Large and small scale Pacific salmon homing behavior using the PIT tag system

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1. Life cycle, propagation system, and changes in stocks of chum and masu salmon in Japan.
2. Large scale masu salmon homing behavior in the Shimoakka Hatchery.
Life cycle of chum and masu salmon in Japan

Masu salmon (O. masou)

- Cold water freshwater species.
- Migrate to ocean to feed.
- Not possible to fertilize eggs in seawater.
- Acquire imprintsing and homing ability.
- In Japan, using salmon imprinting and homing ability, chum and masu salmon are propagated and are very important fisheries resources.
Chum and masu salmon propagation system in Japan

Coastal Fisheries for chum salmon

Upstream migration

Artificial insemination

Disinfection with iodine solution

Egg incubation for 90 days at 8 °C

Feeding with dry pellets
Chum salmon: several months
Masu salmon: 18 months

Release into stream
Chum salmon fry
Masu salmon smolt

Downstream migration

Homing migration

Fish trap

Feeding migration
Chum salmon: The North Pacific Ocean for about 4 years.
Masu salmon: Coastal sea of Japan for one year.
Changes in numbers of juvenile release and adult return of chum salmon in Japan

- **Steady increase from 1970 to 1996** because of favorable oceanic environments and successful enhancement programs.

- **Maximum adult return** (89 millions) in 1996.

- **Sharp decrease of juvenile release** due to the Great East Japan Earthquake in 2011.

- **Fluctuation of 8 years cycle** probably due to the regime shift in the North Pacific Ecosystem.

Hokkaido National Fisheries Research Institute
http://salmon.fra.affrc.go.jp/zousyoku/ok_relret.htm
Changes in numbers of juvenile release and adult return of masu salmon in Japan

- Slightly increase from 1985 to 1990 because of establishment of smolt release
- Maximum adult catch (29 thousands) in 2008
- Big fluctuation of adult catch in each year

![Graph showing changes in numbers of juvenile release and adult return of masu salmon in Japan.](http://salmon.fra.affrc.go.jp/zousyoku/ok_relret.htm)
Support for reconstruction and revitalization after the Great East Japan Earthquake by Japan Science and Technology Agency (JST) Creation of Innovation Technology for Marine Products Industry Production of high homing rate of Pacific salmon in East Japan

2013
1. April 15-19: 1,500 masu salmon smolt were tagged with PIT tag and ribbon tag.
2. May 1-6: Masu salmon smolt were fed with ω3 (rich in DHA) contained pellets.

2014 and 2015
The similar tagging was carried out between the middle and late March.

PIT tag: Biomark, Boise, USA.
Length: 12.5 mm
Weight: 0.1 g

The tagging was carried out by experts in the Hokkaido Aquaculture Promotion Corporation.

Two PIT tag detection antennas (3×1.2 m) were set up at entrance of the Shimoakka Hatchery with remote detection system.
Improvement of olfactory imprinting capability of masu salmon smolt

- We have succeeded in artificial imprinting to a single amino acid before and during smoltification in one-year-old sockeye salmon.
- Juvenile salmon can imprint to their natal stream odors during downstream migration that is deeply involved with smoltification.
- Imprinting is believed to correlate with changes in the brain-pituitary-thyroid axis hormone of Pacific salmon.
- We are now carrying out the experiments to improve olfactory imprinting capability of juvenile Pacific salmon by the oral administration of bioactive substances:

Docosahexaenoic acid (DHA)
- ✓ Increase the number of dendrites
- ✓ Development of axon
- ✓ Maintaining healthy condition of brain functions

N-methyl-D-aspartate (NMDA)
- ✓ Development of the neural network
- ✓ Learning and memory in the mouse brain
- ✓ Forming and recalling the imprinting memory in the chick brain

Thyroid hormone (T₃ & T₄)
- ✓ Potentiates brain development in vertebrates
- ✓ Metamorphosis in frog
- ✓ Imprinting and learning in the bird brain
Effects of bioactive substances (T4, ω3, and NMDA) on the Brain-Pituitary-Thyroid axis of masu salmon smolt

Ueda, Fish Sci, 81:219-228 (2015)

Steel-Dwass *P < 0.05
### Homing rate of adult masu salmon in the Shimoakka Hatchery

<table>
<thead>
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<td>0.002</td>
<td>0.004</td>
<td>0.007</td>
<td>0.065</td>
<td>0.009</td>
<td>0.002</td>
<td>0.001</td>
<td>0.006</td>
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<td>0.020</td>
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<td>0.021</td>
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Homing of $\omega 3$ pellet feeding adult masu salmon in the Shimoakka Hatchery in 2014

Homing rate: **0.333**

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Detecting of masu salmon feeding $\omega 3$ pellet in the Shimoakka Hatchery in 2014

<table>
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Artificial stream waters (ASW) were prepared using the same dissolved free amino acids (DFAA) concentration in each stream.

Two PIT tag detection antennas (60 × 60 cm) in each arm

12.5 mm PIT tag

Matured adult male chum salmon collected at the Chitose Hatchery were moved to the Sapporo Salmon Museum, and PIT tagged (Biomark, Boise, USA).

Chum salmon discriminating behavior of artificial stream water in Y-maze of the Sapporo Salmon Museum
Experimental design of PIT tag system in Y-maze of the Sapporo Salmon Museum

All experiments began with a 1-hour acclimation period in the holding tank.

After acclimation, the screens were removed and the fish were allowed to swim freely into each arm for 3 hours at night to prevent light and visual interference.

One fish per test run to avoid potential shoaling and dominance behavior.
Comparison between Chitose ASW and Toyohira ASW

16 of 20 fish showed upstream movement into either arm (80%)

Average total duration per run

- Chitose ASW: 0:18:13
- Toyohira ASW: 0:14:19

Average number of entries per run

- Chitose ASW: 8.25
- Toyohira ASW: 5.5

Average duration of each entry

- Chitose ASW: 0:02:22
- Toyohira ASW: 0:01:50

Significantly longer total and average duration spent in Chitose ASW arm

*t-test, *p < 0.05
Summary

✓ Large scale masu salmon homing behavior in the Shimoakka Hatchery indicates that masu salmon fed with \( \omega_3 \) that might improve olfactory imprinting ability showed 3 times higher homing rate than control.
✓ Small scale chum salmon homing behavior in the Sapporo Salmon Museum reveals that adult chum salmon that homed to the Chitose River displayed significant preference for Chitose ASW over Toyohira ASW.
✓ These results suggest the usefulness of PIT tag system to clarify salmon homing behavior

Future prospects of fish telemetry

➢ I have studied Pacific salmon homing behavior for 24 years using several telemetry equipments, ultrasonic and radio tracking systems, electromyogram and electrocardiogram transmitters, micro-data loggers with propeller, pressure and temperature sensor, and PIT tag system.
➢ I have revealed several important Pacific salmon homing behavior, but I am still unable to clarify juvenile salmon imprinting behavior.
➢ I would like to ask fish telemetry companies to develop tiny sophisticated eco-friendly fish telemetry equipment.
Thank you for your kind attentions

I am happy to answer your questions