北水試研報　80，45－49（2011）
Sci. Rep. Hokkaido Fish. Res. Inst.

北海道東部当幌川水系におけるカラフトマス天然産卵集団の存在(短報)

虎尾　充*，永田光博，佐々木義隆，竹内勝巳，春日井潔

さけます・内水面水産試験場

Evidence for existence of wild population of pink salmon in the Tohoro River system flowing into Nemuro Strait, eastern Hokkaido, Japan（Short Paper）

MITSURU TORAO*, MITSUHIRO NAGATA, YOSHITAKA SASAKI, KATSUMI TAKEUCHI AND KIYOSHI KASUGAI

Salmon and Freshwater Fisheries Research Institute, *Eniwa, Hokkaido 061-1433, Japan*

The homing migration behavior of the pink salmon *Oncorhynchus gorbuscha* was investigated in the Tohoro River system in eastern Hokkaido. Juvenile pink salmon were released into the Tohoro River after their otoliths were marked with alizarin complexone (ALC). For this study, the number of returned living adult pink salmon and their post-reproduction carcasses were visually counted, and fork lengths of the carcasses were measured. Otoliths were collected from the carcasses in the Tohoro River, where the marked juvenile fish had been released and from the Sakura River, its tributary. It was concluded that the marked fish selectively returned to the Tohoro River and that unmarked fish selectively returned to the Sakura River. Furthermore, unmarked fish were significantly smaller in body size than marked fish. These results therefore suggest that the unmarked fish were a wild population that had been reproducing independent of the released fish.

keywords：ALC otolith marking, homing, *Oncorhynchus gorbuscha*, pink salmon, wild population,

Pink salmon (*Oncorhynchus gorbuscha*) form an important fishery resource in eastern Hokkaido. There have been increasing population fluctuations in these waters in recent years, and resource management technique is therefore needed. However, biological information on pink salmon in Japan for realizing the management is insufficient. Because pink salmon generally have a fixed two-year life cycle, it has been suggested that odd and even-year populations of pink salmon do not interbreed and have different life history traits (Heard, 1991), and two-year cycle dominance in pink salmon fisheries tends to persist (Nagata *et al*.,2008). The population size of pink salmon started sharply increasing in the 1990s and this is believed to be mainly due to an increase in the wild population (Morita *et al*., 2006). While, salmonid fishes tend to return to their natal site for reproduction, but among salmonids, pink salmon have a greater tendency to stray (Quinn, 1984). However, a distribution of wild population and degree of straying of pink salmon in Japan are still poorly understood. We attach importance that knowledge of information of wild population and a straying is important for the resource management of a pink salmon. To investigate whether a wild population was present or not in the Tohoro River system and the homing behavior of pink salmon, we released the marked fish and studied their homing behavior.

Materials and Methods

This study was conducted at the Tohoro River system in

Accepted:May,18,2011.Contribution A469 from the Hokkaido Fisheries Research Department
* Tel：0153-72-6141. Fax：0153-72-5188. Email: torao-mitsuru@hro.or.jp

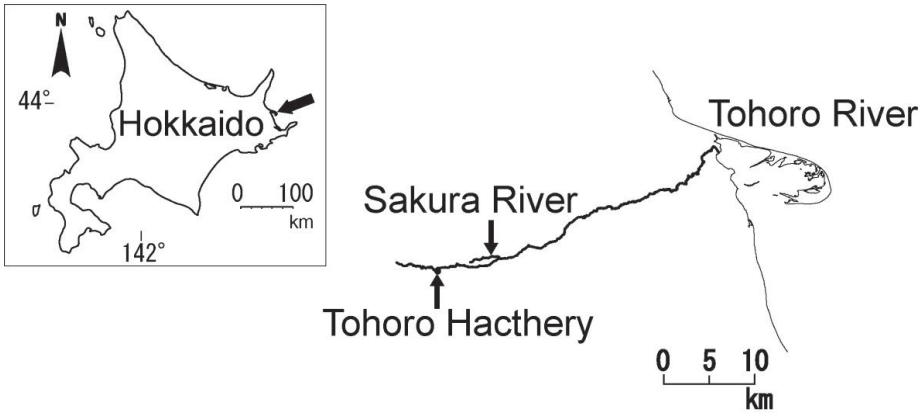

Fig. 1 Area surveyed for adult pink salmon in the Tohoro River and Sakura River (a tributary) during July-October 2008 and 2009. Marked juvenile pink salmon were released from the Tohoro Hatchery in 2007 and 2008.

eastern Hokkaido, where it flows into Nemuro Bay (Fig. 1). To enable identification of the released fish, the otoliths of all 2006-class and 2007-class pink salmon to be released were marked at the eyed egg stage using alizarin complexone (ALC). Altogether, 4.8 million fish of 2006-class were released to Tohoro River, 2.3million fish (48.0%) of which derived from the Tohoro River adult pink salmon. Non-natal fish ratio was 52% (Nishibetu River; 26.8%, Shunbetsu River; 25.3%). Of the 2007 year class, 4.4 million released fish were comprised of 21.2% (0.9 million) of Tohoro River fish and 78.8% (3.4mmillion) of juvenile originated from the transplanted eggs from Nishibetsu River. Between late March and early April in 2007 and between early and mid-April in 2008, the marked fish were released into the Tohoro River from the Tohoro Hatchery of the Nemuro Salmon Enhancement Programs Association.

Surveys on the adult returning were conducted every 10 days between early September and late October in 2008 and between late July and late October in 2009. Two river sections were surveyed: an 800-m section of the Tohoro River including the release point at the Tohoro Hatchery and an 800-m section of the Sakura River (tributary) starting at the confluence of the two rivers (approx. 10 km downstream of the former section). Along these sections, visual counts of live adult fish and post-reproduction carcasses were conducted. The sex and fork length of all the carcasses found were recorded and their otoliths were collected. The otoliths were observed under a fluorescence microscope to check for the presence of ALC marking. Temporal differences in the sightings of the returning pink salmon in the Tohoro River and the Sakura River were analyzed by the chi-square test. Differences in the mix rate of ALC-marking of the otoliths collected from the two rivers were also analyzed by the chi-square test.

Results and Discussion

Figure 2 shows changes in the sightings of adult pink salmon and the counts of post-reproduction carcasses. Based on these trends, the peaks of reproduction in the two rivers are inferred to have occurred approximately 10 days apart from each other. In 2008, the number of sightings was the highest in the Tohoro River in late September at 166, which decreased rapidly to 98 in early October, to 18 in mid-October and to 0 in late October. On the other hand, in the Sakura River, the highest number of sightings was recorded in early October at 1,014, which rapidly decreased to 388 in mid-October and to 20 in late October. Counts of the carcasses peaked between early and mid-October, approximately 10 days after the peak of the sightings. Based on these results, it was suggested that the peak spawning period in the Sakura River occurred approximately 10 days after the peak spawning period in the Tohoro River. In 2009, however, few adult pink salmon were seen in the Tohoro River (two sightings and two carcasses). On the other hand, in the Sakura River where a sufficient number of live adult fish was sighted and post-reproduction carcasses counted, the peak reproduction in 2009 was approximately a month earlier when compared to that in 2008.

Figure 3 shows changes in the number of ALC-marked and unmarked pink salmon among the carcasses. The number of marked fish that returned was significantly higher in the

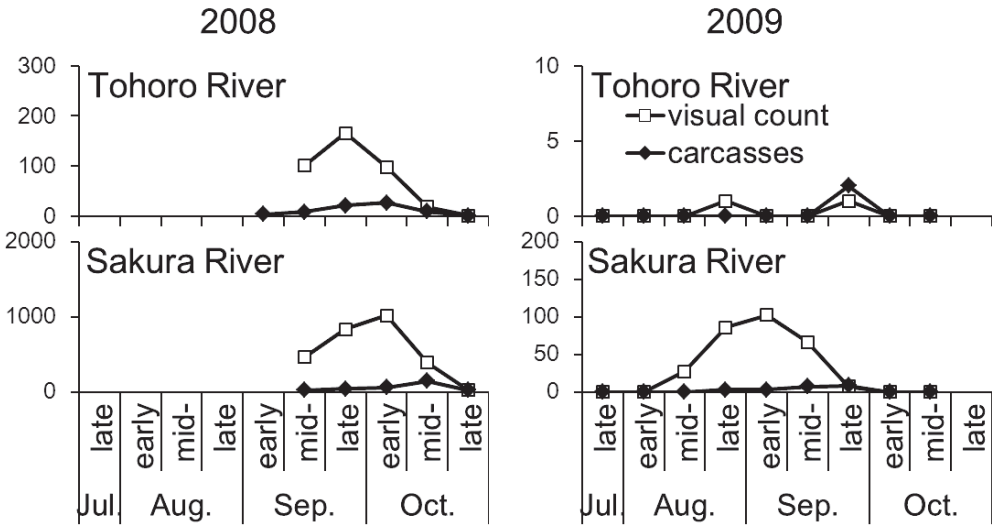

Fig. 2 Changes in the number of adult pink salmon observed and carcasses collected in Tohoro River and Sakura River in 2008 and 2009. Open squares show the number of fish from visual counts. Solid diamonds show the number of carcasses.

Tohoro River when compared to the Sakura River in 2008, indicating that the released (marked) fish selectively returned to the Tohoro River and that the unmarked fish selectively returned to the Sakura River in 2008. In 2008, otoliths were collected from 80 fish in the Tohoro River, 47 of which were ALC-marked (58.8%). On the other hand, in the Sakura River, otoliths were collected from 175 fish, nine of which were ALC-marked (5.1%). In 2008, returns of marked fish were significantly different between the two rivers (chi-square test, $p<0.05$). In 2009, the number of adult pink salmon returned was much smaller than that in 2008 both the Tohoro and Sakura Rivers. The two carcasses found in the Tohoro River was a no tagged fish in 2009. A total of 23 carcasses found in the Sakura River in 2009, of which seven fish were marked fish (30.4%). In 2008, therefore, although a small number of marked fish appear to have strayed into the tributary, the marked fish seem to have selectively returned to the Tohoro River (where they had been released) for spawning. There was also a significant difference in the percentage of marked fish found in the Sakura River between 2008 and 2009 (chi-square test, $p<0.05$). These results may indicate that the proportion of stray fish differed between year classes. Meanwhile, based on the sightings of returned fish and the counts of carcasses, we infer that the peak spawning period differed between the two rivers. This was because unmarked fish spawned later than marked fish, and returns of unmarked fish were higher in the Sakura River.

The unmarked fish were smaller in size than the marked fish (Fig. 4). In 2008, the average fork length of the female carcasses was 45-51 cm for the ALC-marked fish and 37-46 cm for the unmarked fish in both the Tohoro River and Sakura River. Of the male carcasses, the average fork length was 48-57cm for the ALC-marked fish and 37-47 cm for the unmarked fish. For both females and males, the average fork length was significantly higher in the marked fish than in the unmarked fish. On the other hand, in 2009, when the marked fish were larger in the case of males only, the fork length was not significantly different in females between the marked and the unmarked fish. This is because, in 2009, in both females and males, the average fork length of the returned fish was 10 cm longer than in 2008, thereby reducing the relative size difference between the marked and unmarked fish. In both females and males, the unmarked fish tended to be smaller than the marked fish. Also, there was a size difference between fish of different year classes and the even-year fish were larger than the odd-year fish.

In this study, it is suggested that the marked fish mainly ran the Tohoro River and the unmarked fish mainly ran the Sakura River for spawning although there was straying each other. There is a notion that pink salmon are more tend to stray than other Pacific salmon species (Quinn 1984). The unmarked fish found in the Tohoro and Sakura Rivers in this study may be the strays of the hatchery fish released to other rivers. But, the Sakura River population had life-history traits

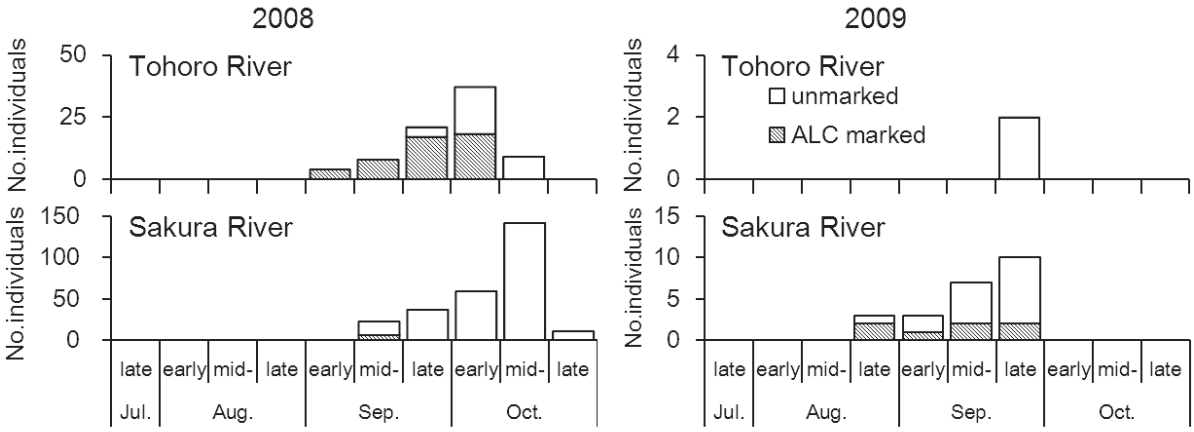

Fig. 3 Changes in the number of ALC-marked and unmarked adult pink salmon carcasses collected in the Tohoro and Sakura Rivers in 2008 and 2009.

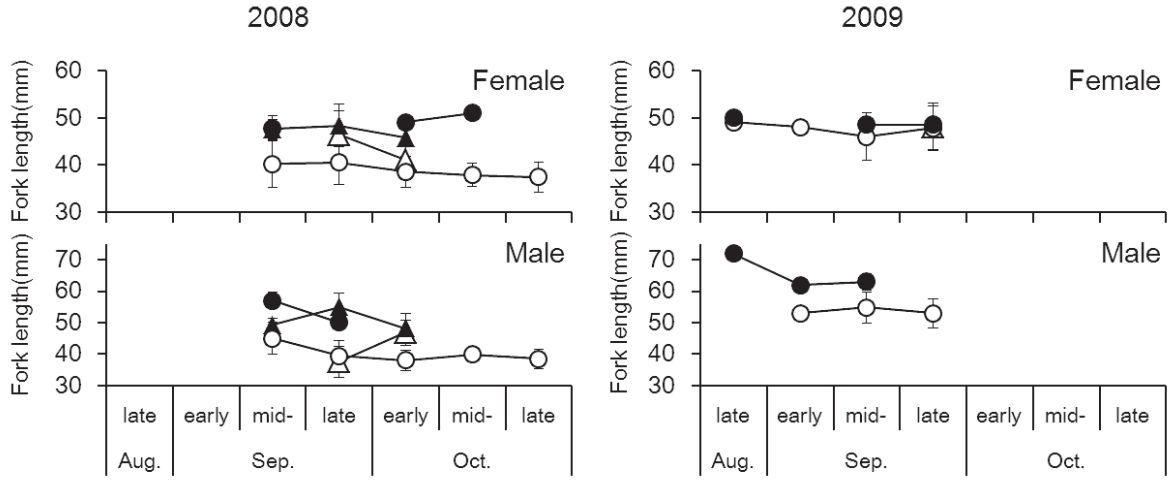

Fig. 4 Comparison of the mean fork length between ALC-marked and unmarked pink salmon carcasses in the Tohoro and Sakura Rivers in 2008 and 2009. Solid and open triangles show ALC-marked and unmarked fish in the Tohoro River respectively. Solid and open circles show ALC-marked and unmarked fish in the Sakura River, respectively.

differing from those of the marked fish (i.e., body size and reproduction timing). Therefore, we conclude that the population of smaller pink salmon in the Sakura River was a population derived from naturally spawned eggs. It is possible that such populations have been reproducing independently of the current artificial hatching and stocking program, and it is necessary in the future to quantitatively monitor these populations and identify how they contribute to the fishery.

LITERATURE CITED

Heard WR. Life history of pink salmon (*Oncorhynchus gorbuscha*). In: Groot C, Margolis L (eds). *Pacific Salmon Life Histories*. UBC Press, Vancouver, Canada. 1991; 119-230.

Morita K, Morita SH, Fukuwaka M. Population dynamics of Japanese pink salmon (*Oncorhynchus gorbuscha*): are recent increases explained by hatchery programs or climatic variations? *Can. J. Fish. Aquat. Sci.* 2006; 63: 55-62.

Nagata M, Ando D, Fujiwara M, Miyakoshi Y, Sawada M, Shimada H, Asami H. A shift in pink salmon dominance

in the Okhotsk Sea of Hokkaido in relation to coastal environments during early sea life. *NPAFC Bulletin* 2008, 4; 237-249.

Quinn TP. A review of homing and straying of wild and hatchery-produced salmon. *Fisheries Research* 1993; 18: 29-44.