Marine Survival of Hatchery Released Pink Salmon (*Oncorhynchus gorbuscha*) Estimated by Coded-Wire Tagging or Thermal Otolith Marking

Renate R. Riffe[1] and **Ole A. Mathisen**[2]
[1] Commercial Fisheries Division, Alaska Department of Fish and Game,
P.O. Box 240020, Douglas, AK 99824, USA
[2] Professor emeritus, University of Alaska, Fairbanks,
1632 San Juan Drive, Friday Harbor, WA 98250, USA

Keywords: Coded -wire tags (CWT), thermal marking, pink salmon

Four major hatcheries in Alaska's Prince William Sound produce pink salmon. In 1996, more than 0.6 billion pink salmon fry were released, all having received a thermal otolith mark unique to each hatchery. Additionally, more than one million fry received a coded wire tag, which allowed identification as to hatchery and specific release group. All survival estimates are based on recovered tags or marks. These two methods produced different results, which are discussed in this communication.

Thermal base marks were laid down in late 1995, at the 'eyed' stage of development, before hatching (Munk et al. 1993). All hatchery pink salmon eggs received thermal otolith marks. A distinct mark was used at each hatchery.

After the eggs hatched into fry in the spring of 1996, a portion of them received two additional marks, a half-length coded-wire tag applied using a Northwest Marine Technology tag injector (MKIV), and removal of the adipose fin to distinguish the fish from its untagged peers. Approximately 1 in 600 pink salmon received a tag. A total of 641.68 million pink salmon fry were released, of which 1.07 million had coded-wire tags.

Mark or tag recoveries were made in 1997 from the commercial fishery. Three components comprise the commercial fishery, the common property fishery, the cost recovery fishery, and the brood stock fishery. Otolith samples were collected systematically as the tenders were being offloaded at processing plants (Joyce and Evans 1998). Using timers set at a specified interval, technicians selected fish and removed the otoliths, working from the beginning of a tender delivery to the end. After all otolith samples had been collected, a weighted sample of 96 otoliths was created by systematically subsampling otoliths taken from each tender, based on the proportion of the total catch that each tender - or its respective processing plant- bought during that opening.

In sampling for coded-wire tags, 20 percent of the catch had to be examined, to compensate for the low tagging ratio and realize desired variance (Geiger and Sharr 1990; Peltz and Geiger 1990; Peltz and Miller 1990). In practice, virtually all tenders had to be sampled to achieve the desired sampling fraction.

The otolith-derived estimate of the contribution of hatchery h to district-period stratum i, C_{hi} was made as follows (Joyce and Evans 1998):

$$\hat{C}_{hi} = \frac{o_{hi}}{n_i} N_i \qquad (1)$$

where,

o_{hi} = Number of otoliths from hatchery h in the sample of stratum i,
n_i = Number of otoliths sampled from stratum i (usually 96),
N_i = Number of fish caught in stratum i.

The total catch over all strata is:

$$\hat{C}_h = \sum_{i=1}^{Q} \hat{C}_{hi} \qquad (2)$$

where,

Q = Number of recovery strata associated with the pink salmon harvest in question.

A variance estimate for $\hat{C}_h$ is given by:

$$\hat{V}(\hat{C}_h) = \sum_{i=1}^{Q} \frac{N_i^2 o_{hi}}{n_i^2}\left(1 - \frac{o_{hi}}{n_i}\right) \qquad (3)$$

All correspondence should be addressed to R. Riffe.
e-mail: renate_riffe@fishgame.state.ak.us

The original tagging ratios had to be expanded by an adjustment factor, due to apparent violations of assumptions concerning tag loss and differential mortality. An adjustment factor combined with the original tagging ratio is equivalent to estimating tag ratios in brood stock or from escapement surveys.

The adjustment factor a_h, for hatchery *h*, was estimated as the ratio of sampled salmon in the brood stock to the expected number of salmon sampled, based on tags found in the sample:

$$\hat{a}_h = \frac{s_h}{\sum_i^T \frac{x_i}{p_i}} \tag{4}$$

where

T = number of tag codes released from hatchery *h*,
p_i = tagging rate at release for the *i*th tag code (defined as number of tagged salmon released with the *i*th code divided by the total number of salmon in release group *i*),
x_i = number of tags of the *i*th code found in s_h and,
s_h = number of brood stock salmon examined in hatchery *h*.

The contribution of release group *t* to the sampled harvests and escapement, C_t , was estimated as:

$$\hat{C}_t = \sum_{i=1}^{L} x_{it} \left(\frac{N_i \hat{a}_h}{s_i p_t} \right), \tag{5}$$

where

x_{it} = number of group *t* tags recovered in the *i*th stratum,
N_i = total number of salmon in the *i*th stratum,
s_i = number of salmon sampled from the *i*th stratum,
p_t = proportion of group *t* tagged,
a_h = adjustment factor for hatchery of origin,
L = number of recovery strata associated with harvests, brood stock, and escapement in which tag code *t* was found.

A variance approximation for $\hat{C}_t$, derived by Clark and Bernard (1987) and Bernard and Clark (1996) was used:

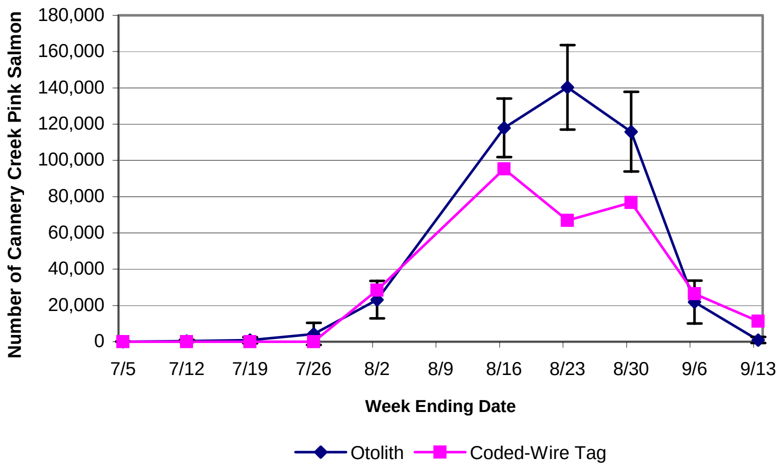
$$\hat{V}(\hat{C}_t) = \sum_{i=1}^{L} x_{it} * \left[\frac{N_i \hat{a}_h}{s_i p_t} \right] \left[\frac{N_i \hat{a}_h}{s_i p_t} - 1 \right] \tag{6}$$

The Prince William Sound hatchery component according to otolith data was 25.67 million pink salmon, while coded-wire tag data estimates totaled to 24.61 million fish. The number of wild fish was 1.11 million for otolith estimates, and 2.17 million for coded-wire tag estimates. Marine survival estimates by hatchery are presented in table 1. Otolith estimates were higher than the coded-wire tag methods three hatcheries, and had much narrower confidence intervals. In general, coded-wire tag estimates were similar to those calculated from otoliths, except where fish which had high tag loss rates for coded-wire tags comprised a large component of the catch (Fig. 1).

Table 1. Marine survival estimates, Prince William Sound hatchery pink salmon returning in 1997.

Hatchery	Otolith		Coded-Wire Tag	
	%Survival	95% Confidence Interval	%Survival	95% Confidence Interval
Solomon Gulch	3.04	3.01–3.07	3.25	2.93–3.57
Cannery Creek	4.10	4.03–4.17	3.78	3.12–4.43
W.H. Noerenberg	3.64	3.57–3.71	3.45	3.06–3.84
A.F. Koernig	6.40	6.28–6.52	5.71	4.82–6.59
Overall	4.00	3.97–4.03	3.84	3.63–4.04

Fig. 1. Number of Cannery Creek pink salmon caught in the Coghill District traditional pink salmon fishery in 1997.



In a related analysis, otoliths were used to classify coded-wire tag samples found to be missing tags. About 96% of those missing tags originated from hatchery fish, of which 31.3% were from Solomon Gulch hatchery, 29% from Cannery Creek hatchery, 28.3% from W.H. Noerenberg hatchery, and 7.77% from A.F. Koernig hatchery. The estimated rates of tag loss attributed to each hatchery were 19.2% for Solomon Gulch hatchery, 38.1% for Cannery Creek hatchery, 25.8% for W.H. Noerenberg hatchery, and 11.7% for A.F. Koernig hatchery.

Coded-wire tag estimates were probably consistently lower due to technicians missing tagged fish. Low tagging fractions for Prince William Sound pink salmon reduced the chance of including groups of fish, present in the harvest at low levels, in the coded-wire tag estimates.

Otolith marking of all fish in a release group appears to produce better estimates and narrower confidence limits, due to a reduced number of assumptions that need to be fulfilled, and a rigorous sampling protocol. The low number of possible differentiable marks limits the usefulness of thermal otolith marking.

REFERENCES

Bernard, D.R., and J.E. Clark. 1996. Estimating salmon harvest with coded-wire tags. Can. J. Fish. Aquat. Sci. 53: 2323–2332.

Clark, J.E., and D.R. Bernard. 1987. A compound multivariate binomial-hypergeometric distribution describing microwire tag recovery from commercial salmon catches in southeast Alaska. Information Leaflet 261. Alaska Department of Fish and Game, Juneau.

Geiger, H.J., and S. Sharr. 1990. The 1988 Tag Study of Pink Salmon from the Solomon Gulch Hatchery in Prince William Sound, Alaska. *In* Pilot Studies in Tagging Prince William Sound Hatchery Pink Salmon with Coded-Wire Tags. Alaska Department of Fish and Game Fishery Research Bulletin No. 90-02.

Joyce, T., and D.G. Evans. 1998. Otolith marking of pink salmon in Prince William Sound salmon hatcheries, 1997. Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 97188), Alaska Department of Fish and Game, Cordova.

Munk, K., W. Smoker, D. Beard, and R. Mattson. 1993. A hatchery water-heating system and its Application to 100% thermal marking of incubating salmon. Prog. Fish-Cult. 55: 284–288.

Peltz, L., and H.J. Geiger. 1990. A Tagging Study of the Effects of Hatcheries on the 1987 Pink Salmon Fishery in Prince William Sound, Alaska. *In* Pilot Studies in Tagging Prince William Sound Hatchery Pink Salmon with Coded-Wire Tags. Alaska Department of Fish and Game Fishery Research Bulletin No. 90-02.

Peltz, L., and J. Miller. 1990. Performance of half-length coded-wire tags in a pink salmon hatchery marking program. Fish marking techniques. Am. Fish. Soc. Symp. 7: 244–252.