1
	3	0.0	2.0	7.8

	Stage	Anal fin 1	2	3	4
Breeding color	1	44.8	0.3	0.0	0.0
	2	34.1	7.8	3.2	0.0
	3	1.2	1.4	2.9	4.3

	Stage	Anal fin 1	2	3	4
Pearl organ size	1	46.0	0.0	0.0	0.0
	2	33.5	5.5	0.9	0.3
	3	0.6	4.0	5.2	4.0

fatter or increased their gonad weight in the pre-mating and mating periods while others did not do so.

Individual variation in GSI value increased in the mating period, but differently between July and August, and between smaller and larger individuals. Individual variation in GSI value for smaller males peaked in July, presumably because the GSI value for unripe males was significantly smaller than that for ripe ones. On the other hand, individual variation in GSI for larger males peaked in August, at the end of the mating period, showing the large differences in gonad quantity among males that frequently performed reproductive behavior depleting their sperm, and males that saved sperm.

Individual variation in GSI value for both smaller and larger females peaked in August. This result may indicate the difference between spent and unspent females at the end of the mating period. The greater variation in GSI value for smaller females also suggests that some smaller females did not develop their ovaries, even at the end of the mating period.

Le Cren (1951) described considerable individual variation (CV) in GSI value in the perch, *Perca fluviatilis*, ranging from 10 to 28% for females and from 8 to 36% for males. Individual variation (CV) of *Z. temmincki* was, however, much greater than that of the perch, reaching a maximum of 64% for males and 130% for females. Individual variation in the GSI values of perch tended to be large when gonad weight was increasing in the pre-mating and mating periods, similar to the result obtained for *Z. temmincki.*

The development of secondary sexual characters is diverse between fish species; some appear only in males in the mating season while others appear in both sexes throughout the year (Norman and Greenwood, 1975; Lagler et al., 1977). In the latter case, however, few quantitative studies have been conducted, and the function of secondary sexual characters remains unexplained.

This study shows that the development of secondary sexual characters of the dark chub was very different between males and females. The development of secondary sexual characters was strongly associated with large body size in males, but not necessarily so in females. The weak association between large GSI values and the development of secondary sexual characters in males suggests that the development of secondary sexual characters does not necessarily indicate their maturity.

In the spawning behavior of *Z. temmincki*, a male presses a female laterally and stirs up the river bed by vibrating its anal fin to bury released eggs (Katano, 1983, in press). Therefore, the presence of pearl organs on the anal fin might be helpful for the "stirring up" behavior. It is also reasonable that the development of pearl organs on the anal fin was limited to large males in the mating period.

In order to obtain females in the mating period, large males utilized pearl organs on the head as a weapon in aggressive encounters, fiercely butting each other (Katano, in press). Aggressive interactions for food were also observed in both males and females in non-reproductive activities (Katano, 1985, 1987). This observation may explain the year-round development of pearl organs on the head. This consideration is supported by the fact that the development of secondary sexual characters did not differ between ripe and unripe females.

The meaning of breeding color is not obvious. Since neither parental care, elaborate courtship display nor female choice of partner was evident in the mating system of the fish (Katano, in press), it seems unlikely that breeding color is developed for parental recognition or mate choice. The year-round appearance of breeding color in both sexes suggests its function in aggressive interactions that were severest during the mating period. Since the bright coloration is greatly associated with the development of pearl organs and large body size for an individual, such coloration might function as a warning signal to other individuals to reduce useless aggressive interactions. If this is true, the secondary red color of *Z. temmincki* should be termed "warning color" rather than "breeding color".

Larger males of the dark chub tended to be dominant over smaller males and females in both mating and non-mating periods (Katano 1983, 1985, 1987, in press). It is likely that the greater development of secondary sexual characters in larger males, in addition to large body size, is responsible for their higher dominance status. The polygynous mating system of the dark chub, where only large dominant males obtained females, is obviously greatly associated with its seasonal, sexual and individual variations in reproductive characters.

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Table 6. Development of secondary sexual characters in *Zacco temmincki.* The sample size of each sex is given in parentheses, and data presented as percentages of the sample size.

Secondary sexual character	Stage	Apr. 8		May 19		Jul. 1		Aug. 11		Nov. 3		Total	
		Male (26)	Female (33)	Male (35)	Female (32)	Male (42)	Female (33)	Male (44)	Female (31)	Male (36)	Female (34)	Male (183)	Female (163)
Breeding color	1	34.6	60.6	14.3	68.8	19.0	48.5	22.7	51.6	50.0	94.1	27.3	65.0
	2	57.7	39.4	60.0	31.2	47.6	51.5	56.8	48.4	50.0	5.9	54.1	35.0
	3	7.7	0.0	25.7	0.0	33.3	0.0	20.5	0.0	0.0	0.0	18.6	0.0
Pearl organ size	1	19.2	69.7	20.0	93.8	14.3	72.7	11.4	58.1	27.8	91.2	18.0	77.3
	2	80.8	30.3	54.3	6.3	38.1	27.3	45.5	41.9	72.2	8.8	55.7	22.7
	3	0.0	0.0	25.7	0.0	47.6	0.0	43.2	0.0	0.0	0.0	26.2	0.0
Anal fin	1	100.0	100.0	74.3	100.0	19.0	100.0	40.9	100.0	100.0	100.0	62.3	100.0
	2	0.0	0.0	14.3	0.0	33.3	0.0	31.8	0.0	0.0	0.0	18.0	0.0
	3	0.0	0.0	11.4	0.0	23.8	0.0	15.9	0.0	0.0	0.0	11.5	0.0
	4	0.0	0.0	0.0	0.0	23.8	0.0	11.4	0.0	0.0	0.0	8.2	0.0

Table 7. Comparison of body length, condition factor and GSI value between individuals of *Zacco temmincki* with stage 1 and stages 2–4 of secondary sexual characters. The results of a one-way ANOVA are shown for each sex and sample. Plus signs show a positive correlation between the development of secondary sexual characters and the three physical characters compared, and minus signs show a negative correlation. Blanks indicate non-significance, although analyses were not conducted for anal fin in females, and in males in April and November since no pearl organs developed in them. $^{*}P<0.05$; $^{**}P<0.01$; $^{***}P<0.001$.

Characters compared	Secondary sexual character	Male					Female				
		Apr. 8	May 19	Jul. 1	Aug. 11	Nov. 3	Apr. 8	May 19	Jul. 1	Aug. 11	Nov. 3
Body length	Breeding color	+***	+***	+***	+***	+***	+*	+***	+***	+***	
	Pearl organ size	+***	+**	+***	+***	+***			+*		
	Anal fin		+***	+***	+***						
Condition factor	Breeding color						+**	+**	+**		
	Pearl organ size				−*					+**	
	Anal fin										
GSI value	Breeding color	−**						+**	+***		
	Pearl organ size	−*		+**				+*	+**		
	Anal fin			+*							

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カワムツの生殖腺重量と二次性徴の季節・性および個体による変異

片野　修

カワムツ *Zacco temmincki* の体長・体重・生殖腺重量および二次性徴の変異と相互関係について解析した．個体の肥満度とGSI値は前繁殖期に著しく増加した．体長とGSI値は雌では後繁殖期を除けば正の相関関係にあったが，雄では負の相関関係を示すか，有意な相関を示さなかった．肥満度とGSI値の個体変異は前繁殖期および繁殖期に増大した．婚姻色と頭部の追星は雌雄ともに一年中みられたが，繁殖期の雄でもっとも顕著であった．臀鰭上の追星は繁殖期の雄に限って発達した．これらの二次性徴の発達は必ずしも個体の成熟や高い繁殖能力を示すものではなく，体の大きさと連関していた．婚姻色は追星の発達と体の大きさを知らせる個体間の信号として，頭部追星は個体間の闘争のための武器として，臀鰭上の追星は産卵時に産卵床を掘りおこす道具として発達すると推定される．

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