# Application of Otolith Thermal Mass Marking in British Columbia, Canada

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The first experiments in British Columbia, Canada, with otolith thermal mass marking of salmon were conducted at Robertson Creek Hatchery in 1989–1990. Large-scale (total production) otolith thermal marking of chinook was subsequently implemented at this same hatchery for the 1992 brood year. Since then thermal mass marking has gradually expanded to include chinook from many other hatcheries in B.C. including Nitinat Hatchery in 1992, Conuma Hatchery in 1994, Chilliwack Hatchery in 1995, and Quinsam Hatchery in 1996. The releases of otolith thermal mass marked chinook salmon from B.C. hatcheries increased from about 9 million in 1993 to more than 20 million by 1997 (Table 1). Releases of otolith thermal marked chum salmon (all from Nitinat River Hatchery) increased to about 35 million during the same period.

The number of hatcheries in B.C. that have implemented thermal otolith mass marking programs has continued to increase since the mid-1990s. Some B.C. hatcheries have also expanded marking in recent years to include routine thermal mass marking of coho and chum salmon, in addition to chinook salmon. However, the total number of thermal otolith marked fish released each year from all B.C. hatcheries has increased more slowly, mainly due to reduced spawner escapements of many B.C. salmon stocks that occurred during the 1995–2000 period. Additional details of the early implementation of thermal otolith mass marking in B.C., including the numerous thermal mark patterns that were applied to each stock each year, were provided in a previous report (Hargreaves et al.1998).

Otolith thermal mass marking of salmon has been applied for several different purposes in B.C. Most of the early applications of the otolith mass marking technique were in support of scientific research activities and objectives. In recent years there has been increasing application of the otolith thermal mass marking for routine stock assessment and fisheries management purposes.

The research applications of otolith thermal mass marking have focused mainly on using this technique to confirm the hatchery origin of salmon smolts in situations where both wild and hatchery salmon co-migrate. This method has also been used to distinguish wild and hatchery smolts during downstream migrations(e.g., Somass River downstream trapping program; Wood et al. 1992), to identify juvenile hatchery and wild fish in estuaries (e.g., Campbell River and Somass Rivers), during the early sea life period (e.g., Nitinat Lake, Alberni Inlet and Barkley Sound), and in the open ocean (e.g., along the B.C. continental shelf; Perry et al. 1996). In recent years otolith thermal mass mark patterns have also been used to confirm the B.C. origin of maturing and adult chum salmon that have been captured in fisheries conducted in the Gulf of Alaska and Bering Sea.

**Table 1.** Number of thermal otolith marked salmon released each year from major British Columbia production facilities.

| | | B.C. SALMON STOCK | | | | | |
|---|---|---|---|---|---|---|---|
| YEAR | SPECIES | Robertson Creek | Nitinat River | Sarita River | Conuma River | Chilliwack River | Quinsam River |
| 1993 | Chinook | 8,400,429 | 500,000 | 156,632 | 0 | 0 | 0 |
| | Chum | 0 | 0 | 0 | 0 | 0 | 0 |
| 1994 | Chinook | 6,939,205 | 6,195,122 | 210,776 | 0 | 0 | 0 |
| | Chum | 0 | 28,363,894 | 0 | 0 | 0 | 0 |
| 1995 | Chinook | 7,272,539 | 6,353,525 | 237,979 | 663,691 | 0 | 0 |
| | Chum | 0 | 30,831,080 | 0 | 0 | 0 | 0 |
| 1996 | Chinook | 8,273,553 | 4,073,259 | 7,086 | 390,040 | 813,089 | 0 |
| | Chum | 0 | 24,649,925 | 0 | 0 | 0 | 0 |
| 1997 | Chinook | 8,451,699 | 7,474,233 | 58,469 | 507,047 | 2,055,821 | 3,628,008 |
| | Chum | 0 | 31,941,437 | 0 | 0 | 0 | 0 |
| 1998 | Chinook | 8,927,415 | 6,341,195 | 307,914 | 176,496 | 1,921,522 | 2,712,900 |
| | Chum | | 34,830,668 | 0 | 0 | 0 | 0 |

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The reason that thermal otolith mass marking was first initiated in B.C. was to provide a new research tool for distinguishing between wild and hatchery chinook during the early sea life period. The main interest of this research was to examine differences in size and behaviour between wild and hatchery chinook that might provide insight into factors affecting survival rates, predation rates, marine growth, and possible competition for food between wild and hatchery chinook during the early sea life period. The Somass River chinook salmon stock, located on the west coast of Vancouver Island, B.C., was selected as the focus for this study. Robertson Creek Hatchery produced about 8–10 million chinook smolts each year, which represented 50–70% of the total (wild plus hatchery) chinook smolt production from the Somass River. Historical data indicated that very large interannual variations in marine survival rates had occurred since 1972 when Robertson Creek Hatchery first began production. The lowest survival rates tended to coincide with strong El Niño years, and it was speculated that increased predation or possibly increased competition for food between hatchery and wild chinook might explain the very poor marine survival rates that occurred in years with strong El Niño events. An extensive sampling program was conducted in Alberni Inlet and Barkley Sound from 1987 to 1993 to investigate these hypotheses. However, progress was initially hampered by the difficulty in distinguishing wild from hatchery chinook during the early sea life period. To overcome this problem experiments were initiated in 1989–1990 to test the practicality and utility of using the otolith thermal mass marking technique to mark all of the chinook released from Robertson Creek Hatchery. These first experiments in B.C. were based on the pioneering work that had previously been done on this technique in other locations and on other fish species (e.g., Volk et al. 1990). The immediate success of the initial experiments at Robertson Creek Hatchery led to the subsequent otolith thermal mass marking of all chinook salmon released from Robertson Creek Hatchery since 1992. This allowed all hatchery chinook to be easily distinguished from wild chinook, even during the early sea life period when variations in growth rates and migration rates quickly obscured the initial differences (e.g., size) between hatchery and wild chinook. Results obtained using the otolith thermal mass mark information showed clear differences in the distribution, abundance, growth rates, migration rates and predation rates of wild and hatchery chinook in Alberni Inlet and Barkley Sound. For example, the numbers of wild and hatchery chinook were approximately equal in the near-shore areas (sampled with beach seines) in 1993, but virtually all of the juvenile chinook that were caught simultaneously in the same time periods in open water areas (using a purse seine) were hatchery fish (Table 2).

Otolith thermal mass marking of salmon has also recently been gaining increasing importance in B.C. as a powerful new tool for stock assessment and fisheries management. Current applications in B.C. include: (1) assessment of the contribution of fish from various hatcheries to local mixed-stock fisheries, (2) allowing independent evaluation of potential biases in alternate marking methods (coded-wire tag, multiple fin-clip, etc.), (3) assessing the hatchery contribution to mixed hatchery and wild spawning populations, (4) determining the straying rates of salmon released from major hatcheries, (5) estimating exploitation rates for key salmon stocks, and (6) evaluating the effectiveness of various fisheries management actions. An example of the latter application is provided in more detail below.

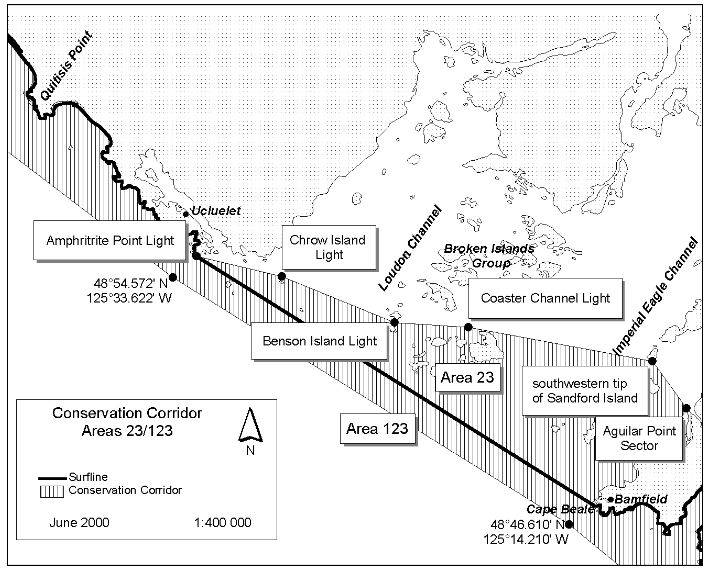
In 2000 the return of chinook to both wild and hatchery stocks along the west coast of Vancouver Island (WCVI), B.C., was forecasted to be extremely low. In order to provide adequate protection to conserve these stocks and achieve even minimal escapement levels, conventional fisheries management would have required complete closure of the recreational fishery along the entire WCVI. This would have been devastating to local recreational fishermen and also to the local communities and businesses, which are heavily dependent on the fishing tourist industry. In consultation with industry representatives, Fisheries and Oceans Canada (DFO) agreed to examine possible alternative management approaches. DFO staff examined historical data from recoveries of chinook with coded-wire tags (CWTs) caught by all fishing gear sectors in previous years when chinook stocks were more abundant. This analysis confirmed that the recreational fishery typically caught substantial numbers of chinook along the entire WCVI. However, this analyses also indicated that very few of the chinook captured by recreational fishermen at locations farther than one nautical mile from shore originated from local chinook stocks spawning

**Table 2.** Origin of chinook salmon captured in near-shore and open water locations during the early sea-life period in 1993 in Alberni Inlet and Barkley Sound, B.C., hatchery fish were identified using otolith thermal mass mark patterns. Chinook that could not be identified clearly as either hatchery or wild based on the otolith thermal mass mark alone are classified as "not certain".

| Time Period | Beach Seine | | | Purse Seine | | |
|---|---|---|---|---|---|---|
| | Hatchery | Wild | Not Certain | Hatchery | Wild | Not Certain |
| 26–27 May | 0 | 62 | 0 | 0 | 1 | 2 |
| 02–13 June | 100 | 85 | 17 | 52 | 3 | 0 |
| 14–25 June | 109 | 118 | 8 | 27 | 5 | 3 |
| Totals: | 209 | 265 | 25 | 79 | 9 | 5 |

along the WCVI. Based on this information DFO implemented a new chinook "conservation corridor" along most areas of the WCVI, which extended from the surf line to approximately one nautical mile offshore (Fig. 1). Within this conservation corridor recreational fishing for all species salmon was prohibited. However, outside (farther offshore) of this corridor recreational fishing and retention of chinook were permitted. The inner "surf line" boundary generally corresponds to the region very close to the shore line where surf (breaking waves) typically occur. The "surf line" boundary is more formally defined and legally described in DFO regulations for the Pacific Region.

**Fig. 1.** Map showing the boundaries of the new conservation corridor (in statistical areas 23 and 123 only) that was implemented by DFO in 2000 to protect adult chinook returning to spawn along the entire west coast of Vancouver Island.




Results from otolith thermal mass marks provided the only data available for assessing the effectiveness of this new chinook conservation corridor. Two major concerns about the new conservation corridor management approach in 2000 were that the chinook returning in 2000 might migrate farther offshore in 2000, or that recreational fishermen might fish illegally inside the corridor, and catch and retain chinook from local WCVI stocks. However, all of the chinook released from the three major hatcheries along the WCVI (Robertson Creek, Nitinat, and Conuma) have been otolith thermal mass marked since 1994. Thus all of the adult chinook that returned from these three stocks in 2000 to spawn were otolith thermal mass marked, with distinctive patterns for each hatchery. Earlier work had confirmed that the chinook from these three main hatchery stocks are also representative (marine survival rates, migration routes and timing, etc.) of the wild chinook stocks along the WCVI. The DFO implemented an appropriate sampling program to obtain otoliths from chinook that were caught during August and September 2000 by recreational fishermen along the WCVI. A total of 485 chinook otoliths were examined for the thermal mass mark patterns that had been applied by the three major WCVI hatcheries. Only one of these chinook was from Robertson Creek Hatchery. These results confirmed that the conservation corridor was in fact very effective, and allowed the continuation of an important recreational fishery while also providing adequate protection for local WCVI chinook stocks. It should be noted that evaluation of this new management strategy could not be done using the conventional CWT method, due to the very small number of chinook that were caught with CWTs.

The implementation and application of otolith thermal mass marking will likely continue to grow in B.C. The use of this method has changed from predominantly a research focus in the early years to mainly stock assessment and fisheries management in recent years.

To a large degree this transition has been made possible by the consistent long-term thermal marking programs that have been implemented at many B.C. hatcheries. Maintaining routine thermal marking programs at these hatcheries for many years has resulted in thermal mass marking of most or all of the adult production that is now returning each year. This in turn provides the opportunity to use these thermal marked salmon in ways that were not even anticipated when these marking programs were initiated, e.g., the use of otolith thermal mark patterns to verify the effectiveness of the conservation corridor for chinook along the WCVI in 2000 (described above). This application was not even anticipated when the thermal marks were originally applied. The conservation corridor would not have been considered by DFO, and the recreational fishery likely would have simply been closed if the otolith thermal mark information was not available to assess the effectiveness of this management approach.

Otolith thermal mass marking in B.C. will likely continue to expand to include other species and more hatcheries. Originally only chinook were thermally marked in B.C. hatcheries. The thermal marking program subsequently expanded to include chum salmon (e.g., Nitinat Hatchery) and more recently coho salmon (e.g., Robertson Creek Hatchery). Additional hatcheries are also currently planning to implement otolith thermal marking programs (e.g., Fraser River system hatcheries in the B.C. interior). There is also steadily growing interest in many small hatcheries throughout B.C. that have low annual production (e.g., Public Involvement Program hatcheries) to use otolith thermal mass marking to evaluate their contribution to local fisheries and spawner escapements.

Continued expansion of otolith thermal mass marking in B.C. and other countries poses some significant challenges. The number of "useable" thermal marks that can be applied is quite limited, and there is already competition for the "best" mark patterns even among B.C. hatcheries. This problem is further amplified if there is any concern in a particular application that thermally marked fish may be encountered (e.g., in mixed-stock fisheries along the B.C. coast) that originate from hatcheries outside B.C. Within Canada there is also inadequate coast-wide coordination of thermal marking programs. In many cases this method is used to address only local questions and problems (e.g., assessing hatchery contribution to spawning populations), and so there is little interest or concern about thermal marks that might be applied by other hatcheries or encountered in more distant locations. However, this potentially can diminish the utility of the otolith mass method in other locations (mixed stock ocean fisheries) if the mark patterns used by all hatcheries along the Pacific Coast are not adequately coordinated. The authors are encouraged by and support the recent initiative through the North Pacific Anadromous Fish Commission for the international coordination of otolith thermal marking patterns and the international sharing of relevant thermal mark data.

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