# Natural Reproduction of Pink Salmon *(Oncorhynchus gorbuscha)* on the Okhotsk coast of Hokkaido, Japan

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The pink salmon population (*Oncorhynchus gorbuscha*) returning to Hokkaido, Japan, increased substantially from 1975 to 2000. Despite constant hatchery fry releases, the pink salmon catch exhibited a biennial oscillation indicating a fixed 2-year life cycle and a large addition of wild fish. Using a mathematical model, Morita et al. (2006) determined that the observed increases in the Japanese pink salmon catch could be explained primarily by climate change, and they attributed production to wild fish production because increasing hatchery releases had little effect on abundance of returning adults.

In Hokkaido, most major rivers have weirs completely blocking the upstream migration of fish in order to capture hatchery broodstock. Therefore, we assumed that rivers with weirs were unsuitable for natural spawning of pink salmon. To check this assumption and investigate the conditions of naturally spawning pink salmon in the Tokoro River, we conducted field surveys to visually inspect spawning streams for counts of pink salmon and redds.

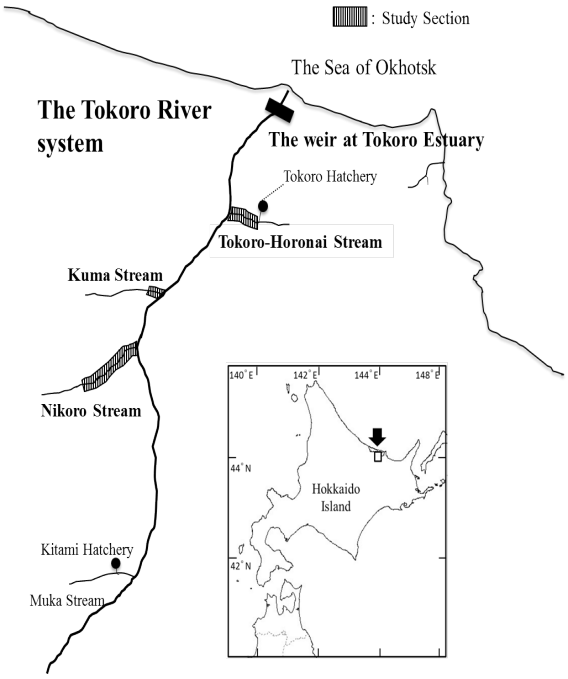


**Fig. 1.** Location of visual surveys conducted in three streams and the weir across the Tokoro River on the Okhotsk coast of Hokkaido.

We visually surveyed three tributaries: Tokoro-Horonai, Kuma, and Nikoro Streams (Fig. 1) with survey lengths (areas) of 821 m (3,454 $m^2$), 317 m (998 $m^2$), and 1,152 m (12,909 $m^2$; Table 1), respectively. In 2010, we quantified the number of pink salmon and redds once every 10 days from the beginning of August until the beginning of October. We could not determine when the redds were made, but we confirmed there was superimposition of the redds by subsequent arrival of salmon on the spawning grounds. We counted all redds found daily during the investigation. Throughout the survey, the weir was not submerged and functioned normally.

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**Table 1.** Description of the tributary streams of the Tokoro River, Hokkaido, Japan.

| Stream | Length (m) | Width (m) | Area ($m^2$) |
|---|---|---|---|
| Tokoro-horonai | 821 | 4.2±1.1 | 3,454 |
| Kuma | 317 | 3.1±0.4 | 998 |
| Nikoro | 2,290 | 10.6±2.5 | 12,909 |
| Total | 3,428 | | 17,361 |

The data from the three streams followed similar trends. The number of naturally spawning pink salmon increased in early September, reached a maximum in mid September, and decreased in late September. In mid September, there were 1376, 20, and 360 spawning pink salmon in the Tokoro-Horonai, Kuma, and Nikoro Streams, respectively. The number of redds also increased in September. There were 1007, 165, and 773 redds in the Tokoro-Horonai, Kuma, and Nikoro Streams, respectively (Fig. 2). The Tokoro-Horonai Stream, which is located nearest to the Tokoro Estuary, had the highest redd density (Fig. 3).

We estimated the number of naturally-spawned eggs in the study areas. Pink salmon eggs are distributed in two or three, and sometimes four redds (Kaganovsky 1949; Soin 1954; Smirnov 1975). Most eggs are laid at low to moderate spawner densities. At high density, spawning is often interrupted and only some eggs are deposited (Semko 1954; Helle et al. 1964). Assuming that one redd contained half of the average female fecundity (approximately 1500 eggs), we estimated the total number of eggs in the study areas by multiplying the number of confirmed redds by half of the female average fecundity. The estimated number of eggs spawned was 755,000, 124,000, and 580,000 in the Tokoro-Horonai, Kuma, and Nikoro Streams, respectively (Table 2).

To collect newly emerged fry and determine the condition of the redds, we removed 0.39 $m^3$ of gravel, (1.0 m X 1.3 m wide X 0.3 m deep) from the redds in the Tokoro-Horonai River on 28 February, 2011. A total of 491 pink salmon, 383 chum salmon (*Oncorhynchus keta*), 6 unknown fry, and approximately 500 dead eggs were collected from the gravel. We estimated 1,459,000 eggs were spawned in the 17,361 $m^2$ study area during the investigation, which suggests a very large total number of eggs were spawned over the entire 1,930 $km^2$ of the Tokoro River.

Although it appeared to be functioning normally, the weir did not block migration completely because many pink salmon migrated upstream over the weir. We assumed the weir contained some gaps through which pink salmon were able to pass. The gaps could have been formed by debris in the water or by water pressure.

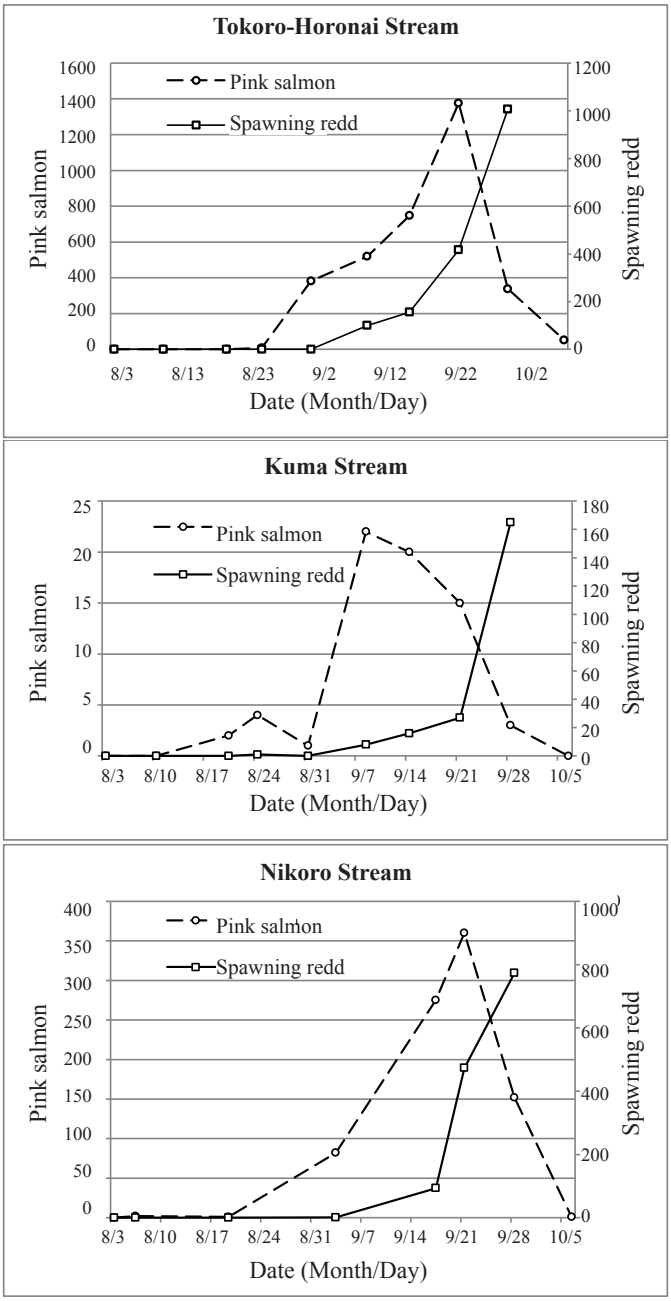


**Fig. 2.** Number of pink salmon and redds observed in three streams of the Tokoro River.

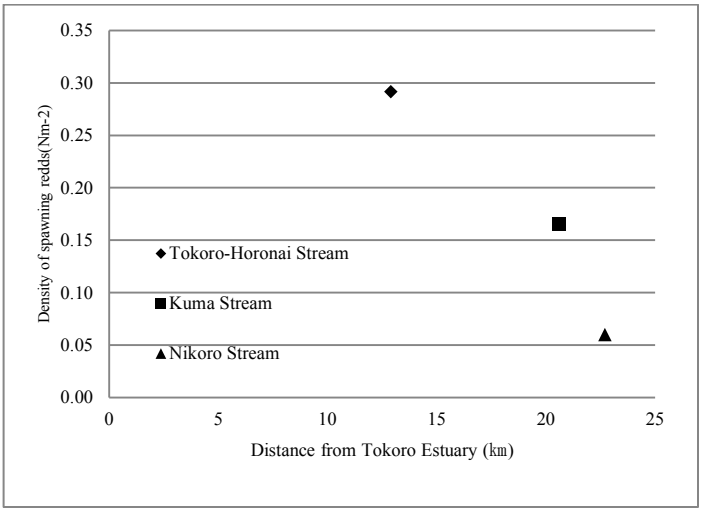


**Fig. 3.** Relationship between the density of redds in three streams of the Tokoro River and the distance from Tokoro Estuary (km).

**Table 2.** The number of redds and estimated number of naturally-spawned pink salmon eggs in the Tokoro-Horonai, Kuma, and Nikoro Streams.

| Stream | Study area ($m^2$) | Redds | Number spawned eggs (thousands) |
|---|---|---|---|
| Tokoro-horonai | 3,454 | 1,007 | 755 |
| Kuma | 998 | 165 | 124 |
| Nikoro | 12,909 | 773 | 580 |
| Total | 17,361 | 1,945 | 1,459 |

The assumption that the weir completely blocks the upstream migration of pink salmon was not correct, and we concluded that a substantial number of naturally-spawning pink salmon were able to move into the river and successfully spawn in the tributaries of the Tokoro River.

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