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Development of deployment and retrieval protocols for Passive Integrated Transponder (PIT) tags: Application to Pacific halibut (*Hippoglossus stenolepis*)

by

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Contents

Abstract

In 2001, a tagging program for Pacific halibut, *Hippoglossus stenolepis*, utilizing Passive Integrated Transponder (PIT) tags, was developed by the International Pacific Halibut Commission. The program's primary goal was to generate a stock-size estimate that was independent of the stock assessment. Primary tasks during program development included determining an appropriate tagging location and tagging methods, developing a data capture system to record tag release information, and establishing a protocol for scanning commercially caught halibut at fish buying stations. Experiments were conducted to estimate tag shedding and tag detection rate, as well as to monitor the performance of field staff conducting the scanning. This report details the development of the PIT tagging and scanning protocols, and describes the final program.

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Introduction

The Passive Integrated Transponder (PIT) tagging program was initiated by the International Pacific Halibut Commission (IPHC) to develop an estimate of the abundance of Pacific halibut that was independent of the stock assessment for the major resource areas off Canada and Alaska. Although mark and recapture type estimators generated from tagging studies have long been considered useful for this purpose, difficulty in estimating rates of tag loss and tag reporting likely introduces significant bias into estimation using external tagging (Trumble et al. 1990). The availability of PIT tags provided IPHC a new approach to stock estimation. The tags are implanted subcutaneously, thus leaving no external markings indicating the tag presence and avoiding the recurring problems of estimating the tag reporting rate observed in earlier tagging studies.

The National Marine Fisheries Service (NMFS) and the Bonneville Power Administration (BPA) established a cooperative program in 1983 to evaluate the technical and biological feasibility of the PIT tag (Prentice et al. 1993) for monitoring the movement of juvenile and adult salmonids in the Columbia River Basin[1]. This early effort has now evolved into a major research tool in the Columbia River Basin under the BPA program. Over twenty million fish have been tagged and monitored since 1987. PIT tags are now used in many non-salmonid applications, including other fisheries, animal behavior studies, and personnel or product tracking applications (Davis et al. 2008).

The PIT tag transmits a unique code to an external reader, where it is displayed in a numeric or alphanumeric form. The tag has no internal battery, hence the term “passive”. The reader powers (energizes) the tag circuitry by radio frequency induction and receives the code back from the tag. During manufacture, the PIT tag is coded with one of 35 billion unique codes. PIT tags now come in a variety of sizes and even shapes; those injected into fish are generally very small, about 10 mm long and 2 mm in diameter (Davis et al. 2008). The tag is inserted with a hypodermic needle into the body or body cavity.

Objectives and goals

The original goals of the PIT tag experiment were laid out by Leaman et al. (2003) as providing, in the short term, a direct estimate of halibut abundance, and in the longer term, estimates of the rates of mixing of larger fish among regulatory areas. The halibut abundance

[1] http://www.psmfc.org/pittag/Overview/index.html

estimate would be obtained through determining the commercial fishery exploitation rate independently from the stock assessment model. This differs from past IPHC tagging studies, which have focused on migration, growth, or survival rates. Inherent in the experimental design was the need to tag or detect tagged fish both efficiently and with a high probability of detection success. Thus, procedures and protocols were to be developed to allow tagging of a large number of halibut, perhaps as many as 50,000 fish, using the IPHC stock assessment survey as a tagging platform. Further, tags were to be released in proportion to the abundance of halibut in each area.

Secondary objectives of the PIT tagging program included gaining information on migration rates and growth. Since tagging would occur throughout the species' range, the estimation of multidirectional movement patterns should be possible. Migration by size was to be determined either by initial size alone (i.e., data gathered when the fish is tagged), or through knowledge of both initial and recapture size, when whole fish were sampled. The study would also generate growth information from those tags recovered from whole fish, rather than from heads only.

Project timeline

Development of the experiment began in the spring of 2001. The first general tagging was conducted in 2003. During the 24-month development period from inception until first tagging, the project progressed through tag and equipment selection, development of a tagging protocol, refining and implementing the tagging and tag scanning procedures, and external technical review of the design of the tagging experiment. Tag scanning was expected to start during the first year of tagging, and to continue for an additional three to five years.

Program elements

The PIT tagging program included a number of elements which needed to be coordinated into tagging and tag recovery protocols. These included determining a tag type and vendor, a location for tag insertion, the tag insertion methodology, equipment and procedures for recording and archiving fish and tag information during the tagging process, and a methodology for tag data recovery. Determining the proper tag location and development of the ensuing tagging protocol was an iterative process, with early failures pointing the way toward later successes. Key to the development of the tag release methodology were live holding studies to determine tag-induced mortality, shedding rates for tagging at various body locations, and tagging procedures. Similarly, the procedures for detecting tags at fish buying stations as halibut that were sold had to be proofed to determine detection rates.

After presentation of the decisions regarding tag choice and vendor selection, the topics of tagging location and tag shedding are presented in a chronological manner.

Tagging and scanning density

Preliminary modeling work by IPHC staff determined the relationship between numbers of fish tagged and percentage of landed fish that would need to be scanned in order to obtain a statistically significant amount of data needed for analysis. This resulted in the scenario that releasing 50,000 tags, with assumed tag shedding rate of around two percent and tag detection efficiency for scanned fish of around 99%, would require that about 25% of the fish landed (in terms of weight) from each regulatory area would need to be scanned.

A review of previous catches on the IPHC's annual stock assessment survey (Dykstra et al. 2004) suggested that tagging all fish on three skates on each survey station would result in close to our goal of 50,000 releases. Since all the fish from a fixed proportion of gear at each station would be tagged, the tagging would be roughly proportional to fish abundance. To accommodate the PIT tagging, the survey program was modified, increasing the number of skates fished at each station by three, and reducing the number of stations which could be fished daily from a maximum of four down to three (Dykstra et al 2003).

Similarly, a review of landings by regulatory area and port was used to determine which ports to staff with portside samplers in order to scan 25% of halibut landed by regulatory area.

Tag and vendor selection

A literature and internet search in 2001 identified major manufacturers of PIT tags and their products. These PIT tag manufacturers, or their representatives, were contacted to evaluate the capabilities and operating characteristics of their tags and tag detectors. Among the aspects considered were tag size, detection range, longevity, cost, and possible delivery schedules. For detection apparatus, considerations included type (portable vs. semi-permanent), information capacity, display characteristics, range, power sources, and cost. General considerations included history in fisheries applications, company presence in the north Pacific region, and the degree of expected product support. Recommendations were also solicited from present and past users. Major tags investigated included those supplied by Biomark[2] (as agent for Destron Fearing, later renamed Digital Angel Corporation[3]), Intersoft[4], AVID[5], and Texas Instruments Incorporated[6]. Other potential suppliers were not considered due to a lack of regional representation. Staff also attended a field demonstration by two vendors.

The final decision was to use a glass-encapsulated PIT tag produced by Destron Fearing and supplied by Biomark (Fig. 1), product code TX1400BE. This tag was 11.5 mm x 2 mm in size, and operated on a newer 134.2 kHz frequency. Optimal read range was described as 7 to 30 cm. In 2003, and prior to the first releases of the broad scale tagging experiment, the tags changed to the TX1400ST model, also supplied by Biomark. With the same dimensions and pricing as the TX1400BE tags, but with a slightly greater read range, the ST version replaced the BE tag in the Destron line.

Tagging platform, tag insertion equipment, and shipboard scanning hardware

For the final large scale tag releases, tags were released from chartered IPHC grid survey vessels. These vessels were supplied with a recording shack (approximately 36”by 38”by 74” high) with an attached measuring cradle. These shacks were further supplied with 110 volt power for the tag readers. For all the tag protocols, tags were inserted using a 10-ml syringe fitted with a 1-1/2 inch, 12-gauge hypodermic needle (Fig. 1). The hypodermic assembly has a push rod that runs through the center of the needle. The length of the rod was such that when the needle plunger was fully depressed, the rod just reached the end of the needle. The tag was slipped into the end of the needle, the needle was inserted into the fish, and the plunger was depressed as the needle was withdrawn. This left the tag in the space occupied by the end of the needle. After briefly investigating a number of glues to help hold the tag in place, the IPHC settled on using plastic ‘Bio-Bond’ sleeves also sold by Destron. The Bio-Bond sleeve is a porous polymer sheath that slips onto the end of the tag; the sleeve promotes the development of fibrocytes and collagen fibers around the implant, thus inhibiting movement of the implant within the animal. The sleeve might also have reduced the possibility of the tag slipping back out of the insertion hole in the short term, by making the tag larger at the leading end.

The first scanner investigated by the IPHC was the Destron Fearing FS2001 Portable Transceiver System[7] (denoted as the Destron reader) The Destron reader consists of a transceiver unit with an internal battery that connects to an antenna. Its dimensions are 24 cm x 11 cm x 8

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[2] Biomark, Inc., 7615 West Riverside Drive, Boise, ID 83714, USA

[3] Digital Angel Corporation, 490 Villaume Avenue, South St. Paul MN 55075, USA

[4] Intersoft, 205 Research Park Dr. Tullahoma, TN 37388, USA

[5] AVID, 3179 Hamner Ave., Suite 5, Norco, CA 91760, USA

[6] Texas Instruments Incorporated, 12500 TI Boulevard, Dallas, TX 75243, USA

[7] Destron Fearing Corp., supplied by Biomark, Inc. (see footnote 2)

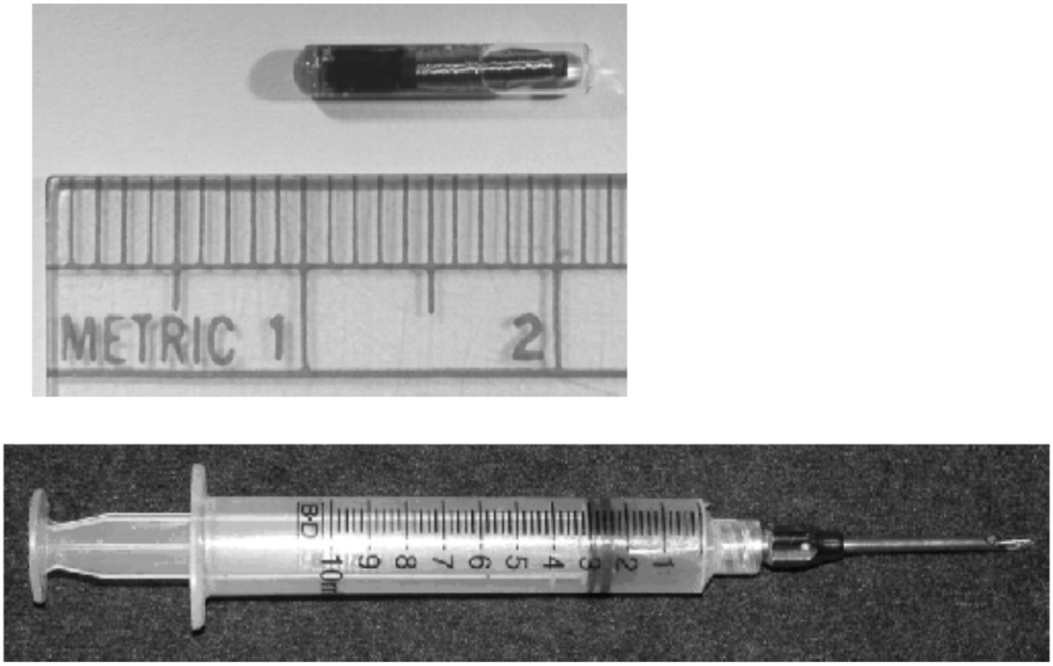

Figure 1. PIT tagging gear: PIT tag (top) and tag injection syringe and needle (bottom).

cm and, with the attached antenna, weighs 2.7 kg. As a portable unit, it is powered by an internal, rechargeable, 12-volt nickel metal hydride battery. Its detection range is about 15 cm, and has a unit cost exceeding $2000 USD.

In 2002, tag detection equipment marketed by Allflex-USA[8] was evaluated, and the Allflex ISO RFID RS250-45 stick reader with a unit cost of $360 was found to be appropriate for tag scanning at sea and streaming the tag number to a PDA. The Allflex stick reader is a 60 cm by 3.2 cm tube weighing 0.6 kg, including its connection cable. It operates on 12-volt DC, supplied though a provided transformer, and has a read range on the order of 20 cm. While designed primarily for cattle and veterinary operations, the ruggedness, simplicity, and lower price of the Allflex stick reader, combined with the known tag location in this project, resulted in the selection of this equipment. While undeniably more sensitive, and more appropriate in situations where either the tag location is unknown, or the tags are intended to be automatically read, the high cost and operational characteristics of the units marketed by Destron, Inc. made these units less suitable for the IPHC operation (Forsberg 2003, Hauser 2003).

Tag location criteria

Potential tagging locations were evaluated in terms of tag size, ease of application and detection, as well as general location on the fish. Tag locations and tagging protocols also took into consideration the maximum or minimum sizes of fish that could be tagged, which depended on either the physical dimensions of the chosen tag or the desired tag location on the fish. Given that the tags would be released on IPHC's assessment survey which uses setline gear that is selective for larger halibut, a fork length of 50 cm was assumed to be the practical minimum size.

[8] Allflex-USA, 2820 Wilderness Place, Suite A, Boulder, CO 80301

Early in 2001, IPHC staff decided that PIT tags would be implanted in the head to facilitate recovery during commercial landings, since heads are generally removed at landing and are often available for sampling for longer periods than the bodies of the fish. Although it was likely that some fish would be scanned for tags prior to heading, the ability to scan heads after heading would greatly increase the recovery rate. Tag locations were evaluated against the following criteria:

1. The location should allow the tag to stay with the head after heading;
2. The tag should not be subject to damage or loss resulting from hooking, landing, hook removal (either manual or automated), or cheeking procedures;
3. The tag should not be subject to damage from stunning as the fish is captured;
4. The tag should have a low shedding rate from the tagging location;
5. There should be minimal fish mortality resulting from the tagging; and
6. The tag would not be in a location where it might be encountered by consumers.

Criterion 2 ruled out any location in the inner jaw or cheek areas, since these are often torn during hooking and hook stripping. Criterion 6 further ruled out the cheek since this is a food product. Areas considered included near the tail, beside the eye, and the site eventually chosen: under the skin along the jaw.

Tag site evaluation included tag durability and shedding studies, as well as scan detection experiments, with particular emphasis on tag retention in the head during the heading process.

Tag durability studies

A major concern with a tag location in the head was the potential for tag destruction caused by the standard industry handling of halibut once aboard the vessel. Immediately after being brought aboard, halibut are typically stunned by a blow to the head, using a club made from wood or other hard material. The concern was that a blow on or near the implanted tag could potentially crack the tag's glass case, disabling it. This potential vulnerability was examined in a small demonstration experiment conducted on six heads which had been collected after heading at a fish plant. Tags were inserted into the heads just above the eye. Following tagging, the heads were repeatedly hit with a wooden club to simulate the stunning practice. The tags were scanned immediately after clubbing to verify tag operation and no loss of tag function was observed. This test was repeated a month later using a different batch of tags, with the same results. The tags were subsequently placed in a refrigerator for six days, and continued to show no loss of tag function.

From 1-3 August 2001, two hundred and eighty-one halibut were released with both an external wire tag and an internal PIT tag. The wire spaghetti tags were constructed of polyethylene tubes covering nickel-silver wire. Each tube was printed with the words "IPHC XXXX", where "XXXX" represented a unique number. Spaghetti tags were applied by first inserting the tag into the shank of a hollow applicator needle. The needle was then inserted between the pre-opercular and the opercular bone of the cheek on the dark side of the fish at an angle, which permitted the needle to pass between the two bones. The curvature of the needle caused it to pass around the pre-opercular bone and come out through the cheek. The tag was pulled through the opening created by the needle, the needle removed from the tag, and the two ends of the tag folded together and twisted so a closed loop was created around the pre-opercular bone (Myhre 1966). The PIT tag was inserted in the dorsal flesh just above the eye. The tagged fish were held overnight with no tag shedding during the first 18 hours after tagging. Wording on the wire tag requested that the heads be returned to IPHC's port-based, commercial fishery samplers, or port samplers, and a $100 USD reward was offered for tags returned with the head. Although this tagging location was not the site ultimately selected for the coastwide releases, the recoveries of these tags gave an indication of tag durability. By the time coastwide tagging started in 2003, fourteen fish had been recovered from this experiment. Time at liberty for these 14 fish ranged from 251 to 417 days. Fork length at release ranged from 98 to 110 cm. All fish were recovered by hook and line gear in depths ranging from 35 to 185 fathoms. All of the 14 PIT tags scanned properly when tested after recovery. In all cases, the fish were at liberty over the spawning period and it is likely that at least some of the fish experienced the deep depths associated with spawning.

The potential effects of depth, pressure, and low temperature were also examined in separate small studies. In April 2002, the Alaska Department of Fish and Game (ADF&G) dropped nine PIT tags to a depth of 500 fathoms (914 m) for six hours, with all tags functioning upon recovery (D. Carlisle, ADF&G, P.O. Box 115526 1255 W. 8th Street *Juneau*, AK 9981, personal communication). In June 2002, two pressure tests were performed by IPHC staff from the chartered vessel *F/V Pacific Sun*. Fifty tags were placed loose inside a PVC container in which small holes had been drilled to allow for water intrusion. The container was attached to an anchor and dropped to a depth of 370 fathoms (677 m). The anchor was retrieved after a 10-hour soak, but had drifted into a shallower depth than desired (280 fathoms, 512 m). Upon retrieval, all tags were functional. This test was repeated several days later, but in this instance, the tags were placed into a plastic, resealable bag before being placed inside the PVC container to facilitate tag removal. The anchor with attached container was set in 440 fathoms (805 m). After nearly 12 hours at depth, the anchor was retrieved, and all tags were found to be fully functional.

Long-term holding facility

During February and March of 2001, a survey of sites that might be suitable to house a long-term tag shedding study was conducted. The main criteria in this search were cost, proximity to collection grounds, and seawater supply suitability. Only sites that would be able to hold halibut in shore-side tanks, as opposed to fish-farm type floating pens, were considered. Eight possible sites were identified and contacted (Table 1). Of the facilities that expressed interest,

Table 1. Shore facilities considered for tag shedding project.

Facility	Interested in project?	Comments
Hatfield Marine Science Center Newport, OR	No	Facility has no space. In the past they had trouble holding 60-100 cm fish, mostly disease problems. They currently have 65 halibut, about 10 cm in size.
Marrowstone Field Station (USGS, BSD) Port Townsend, WA	No	Most halibut tanks are disassembled and removed. A large experiment starting 2001? will use all the facility.
Manchester (NOAA, NMFS) Manchester, WA	No	Have 4 20’ diameter tanks with 60 adult fish. No additional room, but we were invited to tag their existing fish.
West Vancouver Lab (DFO) West Van, B.C.	No	Use uncooled water from Burrard Inlet, with salinity and temperature swings through the year.
Bamfield Marine Station Bamfield, B.C.	Yes	Unfiltered water, 80’ intake, 8-10˚C, 30-32 ppm. Could accommodate above ground tanks
Alaska Sealife Center Seward, AK	?	Indications were that facility would be very expensive
Seward Marine Center (UofA) Seward, AK Seward, AK	Yes	Water from Resurrection Bay, 80’ intake. Good water quality. Indoor room for up to four 12’ tanks.
Kodiak Fisheries Research Center (NMFS) Kodiak, AK	Yes	Very interested, would have erected outdoor tank for us; temperature swings in water supply.

the Seward Marine Center (SMC) was chosen. The Seward Marine Center, an outstation of the University of Alaska, had a good seawater supply, was close to areas for fish collection, and had indoor space for aboveground tanks. The Center staff were contracted to care for the fish, as well as to provide help in periodic tag scanning. As part of the Commission's contract with SMC, holding tanks were purchased and became the property of the SMC at the conclusion of the Commission's experiments. Four 12-foot diameter tanks and as many as six 4-foot diameter tanks were available for the study. These indoor tanks were supplied with seawater from an 80-foot deep intake in Resurrection Bay.

The SMC was contracted for two holding projects in 2001; the first in May and the second in November. The plan was to catch and tag approximately 100 halibut, and then hold those fish for four to six months to verify tag retention over that period. Initial results suggested that shedding rates were quite low, likely less than three percent. Initial testing of a location above the eye and ahead of the dorsal fin proved promising, but concerns about losing the tag during machine heading led to testing a site just ahead of the opercular groove.

Tag shedding studies - short and long term

An important component of any tag release and recovery program is understanding tag loss through loss after release ("tag shedding"), mortality of the tagged fish, or loss of tag function. The tag shedding study was designed with two components. The first component was to ensure potential tag locations had minimal tag loss. The second major study component was to develop a tag detection methodology for use in fish plants to detect tags as they were delivered and sold by commercial fishers. Most of 2001 was spent on the first component of the study. Determining a tag location involved three vessel charters, as well as a number of special projects conducted during existing stock assessment charters. During the course of these experiments, a number of tagging locations were considered, based on criteria described in the previous section.

For phase two, three plant detection studies were conducted to develop a protocol for PIT tag detection at point of sale. Complicating these operations, there was a steep learning curve to understanding the operational characteristics of the scanning apparatus inside fish plants, and earlier trips were plagued with battery and detection field problems with the scanners. These problems were resolved with more appropriate settings within the scanner (to increase the local detection field and to increase battery life), avoidance of other electrical equipment in plants, and a better understanding of the charging units for the scanners. The 2001 field season ended with a viable location for tag insertion, and with a working understanding of the procedures necessary for accurate detection of PIT tags in landed Pacific halibut.

It was not until April of 2002 that the final tagging location was developed; on top of the interopercular plate and just below the opercular groove. As the tagging location and procedures were being developed, hardware and software choices for data capture were also being made, and procedures were being refined to ensure that they could be applied by the much larger group of staff which would be implementing the tagging program from a variety of tagging platforms, and under a myriad of conditions. Tag shedding studies continued in 2002, and ended in 2003 with a double-tagging experiment intended to test *in situ* the retention and durability of PIT tags placed in Pacific halibut using the most recent tagging protocol.

A summary of all the tag shedding projects is shown in Table 2 and abbreviated project summaries follow. Detailed descriptions of each project may be found in Kaimmer and Geernaert (2002, 2003). In the tag shedding studies described below, many of the procedures were common to all. During tag insertion, the needle plunger was depressed as the needle was withdrawn, leaving the tag in place. The scanner was used after insertion to ensure that the tag was in place, and operating. The tagging, scanning, and recording equipment were easily incorporated into the survey shack on the chartered vessels and the tagging presented no problem with record keeping.

Table 2. Summary of live holding experiments conducted in 2001 and 2002 to determine PIT tag shedding rates in Pacific halibut.

Collection vessel code and trip	Start	End	Holding duration (days)	Number held	Number shed	% shed/ held	Tag location
HOT01-1	22-May	19-Jul	58[1]	44	0	0%	[2]dorsal muscle
HOT01-1	23-May	19-Jul	57	117	0	0%	[3]dorsal with glue
Manchester	tagged June 18	scanned June 22	6	11	1	9%	dorsal with bio-bond sleeve
Manchester	tagged June 22	scanned June 26	4	35	3	9%	dorsal with silicone glue and bio-bond sleeve
FTW01-7	1-Aug	2-Aug	*18 hrs*[2]	93	0	0%	Ant. Eye with bio-bond sleeve[3]
FTW01-7	2-Aug	3-Aug	*18 hrs*	100	0	0%	Ant. eye
FTW01-7	3-Aug	4-Aug	*18 hrs*	100	0	0%	Ant. eye
FTW01-11	29-Aug	30-Aug	*18 hrs*	80	3	4%	ahead of opercular groove
FTW01-11	30-Aug	31-Aug	*18 hrs*	123	0	0%	ahead of opercular groove
RSR01-1	12-Oct	19-Feb	129	78	4	5%	ahead of opercular groove
HOT02-01	8-Apr	9-Apr	*18 hrs*[4]	30 cheek 30 tongue 30 operc	1 cheek 0 tongue 0 operc	operc= 0%	operc= interopercular plate
HOT02-01	10-Apr	17-May	37[5]	40 tongue 40 operc	1 tail only	operc= 0%	operc= interopercular plate
HOT02-02	19-May	12-Aug	84	80	3	4%	interopercular plate
FTW02-08	12-Aug	2-Dec	110	78	1	1%	interopercular plate

[1]Lost 11 tags in 24 hours between capture and delivery
[2]Mixed treatment.; Nexaband, Vetbond, superglue, and no glue, this and all subsequent holdings include BioBond sleeve
[3]All subsequent tags were emplaced with the bio-bond sleeve
[4]Plus tail tag in each fish, no shedding of tail tags was observed
[5]Plus tail tag in each fish

In all studies, fish were scanned at the point of delivery, prior to being placed in the holding tanks. For longer-term shore holding, fish were scanned *in situ* at about two-week intervals to verify tag retention and function.

May-July 2001: 58-day shedding study

In May 2001, live halibut were brought to the SMC by the chartered longliner *F/V Hotspur*. The tagging protocol to be tested involved inserting the tagging needle just ahead of the anterior end of the dorsal fin, to penetrate as far as possible through the dorsal musculature to the area above, and as close as possible to the eye. The first trip collected and delivered 44 fish on May 22 (Table 3). There was a very high (27%) short-term shedding rate on the first delivery. The

Table 3. 2001 Short-term tag shedding from capture on *F/V Hotspur* to delivery 12-24 hours later to Seward Marine Center.

Tagging Date	Tank Date	Tagger	Shed at delivery Yes	No	Grand Total	% Shedding Rate
May 22	May 22	#1	12	32	44	27%
May 23	May 24	#1[1]	2	69	71	3%
May 23	May 24	#2[1]	5	41	46	11%
	May 24 total		7	110	117	6%

[1]super-glue gel inserted after tag injection

second trip delivered 117 halibut on May 24. On this trip, "Super Glue gel[9]" was used to seal the injection hole after tag insertion. Seven tags had shed from the 117 fish at the time of delivery and these fish were released.

No additional tag loss was seen in any of the halibut once they were put into the holding tanks. This suggested that the injection path healed quite quickly, and that if the short-term tag shedding problem could be solved, the shedding rate might be near zero percent. Unfortunately, facility problems on July 19 resulted in the loss of all of the fish. The use of glues seemed promising in reducing short-term tag loss, although there were possible complications from using glue in food products.

June 2001: 4-day shedding study, bio-glues, and tag retention sleeves

To further develop the tagging method, 42 fish were tagged at a NMFS facility in Washington State. Silicon glue was used on these fish, as well as the anti-migration 'Bio-Bond' sleeve. A longer push rod in the insertion needle was also tried, so that when fully extended, the rod tip would be about 0.3 cm beyond the end of the needle. The rod was also given a 45 degree angle at the end. With this setup, when the needle is inserted and the plunger is fully depressed, the tag is pushed entirely out of the needle, and ideally given a 'tumble' by the angle on the push rod as the tag is moved beyond the end of the needle, possibly moving the tag out of alignment with the insertion channel. Tags were inserted posterior of the dorsal eye, to lie in muscle tissue just ahead of and above the eye. One group of fish was tagged with the Bio-Bond sleeve only, while another group was tagged with sleeves and glue. Scanning results are shown in Table 4. High short-term shedding rates were seen with both treatment types, leading us to search for a different tag protocol.

Table 4. 2001 Results from tagging at Manchester, WA.

Tank	Number tagged	Tagging protocol	Tags re-tained	Shedding rate (%)
1	11	Sleeve only	10	9.1
2	12	Sleeve + silicone	11	8.3
3	12	Sleeve + silicone	11	8.3
4	11	Sleeve + silicone	10	9.1
Total	46		42	8.7

August 2001: Overnight shedding and double-tag releases

To evaluate a modified tag insertion protocol, the *F/V Free To Wander* was chartered to capture and conduct short-term holding. Fish were caught on setline gear, held overnight for

[9] Super Glue gel, Super Glue Corp. USA

12 or more hours in a flooded fish hold aboard the vessel, retrieved individually, scanned to verify PIT tag retention and operation, and released. The tests were continued comparing the Super Glue gel with NexaBand and VetBond glues, using the relatively inexpensive Bio-Bond sleeves with all glues.

Fish were tagged just above the dorsal eye. The shorter needle rods were used, depressing the plunger as the needle was withdrawn, leaving the tag in the space created by the end of the needle. The first day, three groups of halibut were tagged: 25 with no glue, 25 using Nexaband glue, and 25 using VetBond glue (Table 5). None of these tags had shed by the next day, and the fish were released. On the second day, 100 halibut were tagged without glue. None of these tags had shed by the next day. On the third day, 100 more fish were tagged with no glue, and none of these tags shed during overnight holding.

Halibut which had retained their tags shipboard were released with a neon green wire spaghetti tag for recovery by sport or commercial fishers, for verification of the longer-term operation of PIT tags. Tag posters were distributed to nearby fishing ports offering a $100 reward for returns of these externally tagged fish.

Table 5. 2001 Short-term tag shedding results from first *F/V Free to Wander* trip. All tag shedding was determined within 24 hours of tagging, and fish were released with green external tag.

Date[1]	Glue treatment	Tagger #	Number of fish tagged	Tags shed	Live releases
August 1	Nexaband	1	25	0	25
August 1	VetBond	1	25	0	25
August 1	SuperGlue Gel	1	18	0	18
August 1	No Glue	1	25	0	25
August 2	No Glue	1	100	0	96[2]
August 3	No Glue	1	20	0	20
August 3	No Glue	2	80	0	78[3]
	Total		293		287

[1]All halibut were caught in Prince William Sound. August 1 and 2 releases occurred in Prince William Sound. August 3 releases occurred in Resurrection Bay.
[2]four of the tags placed on August 1 would not scan on August 2. Tags had not shed and were inoperable. Tags were removed and saved for evaluation.
[3]Two fish died while being held in the shipboard tanks. They had become wedged under a circulation pipe.

As a secondary objective, 27 dressed halibut were marked with surveyor's flagging tape and tagged with a PIT tag after dressing. These fish were then clubbed in the area of the PIT tag (to simulate stunning). When the fish were delivered, the marked fish were scanned before and after heading to both verify PIT tag operation subsequent to the stunning, and evaluate tag retention during the heading process. All tags were easily detectable. After mechanical heading, the heads passed through a metal detector which is intended to find and eject heads with hooks or hook pieces prior to head grinding and disposal. The metal detector ejected 24 of the 27 marked heads. Examination of the other three marked heads revealed that the heading process cut through one of the PIT tags, and cut so close to the eye on the other two that the tags were left in the body, rather than with the head.

Due to the lack of success using glues, no glue was used in any of the subsequent tagging trials. The Bio-Bond sleeves, however, were determined to be an inexpensive aid to tag retention, and were incorporated into all further tag trials, as well as the final protocol.

August 2001: Overnight tag shedding

Because of the tag loss observed from the dorsal eye site when fish were headed, the area just ahead of the opercular groove was tested as a possible tag location (Fig. 2). Tagged fish were held overnight on the *F/V Free To Wander*. Bio-Bond sleeves were used, with no glue. From an initial group of 80 fish, 77 tags were retained overnight. A second group of 124 fish had no overnight tag shedding (Table 6). A secondary project on this trip was to store randomly-tagged dead fish in the fish hold, and to then scan heads during offload as a demonstration of plant scanning. Only 148 of 174 fish tagged, or 85%, were identified during the scanning. Poor scanning results were likely due to poorly functioning scanners.

Table 6. 2001 Tag durability and detection results from second *F/V Free to Wander* trip.

Tagging date	Number tagged	Number shed	Shedding rate
Aug 29	80	3[1]	3.8 %
Aug 30	124	0	0 %

[1]Two of the shed tags were from very small halibut.

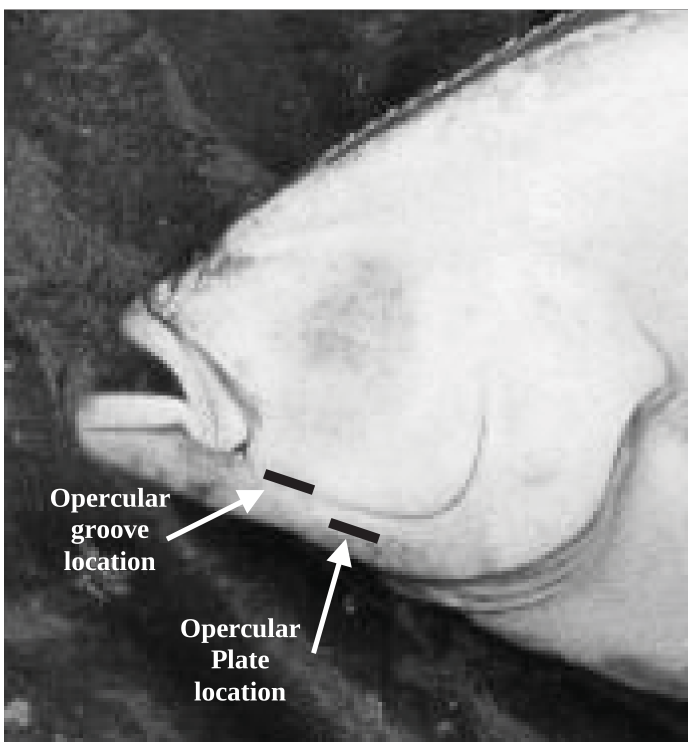

Figure 2. Showing PIT tag locations ahead of the opercular groove, used in 2001, and final protocol location, below the opercular groove, lying on top of the interopercular plate, first used in 2002.

October 2001- February 2002: Overnight and 129-day tag shedding

The SMC was again used for a longer-term shedding study, this time for the opercular groove location. The *F/V Resurrection* delivered 78 tagged fish and all tags were still in place after two weeks. After one month, 76 of the original 78 fish in the tanks had retained their PIT tags, and the tags were operational. By the end of 2001, three fish died from jumping out of the holding tanks, two from unknown causes, and 4 fish had shed tags (Table 7). An overall tag shedding rate of about 1-2% per month through the four-month holding period was observed (tags shed on days 15, 32, 70, and 92).

Table 7. Results of long-term (174-day) shedding experiment 13 October, 2001 - 19 February, 2002 at Seward Marine Center, Seward, AK. All fish were tagged forward of the opercular groove.

Tagging location	Opercular groove
Number tagged	78
Number shed	4
Shedding rate	5.1%

After the conclusion of the holding, halibut were dissected to evaluate tag retention. It was evident that the location ahead of the opercular groove was a highly active site, undergoing flexing as the jaw opened and closed. When the mouth opened by way of a dropping of the lower jaw, the pivot or hinge of the jaw moved backwards. The ‘groove’ between the plates actually expanded, particularly at the posterior end, allowing the interopercular plate to move down and back relative to rest of the head. This movement was the likely cause of the continued shedding of tags.

Staff believed that moving the tag so that it lay entirely on top of interopercular plate, out of the ‘active’ area, would make this a viable tagging protocol.

April - May 2002: Overnight and 37-day shedding, multiple tag sites

The *F/V Hotspur* collected 90 halibut which were tagged in the dorsal tail area just behind the caudal peduncle. While this violated the ‘tag in the head’ protocol, it was determined that this would be worth investigating due to earlier problems with the head location. In groups of 30, the fish were also tagged either in the skin just above the cheek, alongside the tongue, or on top of the interopercular plate, just below and posterior to the end of the opercular groove. This last site put the tags on top of the interopercular plate, between the plate and the skin. Overnight, only one cheek tag had shed, and all of the tail, tongue, and interopercular tags were still in place (Table 8). An additional 80 halibut were then collected and double-tagged each fish, with one tag in the tail and one in the interopercular plate region (Fig. 2). The distance from the insertion point to the tag is approximately 30 mm. These fish were delivered to the SMC and scanned *in situ* weekly. After 37 days of holding, none of the interopercular plate tags had shed, and one tail tag had shed (Table 9). A fair amount of movement was observed in the tail tags; some tags having moved almost to the area of the insertion hole.

May - August 2002: 84-day shedding study

The *F/V Hotspur* was again chartered to conduct interopercular plate tagging and then deliver the tagged fish to the SMC. Eighty fish were delivered and held for 84 days. No tags were shed during this holding period (Table 10). At the completion of the holding, a number of the

Table 8. Results of overnight shedding experiment 8-9 April, 2002 on *F/V Hotspur*. All fish were tagged twice, once in the tail and once in one of the other three areas.

Tagging location	Cheek	Tongue	Interopercular plate	Tail
Number tagged	30	30	30	90
Number shed	1	0	0	0
Shedding rate	3.3%	0%	0%	0%

Table 9. Results of long-term (37-day) shedding experiment 19 April - 17 May, 2002 at Seward Marine Center, Seward, AK. Each fish was double tagged, with one tag over the interopercular plate and one in the tail.

Tagging location	Tail	Interopercular plate
Number tagged	80	80
Number shed	1	0
Shedding rate	1.3%	0%

interopercular plate tags had moved closer to the insertion hole, although in all but three cases, the hole was healed so tags could not be passively lost. In three fish, the tags were poking out (1-2 mm of the tag visible) and probably would have shed eventually. Except for the three fish with extruded tags, all insertion holes were healed.

Of the 61 fish examined, only 11 tags had not moved from the target tag location. Tags in the other 50 fish had moved between 5 and 28 mm toward the insertion hole.

August – December 2002: 110-day shedding study

The *F/V Free To Wander* delivered 78 fish tagged on the interopercular plate to the SMC. At the end of a 110-day holding period only one tag had shed from this batch (Table 11). At this point, it was felt that we had a good tagging location, and a viable tagging protocol. Further studies described below fine-tuned the shipboard and plant procedures.

Grid tagging demonstration charters

The next step was the design and testing of the at-sea procedures for tagging. Several cruises took place during which the protocols were tested, revised, and further tested.

2002 tagging demonstration charter

This charter had multiple objectives, including testing the tag data capture hardware and software, and determining the effect of combining the PIT tag releases with the standard grid operation. The *F/V Pender Isle* was chartered to conduct up to five days of fishing in British Columbia, with each day's fishing mimicking as closely as possible the type of schedule which would be experienced on the combined grid-tagging operation. On each day, three 8-skate sets were laid out in the early morning. Sets were hauled after a minimum 5-hour soak time, and all viable halibut from the first three skates were tagged. All fish from the remaining five skates were handled according to the survey grid protocol, including the collection of otoliths and flesh samples. On four of the five days, the vessel fished survey stations in a manner that included the time effect of running between stations.

Table 10. Results of long-term (84-day) shedding experiment 20 May - 12 August, 2002 at Seward Marine Center, Seward, AK. All fish were tagged over the interopercular plate.

Interopercular plate tags	
Number tagged	80
Number alive at end of holding	60
Number shed	3[1]
Shedding rate	5.0%

[1]Although still carried by the fish, three tags were hanging from the insertion hole, and would likely have eventually shed. These are the three tags counted as 'shed'.

Table 11. Results of long-term shedding (110-day) experiment 14 August - 2 December, 2002 at Seward Marine Center, Seward, AK. All fish were tagged over the interopercular plate.

Interopercular plate tags	
Number tagged	78
Number shed	1
Shedding rate	1.3%

The *F/V Pender Isle* was a large vessel (74 feet) with lots of deck space. There was one main bin where fish were kept during hauling. There were two other bins available if fishing was heavy. A measuring cradle was mounted on the hatch of the vessel and was not connected to the shack, as is usual in standard deck set-ups.

While hauling the "tagging skates", one crewmember worked the roller and another was at the dressing table to pass fish to the IPHC sampler. The third sampler occasionally helped pass fish. The rollerman would land the fish in the bin. The crewmember would put the fish on the dressing table using a tail rope to give purchase and, when necessary, a block and tackle to provide lift. The tail rope was a useful tool for the medium-size fish (over 100 cm, 20 lbs.) – it provided a handle to help move the fish with minimal injury. A block and tackle was rigged to help move large fish (over 140 cm) onto the tagging table.

On the *F/V Pender Isle*, the cradle spanned the gap between two fore-and-aft raised hatches. It was approximately four feet from the outside edge of either hatch to the rail. A plywood board five feet long by two feet wide with no rails was used as a slide to return tagged fish gently to the sea.

Tag data was captured through the Allflex stick reader. Tag numbers were streamed through an RS-232 port to a handheld personal digital assistant (PDA) device manufactured by Casio USA[10].

The most dramatic effect of adding the three tagging skates to the existing five grid skates was in the time necessary to either set or haul the gear. The *F/V Pender Isle* fished tub gear, and re-baited the gear as it was hauled. Because of this, their haul times could be a bit longer than on vessels where the gear is merely hauled and coiled, but not baited. On the tagging skates, fish intended for tagging required careful handling by the crew, using a gaff only in the area under and between the jawbones. This careful handling by the crew, and the handling by IPHC staff to inspect and tag these fish, did not appear to make the hauling of tagging skates any more difficult or time-consuming than grid skates. However, extremely heavy fishing where the

[10] Casio America, Inc., 570 Mount Pleasant Ave, Dover, N.J., 07801

time required for landing large fish could make hauling tag skates slower was not encountered. Fifteen sets were completed during the charter, with starting and ending time recorded for each set. On three of the sets, the gear parted during the grid-skate portion, skewing the average hauling time for these skates. On 10 of the remaining 12 sets, the time was also recorded when the third skate was completed, and the operation switched to the grid fishing. For these 12 sets, the average time to haul a tagging skate was marginally greater than that to haul a grid skate (20 minutes versus 18 minutes).

2003 tagging demonstration charter

Early in 2003, a second tagging demonstration charter was conducted to evaluate the final IPHC tagging protocol and data capture apparatus in a simulated grid operation. Like the 2002 demonstration charter, the objectives for the 2003 charter included determining the effect of combining the PIT tag releases with the standard grid operation as well as examining the effect of the tagging on the working day length for the vessel, but focused primarily on testing the tag data capture hardware and software. The observations and results from the 2003 demonstration charter were instrumental in finalizing a field-tagging manual.

The *F/V Heritage* was chartered from 19-23 April to conduct five days of fishing off Kodiak, Alaska, with each day's fishing mimicking as closely as possible a typical day of combined research survey work and tagging. A total of 13 stations were fished: two each were completed on the first and last fishing days, and three each on the second, third, and fourth days. Each station consisted of an eight skate set, and all sets were laid out in the early morning. Sets were hauled after a minimum five-hour soak time, and all viable halibut from the first three skates were tagged. Fish from the remaining five skates were handled according to the survey grid protocol that included the collection of otoliths. On four of the five days, the vessel fished actual survey stations to assess the impact of the tagging on the day length and running time between stations.

The *F/V Heritage* is 68 feet long with ample deck space. The crew constructed a special aluminum tagging cradle that was mounted on the side of a plywood recording shack. This cradle was in addition to the one used for measuring the fish during the five grid skates. The tagging station and protocols were ultimately adopted for the survey work and are described in a subsequent section.

This experiment also tested the reliability of the electronics in a marine environment. More elaborate waterproofing was recommended for the Allflex stick reader as well as the handheld Allflex-Boulder ISO Compatible RFID Portable Reader, or "Boulder" also manufactured by Allflex-USA (described in a later section). The tag numbers read by the stick reader were streamed through an RS-232 port to a PDA device manufactured by Dell. This equipment and the on-screen programs both performed exceptionally well. The proximity of the vessel radar was also evaluated to see whether active radar had an effect on the data storage cards. It did not appear to.

For one entire day, tags were scanned with the Boulder scanner. Data were then read visually from the data screen on the Boulder and hand-entered onto special data forms. The purpose was to simulate a loss of the stick reader-PDA streaming capability. Although practical, using the Boulder scanner slowed the operation a great deal.

On the tagging skates, fish intended for tagging required careful handling by the crew, using a gaff only in the area under and between the jawbones. This careful handling by the crew, and the handling by IPHC staff to inspect and tag these fish, did not appear to make the hauling of tagging skates any more difficult or time-consuming than grid skates. Several heavy fishing days were experienced with daily catches ranging from 2,300 pounds to 7,600 pounds. Thirteen sets were completed during the charter and just over 24,000 pounds of halibut were dressed. These catch rates would be typical for a relatively normal charter trip and the conclusion was that, though more difficult than regular summer surveys, the PIT tagging project would not be too onerous on the vessel crews or IPHC staff.

September 2003: Double tagging

To test *in situ* the retention and durability of PIT tags using the most recent tagging protocol, a double tagging experiment was conducted in Area 2B using the *F/V Pender Isle*. A total of 2,661 halibut with both external wire spaghetti tags and internal PIT tags were released at three popular fishing grounds in Hecate Strait. Wire tags were inserted following the IPHC's standard wire tagging procedures described earlier in this document.

As an incentive for fishermen to keep tags attached, IPHC offered a double reward for these external tags when they were presented to an IPHC sampler while still attached to the head. Of 253 tags recovered by the end of the 2004 season, 247 of the heads had been examined (Table 12). Functioning PIT tags were scanned and recovered from 242 of these heads. Two heads would not scan, and broken tags were recovered from these heads. These breaks likely occurred during tagging. This gave a total of five tags shed for a shedding rate of 2.0%, about half that seen in the *in vitro* experiments. Combining the 2.1% shedding rate with the 0.8% breakage rate, the estimated tag loss rate was 2.8%

Table 12. Results at end of 2004 of double-tagging experiment with PIT tags placed on the interopercular plate.

Interopercular plate tags	
Number of double-tagged fish scanned	247
Number of tagged fish with retained PIT tag	242
Number of PIT tags shed	5
Number of PIT tags present but not working	2
PIT tag shedding rate	2.0%

Development of portside scanning protocols

Reliable and efficient portside detection of PIT tags in commercially caught halibut was critical to the IPHC PIT tagging program. Prior to the large-scale tag deployment in 2003, the IPHC had to be confident that tags could be detected during portside scanning operations and that scanning could be accomplished with minimal impact to commercial processors.

To address the objectives of the PIT tag experiment the following data were needed from the portside scanning program: scanning rates by regulatory area and the accompanying recovery rates of tags by release and recovery regulatory area. Individual vessel deliveries were the sampling units and the following data were required from each sampled delivery: vessel name and number, regulatory area fished, delivery date, delivery port, number of fish scanned, number of tags detected, and tag IDs of any tags detected. The number of seasonal portside samplers needed and their placement within ports to achieve the desired scanning rate by area were also established prior to the 2003 coastwide release.

Equipment selection

While IPHC staff were conducting pilot studies to identify optimal tag placement and data capture procedures, they were simultaneously evaluating two types of PIT tag readers: the handheld Allflex Boulder and the Destron reader (Tables 13 to 17, Fig. 3). A wand-style Coded Wire Tag (CWT) detector[11] (Fig. 3) was also tested as a tool for finding PIT tags; however the CWT detector only detects metal, so a PIT tag reader would also be required in order to read

[11] Handheld "Wand" Coded Wire Tag Detector, Northwest Marine Technology, Inc., P.O. Box 427 Shaw Island, Washington 98286, USA

the tag. Based on recommendations that came out of these tag reader comparisons, the Boulder reader was selected for portside scanning (Forsberg 2003, Hauser 2003). The Boulder reader weighs approximately 0.5 kg and can detect transponder fields ~5 cm from the reader face. As tags are detected, the Boulder both displays and stores tag numbers in a memory file. When a tag is detected, the unit's LCD screen illuminates and displays the tag number, and the unit beeps. The Boulder is not waterproof, so the units were enclosed in airtight, plastic, resealable freezer bags for use.

Scanning technique

According to the manufacturer, optimal tag readability occurs when the tag is perpendicular to the Boulder's antenna field. In order to optimize tag readability, halibut heads were scanned in three passes in a cross-like pattern so that the tag location was passed vertically twice and horizontally once, with the tag insertion site as the center point of the passes and the unit touching the head (Fig. 4). Speed at which the passes were made was also evaluated and it was determined that the tag needs to be in the reader field a minimum of two seconds to be detected. Faster passes resulted in missed tags during detection tests. The three-pass cross pattern scanning technique allowed for the tag site to be in the reader field for approximately two to three seconds, which was long enough for the reader to energize and read a tag.

Field studies in 2002 (Tables 14 and 15; Hauser 2003) indicated that a single sampler could scan 500 heads per hour using the three-pass cross pattern. The time required to scan whole fish was quite variable and depended on whether fish first had to be lifted out of a tote or just scanned as they passed by on a processing table.

In-field equipment tests

Procedures were also developed for monitoring the effectiveness of the equipment during portside scanning. Certain environmental or application factors may limit read range or increase the time it takes to display the code on the Boulder tag reader. Any electromagnetic field in the area (such as a running motor) or ferrous metal objects near the tag and/or reader may affect the read range. As well, the Boulder units were prone to various malfunctions, mainly due to battery issues and operating environment (temperature and humidity). For this reason, samplers were required to test the function of the Boulder reader by scanning a 'test tag' (a functional PIT tag embedded in plastic) at regular intervals while scanning a delivery of fish. The Boulder tag reader can run off an AC adapter or use four AA type batteries. Due to the environment where fish were scanned, AC power was impractical, so batteries were used to power the units. In 2003, samplers used rechargeable nickel-metal hydride (NiMH) batteries which were later determined to be linked to certain reader malfunctions. Samplers used alkaline batteries in the Boulders after the 2003 season. Cold temperature caused decreased battery life, reduced read range, problems with the LCD display, and complete shutdown of the reader. Other causes of reader failure included moisture, corrosion of components, and various 'hardware' problems (e.g. broken buttons, internal parts coming unsoldered). Samplers dealt with malfunctioning Boulders by carrying spare units. Once the reader stopped reading the test tag normally, or displayed any other problem, the sampler first tried removing/reinserting the batteries or replacing them with fresh batteries. If both those measures failed, the unit was replaced with another Boulder. Switching Boulders throughout a day was common practice, especially in busy ports (Forsberg 2005).

Table 13. Summary of studies used to develop portside scanning protocol and select portside tag detection equipment.

Experiment	Year conducted	Reader type	Results
Detection rate tests on fish seeded on survey vessel (two separate trips) and scanned after unloading and heading.	2001	Destron	85% detection rate: low rate combination of tag loss during heading (old tag site above dorsal eye) and equipment problems
Detection rate in seeded heads (seeded at plant); scan direction and duration tests (developing scan protocol); test of Destron reader as gate or plate scanner (passing heads over or through reader rather than passing the reader over the heads)	2002	Destron/ Boulder	100% detection with both reader types when reader is near tag for at least two seconds Plate/gate scanner not viable option—fish not in reader field long enough
Detection rate comparison between reader types; scan rate (number fish scanned per hour), and readers. Fish were seeded on five separate trips by survey vessels and scanned after unloading either as whole fish or heads. Scanning rate (number of fish scanned per hour) was also recorded.	2002	Destron/ Boulder/ CWT	No significant difference in detection rate between reader types or individuals doing the scanning. Scan rate varied depending on whether whole fish or heads were scanned. CWT eliminated due to need for additional equipment to read tags
Evaluation of readers for ease of use	2002	Destron/ Boulder	Boulder rated most user friendly

Figure 3. Portable PIT tag readers (left to right): Coded Wire Tag detector; Destron-Fearing antenna and transceiver (“Destron reader”); Allflex boulder reader.

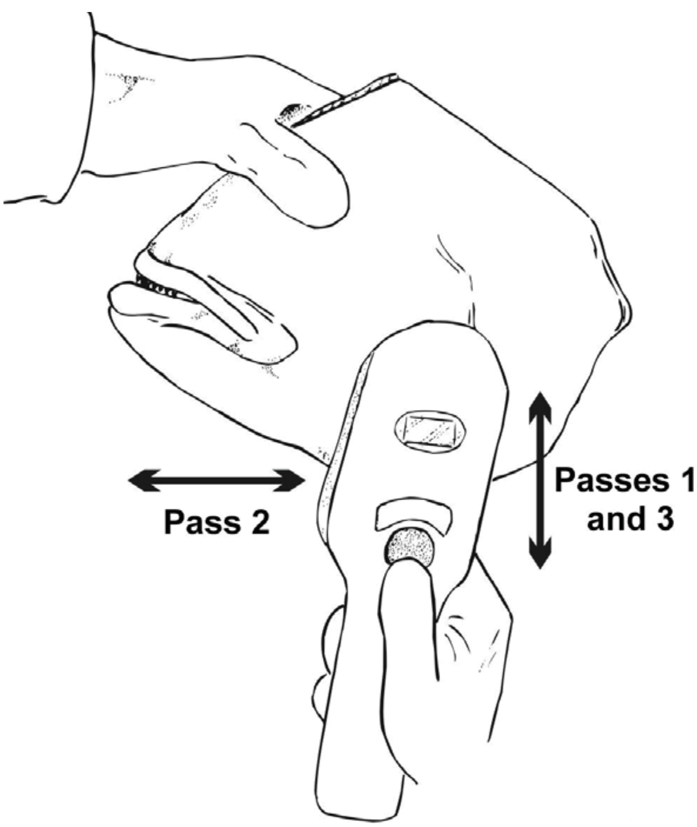

Figure 4. Standardized scanning technique using the Allflex Boulder reader. Scanning should be done in a cross-like pattern in three consecutive passes.

Table 14. Results of detection tests on heads sseded at fish processing plant during 2002.

Date	Reader	# tags seeded	% of seeded tags detected	Scanning rate (pcs/ hr)	Form	People working	Double tags
5/7/02	Destron[1]	10	90.0%	-	heads	2	-
5/7/02	Destron	10	100.0%	-	heads	2	-
5/7/02	Destron	10	100.0%	-	heads	2	-
5/7/02	Allflex	10	100.0%	-	heads	2	-
5/7/02	Allflex	10	100.0%	-	heads	2	-
5/7/02	Allflex	10	100.0%	-	heads	2	-
6/27/02	Allflex	8	100.0%	372[2]	heads	1	-
6/27/02	Allflex	8	100.0%	507	heads	1	-
6/27/02	Allflex	8	100.0%	465	heads	1	-
6/27/02	Destron	8	100.0%	496	heads	1	-
6/27/02	Destron	8	100.0%	429	heads	1	-
6/27/02	Destron	8	100.0%	559	heads	1	-
6/27/02	Destron	8	87.5%	595	heads	2	-
6/27/02	Destron	8	87.5%	549	heads	2	-
7/15/02	Allflex	8	87.5%	545	heads	2	-
7/15/02	Allflex	8	100.0%	750	heads	2	-
7/15/02	CWT	9	100.0%	600	heads	2	-
7/15/02	Destron	7	100.0%	600	heads	2	-
7/15/02	Destron	7	85.7%	857	heads	2	-

[1]First three Destron trials on 5/07 were conducted with 70% scanning power. Subsequent trials on that day for determining number of passes for reliable detection were conducted with 20% power. All later tests with Destron used 20% antenna power.
[2]Time error: Reader was damaged and fixed during test and time was added unintentionally; data excluded from scanning rate analyses

Table 15. Results of detection tests on seeded fish in IPHC survey deliveries during 2002.

Date	Reader	# tags seeded	% of seeded tags detected	Scanning rate (pcs/ hr)	Scanned as whole fish or heads?	People working	Double tags
7/2/02	Destron	65	96.9%	433	heads	2	5
7/10/02	Destron	60	100.0%	555	heads	1	-
7/24/02	CWT	66	98.5%[1]	360	whole	3	5
7/24/02	Destron	66	93.9%	152	whole	2	5
8/1/02	Allflex	65	101.5%[2]	422[2]	heads	1	5
8/1/02	CWT	65	100.0%	542	heads	1	5
8/1/02	Destron	65	92.3%	439	heads	1	5
8/10/02	Allflex	65	98.5%	528	heads	2	4
8/10/02	CWT	65	96.9%	803	heads	2	4
8/10/02	Destron	65	96.9%	616	heads	2	4

[1]Scanning error: Some fish scanned more than once; data excluded from detection rate analyses
[2]Scanning error: 66/65 detected in Allflex file; data excluded from detection rate analyses

Table 16. Mean detection rate (P) and standard deviation (SD) of each PIT tag reader from detection tests of seeded fish in IPHC survey deliveries during 2002.

Reader	P	SD
Allflex	0.98	0.01
Destron	0.96	0.01
CWT	0.99	0.01

Table 17. Ratings of PIT tag readers by three users (shown as 1,2,3). Readers are rated on a scale of 1 (worst) to 5 (best). Zero "0" indicates the lack of that feature in that reader while "-" indicates a missing evaluation.

Characteristics	Allflex Boulder	Destron reader	Coded Wire Tag Reader
Reliable tag storage	4,-,-	5,-,-	0,-,-
Weather resistance	3,3,3	4,4,4.5	5,-,5
Weight	4,5,5	1,2,0	3,5,5
Ease of use	5,5,5	3,3,1	4,5,5
Compact	5,5,5	1,1,0	3,5,4
Storage capacity (no. of tags)	1,020	6,400	0
Computer interfacing ability	5,-,5	5,-,5	0,-,0
Ability to interrogate memory	5,5,5	2,1,1	0,-,0
Unique tag storage	3,-,0	5,-,0	0,-,0
Constant Scan mode capability	2,5,0	5,5,5	5,-,5
Audible beep upon detection	3,4,1	3,4,1	5,-,1
Relative cost	5,5,5	3,1,1	1,-,5
Immediate and quick detection	4,5,5	3,5,4	5,5,5
Power source function and duration	5,5,5	3,3,5	5,-,5
Tag display	5,-,5	5,-,5	0,-,0
Ability to scan all sized heads	5,5,5	3,5,5	5,-,-
Overall rating	63,52,59=174	49,30,40.5=119.5	40,20,39=99

Development of piece-count procedures

The objective of the portside scanning program was to scan at least 25% of the landed halibut by weight in each regulatory area. Individual deliveries were the sampling unit and the following data were collected: landing port, dealer, vessel, vessel number, delivery date, regulatory area fished, number of fish scanned, and number and ID of any tags detected. Hauser (2003) evaluated methods of counting the number of fish scanned. Ultimately, mechanical tally counters were selected for this purpose (Table 18), with stroke tallies on waterproof paper as an alternative.

Development of quality control procedures for portside scanning

Quality control measures to evaluate piece count precision and tag detection rate were established prior to the coastwide PIT tag releases in 2003.

Piece count precision tests

To evaluate accuracy of piece counts during scanning, every 20th offload was scanned twice when possible and the piece counts compared. To avoid being disruptive to plant operations, usually only a portion of the offload was scanned twice, unless it was a small delivery.

Scanning of seeded halibut

To evaluate their ability to detect PIT tags in a load of fish, port scanning personnel, or scan samplers, periodically scanned samples of seeded halibut. Seeding involved inserting a small, known number of bio-sleeved PIT tags into a larger group of dead fish or heads. The known seeded heads/fish were mixed with untagged heads/fish, scanned, and then the number of tags detected was compared with the number seeded. Seeding tests were initially done on IPHC research survey deliveries, with the shipboard biologists, or sea samplers, seeding fish on board the vessel before fish were put in the hold. Scan samplers were informed that a survey delivery contained seeded fish so that they could be sure to scan all the fish in that delivery, but were not told how many fish had been seeded until after they had finished scanning the offload.

In 2003 and 2004, sea samplers seeded PIT tags in every trip of IPHC setline survey halibut delivered to ports staffed by a scan sampler. IPHC sea samplers injected PIT tags into the standard interopercular plate location of between zero and five dressed, pre-scanned halibut before the fish were put in the hold and iced. Tests on externally-marked, seeded fish in 2001 indicated that tag shedding could be higher in fish tagged when dead since there is no healing of the injection channel as there is in live fish. In an attempt to prevent tag loss from dead-tagged seeded fish, sea samplers applied a small amount of Super Glue gel at the entrance to the injection site and allowed the glue to dry for 15 minutes before fish were put in the hold and iced. Additional tests of tag retention in dead-tagged fish were conducted on survey vessels in 2003: a total of 250 fish were both PIT tagged and externally marked with a gangion tied through the jaw (50 per trip, by four different vessels landing at different processing plants). The number of marked

Table 18. Piece count estimates from 2002 seeded survey offloads. The method by which tally counts were collected is included: all counts were made using mechanical tally counters however some methods employed multiple samplers.

Date	Scanner	Archipelago count	Tally counter count	Tally Method
7/24/02	Destron	548	548	One of team lifts fish & tallies
7/24/02	CWT	548	779[1]	One of team tallies pieces and tags
8/1/02	Boulder	542	603	Lift head with tally hand, scan, then tally
8/1/02	Destron	542	550	Lift head with tally hand, scan, then tally
8/1/02	CWT	542	540	Tally on “mounted” tally counter after scanning
8/10/02	Boulder	303	308	One of team tallies after scanning
8/10/02	Destron	303	308	One of team tallies as tossing heads onto table
8/10/02	CWT	303	307	One of team tallies as tossing heads onto table

[1] Scanning done on whole fish. Samplers lost track of which totes had already been scanned and counted—some totes scanned and counted twice.

fish without PIT tags provided an estimate of tag loss in seeded fish. Of these 250 fish that were both PIT tagged and externally marked, one tag was shed (for a seeded tag loss of 0.4%). Scan samplers in 2003 and 2004 were instructed to scan all fish in seeded survey deliveries as the fish were unloaded. However, the distribution of survey landings was not equal among sampled ports, with some ports receiving no survey deliveries. Furthermore, in using the survey deliveries as a testing platform, detection tests could not be conducted throughout the eight and a half month commercial halibut season (Williams and Chen 2005).

To achieve a more even distribution of seeded PIT tag detection tests among ports and over the season, port samplers began seeding commercial deliveries of halibut in 2005. Halibut selected for seeding were pre-scanned to check for PIT tags before they were seeded. If the selected fish had no PIT tag, the port sampler injected a sleeved PIT tag in the standard interopercular plate location, and then scanned the fish to make sure the tag was in place and functioning before mixing it in with the untagged fish in the sample, which would subsequently be scanned by the scan sampler in that port (Forsberg 2006). Because seeded fish from commercial samples undergo less handling after tag insertion (bypassing the steps into and out of the hold that seeded survey fish would be subject to), the glue step was omitted from commercial seeding procedures. In 2005 and 2006, some fish in each seeding test were both PIT tagged and externally marked with an electrical cable tie fastened through the jaw in order to evaluate tag retention in port-seeded halibut. Externally marked, seeded fish were counted and checked for the presence of a PIT tag. The number of marked fish without PIT tags provided an estimate of tag loss in seeded fish. Seeded tag loss was negligible in 2005 (0.5%) and there were no seeded tags shed in 2006; for this reason, no seeded fish were externally marked in tests conducted between 2007 and 2009.

The port samplers' goal was to seed 25 tags in unmarked fish per port per month. The seeding was to be done over as many deliveries as possible/practical for a given port, with a target minimum of 100 unmarked, seeded fish per port for the season. Target numbers of monthly tests were generated for each port based on predicted numbers of landings. Dice rolls were used to determine the number of fish to seed in a test. Zero was included as a potential number to seed. The number six on the die was used to represent zero. The number of dice rolls used per test also varied by port depending on the target number of monthly tests. The number seeded per test varied between zero and 25, depending on the number of rolls used in the port.

Seeding was conducted at various stages of processing depending on the port or plant. Seeding was done on whole fish, heads, or filleted carcasses. Seeding could also be done on fish that had already been scanned, on fish that were graded by size, or on fish from mixed vessels. Seeded whole fish were scanned either as whole fish or as heads after the fish were headed and/or cheeked. Because scan samplers were required to scan 100% of the fish in a seeded sample, most seeding tests were conducted on portions of a delivery to minimize inconvenience to the processing plants. Minimum sample sizes were established for the various stages of processing during which tests were conducted as follows:

1. Samples using whole fish in totes set aside: minimum of 1,500 lbs (one large tote or two small totes).
2. Heads in totes set aside: minimum half a tote of heads or 100 heads, whichever was greater.
3. Whole fish currently being offloaded: in this situation there was less time available to seed and scan, so sample size was smaller. The sample unit was usually a sling or brailer of fish. Because sling size varied, the minimum was 800 pounds or 25 fish. (Minimum sample size also needed to be greater than the total number seeded in the test).

Peer review of the experiment

During 2002, IPHC commissioners and staff felt it would be appropriate to obtain an independent review of the proposed tagging project. To this end, three researchers with backgrounds in fish tagging and PIT tags were invited to participate on a review panel, examining the objectives and study design. The panel met with the IPHC staff in June 2002 to review the project and subsequently presented the IPHC staff with a critique, including specific recommendations for improvements (Parker et al. 2003). IPHC staff considered these recommendations and incorporated many of them into the final project protocol (IPHC 2003). Members of the review panel included Dr. Steven Parker, Oregon Department of Fish and Wildlife[12]; Dr. Carl Schwarz of Simon Fraser University[13]; and Dr. John Skalski of the University of Washington[14].

PIT tag release methods – the final protocol

PIT tag marking station

The PIT tag "marking station", developed around a semi-automated computerized data-entry system, was used to maximize the tagging rate and date reliability and simultaneously minimize the time a fish was out of the water. Equipment for PIT tagging included: the tag itself; a plastic Bio-Bond anti-migration sleeve for the tag; a modified syringe and hypodermic needle for inserting the tag; an Allflex stick-style tag reader to activate the tag and read the tag number; and a small computer (PDA) to receive and store the electronic data (Fig. 5). Associated equipment included: containers for transporting and cleaning tag equipment; a power supply for the stick reader and computer; and backup tag readers. As well, each vessel had at least one spare backup of each of the tagging items, including the stick reader, PDA, and power supply.

Generally, two sea samplers worked together, one outside on deck handling the fish and tags, and the other in a small custom-built structure (shack). The shack has been used on IPHC surveys for many years and is necessary to protect data and equipment from the elements.

As each fish was placed into a measuring cradle on deck (Fig. 6) and tagged, the PIT code was scanned into the PDA. The IPHC shack person entered the length and injury code into the PDA, and confirmed that the tag number had been downloaded from the tag reader. After re-scanning the fish to ensure that the tag was in place, the fish was returned to the sea. The shack person also loaded the tagging needle for the next fish.

Fish selection for tagging

The goal was to tag all fish on the first three skates of each set. The only fish not tagged were those which were definitely dead or those with fatal injuries. This group included fish gaffed in the head (other than under the jaw) or body, halibut which sustained injuries while on the gear (from amphipod species or "sand fleas", or other predation), or fish which were bleeding from the gills.

Tag, sleeve, and injector

As described earlier, the PIT tags released during the grid survey were Biomark TX1400ST tags, each of which was encased in a Bio-Bond™ sleeve to reduce tag migration.

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[12] Oregon Department of Fish and Wildlife, 2501 SW First Avenue, Portland, OR 97207

[13] Department of Statistics and Actuarial Science, Simon Fraser University, 8888 University Drive, Burnaby, BC, Canada, V5A 1S6

[14] School of Aquatic and Fishery Sciences, University of Washington, 1325 Fourth Avenue, Suite 1820, Seattle, WA, 98101-2509.

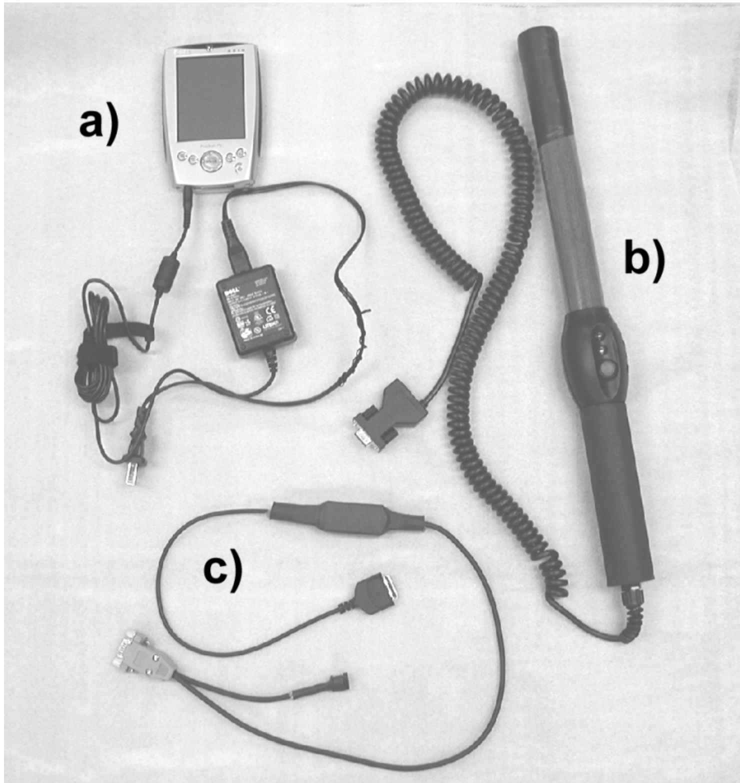

Figure 5. Equipment for data capture during tagging, including a) PDA pocket PC, b) Allflex stick reader, and c) custom data transfer/power cable.

Figure 6. IPHC data recording shack, showing needle tray, measuring cradle, and stick reader in holder.

The tags were injected with modified 12-gauge hypodermic syringes, also previously described in this document.

Taggers were provided with a needle jar and 70% ethanol. At the end of each day, injectors and needles were put into the jar, needle down, with enough solution to cover the needles. Dull needles were replaced as required.

PIT tag injection

The needle was inserted under the fish's skin about 1/2 cm below the opercular groove just over one needle length behind the forward end of the groove (as was shown in Fig. 2). The needle was initially inserted 'deep' to get through the thick skin covering the interopercular plate. Once the tip of the needle was under the skin, the needle was levered flat alongside the operculum and slipped forward, so that it ran under the skin as it was inserted. The plunger was depressed as the needle was withdrawn, leaving the tag at the end of the insertion path.

Shipboard tag reader

Although billed as waterproof, the Allflex stick reader and its connections were further protected. This was accomplished by placing a sleeve of plastic shrink tubing over the on-off switch, and wrapping a waterproofing tape over the tip of the reader, over the ends of the sleeve, and over the plug connection at the reader's base. The sleeve was then heated with a hair dryer to shrink the plastic until it conformed to the shape of the reader. Additionally, to protect the seam on the scanning end of the stick reader, the tips of the readers were dipped in a rubber coating.

PDA and electronic data capture

Release data were captured into a DELL Axim X5 PDA PocketPC. Although equipped with rechargeable batteries, it was able to operate on 120 volt AC supplied by IPHC chartered vessels. Data entry was facilitated by an entry program written in-house by an IPHC staff programmer. Programming was done using Microsoft's Embedded Visual Tools v3.0, using almost all Visual Basic, though with some Visual C++. Testing in the development environment used the PocketPC emulator in the Microsoft Windows Pocket PC 2002 SDK. The programs used a Pocket Access database and text files for storing tagging data on the devices. Data were sent to the program from the scanning devices via a serial cable connection and a program called SerialLink (v1.4) by Syware Inc[15].

This PDA housed two expansion slots: a CompactFlash Type II on top and a Secure Digital slot on the left side. For the IPHC application, 64-MB secure digital (SD) and 128-MB compact flash (CF) cards were used. The SD card carried data that could be used to "restore" the PDA to its original operating configuration in case of loss of programming. The CF card was used to perform daily data backups onto a spare card. The CF card was also used to transport data from the field.

A serial cable, custom manufactured by Gomadic Corp.[16], was used to stream data from the stick reader to the PDA. When connected to a power supply, this cable also supplied DC power to both the stick reader and the PDA.

Some problems were encountered delivering appropriate power to the custom serial cable. A variety of power supplies were used, including both 6- and 12-volt 1.5 amp supplies provided by Allflex, and 6- and 9-volt supplies purchased from Radio Shack[17]. In the original IPHC testing, Allflex provided 6-volt power supplies, and these worked well with the combined cable. On one

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[15] SYWARE, Inc., PO Box 425091, Kendall, Cambridge, MA 02142

[16] Gormadic Corporation, 12930 Cedar Len Lane #250, Hernon, VA 20171. Cable was custom designed for our purpose by Gormadic Corp.

[17] Radio Shack, 137 Sir Lancelot Drive, Lansing, MI 34567. 9-volt stock #273-1771, 6-volt 273-1763. Type N plug adaptor #273-1717.

large order for gear, the stick readers came with 12-volt supplies. In some instances, the use of these 12-volt supplies caused the cable to overheat, which was associated with a loss of scanning range on the stick readers. This was especially pronounced when the PDA internal battery needed charging. Thereafter, the12-volt supplies were discontinued, and the 6- and 9-volt power supplies from Radio Shack were used with minimal further problems. It was also necessary to use a high quality surge protector. The 120-volt AC power supplied by some of the vessels burned out the simple power bars. There were no further problems once a surge protector with a higher joule rating and a re-settable circuit breaker[18] was used.

The PDAs were contained within an Armor 2600 waterproof PDA case by OtterBox[19]. Although one hole was drilled to allow communication/power cable access to the PDA, the case protected the PDA from moisture or abuse. This PDA case has a soft, clear face, allowing use of the stylus when the case was shut.

The IPHC developed PDA software to enable field staff to quickly record and store PIT tag data as they were collected, while simultaneously validating the format and values of those data. This software allowed the PIT tag transceivers (stick reader) to be connected directly to the PDA, minimizing the potential for error due to hand data entry. The software used a system of dropdown menus for some data values that streamlined program operation and data entry, and permitted consistent, standardized data input. The software also allowed a user to review data previously stored to the PDA, and to append or modify corresponding information in the records associated with those data. In general, there were two types of data collected. The first was the generic information global to each set. These global descriptors included date (supplied by the PDA), vessel code ("Vsl", available as a dropdown), and set number (again, a dropdown menu item). The second type of information collected was specific to each PIT tag code and provided detailed information on the tagged animal, such as skate number ("Sk"), fork length ("Len"), hook removal injury ("Inj", Table 19), and tag number ("tag#"). In addition to recording data at the time of tag insertion, the user could enter data on recaptured PIT-tagged fish that were marked previous to the current tag session. Some of the collected information was verified against various domains of allowable values at the time of data entry. Besides helping to standardize data input, this also helped to ensure that data values were valid, complete, and properly correlated with the correct tagged fish. The final product of the entry and validation software was a data file that could be uploaded to, and incorporated into, the IPHC mark/recapture database.

Electronic data backup

A backup of all PIT tag related data was made to an external storage card at least daily during the field tagging operation, at the close of each day's fishing. One backup storage card was used per trip and stored separately from the PDA when not in use.

The backup was a straight cumulative file copy. All data from day one to current were backed up separately each time the backup occurred. This created redundant data, but also provided the best options for recovery in case of problems. A unique directory was created on the storage card for each backup run.

At the end of the trip, the backup storage card was sent to the IPHC office where the data were retrieved. Also at the end of each trip, the work storage card (which stayed in the PDA during normal use) became the new backup storage card and a new card was inserted into the PDA to become the working storage card for the next trip.

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[18] Belkin SurgeMaster Gold Series F9G930-10-GRY, Belkin Corporation, PO Box 5649, Compton, CA 90224-5649

[19] Otter Products, LLC, Bldg 1 Old-Town Square, Suite 303, Fort Collins, CO 80524

Table 19. Hook removal injury codes.

Severity	Code	Description
Minor	**NI**	No apparent injury
	TL	Torn lip
	TC	Torn cheek; small hole through cheek only
Moderate	**TJ**	Torn jaw; jaw is torn on one side or other, little or no tearing in cheek area
	CJ	Cheek and jaw; tear in cheek extending through jaw
	EY	Hook penetrates eye
Severe	**TF**	Torn face; torn through cheek and jaw as above but large flap of side of head is ripped or missing
	SJ	Split jaw: lower jaw is split laterally
	TS	Torn snout; upper jaw is split laterally, usually tearing through snout as well
	UN	Unknown or unrecorded

Tag recovery (port scanning)

For the recovery side of the PIT tag program, scan samplers were placed in major landing ports with the goal of scanning at least 25% of the commercial landings by IPHC regulatory area. IPHC already places port samplers in many key ports (Clark et al. 2000) on the basis of the high degree of access to the commercial landings, so the scan samplers were placed in the same ports. Scan samplers were instructed to scan as many fish as possible in their port on their scheduled work days (six days a week; Monday to Saturday).

Port staffing

In Alaska and British Columbia (B.C.), scan samplers were deployed in the same ports staffed by IPHC port samplers, with the addition of Ucluelet and Tofino in B.C. Sampled ports received a major portion of the commercial catch.

IPHC hired seasonal employees for Alaska, while B.C. ports were sampled under a contract with Archipelago Marine Research (AMR)[20]. Scanning of the commercial catch took place in the Alaskan ports of Petersburg, Sitka, Juneau, Seward, Homer, Kodiak, Dutch Harbor, and St. Paul and in the B.C. ports of Port Hardy, Vancouver, Prince Rupert, Ucluelet, and Tofino. The start of portside commercial scan sampling was concurrent with the start of tagging operations in 2003 and continued through the end of commercial landings for the year. Scan sampling was concurrent with the commercial halibut season in subsequent years in all B.C. ports and most Alaskan ports; some ports in Alaska where deliveries are concentrated in the summer months were staffed for shorter periods to coincide with landings.

In Area 2A, scan sampling was conducted for the directed commercial fishery by IPHC staff in Newport, Oregon following scheduled fishing periods. Halibut landed as incidental catch in the Washington sablefish fishery were scanned in Bellingham, WA throughout that fishery and the Washington tribal commercial halibut fisheries were scanned by tribal biologists.

Area 2A was the only regulatory area where sport catch was scanned, because a third of the 2A catch limit is allocated to the sport fishery. Scanning of Area 2A sport-caught halibut was conducted in Newport, Depoe Bay, and Garibaldi, OR by ODFW staff and in Neah Bay, La Push, Westport, and Ilwaco, WA by Washington Department of Fish and Wildlife staff during the sport fishery openings.

[20] Archipelago Marine Research, 525 Head Street, Victoria, BC V9A 5S1, Canada

Data collected

Individual vessel (or packer) deliveries were the sample unit. For each sample, the port, dealer, vessel, vessel number, delivery date, regulatory area fished, number of fish scanned, and number and ID of tags detected (if any) were recorded. Samplers were instructed to sample whole trips when possible, however partial offloads were also scanned (e.g., when there were simultaneous deliveries at different sites and the sampler arrived after the start of the offload). For vessels fishing multiple regulatory areas, each area was treated as a separate sample, with a separate piece count and tag tally kept for each regulatory area.

Since PIT tag numbers are very long, samplers were careful to avoid transcription errors in recording the ID number of detected tags. Tag numbers could be saved in the memory of the reader, however samplers watched the LCD screen on the Boulder while they scanned. If a tag was detected, the number was written down in a Rite-in-the-Rain® book and the tag (and fork length and otoliths) retrieved if possible. At the end of the scan sample, the sampler queried the Boulder's memory and copied the tag number a second time, comparing the two numbers to make sure they matched before clearing the Boulder's memory. At the end of every sample, samplers viewed the memory even if they did not notice a tag during scanning, since with possible background noise and glare in the plant during scanning, it was possible to miss seeing a tag number appear on the LCD display at the time of detection. After checking the memory for tags, the memory was cleared before the next sample.

It was possible to download tag numbers from the Boulder to a computer, but given the wet conditions the samplers worked in and the need to clear the memory after each scan sample, computer downloading was not practical.

To facilitate accurate counting of fish or heads, samplers employed either batch counts, or an individual fish tally. For batch counts, the sampler scanned and kept count in their head up to a fixed number of fish (such as 10 or 20) then kept track of the number of batches scanned by keeping a stroke tally in a Rite-in-the-Rain® book, or using a mechanical tally counter. For individual fish tallies, the fish were counted individually with a tally counter or marked off on a stroke tally or pre-numbered worksheet.

Quality control tests of piece counts and tag detection (seeding tests) were performed regularly as described in the *Development of portside scanning protocols* section.

Program evaluation

The development of the PIT tagging program was a sequential process, and in many cases was iterative, where the next step was predicated on the results of the previous step. Studies in 2001 were to evaluate the appropriate tag shape and insertion point, test tagging mortality and tag retention, and assess the configuration of detection equipment in the fish plants. It was also planned to conduct one tagging charter to establish baseline tagging capability and rates, and use one of the survey vessel trips to insert tags on landed fish and evaluate detection capability under normal operating conditions. Broad scale tagging was expected to begin during the 2002 survey year. Initially investigated were the types of PIT tags available, and a type and size were then selected. This then led to parallel investigations which included determining a tagging location and protocol, choosing and developing the hardware and software for tag data capture, and establishing a protocol for scanning fish landings in commercial ports. Determining an appropriate tagging location took two years. The opercular location chosen intially was not observed to have shedding until late in 2001, after almost six months of captive holding. Since this shedding rate was unacceptable, we delayed the experiment until further experiments resulted in an acceptable tagging location, and broad-scale tag releases did not commence until 2003.

This delay was fortunate on many counts, not least of which was the additional time available for refining the hardware and software applications. While shedding was observed on the order of 2-5% from the interopercular plate location, it was minimal, occurred during the first few days post-tagging, and could be estimated by the long-term holding studies. The holding studies were, at best, an indication of the shedding rates that would be experienced by fish released directly back into the sea, and were probably high estimates. Capturing and tagging halibut, then carrying them to shore and again handling them into tanks, likely gave more opportunity for shedding than a simple tag and release over the side. As well, fish released at sea should have a much lower exposure to infectious bacteria than those in the holding studies, and the tag insertion holes should heal more quickly. With almost 200 tags returned from the 2003 double-tagging releases by the end of 2004, the estimated shedding rate was on the order of 2-3%. PIT tag retention in the double-tagged fish was much more predictive of what was actually occurring in released fish.

The 'extra' year was also used to develop data capture and data flow procedures, ensuring that the 12-digit tag numbers were recorded and processed into the IPHC database with a high degree of accuracy. The extra time also allowed the evaluation and selection of tag scanning hardware that was much less expensive, and seemed more appropriate to the application, than that previously considered.

The major effect on the charter vessels from conducting a combined grid survey and tagging operation was in the overall time required to haul the gear. During 2002, many vessels were able to complete four grid stations daily, fishing five skates per station, for a total of 20 skates per day. With eight-skate stations, hauling the added skates added about one hour per station. During the combined tagging-grid charter days, vessels were not allowed to fish more than three stations per day. Most vessels were able to fish the three 8-skate stations totaling 24 skates in the same or less time that it took to fish four, 5-skate stations during 2002. In terms of the length of each working day, the time to haul the added skates was offset by time saved in only running between three stations as opposed to the four stations many boats fished during 2002. The end result was an increase in the number of days required to complete a charter area. The charter bids were higher in reflection of both the number of skates fished daily, as well as the increased number of days fishing in each area.

The release and scanning phases of the experiment were successfully completed. There were almost 67,000 halibut tagged and released in 2003 and 2004. Scanning was conducted from the fall of 2003 through 2009. This report presents the results of the initial investigations into choosing and developing the gear and protocols used for both tagging and scanning for tags in Pacific halibut, as well as detailing the final tagging and scanning protocols. Primary sources for this report are progress reports contained in Kaimmer and Geernaert (2002, 2003, 2004), as well as Forsberg (2003, 2004).

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