Replacement pattern of the pharyngeal teeth in cyprinid fish, *Tribolodon hakonensis*

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Cyprinid fish, lacking teeth on the jaws, have well-developed dentition on the pharyngeal bones. They continue to replace these teeth throughout their life span just the other non-mammalian vertebrates with their jaw teeth. This phenomenon occurs because the small teeth present in the larvae and juveniles are inadequate for the jaws of adults, and because the change of preys as they grow requires morphological changes of the teeth. The pharyngeal teeth are replaced with regularity in cyprinid fish. The tooth germs are initiated in cyclic order, 5-3-1-4-2 in the row bearing five teeth and 3-1-4-2 in the row bearing four teeth, i.e. the teeth are replaced alternately and cephalad¹⁻⁴⁾. This replacement pattern is the same as that of jaw tooth replacement seen in the other non-mammalian vertebrates.

The authors have undertaken the analyses of pharyngeal teeth in cyprinoids to study the replacement pattern. In the present paper, they will examine the pharyngeal teeth of Japanese dace, *Tribolodon hakonensis*, which has a double-row and bilaterally asymmetrical dentition.

Materials and Methods

Specimens of *T. hakonensis* were collected from Lake Biwa in April, 1981. The specimens observed were 36 adults of 23.8-29.6 mm standard length (SL).

They were fixed in 10% formalin, cleared in 1% KOH, and stained with alizarin red S. The pharyngeal arch was taken from the head region together with the mucous membrane. They were immersed in pure

glycerine and examined under a stereoscopic microscope.

The replacement succession was determined on the basis of the difference in the developmental stage among tooth germs, which was judged from the size and/or stainability with alizarin red S.

Results and Discussion

The dental formula of the present species is usually expressed as 0.2.5-4.2.0.⁵⁾ The left pharyngeal arch has five major row teeth and two minor row teeth, the right arch four major row teeth and two minor row teeth; dentition is bilaterally asymmetrical. Of the 36 examined, one had a bilaterally symmetrical dentition, the dental formula of which was represented as 0.2.4.-4.2.0. This one was excluded from the present analysis.

The major row is called the A row and the minor row the B row. The individual tooth is numbered in order from the anterior to posterior in each row. The tooth germs of the replacement teeth are numbered in the same way as the functioning teeth.

It is well-known that the pharyngeal teeth are replaced in cyclic order, 5-3-1-4-2 in the row bearing five teeth and 3-1-4-2 in the row bearing four teeth¹⁻⁴⁾. The succession of these cyclic orders occurred with high frequency (Tables 1, 2 and 3). In the present species, the teeth are generally replaced in the order of 5-3-1-4-2 or 3-1-4-2.

There was a difference in the occurrence frequency of the replacement pattern between the right and left major row. The tooth succession of the order, 5-3-1-4-2, on the

Table 1. Number of tooth germ successions in each row of 35 analyzed cases. Germ successions with an asterisk do not fit the cyclic order, 5-3-1-4-2 or 3-1-4-2.

Right arch		Left arch	
Major row	Minor row	Major row	Minor row
4 (1-4-2-3)	1 (1)	3 (4-2-5)	1 (2)
4 (3-1-4-2)	2 (2-1)	3 (4-2-5)	1 (1)
4 (3-1-4-2)	0	4 (3-4-1-2)*	1 (2)
4 (3-1-4-2)	1 (2)	4 (3-4-2-5)*	1 (2)
2 (4-2)	0	3 (2-5-3)	0
3 (2-3-1)	1 (2)	3 (2-3-1)*	0
3 (2-3-1)	0	2 (3-1)	0
2 (2-3)	1 (1)	2 (5-3)	0
2 (2-1)*	1 (1)	4 (2-1-3-5)*	0
4 (3-1-4-2)	1 (1)	3 (4-2-5)	0
4 (3-1-4-2)	1 (2)	3 (4-2-5)	1 (1)
2 (3-1)	1 (2)	4 (3-5-4-2)*	0
3 (2-3-1)	1 (1)	2 (3-1)	0
4 (1-4-2-3)	0	3 (2-5-3)	1 (2)
4 (3-1-4-2)	1 (1)	2 (4-2)	0
2 (3-1)	1 (1)	4 (3-1-4-2)	1 (2)
2 (4-2)	0	4 (2-5-3-1)	0
3 (2-3-1)	0	3 (1-4-2)	0
3 (3-1-4)	0	3 (3-1-4)	0
2 (4-2)	0	3 (4-2-1)*	0
2 (4-2)	0	4 (4-2-5-1)*	0
3 (3-1-4)	0	4 (3-1-4-2)	1 (1)
3 (2-3-1)	0	4 (2-5-3-1)	0
3 (1-4-2)	1 (2)	3 (4-2-5)	0
4 (2-3-1-4)	1 (2)	4 (3-1-4-2)	0
4 (3-1-4-2)	0	4 (4-2-5-1)*	0
4 (4-1-2-3)	0	3 (2-3-1)	0
3 (3-1-4)	0	3 (3-1-4)	1 (2)
4 (3-1-4-2)	0	4 (4-2-5-1)*	0
4 (2-3-1-4)	1 (2)	4 (3-1-4-2)	0
3 (3-1-4)	0	4 (3-1-4-2)	0
2 (4-2)	1 (1)	4 (4-2-5-3)	0
3 (3-1-4)	0	4 (3-1-4-2)	0
4 (3-1-4-2)	1 (1)	3 (4-2-5)	1 (2)
4 (3-1-4-2)	1 (1)	3 (4-2-5)	0

left arch took place less frequency than that of the order, 3-1-4-2, on the right arch: it occurred with a frequency of 74.3% on the left major row and with a frequency of

Table 2. Frequency distribution of tooth germ successions in major rows of 35 right arches

No. of tooth germs	Germ succession	No. of arches
Regarded as a part of full succession 4-2-3-1		34 (97.1%)
4	3-1-4-2	10
	2-3-1-4	3
	1-4-2-3	2
	4-1-2-3	1
3	2-3-1	6
	3-1-4	4
	1-4-2	1
2	4-2	5
	3-1	2
	2-3	1
Other		1 (2.9%)
2	2-1	1

Table 3. Frequency distribution of tooth germ successions in major rows of 35 left arches

No. of tooth germs	Germ succession	No. of arches
Regarded as a part of full succession 5-3-1-4-2		26 (74.3%)
4	3-1-4-2	6
	2-5-3-1	3
	4-2-5-3	1
3	4-2-5	7
	2-5-3	2
	3-1-4	2
2	1-4-2	1
	3-1	2
	5-3	1
Others	4-2	1
		9 (25.7%)
4	4-2-5-1	3
	3-4-2-1	1
	3-4-2-5	1
3	2-1-3-5	1
	3-5-4-2	1
	2-3-1	1
	4-2-1	1

97.1% on the left major row (Tables 2 and 3). The authors accordingly analyzed the bilaterally asymmetrical dentition of the replacement pattern.

The existent rate of the tooth germs was expressed as the number of tooth germs per functioning tooth in each row. The rate becomes 0.4 in the case where there are four tooth germs in the left major row, and 1.0 in the case where there are four teeth in the right major row. The mean of the existent rate of the tooth germs was estimated according to the Student's *t*-distribution (95% confidence, Table 4). There was a significant difference in the mean of the existent rate in each row according to the Student's *t*-test or Aspin-Welch's *t*-test, which was given at the 95% confidence level. The existent rate of the tooth germs (0.79 ± 0.07) in the right major row bearing four teeth was higher than that (0.68 ± 0.05) in the left major row bearing five teeth. Therefore, it is concluded that a tooth row bearing more teeth does not replace teeth more frequently for the major rows of the bilaterally asymmetrical dentition. The existent rate of the tooth germs in the minor row was very low in spite of the small number of teeth. The

minor row seems to replace the teeth less frequently, because their teeth are not more functional, than the major row. The correlation coefficients were calculated between the numbers of the tooth germs in each row. The correlation coefficients showed that the number of the tooth germs in each row does not correlate each other. Therefore, it is concluded that each row replaces the teeth, independently.

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Table 4. The existent rate, the number of tooth germs per functioning tooth, in each row.

Tooth row	mean (95% confidence interval)
Right arch	
Major row	0.79 ± 0.07
Minor row	0.27 ± 0.09
Left arch	
Major row	0.68 ± 0.05
Minor row	0.15 ± 0.08