



Title	Early maturation of rosyface dace, <i>Tribolodon sachalinensis</i> (Cyprinidae, Cypriniformes), in a small isolated population
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4 Running head: Early maturation of rosyface dace

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21 **Abstract.** Age at maturity is one of the key parameters of life-history. Whereas large
22 variations in adult body size have been reported in *Tribolodon sachalinensis* (Nikolsky,
23 1889), age and size at first maturity have rarely been examined. Here, we report early
24 maturation (+1 male) and sexual difference in age at maturity in an isolated population in
25 Hokkaido, northern Japan, which is different from a previous study.

26

27 **Keywords:** live fast and die young, sexual size dimorphism, growth rate, promiscuous,
28 reservoir.

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Introduction

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31 Life-history schedules of organisms, such as when to begin reproduction and when to
32 die, are crucial to life-time fitness (Stearns, 1992). Age and/or size at maturity are known to
33 vary within species (e.g. Morita and Fukuwaka, 2007) and understanding those variations is
34 important because they significantly affect demography and extinction risk (Stearns, 1992).
35 Rosyface dace *Tribolodon sachalinensis* (Nikolsky, 1889) (Cyprinidae, Cypriniformes),
36 which are distributed from northern Japan (Tohoku and Hokkaido) to Sakhalin and Chishima
37 Islands (Sakai et al., 2002), have large variations in body size of mature individuals both
38 within and among populations: spawners range in size from 20–45 cm SL (i.e. standard
39 length) in a large river in Sakhalin and from 8–22 cm SL in Japan and a small river in
40 Sakhalin (Ito, 1975; Gritsenko, 1982). In this species, egg numbers of 8 cm, 20 cm and 40
41 cm SL females are approximately 1,100, 7,200 and 160,000, respectively (Sakai, 1995). Such
42 large inter- and intra-population variations in fecundity strongly indicate the importance of
43 life-history schedules in the rosyface dace, since age strongly affects body size in this fish
44 (Sakai, 1995). However, the age of spawners has only been studied in one river (Mu river,
45 central Hokkaido: Sakai, 1995) and the earliest maturation of this species is reported as
46 age-3+ for both sexes (Sakai, 1995). Here, we report early maturation (+1 male) and sexual
47 differences in age at maturity in a small isolated population in Hokkaido, northern Japan.

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Materials and Methods

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51 *Study area.* Our sampling sites were a tributary of the Shiodomari River (hereafter SH,
52 41°82' N; 140°93' E) in southern Hokkaido and the Yukutora-shupetsu River (hereafter YS,
53 43°19' N; 142°56' E) in central Hokkaido. SH is small (3–5 m wide) and separated from the

54 main stem by a waterfall (ca. 5 m high). YS is also a relatively small stream (5–10 m),
55 draining into the Kanayama reservoir (920 ha, 57 m, constructed in 1967). SH and YS
56 populations are isolated by a natural waterfall and man-made dam, respectively.

57

58 *Sexing and age estimation.* During breeding season (mid–late June) in 2016, we
59 collected fish by using a backpack electrofisher (Model 12B, Smith-Root, Vancouver,
60 Washington, USA). Fish collected were anesthetized with clove oil (FA100: DS Pharma
61 Animal Health Co., Ltd.) and measured for fork length (FL) nearest to 1 mm. As SH was
62 small habitat and thus population size could be small, non-lethal methods were employed for
63 evaluating sexes and ages. Scales were used for age estimation (Sakai, 1995). Sex were
64 determined by squeezing the abdomen to release gametes from the gonoduct. When no sperm
65 or eggs were emitted, we classified fish as “unidentified”. These individuals were either
66 immature juveniles or mature adults that had yet to become sexually active or were already
67 spent.

68

69 *Statistical analyses.* All statistical analyses were performed using R (R Development
70 Core Team, 2016). First, we compared the average size and age of spawning individuals
71 between the populations and between sexes within the populations by Welch’s t-test. Second,
72 to compare growth rates between the populations, the von Bertalanffy growth equation
73 (VBGE) were fitted to the FL and estimated age using the nonlinear least-squares method
74 (Kimura, 1980). VBGE is $L_t = L_\infty (1 - e^{-k(t-t_0)})$, where L_t is the length at age t , L_∞
75 is the asymptotic length, k is the growth coefficient, and t_0 is the theoretical age at $L = 0$.
76 Using R package “fishmethods” (Nelson, 2015), likelihood ratio tests for the parameters (L^∞ ,
77 k , t_0) were conducted. This test compares likelihood of the null hypothesis (H_0), which
78 assumes all VBGE parameters are same in two populations, and alternative hypothesis (H_1),

79 which assumes all parameters are different. When H_0 showed significantly lower likelihood
80 comparing to H_1 , VBGEs are not same between two populations (Kimura, 1980).

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Results and Discussion

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85 A total of 187 and 65 individuals were determined for age and sexual status in SH and
86 YS, respectively (Fig. 1). The average FL of spawners (including both sexes) was more than
87 two times larger in YS compared to SH (98.6 mm and 223.0 mm for SH and YS, respectively,
88 $P < 0.001$), whereas the average age was only slightly older in YS (age- 3.3+ and 4.6+ for SH
89 and YS, respectively, $P < 0.001$). The smallest and largest spawners were also much larger in
90 YS than SH (smallest: 66 mm and 157 mm for SH male and YS male, largest: 158 mm and
91 390 mm for SH male and YS female, respectively). Although sample size is limited,
92 estimated growth curves were different between the streams ($X^2=714.2$, $P < 0.001$), indicating
93 faster growth in YS (Fig. 1).

94

95 Both males and females first matured at age-3+ in YS, which is consistent with Sakai
96 (1995). However, SH males generally matured from age-2+ (31 individuals) with one
97 individual maturing at age-1+ whereas most female matured from age-3+. It is known that
98 reductions in stream habitat size suppress fish body size (Jellyman et al., 2014) and
99 genetically or environmentally induced lower growth rates are reported in small isolated
100 populations of salmonids (Northcote, 1981; Morita and Fukuwaka, 2007). Younger age and
101 smaller size at maturity in SH may be adaptive in the more restricted environment.

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103 Although growth was much faster in YS, the average spawner age was similar. This may
104 contradict with some theoretical and empirical studies that showed faster growth inducing
105 earlier maturity (Stearns, 1992; Morita and Fukuwaka, 2007). It remains unknown why daces
106 in YS do not mature earlier despite the higher growth rate. Because rosyface dace show large
107 variations in body size among populations, further study considering biotic/abiotic
108 environmental factors would contribute to a better understanding of life-history evolution.

109

110 Another potentially interesting topic is the inter-population variations in the sexual
111 differences of age at maturity. Males matured younger in SH, whereas no sexual difference
112 was observed in YS and other populations (Sakai, 1995). In many organisms, resources
113 allocated to reproduction vs. survival/growth differ between sexes (Bonduriansky et al.,
114 2008). With the fecundity selection, reproductive success should be significantly linked to
115 body size in females. In males with alternative mating tactics (e.g. sneakers) or promiscuous
116 mating behavior, the advantage of a large body size in reproduction will be weaker than for
117 females (Parker 1992). Since rosyface dace are promiscuous (Ito, 1975), males would gain
118 higher fitness when they invest in early reproduction rather than growth and longevity (i.e.
119 ‘live fast and die young’ strategy). Additionally, since this fish shows linear growth (Fig. 1),
120 females would gain higher fitness when they invest in growth and longevity rather than early
121 reproduction (Bonduriansky et al., 2008). Inter-population variations of the sexual
122 differences in body size and age at maturity may provide new insights into the theories of life
123 history evolution.

124

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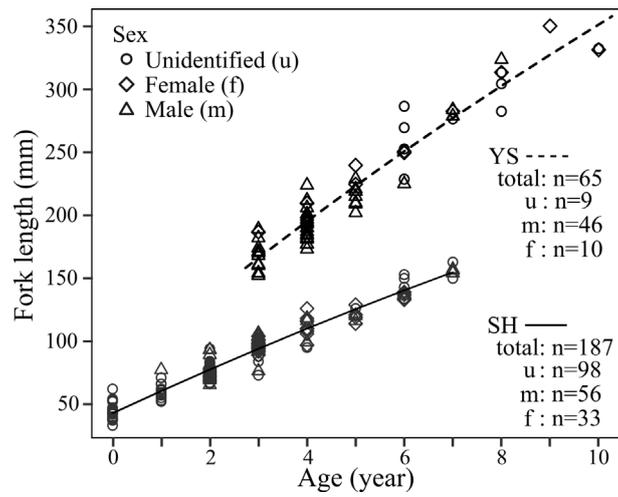
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Figures



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160 Fig. 1. Growth curve in a tributary of the Shiodomari River (SH) and the Yukutora-shupetsu River (YS).

161 Estimated VBGE are $L_t = 579.3 \times (1 - e^{0.0333(t-2.316)})$ in SH, and $L_t = 1064 \times (1 - e^{-0.0328(t-2.209)})$

162 in YS.