# Captive holding to develop external archival tagging protocols for Pacific halibut, and comparison to internal implantation

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## Abstract

In 2006 the IPHC began investigating the use of fishery-recaptured archival tags in order to extend its electronic tagging program to study multi-year behavior of individual halibut and behavior of fish that have traditionally been considered too small to carry Pop-up Archival Transmitting tags. The program began with a captive holding experiment designed to develop surgical techniques for internal tag implantation, and in 2009 a second holding experiment was initiated in order to investigate external tag-mounting protocols and compare them to internal tag implantation results. A total of 30 halibut in captivity at the Oregon Coast Aquarium (Newport, Oregon) were tagged with "dummy" archival tags using a variety of experimental treatments that included through-body dorsal attachment, opercular attachment oriented perpendicular to the main axis of the fish, and dart-and-tether, a treatment of intracoelomic implantation that will allow external tagging results to be directly compared to the effectiveness of surgical methods. This report provides a brief description of the methods employed, update of the status of tagged individuals, and description of new methods initiated in 2011. The 2011 methods were: 1) a modified opercular orientation; 2) two alternative dart configurations; and 3) intramuscular implantation. Monitoring for tagging effects is ongoing and expected to continue through 2012.

## Introduction

In 2002 the IPHC began an electronic archival tagging program with the intention of investigating seasonal movements of halibut. This program has five main goals: 1) quantify migration distances between summer and winter grounds, 2) identify winter spawning areas in poorly-studied regions such as the Bering Sea, 3) examine basin-specific differences in interannual site fidelity, 4) define seasonal migration periods and seasonal depth-specific habitat use, representing the stock's transition between shallow-water summer distribution and deep-water winter distribution, and 5) define active spawning periods on a regional basis as evidenced by short-period vertical migratory behavior.

Electronic archival tags have been proven an effective tool for studying behavior and environmental conditions experienced by a variety of marine fish species, including plaice (*Pleuronectes platessa*; Hunter et al. 2003, Solmundsson et al. 2003), bluefin tuna (*Thunnus thynnus*; Block et al. 2001, Kitagawa et al. 2004, Teo et al. 2004), bigeye tuna (*Thunnus obesus*; Schaefer and Fuller 2005) and school sharks (*Galeorhinus galeus*; West and Stevens 2001). To date, such studies on Pacific halibut have been conducted using pop-up archival transmitting (PAT) tags that allow the accumulated data to be retrieved without the need to recapture the fish (Loher and Seitz 2006, Loher 2008, Loher and Blood 2009, Loher and Clark 2010, Seitz et al. 2011). However, while PAT tags have proven valuable for studying a variety of processes, deployments of more than one year are inadvisable due to tag loss and battery-life limitations and their relatively large size means that only the behavior of relatively large halibut can be studied. In order to fully understand halibut movement, behavior, and population structure, the IPHC's electronic tagging program must expand to include smaller fish and longer periods of observation for individual fish.

In recent years, electronic archival tags have become increasingly smaller and battery life and memory capacity have advanced to such a degree that they have the capacity to record high-resolution data for periods in excess of five years, and their capabilities are continually increasing. This provides an opportunity to monitor behavior for periods that span the juvenile-to-adult transition in long-lived species such as halibut. However, extreme tag life challenges our previous definitions of "long-term" tag retention and holding studies. As opposed to being limited by tag life, modern behavioral studies may be constrained to a greater degree by the ability to secure tags to fish and recover unbiased data after periods that may well approach a decade. The current study investigates methods for externally-affixing tags to halibut for periods of five years or more, and compares retention and apparent physiological and behavioral impacts of external tagging methods to those already developed for internal implantation (*sensu* Loher and Rensmeyer 2011).

## Summary of tagging

In total, ten tagging treatments are employed in this study. The configurations are:

1) Intracoelomic implantation of a cylindrical tag (model LAT 1800cl).
2) External to the dorsal musculature using a cylindrical tag (model LTD 2310) mounted on polyvinylchloride (PVC) cradle.
3) External to dorsal musculature using a flattened ("flat pack") tag (model LAT 1800fp) resting directly on the fish.
4) Attachment to the operculum (LAT 1800fp), oriented perpendicular to the fish's main axis.
5) Attachment to the operculum (LAT 1800fp), oriented parallel (longitudinal) to the fish's main axis.
6) External to the dorsal muscular via dart-and-tether (LAT 1800fp), using a flat titanium dart.
7) External to the dorsal muscular via dart-and-tether (LAT 1800fp), using a flat stainless steel dart.
8) External to the dorsal muscular via dart-and-tether (LAT 1800fp), using a cylindrical PVC dart.
9) Embedded in the dorsal muscular via dart-and-tether (LAT 1800cl), using a flat stainless steel dart.
10) Embedded in the dorsal muscular via dart-and-tether (LAT 1800cl), using a cylindrical PVC dart.

Treatments 1-4 and 6 were initiated at the beginning of the experiment, during November, 2009, and are fully detailed in Loher and Geernaert (2010, 2011). Treatment 5 was initiated on March 24, 2011, and Treatments 7-10 on May 20, 2011. Tagging protocols for treatments 5 and 7-10 follow.

Longitudinal opercular attachment (Treatment 5) was initiated following observation of a relatively high rate of tag shedding associated with perpendicular orientation (Treatment 4; Loher and Geernaert 2010). Tags oriented perpendicularly were initially observed rotating posteriorly, relative to their original plane of attachment (Fig. 1A), followed by migration of the tagging wires posteriorly through the preopercular. This was unexpected, considering that shedding of conventional wire tags attached to the preopercular is relatively low (Myhre 1966). Perpendicular attachment was originally chosen because it allows the tag to be secured at both ends, providing a redundant attachment point should one end fail. However, by orienting the tag perpendicular to the fish's long axis, we hypothesize that the tags are subjected to sufficient drag force during swimming to cause resumption of facial remodeling (i.e., the mechanism whereby one eye migrated over the top of the head during early development), ultimately result in tag ejection. Longitudinal attachment, although it relies on only a single attachment point, is expected to reduce drag. Thus, on March 24, 2011, four fish ranging in length from 59-93 cm fork length (FL) that had shed dorsally-attached tags were fitted with perpendicularly-oriented opercular LAT 1800fp tags (Treatment 5; Fig. 1B).

Modified dart-and-tether tagging (Treatments 7-10) were inspired by two observations: 1) no tag shedding in Treatment 6 with apparently good post-insertion healing and lack of a persistent wound in the initially-tagged individuals, and 2) tendency for dorsally-attached tags in Treatment 3 to become embedded in the flesh as the fish grow, becoming essentially intramuscularly implanted. With respect to the former, our intent is to test tag retention using smaller darts that will produce less overall physiological tag impact and may be suitable for use on relatively small fish. The second observation is actually consistent with the use of intramuscular tag implantation in other species. Intramuscular implantation can be preferable to external attachment because the latter can cause drag and lift effects, potentially reducing swimming performance (Arnold and Holford 1978; Lewis and Muntz 1984) and increasing energetic costs to the tagged fish (Grusha and Patterson 2005). Biofouling may further increase drag (Thorstad et al. 2001) and may directly affect fish health (Dicken et al. 2006). As such, intramuscular implantation (Brill et al. 1997, Musyl et al. 2003) has been employed in cases where intracoelomic implantation was deemed less desirable.

Initial dart-and-tether attachment (Treatment 6) employed the dart configuration that was used for attachment of PAT tags because this configuration has been proven effective. However, given that PAT tags weigh approximately eight times that of LAT 1800 tags, and presumably generate orders of magnitude higher drag force during swimming, it seems logical that high retention of LAT 1800 tags might be achieved using a considerably smaller dart. The darts used in the current study in Treatment 6 measured 63 mm x 12 mm, weighed 4.7 g in air, and were attached to the tags using 1.81 mm diameter (400 lb test) polyolefin-coated nylon monofilament line. The darts used in Treatments 7 and 9 (Fig. 2; upper image in each panel) measured 32 mm x 9 mm, and those used in Treatments 8 and 10 measured 22 mm in length with a maximum shaft diameter of 9 mm, "wingspan" of 19 mm (Fig. 2; lower image in each panel). These darts were attached to the tags using 1.17 mm diameter (150 lb test) polyolefin-coated monofilament. The LAT 1800fp tags applied in 2011 were attached using the same general protocol as in the earlier treatment: the dart was embedded through the fish's pterygiophores, roughly 4 cm (1.5 in) medial to the dorsal fin, on the eyed-side of the halibut where the body begins to taper towards the tail. For Treatments 7 and 8 the LAT 1800fp was employed, and was affixed externally to the fish on a leader measuring approximately 14 cm. Treatments 9 and 10 employed a much shorter leader (approximately 4 cm; Fig. 2B) that allowed the entire tag body to be inserted below the skin in the dorsal musculature.

This was achieved by first making a narrow incision in the skin and dorsal musculature using a sterile scalpel and then inserting the dart and tag along the axis of that incision. LAT 1800cl tags were used, and inserted so that their light stalks remained exposed after insertion. The incision was not sutured in order to test for healing and retention probability in the absence of additional surgical procedure. Two fish were tagged with each new dart treatment; tagged fish ranged from 66-101 cm FL.

## Results to date

Physical examination and behavioral observation of tagged fish has occurred at 0, 2, 5, 13, 22, 32, 44, 54, 69, 77, and 86 weeks following initial tagging. Treatments 1-4 and 6 were initiated at week 0; Treatment 5 was initiated at week 69; Treatments 7-10 were initiated at week 77. A check at week-106 will presumably have occurred by the time this volume goes to press, and monitoring is expected to continue at 12-16 week intervals throughout 2012. Two mortalities have occurred since the beginning of the post-tagging period: one fish had been internally implanted (Treatment 1) and died during week 6; one fish was an untagged control and died during week 48. In the case of the internally implanted individual, it had experienced complete suture failure shortly after implantation; all stitches had torn from one or both margins of the incision as a result of considerable abdominal distension associated with heavy feeding. Because of this, its intestines were visible, and sometimes extruded through the gaping incision when fully fed. This fish's incision had been closed using only three stitches, a procedure now deemed unacceptable, given that no suture loss has been observed in any individual where four or five stitches were used. The cause of mortality of the untagged control fish was not apparent.

Persistent irritation and/or open tagging wounds have been observed for all through-body dorsal (Treatments 1 & 2) and opercular (Treatments 3 & 4) attachment configurations. Tag shedding has been observed for both of the through-body dorsal methods (i.e., with a cradle and direct-to-body) and for perpendicular opercular attachment. Given that the cradle-mounted configuration represents one that we do not expect to employ again *in situ*, Treatment 2 was terminated at week 77; the tags were removed from those individuals that still bore them (n = 2) in order to allow the fish to heal sufficiently to be double-tagged with geomagnetic-sensing tags (see Loher and Nielsen, this volume) in 2012. No obvious behavioral differences have been noted between treatment groups; behavioral data will be statistically analyzed at the end of the experiment.

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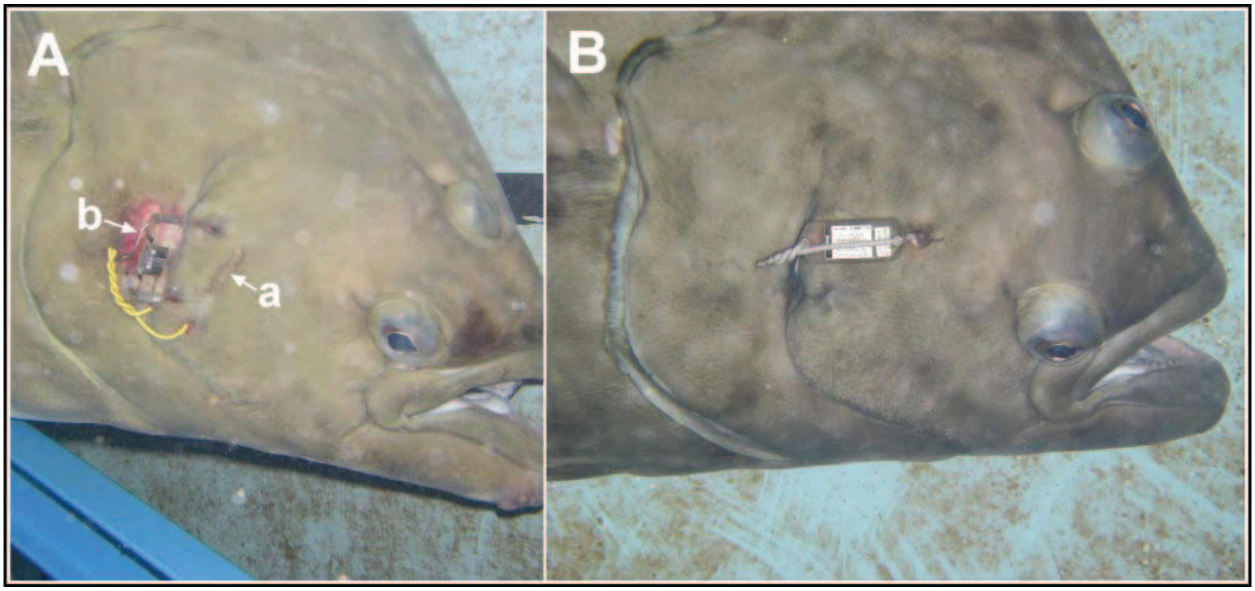


**Figure 1. Attachment of dummy archival tags to the operculum of Pacific halibut in an orientation perpendicular (A) and parallel (i.e., longitudinal) (B) to the fish's main axis. With respect to the former, note that the tag has rotated posteriorly; it originally rested on the preopercular bone (a), but has tipped 90 degrees, such that the side of the tag is facing up, and is presently resting on the opercular, where its motion upon swimming is causing persistant inflamation (b). Note, also, that (A) was taken 44 weeks after tag attachment, whereas (B) was taken after only 12.**

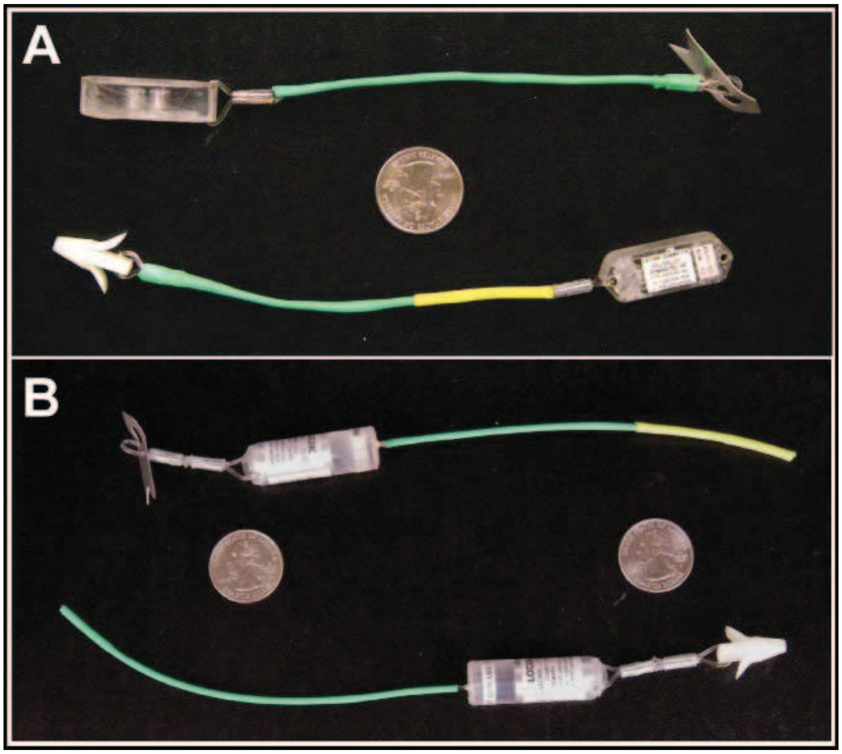


**Figure 2. New dart-and-tether configurations added to the holding experiment in 2011. Two small dart models were used: a thin stainless steel dart (upper image in each panel), similar to the original dart tested, and a plastic "winged" dart (lower image in each panel) originally designed for intramuscular implantation in billfishes. A long leader-length was employed (A) where the tag was to remain external to the fish, and a shortened configuration (B) where the intent was to "bury" the tag intramuscularly. In both cases, the dart was inserted through the fish's pterygiophores so that it was anchored by bone, not muscle.**