Eurasian J. For. Res. 1: 39-42 , 2000

Life cycle of masu salmon (*Oncorhynchus masou*) in Shumarinai Lake, northern Hokkaido, Japan

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Abstract

We described some life-history traits of masu salmon (*Oncorhynchus masou*) in Shumarinai Lake, northern Hokkaido, Japan. Males occurred both lake-run form and fluvial form but all females were lake-run form. Age at maturity of lake-run form was 1+~3+ in males and 2+ and 3+ in females. Males of fluvial form (mature male parr) matured at 0+~2+. Mean fork length at maturity of lake-run form was about 280mm in males and about 350mm in females, being markedly smaller than the sea-run adults. This appeared to be due to the low food abundance and the relatively low water temperature for longer periods in Shumarinai Lake. The life cycle of masu salmon in Shumarinai Lake is similar to that of the sea-run populations, which include both the semelparous migratory type (almost all females and a few males) and the iteroparous stream-resident males. However, two particular life cycles probably exist in Shumarinai populations: juvenile parr migrating to the lake before smoltification and "Jack" (precocious lake-run males) that do not winter in the lake after smoltification. These life cycles are peculiar to lacustrine populations.

Key words: masu salmon, Shumarinai Lake, lacustrine population, smolts, mature male parr, lake-run adults, juvenile parr, Jack

Introduction

Masu salmon (*Oncorhynchus masou*) distribute in far-east Asia, and as with other salmonids, have several life history forms within the species, i.e., sea-run form and fluvial form (Kato 1991). In the northern part of their distribution, most populations consisted of sea-run fish and some fluvial male (mature male parr). In populations around the southern limit of their distribution, all males and females have a fluvial life cycle. Moreover, throughout their distribution, lake-run form has occurred in lakes constructed artificially by dams or by introduction to natural lakes which masu salmon did not originally inhabit (Osanai 1962, Honda *et al.* 1980, Yamamoto *et al.* 2000). Many researchers have reported on the life-history of the sea-run form (e.g., Kubo 1980, Mayama 1992, Kiso 1995) and fluvial form (e.g., Kimura 1989, Kiso 1995). In lacustrine populations, there are some reports on the food habits (Osanai 1962, Honda *et al.* 1980) and size and age at maturity (Honda *et al.* 1983, Yamamoto *et al.* 2000). However, little is known about life-history traits and the life cycle of lacustrine populations, except that Yamamoto *et al.* (2000) reported on the male life cycle in Toya Lake, northern Japan. We described here several life-history traits of masu salmon in Shumarinai Lake, northern Hokkaido, Japan, and estimated their life cycle.

Study area and Methods

Shumarinai Lake, 23.7km^2 surface area and 31m maximum depth, is located in northern Hokkaido (Fig. 1) and was artificially constructed in 1943 by damming the upper reach of the Uryu River (Ishikari River-System) for a hydroelectric power. Masu salmon land-locked by the dam originate from the Uryu River fish (Osanai 1962). In addition to masu salmon, Japanese smelt *Hypomesus nipponensis* (introduced), Japanese huchen *Hucho perri*, whitespotted charr *Salvelinus leucomaenis*, Japanese dace *Tribolodon hakonensis*, carp *Cyprinus carpio* (introduced), and crucian carp *Carassius aurathus* (introduced) inhabit in Shumarinai Lake (Osanai 1962, Tamate unpubl. data).

From 1996 to 1999, sampling were performed in two inlet streams (Bifukakoshizawa Creek and Akaishi Creek) by electrofishing, cast net and angling. Smolts were captured from mid-May to early-July. Mature parr (with typical parr marks) and lake-run adults (without clear parr marks) were collected from late-July to mid-September. All fish measured were raw. Fork length and body weight of each fish were measured, and their sex and degree of ripeness were examined by direct observation of the gonads. Scales were used to determine age and spawning marks noted (Kiso 1995). Data in each

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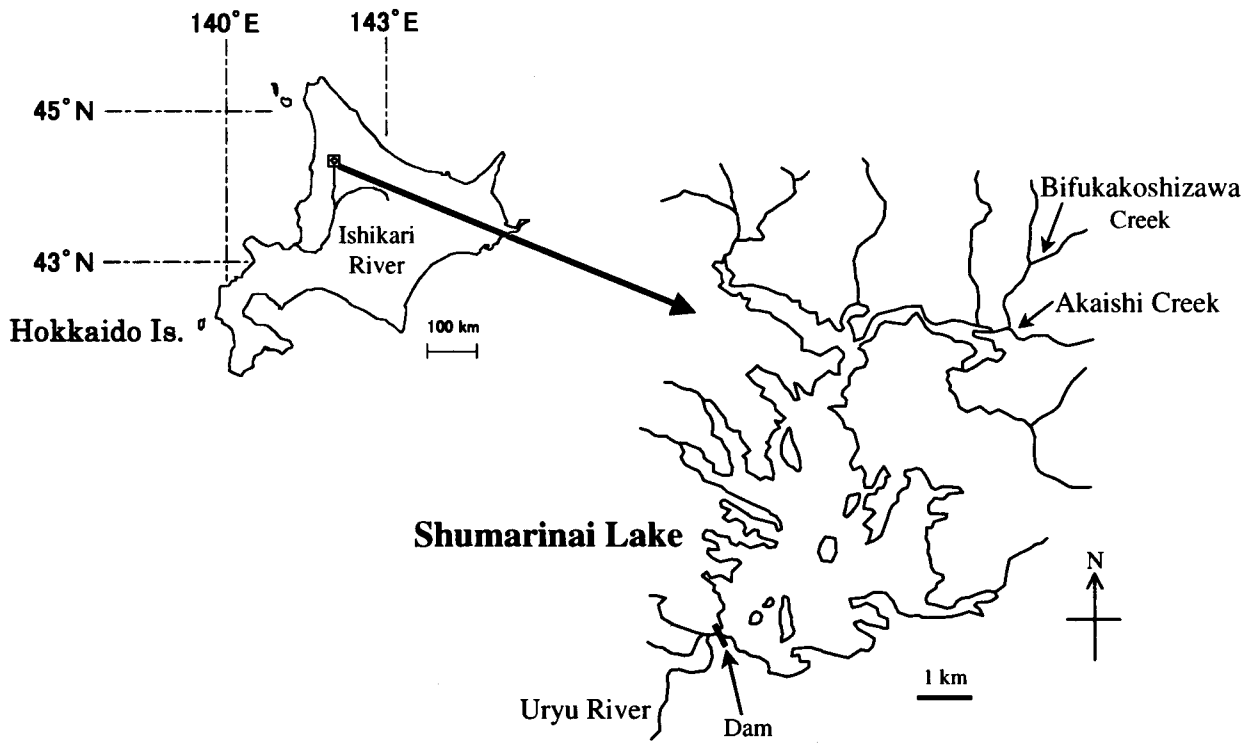

Fig. 1. Map of the Shumarinai Lake system.

year were pooled because of small number of individuals collected. We also analyzed parr captured in the lake by nets used to collect Japanese smelts by a fisherman.

Results and Discussion

Of smolts collected (N = 59), 84.7% were 1+ and 15.3 % were 2+. Most of smolts consisted of females: 78.0% of 1+smolts (39 / 50) and 88.9% of 2+ smolts (8 / 9) were females. The 1+smolts tended to be smaller in body size than 2+smolts (Fig. 2A. mean fork length in 1+smolts = 126.1mm±9.4 S.D., N = 50; 2+smolts 138.6± 10.9, N = 9; Mann-Whitney U-test, U = 78.0, P <0.002). Age composition, sex ratio and size of smolts in Shumarinai masu salmon appear to be similar that of sea-run populations in Japan (see Kato 1991).

All of 78 mature parr examined were male. Of these male parr, 36 (46.2%) and 41 (52.6%) were 0+ and 1+, respectively. Only one individual was 2+ (2.2%). Size of parr increased with age at maturity (Fig. 2B. 0+parr = 108.4± 10.6, N = 36; 1+parr = 153.0±17.5; N = 41; 2+parr = 243.0, N = 1). Some of 1+ and 2+ parr had a spawning mark in the previous year in their scales (no. of individuals having spawning mark in 1+ parr = 5, in 2+parr =1): thus, some mature parr will survive after the first breeding and mature again in the next autumn.

Of the 51 lake-run adults collected, 2+ females and 2+males were 30 (58.8%) and 15 (29.4%), respectively. The 3+ females and 1+ males were few (3+females 7.8%, 1+ males 3.9%). Thirty four (66.7%) of lake-run adults were females. Excluding the occurrence of 1+ lake-run males, age composition and sex ratio of lake-run adults do not appear to differ in comparison with that of sea-run populations in Japan (see Kato 1991). Lake-run females tended to be larger than lake-run males (Fig. 2C. 2+females = 347.2±27.8, N = 30; 3+females = 353.8±11.1, N = 4; 1+males = 197.5±10.6, N = 2; 2+males = 290.3±40.7, N = 15; females vs. males, Mann-Whitney U-test, U = 58.5, P < 0.001). According to Kato (1991), the mean fork length of sea-run adults ranged from 375mm (males, Tokoro River, Japan) to 660mm (males, Samarga River, Russia), usually more than 450mm. Thus, the body size of migratory adults in Shumarinai Lake was extremely small, compared with that of sea-run populations. This appears to be due to low food abundance (due to low production of Japanese smelts) and relatively low water temperature for longer periods (due to freezing over during the winter) in Shumarinai Lake (see Tamate and Maekawa 2000). No lake-run adults had spawning marks of the previous year in their scales; all lake-run adults die after breeding.

Thirty four parr were captured in the lake from late-May to late-October, and consisted of 0+parr, 1+ immature parr and 1+ potential mature parr which were judged to mature during the year of capture (range of fork length in 0+parr = 82-147mm, N =13; 1+ immature parr = 66-156mm, N = 17; 1+ potential mature parr = 99-110mm, N = 4). Most of 0+ parr consisted of females (ratio of females in 0+ parr = 84.6%), but such a trend was not recognized in the 1+ immature parr (52.9%). Some of these fish may became smolts in the next year. The 1+ potential mature parr were males, and may migrate up to inlet streams before spawning season, so-called "puerile" (Yamamoto *et al.* 2000). In Toya lake, which is located in southwestern Hokkaido, Japan, "puerile" usually occur (Yamamoto *et al.* 2000). However, in Shumarinai Lake, few puerile males appear to occur because they have rarely been caught in the lake.

The life cycle of lake-run masu salmon is similar to that of the sea-run populations, which include both the semelparous migratory females and males and the iteroparous stream-resident males. However, two particular life cycles probably occur in Shumarinai masu salmon. In anadromous masu salmon, the parr undergo smoltification in the spring and migrate to the sea after the juvenile parr live for one or two years in rivers. They return to their natal streams after 1 yr of marine life (e.g., Kubo 1980, Kato 1991, Mayama 1992, Kiso 1995). In Shumarinai Lake, a few juvenile parr migrate to the lake. Therefore, some fish will smoltify in the lake during the next spring and spend about two years in the lake (thus, two years of lacustrine life). Another unique life cycle is that Jack, which is a precocious lake-run male and do not winter in the lake after smoltification, occur in Shumarinai Lake system. There are no reports of maturing anadromous masu salmon which did not winter in the sea (Kato 1991), except that Tsiger *et al.* (1994) reported on the occurrence of Jack in South Primor'e, Russia. These life cycles may be peculiar to lacustrine populations.

Acknowledgements

We are grateful to the members of the Fisherman's Society at Lake Shumarinai, especially K. Uto and N. Nakano, for their assistance. We could not have accomplished this study without the assistance of the staff of the Uryu Experimental Forest and many graduate and undergraduate students at Hokkaido University. This research was supportted by a grant-in-aid from the Ministry of Education, Science, Sports and Culture (No.10640606) and the Minisry of Agriculture, Forestry and Fishery.

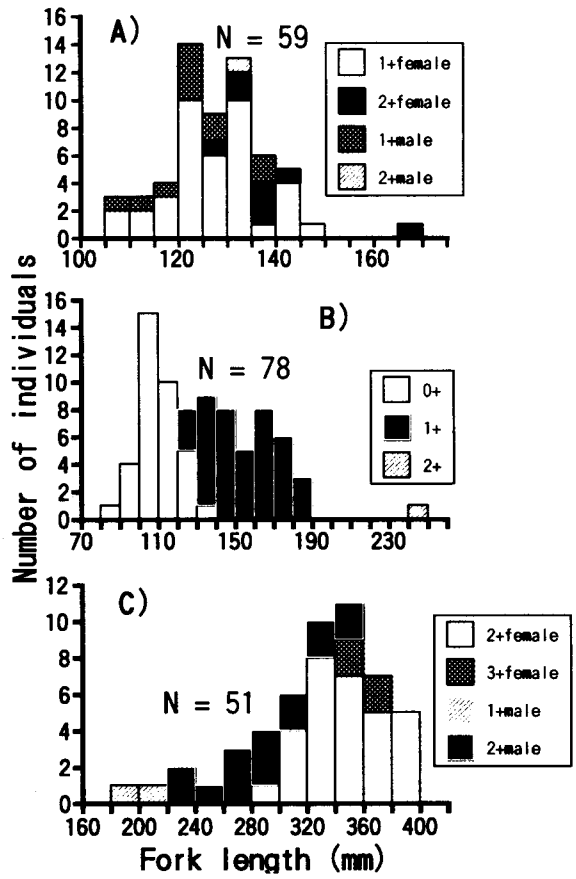

Fig. 2. Fork length distribution of A) smolts, B) mature male parr, and C) lake-run adults caught in Bifukakoshizawa Creek (smolts caught in Akaishi Creek. also) from 1996 to 1999.

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