Evaluation of loss rate of coded-wire tags implanted into adipose eye tissue of masu salmon *Oncorhynchus masou* and effect on growth of tagged salmon

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In Japan, fin-clipping has long been used to evaluate the effectiveness of masu salmon *Oncorhynchus masou* enhancement programs and to obtain biological information, such as migration, growth and survival rate of fish. However, with the exception of the adipose fin, some fins of salmonids regenerate after a relatively short time and their mutilation affects the survival of fish after stocking. Furthermore, the limited combinations of fin-clips do not allow for many codes and thus limits the number of variables that can be evaluated. In North America, a method of marking fish by implanting a coded-wire tag (CWT) has established itself as a reliable alternative to fin-clipping. Coded-wire tags for salmon are almost always implanted into the nasal cartilage of the snout or nose, with adipose fin-clipping often serving as an external flag. When fin-clipped salmon are caught by commercial or sport fishermen, the tags can be easily recovered from the snouts of the discarded heads. In Japan, however, salmon heads are valuable as foods and they cannot be recovered from fish in fish markets. This cultural difference between North America and Japan, therefore, necessitates novel approaches to implanting CWT. It was reported that adipose eye tissue in masu salmon should be a suitable location for CWT tagging both because it would be possible to remove this tissue in the fish market without reducing the fish’s commercial value and because it has a high tag retention rate in an artificial rearing experiment. It was unknown, however, whether this high tag retention rate could be maintained after CWT-implanted masu salmon were stocked into natural streams and the ocean. In the present study, approximately 30 000 tagged masu salmon smolts were stocked to investigate the tag loss rate and effect on growth for recovered adults. Masu salmon smolts for stocking were reared at Kumaishi Research Branch of the Hokkaido Fish Hatchery, located in south-western Hokkaido (Fig. 1). From 26–28 October 1999, the fish were marked by removal of the adipose (Ad) and left ventral (LV) fins with a sharp pair of surgical scissors, to provide quick and easy flags for visual identification in the field. These fish were reared in two concrete ponds (3.5 × 24.6 × 0.4 m) until stocking. From 10–13 April 2000, half-length CWT (0.5 mm long) were implanted into the fish, according to the procedures described by Nagata et al. After fish were anesthetized, CWT were implanted into adipose eye tissue (transparent post-ocular tissue), which is located behind the eyes of smolts using four Mark IV CWT injectors (Northwest Marine Technology Inc., Shaw Island, WA, USA). Fork length and body weight of smolts at the time of tagging was 14.3 ± 0.8 cm and 29.9 ± 4.8 g, respectively (N = 295, mean ± SD). Average tagging speed was 390 fish/h/machine and 30 507 fish were tagged. Every day before stocking, all dead fish in the ponds were collected and checked for tag retention using a wand detector (Northwest Marine Technology Inc.). On 12 May, 7 days before stocking, 293 live smolts were sampled randomly from the ponds to examine tag retention. On 19 May, all fish were released from the ponds at Kumaishi Research Branch.

To compare the mortality between CWT-tagged and untagged fish, a control group (untagged fish) was reared in separate but equivalent ponds. A total of 31 690 fish were marked by removal of the...
adipose and right ventral (RV) fins from 29 October to 2 November 1999. These untagged fish (AdRVnoCWT) were reared until stocking (19 May), and the number of dead fish recorded after 14 April, similar to the tagged fish (AdLV CWT).

Adults returning to Ken-ichi River were recaptured by cast-netting and electrofishing and spawned-out carcasses were collected from spawning grounds in September and October of 2001. Adult fish with AdLV fin-clips were examined for CWT with a wand detector. To compare the mortality in tagged and untagged fish, and tag loss rate in smolts and adults, Fisher’s exact probability test ($\alpha = 0.05$) was conducted. In addition, to compare the growth of tagged and untagged fish after stocking, AdLV- and AdRV-marked fish were measured for fork length to the nearest 0.1 cm, and a $t$-test ($\alpha = 0.05$) was conducted.

A total of 29 768 tagged fish were stocked, 739 having died in the ponds before stocking. Fork length and body weight of CWT-tagged and untagged smolts at stocking were $15.6 \pm 0.8$ cm, $37.3 \pm 6.0$ g ($N = 293$), and $15.7 \pm 1.0$ cm, $37.7 \pm 7.3$ g ($N = 273$), respectively. Size at the time of stocking was not significantly different between the tagged and untagged fish ($t$-test: $P_{FL} = 0.10$, $P_{BW} = 0.80$).

Tag loss at 29 days after tagging was 7.2% (21 out of 293). Total mortality before stocking for the tagged fish was 2.4% (739/30 507), while that for the untagged fish was 2.0% (641/31 690). There was a significant difference in the mortality between tagged and untagged fish ($P = 0.0007$).

From 7 September to 26 October 2001, 96 adults were captured from Ken-ichi River. These fish were captured between 513 and 542 days after tagging. Of those fish, 43 were AdLV-marked fish (9 females and 34 males) and 23 were AdRV-marked fish (7 females and 16 males) and 30 were unmarked native fish. Of the AdLV-marked adult fish, 37 had retained, but six had lost their CWT (Fig. 2), so the tag loss rate from tagging to adult recovery was estimated at 14.0%. There was no significant difference in the tag loss rates between smolts and adults ($P = 0.13$). Fork length of fish that retained their tags was $51.7 \pm 4.0$ cm ($N = 6$) in females and $47.8 \pm 4.4$ cm ($N = 31$) in males, respectively. In contrast, fork length of untagged fish was $52.9 \pm 3.8$ cm ($N = 7$) in females and $46.9 \pm 5.5$ cm ($N = 16$) in males, respectively (Fig. 3). There was no significant difference in size between tag-retained and untagged fish ($P_{females} = 0.60$, $P_{males} = 0.54$).

Tag loss rate is the most serious problem when results from tagging experiments are quantified and the tag should not change the survival or growth rate. Insertion of the CWT into the snout and adipose eye tissue had no effects on survival and growth of salmonids. Although the mortality of the tagged group in the ponds after tagging was 0.4% higher than that for the untagged group, it was thought that handling stress during tagging rather than CWT itself caused a significant number of
Fig. 3 Mean fork length (± SD) for tag-retained (AdLV CWT) and untagged (AdRVnoCWT) fish recaptured in 2001. Values in parentheses denote the number of individuals measured. Ad, adipose fin clipping; LV, left ventral fin clipping; RV, right ventral fin clipping.

Additionally, there was no significant difference between the two groups in the size of the fish at release or as adults. Therefore, we conclude that insertion of CWT into adipose eye tissue of masu salmon has little or no effects on survival and growth. Tag loss rate was estimated as 7.2% at 29 days and 14.0% in adults at 513–542 days after tagging; therefore, the tag loss rate in the ocean was estimated at 7%. We thought that tag loss rate after stockling did not increase because this difference was not significant. Blankenship\(^\text{11}\) reported that in eight groups of coho salmon Oncorhynchus kisutch and chinook salmon Oncorhynchus tshawytscha (0.9–7.6 g) held in hatchery ponds and examined for CWT loss over periods of 121 and 293 days, respectively, after tagging, the tag loss rate decreased sharply soon after tagging with no significant loss after 29 days. In previous papers, tag loss rate in the adipose eye tissue of rainbow trout Oncorhynchus mykiss was 4.0% at 238 days after implantation,\(^\text{10}\) and was 4.8% in masu salmon, in which an artificial rearing experiment was conducted over 11 months.\(^\text{7}\) These studies suggest that the loss of tags implanted into the adipose eye tissue of masu salmon occurs during the short period after tagging, but that thereafter tag loss is rare, the same as with nose tags. Ostergaard\(^\text{12}\) reported that redesigning the head mold (device which fixes the fish head on the tip of the needle), increasing the depth of tag penetration into the snout of lake trout Salvelinus namaycush, and correcting the placement of the needle in the head mold have resulted in a total increase of 8% in retention of tags. Further improvements of tagging techniques are needed to reduce the tag loss from adipose eye tissue, the same as nose tags. We assert that tagging by implanting CWT into the adipose eye tissue in combination with an adipose fin-clipping is practical for masu salmon in Japan.

REFERENCES


