Temporary Residence of Precocious Sockeye Salmon 
\textit{(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 \textit{(Bruchyphallus crenatus} and/or \textit{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 \textit{(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.
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 × 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 Engineering 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 gibbus* 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.

<table>
<thead>
<tr>
<th></th>
<th>Number of fish</th>
<th>Fork length (mm)</th>
<th>Body weight (g)</th>
<th>Gonad weight (g)</th>
<th>GSI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smolt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>52</td>
<td>120 (100-136)*</td>
<td>20.0 (11.9-26.0)</td>
<td>0.002 (0.004-0.032)</td>
<td>0.1 (0.02-0.18)</td>
</tr>
<tr>
<td>Male</td>
<td>27</td>
<td>118 (84-132)</td>
<td>19.0 (6.5-26.6)</td>
<td>0.002 (0.001-0.005)</td>
<td>0.01 (0.0-0.03)</td>
</tr>
<tr>
<td>Maturing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>25</td>
<td>126 (99-146)</td>
<td>24.1 (11.4-37.2)</td>
<td>0.05 (0.011-0.1)</td>
<td>0.23 (0.05-0.64)</td>
</tr>
</tbody>
</table>

*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.

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 \( \mu m \).

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.

<table>
<thead>
<tr>
<th>No</th>
<th>Date of capture</th>
<th>Days from release to capture</th>
<th>Fork length (mm)</th>
<th>Body weight (g)</th>
<th>Gonad weight (g)</th>
<th>GSI* (%)</th>
<th>Scale width (µm)</th>
<th>Number of scale circuli in zone II</th>
<th>Number of marine digenean parasites</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>July 10</td>
<td>57</td>
<td>201</td>
<td>112.7</td>
<td>4.2</td>
<td>3.70</td>
<td>807</td>
<td>285</td>
<td>1092</td>
</tr>
<tr>
<td>2</td>
<td>July 10</td>
<td>57</td>
<td>215</td>
<td>134.5</td>
<td>5.2</td>
<td>3.88</td>
<td>724</td>
<td>360</td>
<td>1084</td>
</tr>
<tr>
<td>3</td>
<td>July 12</td>
<td>59</td>
<td>203</td>
<td>105.7</td>
<td>5.4</td>
<td>5.12</td>
<td>640</td>
<td>502</td>
<td>1112</td>
</tr>
<tr>
<td>4</td>
<td>July 12</td>
<td>59</td>
<td>190</td>
<td>92.2</td>
<td>4.2</td>
<td>4.51</td>
<td>738</td>
<td>330</td>
<td>1068</td>
</tr>
<tr>
<td>5</td>
<td>July 16</td>
<td>63</td>
<td>211</td>
<td>123.7</td>
<td>5.1</td>
<td>4.14</td>
<td>812</td>
<td>314</td>
<td>1126</td>
</tr>
<tr>
<td>6</td>
<td>July 24</td>
<td>71</td>
<td>207</td>
<td>127.5</td>
<td>5.5</td>
<td>4.32</td>
<td>767</td>
<td>428</td>
<td>1195</td>
</tr>
<tr>
<td>7</td>
<td>July 25</td>
<td>72</td>
<td>219</td>
<td>138.1</td>
<td>5.4</td>
<td>3.92</td>
<td>891</td>
<td>350</td>
<td>1241</td>
</tr>
<tr>
<td>8</td>
<td>July 25</td>
<td>72</td>
<td>203</td>
<td>101.7</td>
<td>3.9</td>
<td>3.83</td>
<td>631</td>
<td>514</td>
<td>1145</td>
</tr>
<tr>
<td>9</td>
<td>August 19</td>
<td>97</td>
<td>220</td>
<td>136.3</td>
<td>6.6</td>
<td>4.87</td>
<td>748</td>
<td>450</td>
<td>1198</td>
</tr>
<tr>
<td>10</td>
<td>August 31</td>
<td>109</td>
<td>217</td>
<td>113.4</td>
<td>5.8</td>
<td>5.15</td>
<td>795</td>
<td>333</td>
<td>1128</td>
</tr>
</tbody>
</table>

Mean: 72.09 118.6 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). Thus 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


早熟ベニザケの一時的な海洋生活

浦和茂彦・階山雅秀

1994年の7-8月に、北海道太平洋海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、3カ月前の5月中旬に河川に放流された孵化場養殖ベニザケ（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は海洋起源の吸虫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。雌雄解析により、これらは沿岸に少なくとも2カ月間滞在し急速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探す初めての報告である。