Bulletin of the National Salmon
Resources Center, No. 2: 9-13
December 1999

さけ・ます資源管理センター
研究報告 第2号 9-13頁
1999年12月

Temporary Residence of Precocious Sockeye Salmon (*Oncorhynchus nerka*) in the Ocean

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Abstract.– Ten precocious males of sockeye salmon (age 1.0, 190-220 mm in fork length) were captured in the Bibi River of the Abira River system along the Pacific coast of Hokkaido, Japan, during July and August 1994. Their origin was a hatchery-reared sockeye salmon stock (84-146 mm in fork length) released in the river in the middle May of the same year. Most of precocious males captured in the river were infected with the marine digenean parasites (*Brachyphallus crenatus* and/or *Lecithaster gibbosus*), indicating their ocean residence. The scale patterns suggested that they rapidly grew in the ocean for at least 2 months. This may be the first report evidencing the seaward migration of yearling precocious sockeye salmon and their temporary residence in the ocean environment.

Key words : sockeye salmon, precocious male, seaward migration, marine parasite, scale pattern

Introduction

Sockeye salmon (*Oncorhynchus nerka*) show various life history patterns. They are typically anadromous fish, whose young usually remain in a freshwater lake for at least a year before migrating to the ocean. The length of their ocean life before maturing varies from one to four years (Burgner 1991). There are two forms that remain in fresh water to mature and reproduce. One is kokanee, and the other form is residual sockeye salmon. The residual sockeye salmon are mostly males in North America, and they mature at the size of 16-38 cm in length without ocean life (Ricker 1940).

In Japan, only residual sockeye salmon initially reproduced in several lakes. Recently, however, anadromous sockeye populations are successfully produced in several rivers on Hokkaido by artificial enhancement using the residual form (Urawa 1991; Kaeriyama et al. 1992). Since 1985 hatchery-reared sockeye salmon smolts have been annually released in the Bibi River along the Pacific coast of Hokkaido, Japan (Urawa et al. 1999). These fish originated from the residual population in Lake Shikotsu. Japanese sockeye salmon are estimated to migrate in western waters of the North Pacific Ocean (Ito 1972; Nagasawa and Ito 1999). They spend one or two years (occasionally three years) in the ocean before returning to the natal river from late June to early September for spawning. The spawning season is usually between October and November.

In the summer of 1994, yearling precocious males were accidentally captured in the Bibi River 2-3 months after the releases from a hatchery. By using parasites as biological indicator and scale patterns we confirmed that they migrated to the ocean, where they stayed for several months before successfully returning to the river. In this paper, we give the first report evidencing the temporary residence of yearling precocious sockeye salmon in the ocean environment.

Materials and Methods

Study site

The Bibi River is a small stream within the Abira River system, which flows into the Pacific coast of Hokkaido (Fig. 1). There is Lake Utonai (230 ha, 0.6 m in mean depth) in the lower Bibi River. It is about 3 km from Lake Utonai to the mouth of the Abira River.

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Contribution A No. 11 from the National Salmon Resources Center.

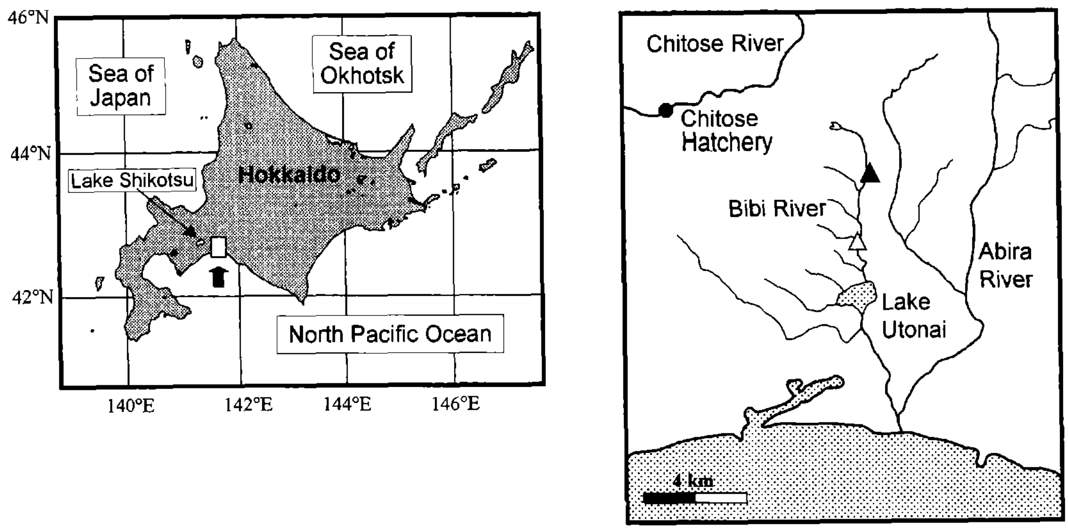

Fig. 1. Maps showing the study field (thick arrow) in the Bibi River on southwestern Hokkaido, Japan. Closed and open triangles indicate the release and capture sites for sockeye salmon, respectively.

Fish releases

On May 17, 1994, a total of 107,700 sockeye salmon (age 1.0, 84-146 mm in fork length, 6.5-37.2 g in body weight) were released into the upper Bibi River, about 4 km upstream from Lake Utonai (Fig. 1). These fish (1992 brood year stock) were reared at the Chitose Hatchery for 15 months. About one hundred fish were randomly collected just before releasing in the river for measuring their body size and scale patterns.

Capture of fish in the river

Ten precocious sockeye males were captured with adult sockeye salmon (ocean age 1 or 2) by a net trap in the Bibi River (about 2 km upstream from Lake Utonai) during July and August 1994 (Fig. 1). These live fish were transported to the Chitose Hatchery immediately after the captures.

Measurement of fish

Fresh fish samples were measured for fork length, body weight (BW in g), and gonad weight (GW in g). A gonadsomatic index (GSI in %) was calculated by a formula: $GSI = 100 \times GW/BW$. Males whose GSI was over 0.05% were judged as precocious (maturing) fish.

Parasite and scale analysis

The scales were collected from each fish, and the scale patterns were observed under a microscope. Intervals between scale circuli were measured using a scale analysis system (ARP, Ratoc System Engineer Co.). The stomach and intestine of precocious males captured in the river were examined for parasites by a stereomicroscope. The detected parasites were identified by morphological characteristics. The ecological terms (prevalence and intensity) used here are in accordance with those of Margolis et al. (1982).

Results

Released fish

Sockeye salmon released in the Abira River were composed of 50% female smolts, 26% male smolts, and 24% precocious males (n=104, Table 1). The body surface of precocious males was dark and greenish, while smolts had slimmer and silvery body.

Precocious males

The precocious sockeye males which were captured in the river had silvery thick body (Fig. 2). The body size was 190-220 mm in fork length and the body weight was 92-138 g (Table 2). The gonad weight increased to 3.9-6.6 g, although it was less than 0.1 g when they were released in the river. Most of their stomachs were empty.

Parasites

Two species of digenean parasites *Brachyphallus crenatus* and *Lecithaster gibbosus* were detected from the digestive tract of precocious sockeye males. The former species was found in the stomach and occasionally intestine, while the latter species was

Table 1. Body size, gonad weight and gonadsomatic index (GSI in %) of hatchery-reared sockeye salmon when they were released in the Bibi River. Total number of fish measured = 104.

	Number of fish	Fork length (mm)	Body weight (g)	Gonad weight (g)	GSI (%)
Smolt					
Female	52	120 (100-136)*	20.0 (11.9-26.0)	0.002 (0.004-0.032)	0.1 (0.02-0.18)
Male	27	118 (84-132)	19.0 (6.5-26.6)	0.002 (0.001-0.005)	0.01 (0-0.03)
Maturing					
Female	0	–	–	–	–
Male	25	126 (99-146)	24.1 (11.4-37.2)	0.05 (0.011-0.1)	0.23 (0.05-0.64)

*Mean with range in parentheses.

Fig. 2. A precocious male of sockeye salmon caught in the Bibi River on July 24, 1994. The body size was 207 mm in fork length.

Fig. 3. A scale of precocious male of sockeye salmon caught in the Bibi River on July 24, 1994. The scale pattern was divided into two zones by the presence of a check (arrow head). Scale bar = 0.5 mm.

only in the intestine. The prevalence was 70% for *B. crenatus*, 40% for *L. gibbosus*, and 80% when combined (Table 2). The mean intensity of *B. crenatus* and *L. gibbosus* was 9.1 and 2.0 parasites, respectively.

Scale patterns

The hatchery-reared sockeye salmon had 17-25 circuli on a scale (n=20) when they were released in the Bibi River. The scale pattern of precocious males captured in the river was divided into two zones by the presence of a check (Fig. 3), and there were 8-14 circuli in second zone (Table 2). The circuli in second zone had wide space, whose average was 44 μm.

Discussion

Fish parasites are occasionally useful for tracing the migration route of salmonids (Urawa 1989). The digeneans *B. crenatus* and *L. gibbosus* are known to infect various marine fishes in the coastal waters, although their life history is not well known. These parasites have been frequently used to estimate

Table 2. Size, scale characteristics, and burden of marine digenean parasites (*Brachyphallus crenatus and Lecithaster gibbosus*) in precocious males of sockeye salmon caught in the Bibi River during July and August 1994. The fish were initially released in the river on May 14, 1994.

No	Date of capture	Days from release to capture	Fork lenght (mm)	Body weigh (g)	Gonad weight (g)	GSI* (%)	Scale width (μm)			Number of scale circuli in zone II	Number of marine digenean parasites		
							Zone I	Zone II	Total		*B. crenatus*	*L. gibbosus*	Total
1	July 10	57	201	112.7	4.2	3.70	807	285	1092	8	3	0	3
2	July 10	57	215	134.5	5.2	3.88	724	360	1084	9	0	0	0
3	July 12	59	203	105.7	5.4	5.12	640	502	1142	13	16	0	16
4	July 12	59	190	92.2	4.2	4.51	738	330	1068	8	5	1	6
5	July 16	63	211	123.7	5.1	4.14	812	314	1126	9	9	1	10
6	July 24	71	207	127.5	5.5	4.32	767	428	1195	10	14	3	17
7	July 25	72	219	138.1	5.4	3.92	891	350	1241	9	0	3	3
8	July 25	72	203	101.7	3.9	3.83	631	514	1145	14	10	0	10
9	August 19	97	220	136.3	6.6	4.87	748	450	1198	10	0	0	0
10	August 31	109	217	113.4	5.8	5.15	795	333	1128	9	7	0	7
Mean		72	209	118.6	5.1	4.34	755	387	1142	10	6.4	0.8	7.2
SD		18	10	15.9	0.8	0.54	79	81	55	2	5.8	1.2	6.1

*GSI, gonadsomatic index.

anadromous migration of salmonids (Black 1981; Dick and Belosevic 1981; Frimeth 1987). We found these marine digenean parasites in eight of ten precocious sockeye salmon males captured in the Bibi River. This is a direct evidence that maturing sockeye males migrated to the ocean, where they could live before returning to the river.

Lake Utonai, approximately 4 km down from the release site in the Bibi River, is not an adequate habitat for sockeye salmon, because it is a shallow lake (only 0.6 m in mean depth) with high water temperatures during late spring and summer. Therefore, most released sockeye salmon, including precocious males, should have migrated down to the coastal water after a short stay in fresh water. The inception of maturity was thought to inhibit the smoltification process in salmonids (see Foote et al. 1991), but maturation had no inhibitory effect on seawater adaptability of landlocked kokanee salmon during the typical smolting period of *O. nerka* from April through June (Foote et al. 1994). Seawater challenge tests showed that some precocious males of sockeye salmon reared at the Chitose Hatchery had considerable seawater adaptability in the late spring (Urawa et al. 1999). In the present case, the rate of precocious males was relatively high (24%) among sockeye salmon (n=107,700) released from a hatchery. Thus it should be possible that some precocious males could survive in the coastal seawater.

The scale pattern of precocious males had two zones. The first zone was apparently formed when fish were reared at Chitose Hatchery. In addition to the initial circuli in the first zone, 8-14 circuli with wide intervals were found in the second zone. There is a positive correlation between interval of circuli and growth of sockeye salmon (Suzuki and Kaeriyama 1990). The formation of wide circuli indicates that precocious males rapidly grew in the coastal seawater for a short period. It is reported that a circulus forms every 7-11 days under a favorable feeding condition (Suzuki and Kaeriyama 1990). Then precocious males might stay in the ocean for at least 2 months.

In North America, sockeye salmon which return after one-year ocean life are almost males called as "jacks". These ocean age-.1 mature fish are rarely found among North American populations (Burgner 1987), while they frequently appear in Japanese population (Urawa et al. 1999). In Japan, adult females also return commonly as age-.1 (jells). As far as we know, however, there has been no record that maturing sockeye salmon migrate to sea. This may be the first report evidencing the seaward migration of yearling precocious sockeye salmon and their successful residence in the ocean environment.

Acknowledgements

We thank the staffs of the Chitose Branch of the National Salmon Resources Center for their support to our study. We also thank William R. Heard, Auke Bay Laboratory, Alaska Fisheries Science Center, for helpful suggestions on the manuscript.

References

Black, G. A. 1981. Metazoan parasites as indicators of movements of anadromous brook charr (*Salvelinus fontinalis*) to sea. Can. J. Zool., 59: 1892-1896.

Burgner, R. L. 1987. Factors influencing age and growth of juvenile sockeye salmon (*Oncorhynchus nerka*) in lakes. In Sockeye salmon (*Oncorhynchus nerka*) population biology and future management (edited by H. D. Smith, L. Margolis, and C. C. Wood). Can. Spec. Publ. Fish. Aquat. Sci., 96. pp. 129-142.

Burgner, R. L. 1991. Life history of sockeye salmon (*Oncorhynchus nerka*). In Pacific salmon life history (edited by C. Groot and L. Margolis). UBC Press, Vancouver. pp. 1-117.

Dick, T. A., and M. Belosevic. 1981. Parasites of Arctic charr *Salvelinus alpinus* (Linnaeus) and their use in separating sea-run and non-migrating charr. J. Fish Biol., 18: 339-347.

Foote, C. J., W. C. Clarke, and J. Blackburn. 1991. Inhibition of smolting in precocious male chinook salmon, *Oncorhynchus tshawytscha*. Can. J. Zool., 69: 1848-1852.

Foote, C. J., I. Mayer, C. C. Wood, W. Craig, and J. Blackburn. 1994. On the development pathway to nonanadromy in sockeye salmon, *Oncorhynchus nerka*. Can. J. Zool., 72: 397-405.

Frimeth, J. P. 1987. Potential use of certain parasites of brook charr (*Salvelinus fontinalis*) as biological indicators in the Tabusintac River, New Brunswick, Canada. Can. J. Zool., 65: 1989-1995.

Ito, S. 1972. Notes on the offshore distribution of sockeye salmon with a large freshwater zone on scale. Bull. Far Seas Fish. Res. Lab., 7: 125-135. (In Japanese with English summary.)

Kaeriyama, M., S. Urawa, and T. Suzuki. 1992. Anadromous sockeye salmon (*Oncorhynchus nerka*) derived from nonanadromous kokanees: life history in Lake Toro. Sci Rep Hokkaido Salmon Hatchery, 46: 157-174.

Margolis, L., G. W. Esch, J. C. Holmes, A. M. Kuris, and G. A. Schad. 1982. The use of ecological terms in parasitology. J. Parasitol., 68: 131-133.

Nagasawa, K., and S. Ito. 1999. Distribution, migration and growth in the North Pacific Ocean of sockeye salmon (*Oncorhynchus nerka*) produced from the lacustrine form. In Stock enhancement and sea ranching (edited by B. R. Howell, B. Moksness, and T. Svåsand). Fishing News Books, Oxford. pp. 168-181.

Ricker, W. E. 1940. On the origin of kokanee, a freshwater type of sockeye salmon. Proc. Trans. R. Soc. Can. Ser. 3, 34: 121-135.

Suzuki, T., and M. Kaeriyama. 1990. Scale formation of juvenile sockeye salmon reared under the different feeding levels. Sci. Rep. Hokkaido Salmon Hatchery, 44: 23-28. (In Japanese with English summary.)

Urawa, S. 1989. Parasites as biological indicators contributing to salmonid biology. Sci. Rep. Hokkaido Salmon Hatchery, 43: 53-74. (In Japanese with English summary.)

Urawa, S. 1991. A review of sockeye salmon production in the Nishibetsu River in eastern Hokkaido, Japan. Tech. Rep. Hokkaido Salmon Hatchery, 160: 3-10. (In Japanese with English summary.)

Urawa, S., M. Ban, M. Fukuwaka, T. Suzuki, and M. Kaeriyama. 1999. Progressive technologies for artificial production of anadromous sockeye salmon in Japan. Bull. Tohoku Natl. Fish. Res. Inst., 62. (In press.)

早熟ベニザケの一時的な海洋生活

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1994年の 7-8 月に，北海道太平洋沿岸の安平川水系美々川でベニザケの早熟雄（年齢 1.1，尾叉長190-220 mm）が10個体採集された．これらの起源は 2，3 カ月前の 5 月中旬に同河川に放流された孵化場産ベニザケ（放流時の尾叉長84-146 mm）であった．再捕された早熟雄の大部分に海洋起源の吸虫 2 種（*Brachyphallus crenatus* と *Lecithaster gibbosus*）が寄生していたことから，早熟雄は降海したことが示された．鱗相解析により，これらは沿岸に少なくとも 2 カ月間滞在し急激に成長したと推定された．これは，ベニザケの早熟雄 1 年魚が降海して海洋環境に順応して生活したことを示す初めての報告である．