飼育水温がヤマノカミの摂餌と成長に及ぼす影響

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Effects of water temperature on feeding and growth of the catadromous roughskin sculpin, *Trachidermus fasciatus*, reared in the laboratory

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Abstract: Effects of water temperature on feeding and growth of the catadromous roughskin sculpin *Trachidermus fasciatus* were studied at 9 different temperatures from 12 to 28°C for 30 days. At each of the 9 temperatures, six young fish were reared in aquaria and the rearing examination was repeated in 3 consecutive years ($n = 162$). Results indicated that for daily feeding rate the optimal water temperatures ranged from 21 to 26°C, while ranging from 19 to 20°C for daily growth rate, and ranging from 16 to 18°C for feeding efficiency. The optimal water temperatures for daily growth rate and feeding efficiency were lower than those for daily feeding rate. These results indicate that the optimal water temperature range is from 16 to 22°C, and that a water temperature of 12°C is too low and 28°C is too high for sustainable growth of *T. fasciatus*.

Key words: *Trachidermus fasciatus*; Effect of water temperature; Feeding; Growth

The seven species of freshwater sculpins (1 of the genus *Trachidermus* and 6 of the genus *Cottus*) inhabiting the Japanese Archipelago exhibit various behaviors such as catadromous, amphidromous, lacustrine and fluvial life histories (Goto 1990). The catadromous roughskin sculpin, *Trachidermus fasciatus*, occurs in Ariake and Isahaya bays and the rivers flowing into these water bodies in Kyushu Island, Japan (Tsukahara 1952). Elsewhere, this fish is found along the southern and western coasts of the Korean Peninsula, and the eastern coast of China (Choi et al. 1990; Wang and Chen 2010). This fish is a rare and valuable target species of fisheries in China, and has been included in the list of the wildlife under special state protection as a class II protected animal by the Chinese government (Wang and Chen 2010). Whereas, *T. fasciatus* is not considered as an edible fish in Japan (Takita 1989), however it has been designated as an "endangered species" by the Ministry of the Environment (Ministry of the Environment 2013). Also, this fish has been designated as a "critically endangered species" in Nagasaki Prefecture, an "endangered species" in Fukuoka and Kumamoto Prefecture, and a "vulnerable species" in Saga Prefecture, respectively (Saga Prefecture 2004; Nagasaki Prefecture 2011; Fukuoka Prefecture 2014; Kumamoto Prefecture 2014).

Spawning of *T. fasciatus* occurs in coastal waters in winter (Onikura et al. 2002). The

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larvae grow in tidal reaches near river mouths in early spring, the juveniles ascend rivers from late spring and grow in the rivers until early in winter (Onikura et al. 1999a; 1999b). The distribution ranges of this fish within almost all of the rivers flowing into Isahaya Bay and northwestern Ariake Bay have been disrupted by the weirs built near the river mouths, limiting the distribution to the lower reaches of the rivers (Takita and Chikamoto 1994). It seems that these distribution patterns are not the original distribution but have been restricted by modifications (weir construction) of the rivers (Takita and Chikamoto 1994).

Effects of water temperature on growth in terms of total length (*TL*) of *T. fasciatus* have been studied using 3 different temperatures at 20, 24, 28°C for 10 days (Onikura et al. 1998). However, data are not yet adequate for estimation of the optimal water temperature for this fish. For accumulation of basic ecological data in order to develop conservation strategies for *T. fasciatus*, the effects of water temperature on feeding and growth of this species were examined in the laboratory, using 9 different temperatures from 12 to 28°C for three periods of 30 days.

Materials and Methods

Fish rearing and diet

To conduct the study, several yearling fish of *T. fasciatus* measuring 70–95 mm in *TL* were collected in the tidal reaches of the Ushizu River, a tributary of the Rokkaku River system, northwestern Kyushu Island, Japan, on 5 October in 2011, 7 October in 2012, and 17 September in 2013, respectively. The yearlings were reared in freshwater aquaria by feeding freshwater shrimps such as *Palaemon paucidens*. From early January, salinity (S) of rearing water was gradually raised until it reached ca. S = 30 by mid-January. Each year a male and a female (respectively as male 143 mm *TL* and female 149 mm *TL* on 19 January 2012; 137 mm *TL* and 157 mm *TL* on 21 January 2013; and 159 mm *TL* and 146 mm *TL* on 20 January 2014) were transferred to an aquarium (60 × 30 × 35 cm), in which a hollow concrete block (ca. 90 mm in width and ca. 200 mm in length) had been placed in the left corner as a spawning nest. Spawning was observed on 8 February 2012, 1 March 2013, 17 February 2014 and hatching mainly occurred on 6 March 2012, 18 March 2013, and 10 March 2014, respectively. Newly hatched pelagic larvae were reared in several polycarbonate tanks (30 *l*) and kept in a running seawater system with a flow rate of 200 m*l*/min and aeration (600 m*l*/min). *Artemia* sp. (Brine Shrimp Eggs-90, Kitamura Co., Ltd.) nauplii enriched with a commercial enrichment product (Power full brine, Kitamura Co., Ltd.) were given every day at 8:00–9:00 and 16:00–17:00, until 30 days after hatching. *Artemia* density was increased from 5 to 10 individuals/m*l* according to the fish growth. From 20 to 70 days after hatching, they were fed with dry pellets, love-larva No. 4 (Hayashikane Sangyo Co., Ltd.). From 45 days after hatching, salinity was gradually lowered until it reached ca. S = 0 at 60 days after hatching. The juveniles at 50 days after hatching started to settle in the tanks. The juveniles 61 days after hatching were kept in FRP tanks (150 *l*), in a running freshwater system with a flow rate of 200 m*l*/min, aerated (600 m*l*/min) and filtered with 2 sets of Tetra Brillant Filter (Tetra Co., Ltd.). A paste diet for eel (Unagi High Step, Hayashikane Sangyo Co., Ltd.), prepared by blending 100 g dry weight of diet with 90 m*l* of water, was given from 60 days after hatching. Rearing water temperature was not controlled, it ranged from 6 to 9°C in winter and 26 to 29°C in summer. Photoperiod was not controlled during the fish rearing.

Rearing experiments over periods of 30 days were conducted 3 times, using fish at 183, 152 and 169 days after hatching for these experiments in 2012 (as 1st period), in 2013 (as 2nd period) and in 2014 (as 3rd period), respectively. The water temperatures just before the rearing experiments were 23, 25 and 26°C in 2012, 2013 and 2014, respectively.

After 3 days of fasting, 54 fish were randomly allocated to 9 groups (6 fish each). Body weight (*BW*) was measured to the nearest 0.01 g (Table 1). Each fish was individually marked by the removal of spines of the first dorsal fin and soft rays of the second dorsal fin in different combinations. Each group of 6 fish was kept in a freshwater aquarium (60 × 30 × 36 cm), in a running water system with a flow rate of 50 ml/min, aerated (600 ml/min) and filtered with one set of Tetra Brillant Filter. Water temperature of the 9 aquaria was controlled at 12, 14, 16, 18, 20, 22, 24, 26 and 28°C (±0.5°C) using a Rei-Sea Cooler (RZ-150Y, Rei-Sea Co., Ltd.) with a 200 W heater, respectively. Rates of adjustment of water temperature were within 2°C per 3 hours. Photoperiod was not controlled during the experimental periods.

The fish were fully fed the paste diet at 17:00–18:00 for a period of 30 days. The diet was pelletized to 0.080 g per piece from 1 to 10 days and 0.100 g per piece from 11 to 30 days during the 1st and 2nd periods, 0.100 g per piece from 1 to 5 days and 0.120 g per piece from 6 to 30 days during the 3rd period, according to the sizes of fish. Daily diet intake (g, *DDI*) in each aquarium was calculated from the number of pieces eaten by the 6 fish in each aquarium for the period of 30 days. After completion of the 30 days feeding period and 3 additional days of fasting, *BW* was measured to the nearest 0.01 g (Table 1).

Daily growth rate (*DGR*) was individually calculated as follows:

$$DGR\ (\%) = 100\ (W_2 - W_1)\ W_1^{-1}\ T^{-1}$$

where, W_1 is the initial *BW*, W_2 is the final *BW* and T is the rearing interval (30 days). Daily feeding rate (*DFR*) in each aquarium was calculated as follows:

$$DFR_n\ (\%) = 100\ DDI_n\ TW_n^{-1}$$

where, DDI_n is *DDI* on the n-th day, TW_n is total *BW* of all fish in each group on the n-th day. TW_n was calculated using the linear equation between the initial *BW* of all fish ($n = 6$) and final *BW* of all fish ($n = 6$) of each group (Table 1). Feeding efficiency (*FE*) in each aquarium was calculated as follows:

$$FE\ (\%) = 100\ TDI\ (TW_2 - TW_1)^{-1}$$

where, *TDI* is the total diet intake for 30 days, TW_1 and TW_2 is the total of initial *BW* and final *BW* of all fish in each group, respectively (Table 1).

Data analysis

The sizes of both genders of mature fish have been shown to be similar (Onikura et al. 1999b). Therefore, growth of this fish was estimated without discrimination of the gender in this study.

DFR, *DGR* and *FE* were analyzed using the

Table 1. Growth, total diet intake (*TDI*), daily feeding rate (*DFR*), and feeding efficiency (*FE*) of *Trachidermus fasciatus* among the 9 groups reared in different water temperatures in three periods (each 30 days)

WT (°C)	12	14	16	18	20	22	24	26	28
1st period									
BW (g)									
Initial (n=6)	7.79 ± 1.18	8.15 ± 1.55	7.90 ± 1.82	7.91 ± 2.49	8.27 ± 1.67	7.75 ± 1.58	8.18 ± 1.68	8.24 ± 2.41	8.45 ± 1.49
Final (n=6)	15.03 ± 3.02	16.93 ± 3.16	18.13 ± 2.93	19.29 ± 3.99	20.03 ± 4.92	20.04 ± 5.35	21.64 ± 5.05	17.14 ± 3.17	12.30 ± 3.13
DGR (%, n=6)	3.05 ± 0.40^{a}	3.60 ± 0.44^{ab}	4.46 ± 0.74^{ab}	5.04 ± 1.31^{abc}	4.70 ± 0.64^{abcd}	5.18 ± 0.74^{abcde}	5.47 ± 0.97^{bcdef}	3.84 ± 1.28^{abcdef}	1.46 ± 0.45^{ab}
TDI (g)	52.19	67.01	76.37	87.44	88.13	97.97	105.94	85.04	60.88
DFR (%, n=30)	2.55 ± 1.17^{a}	3.06 ± 1.35^{ab}	3.40 ± 1.11^{ab}	3.84 ± 2.00^{ab}	4.10 ± 1.98^{b}	4.34 ± 2.18^{b}	4.25 ± 1.76^{b}	4.00 ± 1.67^{b}	3.28 ± 0.66^{ab}
FE (%)	83.23	78.60	80.42	78.09	80.06	75.25	76.24	62.83	37.98
2nd period									
BW (g)									
Initial (n=6)	7.18 ± 1.04	7.13 ± 1.22	7.06 ± 1.00	7.61 ± 1.57	7.48 ± 1.44	7.30 ± 1.96	7.20 ± 1.98	7.09 ± 1.94	7.97 ± 2.83
Final (n=6)	11.84 ± 1.36	13.58 ± 2.36	14.97 ± 2.67	15.90 ± 3.31	16.52 ± 2.92	16.22 ± 3.40	14.27 ± 2.90	14.01 ± 4.11	11.63 ± 3.55
DGR (%, n=6)	2.19 ± 0.32^{a}	3.03 ± 0.42^{ab}	3.72 ± 0.47^{abc}	3.65 ± 0.57^{abcd}	4.05 ± 0.31^{bcde}	4.20 ± 1.02^{abcdef}	3.41 ± 0.93^{abcdef}	3.21 ± 0.76^{abcdef}	1.58 ± 0.36^{ab}
TDI (g)	38.32	49.44	60.14	62.26	68.78	67.17	63.15	69.45	53.23
DFR (%, n=30)	2.24 ± 2.25^{a}	2.64 ± 0.91^{ab}	3.06 ± 0.89^{ab}	2.99 ± 0.93^{ab}	3.30 ± 1.05^{b}	3.28 ± 1.30^{b}	3.32 ± 1.41^{b}	3.81 ± 1.51^{b}	3.09 ± 1.40^{ab}
FE (%)	73.02	78.38	78.97	79.87	78.87	79.65	67.17	59.73	41.25
3rd period									
BW (g)									
Initial (n=6)	12.59 ± 4.08	12.52 ± 4.02	12.17 ± 4.18	12.68 ± 3.94	11.63 ± 2.94	11.22 ± 2.85	12.05 ± 2.98	11.71 ± 3.08	11.42 ± 2.67
Final (n=6)	20.29 ± 7.49	20.17 ± 6.46	23.52 ± 6.54	25.62 ± 7.69	23.13 ± 5.16	24.24 ± 4.97	20.47 ± 5.84	17.54 ± 3.40	17.19 ± 1.99
DGR (%, n=6)	1.98 ± 0.37^{a}	2.01 ± 0.58^{ab}	3.23 ± 0.55^{ab}	3.47 ± 0.69^{ab}	3.38 ± 0.74^{ab}	3.98 ± 0.91^{bc}	2.31 ± 0.47^{abc}	1.88 ± 0.46^{ab}	1.85 ± 0.85^{ab}
TDI (g)	67.96	74.32	96.38	100.06	100.28	108.02	93.56	72.54	91.96
DFR (%, n=30)	2.27 ± 1.27^{a}	2.46 ± 1.46^{ab}	2.97 ± 1.28^{abc}	2.99 ± 1.13^{abc}	3.30 ± 1.03^{abc}	3.42 ± 0.96^{bc}	3.61 ± 1.22^{c}	3.06 ± 1.50^{abc}	3.65 ± 1.12^{c}
FE (%)	67.97	61.69	70.67	77.61	68.76	72.35	54.02	43.51	37.69

Different alphabetical letters show significant differences (Dunn's multiple comparison test, $P < 0.05$).

values for each experimental period, respectively. *DFR* and *DGR* were analyzed with non-parametric statistical tests (Kruskal-Wallis test and Dunn's multiple comparison test), also *DFR*, *DGR* and *FE* were analyzed with parametric statistical tests (regression analysis) using JMP 9 (SAS Institute Inc.). For all statistical tests, significance was assessed at $P = 0.05$.

Results

Effect of water temperature on feeding

Mean values of *DFR* in the 1st period were higher than those in the other periods of *DFR* (Fig. 1). *DFR* among the 9 groups were significantly different in the 3 periods (Kruskal-Wallis test; 1st period, $Hc = 27.89$, $P < 0.001$; 2nd period, $Hc = 30.67$, $P < 0.001$; 3rd period, $Hc = 30.71$, $P < 0.001$). Also, *DFR* at 12°C was lower than values at 20, 22, 24, and 26°C in the 1st and 2nd periods (Dunn's multiple comparison test; 1st period; 12°C vs 20°C, $Q = 3.46$, $P < 0.05$; 12°C vs 22°C, $Q = 3.75$, $P < 0.01$; 12°C vs 24°C, $Q = 3.94$, $P < 0.01$; 12°C vs 26°C, $Q = 3.55$, $P < 0.05$; 2nd period; 12°C vs 20°C, $Q = 3.75$, $P < 0.01$; 12°C vs 22°C, $Q = 3.67$, $P < 0.01$; 12°C vs 24°C, $Q = 3.81$, $P < 0.01$; 12°C vs 26°C, $Q = 4.61$, $P < 0.01$), *DFR* at 12, 14°C were lower than values at 24, 28°C and *DFR* at 12 was lower than value at 22°C in the 3rd period (12°C vs 22°C, $Q = 3.27$, $P < 0.05$; 12°C vs 24°C, $Q = 3.90$, $P < 0.01$; 12°C vs 28°C, $Q = 4.05$, $P < 0.01$; 14°C vs 24°C, $Q = 3.28$, $P < 0.05$; 14°C vs 28°C, $Q = 3.43$, $P < 0.05$; Table 1).

The relationship between water temperature and *DFR* among the 9 groups in each experimental period is given by the following equations, respectively:

1st period:

$$DFR = -4.701 + 8.187\ \mathrm{E}^{-1}\ WT - 1.882\ \mathrm{E}^{-2}\ WT^2\ (R^2 = 0.106, P < 0.001)$$

2nd period:

$$DFR = -1.149 + 3.7973\ \mathrm{E}^{-1}\ WT - 7.882\ \mathrm{E}^{-3}\ WT^2\ (R^2 = 0.095, P < 0.001)$$

3rd period:

$$DFR = -7.737\ \mathrm{E}^{-1} + 3.272\ \mathrm{E}^{-1}\ WT - 6.302\ \mathrm{E}^{-3}\ WT^2\ (R^2 = 0.100, P < 0.001)$$

where, *WT* is the water temperature. These equations indicate that 21.8°C in the 1st period, 24.1°C in the 2nd period and 26.0°C in the 3rd period had the highest values for *DFR*, respectively (Fig. 1).

Effect of water temperature on growth

Mean values of *DGR* in the 1st period were higher and those in the 3rd period were lower than those in the 2nd period, respectively (Fig. 2). *DGR* among the 9 groups were significantly different in the 3 periods (Kruskal-Wallis test; 1st period, $Hc = 35.19$, $P < 0.001$; 2nd period, $Hc = 32.77$, $P < 0.001$; 3rd period, $Hc = 36.23$, $P < 0.001$). Also, *DGR* at 28°C was lower than values at 18, 20, 22, 24°C, and *DGR* at 12°C was lower than that at 24°C in the 1st period (Dunn's multiple comparison test; 28°C vs 18°C, $Q = 3.78$, $P < 0.01$; 28°C vs 20°C, $Q = 3.36$, $P < 0.05$; 28°C vs 22°C, $Q = 4.11$, $P < 0.01$; 28°C vs 24°C, $Q = 4.31$, $P < 0.01$; 12°C vs 24°C, $Q = 3.30$, $P < 0.05$). *DGR* at 28°C was lower than values at 16, 18, 20, 22°C, and *DGR* at 12°C was lower than that at 20°C in the 2nd period (Dunn's multiple comparison test; 28°C vs 16°C, $Q = 3.54$, $P < 0.05$; 28°C vs 18°C, $Q = 3.32$, $P < 0.05$; 28°C vs 20°C, $Q = 4.18$, $P < 0.01$; 28°C vs 22°C, $Q = 3.98$, $P < 0.01$; 12°C vs 20°C, $Q = 3.36$, $P < 0.05$). *DGR* at 22°C was higher than values at 12, 26, 28°C in the 3rd period (Dunn's multiple comparison test; 22°C vs 12°C, $Q = 3.41$, $P < 0.05$; 22°C vs 26°C, $Q = 3.60$, $P < 0.05$; 22°C vs 28°C, $Q = 3.32$, $P < 0.05$; Table 1).

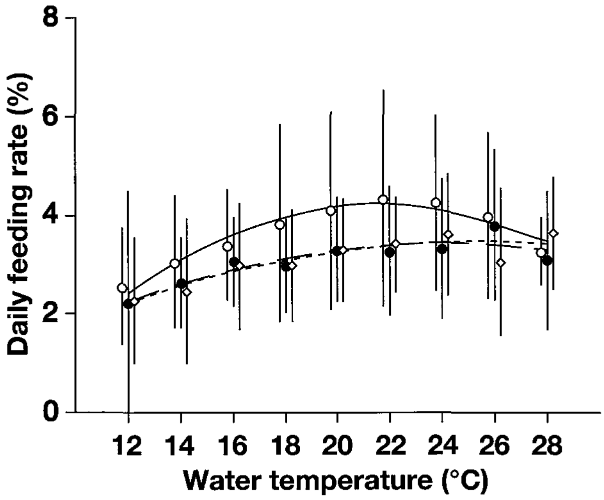

Fig. 1. Daily feeding rate (*DFR*) of *Trachidermus fasciatus* at 9 different water temperatures in three periods (each 30 days; —○—, 1st period; —●—, 2nd period; - -◇- -, 3rd period). Error bars indicate the standard deviation.

The relationship between water temperature and *DGR* for the 9 groups during each experimental period is given by the following equations, respectively:

1st period:

$DGR = -12.38 + 1.797\,WT - 4.566\,\mathrm{E}^{-2}\,WT^2$ ($R^2 = 0.579$, $P < 0.001$)

2nd period:

$DGR = -8.777 + 1.305\,WT - 3.303\,\mathrm{E}^{-2}\,WT^2$ ($R^2 = 0.615$, $P < 0.001$)

3rd period:

$DGR = -7.480\,\mathrm{E}^{-1} + 1.110\,WT - 2.820\,\mathrm{E}^{-2}\,WT^2$ ($R^2 = 0.462$, $P < 0.05$)

where, *WT* is the water temperature. These equations indicate that 19.7°C in the 1st period, 19.8°C in the 2nd period and 19.7°C in the 3rd period had the highest values for *DGR*, respectively (Fig. 2).

Effect of water temperature on feeding efficiency

Values of *FE* in the 3rd period were lower than those in the other periods (Fig. 3). The relationship between water temperature and *FE* among the 9 groups in each experimental period is given by the following equations, respectively:

1st period:

$FE = -26.72 + 13.26\,WT - 3.926\,\mathrm{E}^{-1}\,WT^2$ ($R^2 = 0.814$, $P < 0.01$)

2nd period:

$FE = -25.29 + 12.26\,WT - 3.496\,\mathrm{E}^{-1}\,WT^2$ ($R^2 = 0.965$, $P < 0.0001$)

3rd period:

$FE = -26.67 + 11.50\,WT - 3.320\,\mathrm{E}^{-1}\,WT^2$ ($R^2 = 0.871$, $P < 0.01$)

where, *WT* is the water temperature. These equations indicate that 16.9°C in the 1st period, 17.5°C in the 2nd period and 17.3°C in the 3rd period had the highest values for *FE*, respectively (Fig. 3).

Discussion

Feeding and growth patterns of *T. fasciatus* were different among the 9 different conditions of water temperature, in this study. This rearing examination indicates that water temperatures ranging from 21 to 26°C were optimal for *DFR*, those ranging from 19 to 20°C were optimal for *DGR*, those ranging from 16 to 18°C were optimal for *FE*, respectively (Figs. 1, 2, 3, Table 1). These results indicate that the optimal water temperatures for *DGR* and *FE* are lower than those for *DFR*. We consider that the low values of *DGR* in the lower water temperatures were affected by low values of *DFR*. Whereas, the low values of *DGR* in higher water temperatures were affected by the low values of *FE*. It seems that the lower values of *DGR* and *FE* in high water temperatures are caused by high utilization of energy except for growth. The values of *DFR*, *DGR* and *FE* were different among

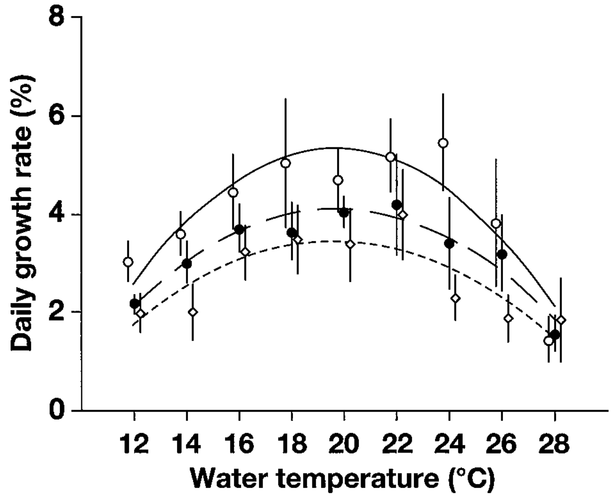

Fig. 2. Daily growth rate (*DGR*) of *Trachidermus fasciatus* at 9 different water temperatures in three periods (each 30 days; —○—, 1st period; —●—, 2nd period; - -◇- -, 3rd period). Error bars indicate the standard deviation.

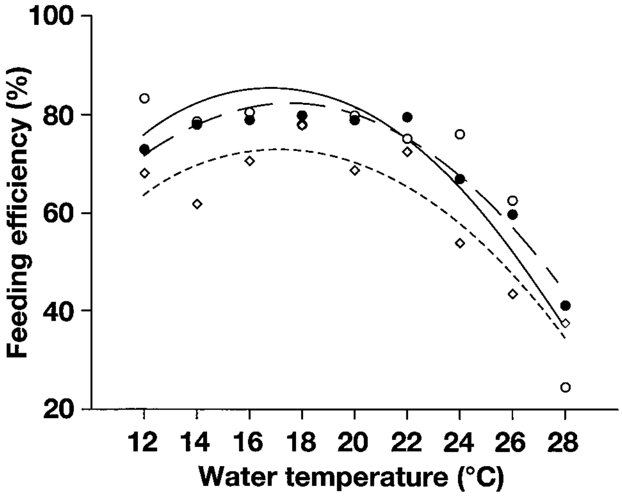

Fig. 3. Feeding efficiency (*FE*) of *Trachidermus fasciatus* at 9 different water temperatures in three periods (each 30 days; —○—, 1st period; —●—, 2nd period; - -◇- -, 3rd period).

the 3 periods, however we could not clarify the causes of these differences. These results indicate that the range of optimal water temperature is from 16 to 22°C, and a water temperature of 12°C is too low, and 28°C is too high for high growth rates of *T. fasciatus*. This rearing examination supports the result by Onikura et al. (1998) that growth in *TL* at 20 and 24°C was better than at 28°C.

Growth rates in *TL* of *T. fasciatus* in the high water temperature period from July to September (26–28°C) were lower than those from May to July (19–22°C) and from September to January (9–20°C) in the Kashima River in Kyushu Island (Onikura et al. 1999b; Takeshita 2011). It seems that the high water temperature leads to a stagnant growth phase in summer. Solitary specimens of *T. fasciatus* were observed in the rivers in spring and autumn, whereas in summer this fish gathered in groundwater springs, which the water temperature was slightly lower than surrounding waters (Takeshita unpubl. data). This distribution pattern may indicate avoidance of high water temperatures in summer.

Effects of water temperature on growth of *T. fasciatus* were compared with 2 closely related diadromous freshwater sculpins inhabiting southwestern Japan. Growth in *TL* of the catadromous fourspine sculpin *Cottus kazika* was reported in the Gonokawa River, western Honshu Island and the rearing examination for 60 days (Takeshita et al. 2005). Seasonal growth patterns in the river suggest that *C. kazika* grew rapidly from September to November and from April to July, but only minimally from July to September (Takeshita et al. 2005). These seasonal growth patterns of *C. kazika* are similar to those of *T. fasciatus* in the Kashima River (Onikura et al. 1999b; Takeshita 2011). Also, the rearing examination using 8 different temperatures from 12 to 26°C indicated that the growth in *TL* of *C. kazika* was better at 16–22°C than at 12–14°C and 24–26°C, and 20°C was the optimal temperature for growth in *TL* (Takeshita et al. 2005). Therefore, it seems that optimal water temperatures for growth in both catadromous sculpins are similar.

Effects of water temperature on feeding and growth of the amphidromous sculpin *C. pollux* middle-egg (ME) type were reported using 9 different temperatures from 10 to 26°C for 30 days (Takeshita et al. 2014). Takeshita et al. (2014) indicates that water temperatures ranging from 18 to 20°C were optimal for *DFR*, those from 14 to 17°C were optimal for *DGR*, and those from 11 to 16°C were optimal for *FE* among males and females of *C. pollux* ME. Therefore, optimal water temperatures for *DFR*, *DGR* and *FE* of *T. fasciatus* were higher than those of *C. pollux* ME, respectively. Also, the values by the polynomial equations of *DGR* and *FE* of *C. pollux* ME in 26°C had been near or below zero (Takeshita et al. 2014). It seems that effects of high water temperatures (26 and 28°C) are not so severe for *T. fasciatus* to feed and grow, as the effects for *C. pollux* ME.

The distribution range of this fish in almost all of the rivers flowing into Ariake and Isahaya bays have been disrupted by the construction of weirs near the river mouths with or without pool type fish ladders (Takeshita unpubl. data). In waters where *T. fasciatus* inhabits these rivers, the water temperature reaches to 29°C in summer (Takeshita et al. unpubl. data). Based on the above results, it is suggested that the population of *T. fasciatus* is unable to migrate upstream and remain in waters unsuitable for growth in summer due to the barrier effect of these weirs. It is necessary to reform the pool type fish ladder to a stream type fish ladder, or build the latter type fish ladder for conservation of *T. fasciatus* in Japan.

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飼育水温がヤマノカミの摂餌と成長に及ぼす影響

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佐賀県六角川水系牛津川で採集したヤマノカミを飼育して産卵させた。それらを孵化させ，飼育した個体を用い，水温が摂餌と成長に及ぼす影響について，水温を12～28℃の９段階に調整して調べた。各水槽に６個体ずつ収容し，30日間の給餌実験を３年にわたり１回ずつ行った。日間給餌率は21～26℃，日間増重率は19～20℃，餌料効率は16～18℃で高く，それらが至適水温と考えられた。また，日間増重率と餌料効率の至適水温は，日間給餌率の至適水温より低かった。以上の結果から，本種は水温16～22℃では高成長を示すが，12℃及び28℃では成長率が低下すると考えられた。