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INSHORE MOVEMENT AND HABITAT USE BY JUVENILE SABLEFISH *Anoplopoma fimbria*, IMPLANTED WITH ACOUSTIC TAGS IN SOUTHEAST ALASKA

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ABSTRACT

Acoustic tags were used to monitor age-0 and age-1 juvenile sablefish (*Anoplopoma fimbria*) inshore habitat use in Southeast Alaska. A total of 30 acoustic tags were surgically implanted in juvenile sablefish and released in St. John Baptist Bay during October 2003 (n = 13, mean fork length (FL) 241.9 mm) and May 2004 (n = 17; mean FL 322.1 mm). Manual relocation of acoustically tagged sablefish was conducted opportunistically from the NOAA ship *John N. Cobb* and a skiff during 2003 and 2004 using an acoustic tracking receiver. Remote relocation of acoustically tagged sablefish was conducted using hydrophone buoys deployed below the water's surface in St. John Baptist Bay during 2003 and 2004. Results indicate that acoustic tagging was an efficient method for determining habitat utilization of juvenile sablefish in St. John Baptist Bay. All acoustically tagged juvenile sablefish were relocated at least once using either manual relocation methods or by remotely deployed hydrophone buoys; multiple records were available from more than half of the tagged sablefish. Results indicated that age-0 juvenile sablefish utilized relatively shallow waters of the inner bay (average water depth 18.6 m), while age-1 juvenile sablefish utilize the relatively deeper waters of the outer bay (average water depth 58.9 m). Age-0 juvenile sablefish were predominantly located near the bottom but they also utilized the entire water column, making frequent excursions to the surface.

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INTRODUCTION

Sablefish spawning is pelagic at depths of 300-500 m near the edges of the continental slope (McFarlane and Nagata 1988), with eggs developing at depth and larvae developing near the surface as far offshore as 180 miles (Wing 1997). Average spawning date in the Gulf of Alaska based on otolith analysis is 30 March (Sigler et al. 2001). During National Marine Fisheries Service (NMFS) surveys of the outer continental shelf, most young-of-the-year sablefish are caught in the central and eastern Gulf of Alaska (Sigler et al. 2001). Near the end of the first summer, pelagic juveniles less than 20 cm fork length (FL) drift inshore and spend the winter and following summer in inshore waters, reaching 30-40 cm FL by the end of their second summer (Rutecki and Varosi 1997a). After their second summer, they begin moving offshore. Fish first appear on the upper continental slope, where the NMFS longline survey and commercial longline fishery primarily occur, at age 2 and length about 50-53 cm FL. Only 10% are estimated to reach the slope at age 2, with most sablefish typically reaching their adult habitat, the upper continental slope, continental shelf gullies and deep fjords, by age 4 to 5 (Sigler et al. 2000).

Little is known about sablefish life history between the time they leave the inshore waters at age 1+ until the time they are fully recruited to the fishery at age 4 or 5. Tagging juvenile sablefish annually in southeastern Alaska has been an ongoing component of migration studies (Rutecki and Varosi 1997a, 1997b). Juvenile sablefish (age 0 and age 1+) are common, but rarely abundant, in the inland waters of southeastern Alaska. However, at one location, St. John Baptist Bay in Salisbury Sound, consistent catches of juvenile sablefish have been reported nearly every year that tagging surveys have been conducted. Juvenile sablefish are typically found in the bay from August as age 0+ fish until September or October of the following year as age 1+ fish. The purpose of this study was to monitor ages 0+ and 1+ juvenile sablefish habitat use in inshore waters and to determine the timing of the transition from inshore to offshore waters. Habitat uses include the length of time juvenile sablefish are in the bay, whether they move in and out of the bay, and distribution within the water column. The choice of St. John Baptist Bay as a study sight is particularly germane to the understanding of juvenile sablefish nursery requirements since the bay has been used in the past as a log-transfer facility.

METHODS

The St. John Baptist Bay study site is located off of Baranof Island, 39 km north of Sitka, Alaska (Figs. 1 and 2). The NOAA ship *John N. Cobb* (28.4 m long) and a skiff (5 m long) were used to conduct the study. Juvenile sablefish were caught by hand jigging. Immediately after capture the fish were placed in 667 L tanks of flowing seawater on board the NOAA ship *John N. Cobb*.

Tagging Procedures

Prior to tagging, fish were dipnetted from the live tanks and anesthetized with tricaine methanesulfonate (MS222). A small incision was made through the skin with a scalpel in the midventral body wall at the linea alba (the mid-line of the belly), the incision was irrigated with a 3% Betadine solution, and an 11 mm by 45 mm LOTEK acoustic tag was inserted into the body cavity. The incision was closed with 3-4 surgical staples. The fish were held in the live tanks and released the following day. In 1999, a pilot study utilizing similar tagging procedures determined that juvenile sablefish held in captivity retained dummy acoustic tags of the same size for the duration of the study (118 days) and had completely healed from surgery (Appendix A). In 2002, during a pilot study utilizing similar tagging procedures, acoustically tagged juvenile sablefish released in St. John Baptist Bay appeared to swim actively to the bottom and then to swim out of range of the acoustic receivers within seconds, suggesting that any adverse effects from the tagging were minimal (Appendix B).

Acoustic Tags

We used LOTEK CTP-M11-12 (2003), and LOTEK CTP-M11-18 (2004) microprocessor coded acoustic sensor transmitters; diameter 11 mm, length 45 mm, weight 8 g, frequency 77 kHz and typical operational life ≥ 30 days at a 5 second burst rate. Each acoustic tag transmitted a uniquely identifiable acoustic signal and the ambient pressure and temperature. Ambient pressure was transmitted once every 5 seconds, and ambient temperature was transmitted once per minute. The resolution of the pressure sensor was dependent upon the tags initial calibration. In 2003, the CTP-M11-12 tags were calibrated to 0-50 psi, whereas in 2004, the CTP-M11-18 tags were calibrated to 1-150 psi. The resolution of the temperature sensor on both CTP-M11-12 and CTP-M11-18 tags was 0.5° C. However, accurate interpretation of calibrated pressure and temperature records was problematic as discussed below.

Manual Relocation

Manual relocation of acoustically tagged sablefish was conducted opportunistically from the NOAA ship *John N. Cobb* and a skiff during 2003 and 2004 using an acoustic tracking receiver. For manual relocation, we used a LOTEK MAP-600 real time (MAP-RT) acoustic tracking receiver, equipped with LOTEK MapHost software and dual hydrophones on different length cables: 18 ft and 24 ft. The MAP-RT MapHost software was tuned empirically to local conditions in St. John Baptist Bay in coordination with a representative from LOTEK Wireless Inc. The MapHost settings which reduced noise but allowed for maximum tag detection were VCA Gain (70), Detector Scale (6), Offset (4), Norm (12), and Window (128).

Remote Hydrophone Buoys

Remote relocation of acoustically tagged sablefish was conducted with two hydrophone buoys deployed below the water surface in St. John Baptist Bay during 2003 and 2004. The buoys served as an acoustic gate and recorded the presence or absence of acoustically tagged sablefish as well as the ambient water pressure and ambient temperature experienced by acoustically tagged sablefish at the time of data transmission. The acoustic gate operated for the battery life of each buoy (≥ 90 days) which was designed to be longer than the battery life of each tag (≥ 30 days).

Remote relocation utilized two LOTEK WHS 3100-300 MAP submersible data-loggers (MAP-SDL) equipped with LOTEK MapHost software. Before buoy deployment, the MapHost software of each LOTEK MAP-SDL was programmed to the same settings as those empirically derived for the LOTEK MAP-RT: VCA Gain (70), Detector Scale (6), Offset (4), Norm (12), and Window (128). Additional MapHost software settings required for the MAP-SDL were Symbol Filter (off), Sleep Interval (0), and Wake Interval (60). Under these MapHost software settings, the battery life of each MAP-SDL was expected to be ≥ 90 days. In contrast, the battery life of the acoustic tags was expected to be ≥ 30 days. As a result, the full MAP-SDL digital memory (128 MB) was allocated for the study so that transmitted data from all tags would be recorded continuously until the end of battery life of each tag, or the end of battery life of the MAP-SDL, whichever occurred first.

The hydrophone buoy assembly was designed to hold each LOTEK MAP-SDL in a vertical orientation (hydrophone pointing either up or down) within the water column below the water surface. Each acoustic buoy assembly consisted of two steel longline survey anchors at the bottom, followed by 1.5 m of steel 3/8 chain, 9 – 14 m of positive buoyancy yellow polypropylene line, a MAP-SDL, (~ 1.8 m L), 2 – 3 m of positive buoyancy yellow polypropylene line, and 2 – 5 positive buoyancy hardball floats of various dimensions at the top. To avoid contact with vessel traffic in the area, the total length of each hydrophone buoy assembly was less than the total water depth with hardball floats remaining below the water surface. The configuration of each buoy assembly was similar except that the hydrophone of buoy 1 in 2003 (1-2003) was oriented towards the surface (pointed up) while the hydrophones on buoy 2 in 2003 (2-2003), and buoys 1 and 2 on 2004 (1-2004 and 2-2004) were oriented towards the bottom (i.e., pointed down).

The geographic locations of remotely deployed buoys were calculated from the NOAA ship *John N. Cobb* automatic radar plotting aid (ARPA) linked to a differential global positioning system (DGPS). Bottom depth for remotely deployed buoys was determined from a skiff-mounted depth sounder immediately after buoy deployment and varied depending upon the height of the tide. Acoustic buoys were retrieved by scuba divers.

Range Detection Tests

Range detection tests were conducted to determine the maximum range of acoustic tag detection in St. John Baptist Bay in 2003 and 2004. The range detection tests were conducted by physically attaching an acoustic tag at a known depth to a fixed or drifting buoy, slowly backing away from the buoy in a skiff, and periodically deploying hydrophones from a manual acoustic tracking receiver. The acoustic tracking receiver (LOTEK MAP-RT with dual hydrophones of different lengths: the first 18 ft cable and the second 24 ft cable), and the test tags (LOTEK CTP-M11-12 in year 2003, and LOTEK CTP-M11-18 in year 2004) were identical to those deployed to track juvenile sablefish during 2003 and 2004. The LOTEK MAP-RT MapHost software settings were also the same as those used to track juvenile sablefish in 2003 and 2004 (VCA Gain-70, Detector Scale-6, Offset-4, Norm-12, and Window-128).

During range detection tests, the geographic position of the deployed buoys and the skiff were calculated from the NOAA ship *John N. Cobb* shipboard fix with ARPA DGPS corrected locations. The distance from the skiff to each buoy was computed with ArcView software from the geographic locations. The distance from each acoustic tag to the skiff at the last location where the acoustic tag could consistently be detected was considered the maximum acoustic tag detection limit. The results of the range detection tests were applied to estimate the maximum range of acoustic tag detection with the LOTEK MAP-RT and MAP-SDL hydrophones in St. John Baptist Bay and Salisbury Sound.

Data Processing

Acoustic data from the LOTEK MAP-RT and MAP-SDLs were physically stored on removable flash memory. At the end of each deployment, the flash memory cards were physically retrieved from the units and returned to LOTEK for data download and conversion to ASCII. The ASCII data were then processed at the Auke Bay Laboratories with LOTEK BioMAP data management software to obtain a separate ASCII file for each released tag from each deployment. The ASCII data were then exported from BioMAP to R statistical software (Version 2.8.1[1]) for data analysis.

Data Analysis

Analysis of pressure and temperature data was only possible for remotely deployed hydrophone buoys (MAP-SDLs) deployed during the year 2003. Analysis of pressure and temperature data was not possible from manually recovered acoustic transmissions (LOTEK MAP-RTs) during the years 2003 and 2004 or from remotely deployed hydrophone buoys during the year 2004 (LOTEK MAP-SDLs) because of technical problems most likely

[1] R Development Core Team. 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0, URL http://www.R-project.org.

associated with the use of incorrect MapHost pressure and temperature calibrations in the field.

RESULTS

A total of 30 acoustic tags were deployed on juvenile sablefish in St. John Baptist Bay: 13 tags were released in October 2003 and 17 tags were released in May 2004 (Tables 1 and 2). Tagged juvenile sablefish were age 0 in 2003 and age 1 in 2004. (e.g., Rutecki and Varosi 1997a, 1997b). Average fork length (FL) of tagged fish was 241.9 mm in 2003 and 322.1 mm in 2004. All juvenile sablefish were tagged and released from the NOAA ship *John N. Cobb* anchorages in St. John Baptist Bay. In October 2003, the anchorage was located at 57° 17.178 N by 135° 33.723 W at water depth 21.3 m. In May 2004 the anchorage was located at 57° 17.21 N by 135° 33.98 W at water depth 22.9 m.

During 2003, 85% (11 of 13) of acoustically tagged juvenile sablefish were relocated at least once with manual relocation methods and 100% (13 of 13) were relocated at least once with remotely deployed hydrophone buoys (Table 1). During May 2004, 88% (15 of 17) of acoustically tagged juvenile sablefish were relocated at least once with manual relocation methods, and 94% (16 of 17) were relocated at least once with remotely deployed hydrophone buoys (Table 2). During 2003 and 2004, multiple records were available from most acoustically tagged sablefish (Tables 1 and 2).

Manual Relocation

In 2003, manual relocation occurred at seven sampling locations in St. John Baptist Bay over the period of 3 – 4 October (Table 3). Acoustic tag relocations were concentrated at the head (east end) of the bay and around the October 2003 NOAA ship *John N. Cobb* anchorage location (Fig. 1). Acoustic tags were not detected at the two sampling locations at the mouth (west end) of St. John Baptist Bay and as a result acoustic sampling was not conducted farther outside St. John Baptist Bay (Fig. 1). Pressure and temperature were not available from manually relocated acoustic tags in 2003; however, juvenile sablefish were assumed to be near the bottom where they have been targeted for tagging in other studies (e.g., Rutecki and Varosi 1997a, 1997b). Average water depth was 18.6 m from the five sampling locations with relocated juvenile sablefish.

In 2004, manual relocation occurred at 70 sampling locations in St. John Baptist Bay and Salisbury Sound over the period of 12 – 14 May (Table 4). Acoustic tag relocations were concentrated outside the mouth (west end) of St. John Baptist Bay and in Salisbury Sound (Fig. 2). Pressure and temperature were not available from manually relocated acoustic tags in 2004; however, as described above, juvenile sablefish were assumed to be near the bottom. In 2004, average water depth was 58.9 m from the 45 sampling locations with both relocated juvenile sablefish and with available water depth measurements.

Remotely Deployed Hydrophones

In 2003, two remote hydrophone buoys were deployed during the period 2 October – 18 November. Acoustically tagged age-0 juvenile sablefish in 2003 appeared to be concentrated at the head (east end) of St. John Baptist Bay. As a result, remotely deployed hydrophone buoy locations were chosen in the inner bay, east of the 2003 NOAA ship *John N. Cobb* anchorage (Table 5, Fig. 3). In 2004, two remote hydrophone buoys were deployed during the period 12 May – 7 September. Acoustically tagged age-1 juvenile sablefish in 2004 appeared to be concentrated outside the mouth (west end) of St. John Baptist Bay. As a result, remotely deployed hydrophone buoy locations were chosen near the mouth of the bay, west of the 2004 NOAA ship *John N. Cobb* anchorage (Table 5, Fig. 3).

In 2003, the downward-pointing hydrophone on buoy 1 (1-2003) was approximately 9 m above the seafloor at a water depth of 20.1 m, while the upward pointing hydrophone on buoy 2 (2-2003) was approximately 11 m above the seafloor at a water depth of 18.6 m. In 2004, the downward-oriented hydrophone on buoy 1 (1-2004) was approximately 9 m above the seafloor at a water depth of 21.6 m, while the downward-oriented hydrophone on buoy 2 (2-2004) was 14 m above the seafloor at a water depth of 23.2 m.

Range Detection Tests

In 2003, one acoustic tag was physically attached to each remotely deployed buoy (buoy 1-2003 and buoy 2-2003) for the duration of the deployment. The approximate depth of the acoustic tag on buoy 1 (1-2003) was 11 m above the seafloor at a water depth of 20.1 m. The approximate depth of the acoustic tag on buoy 2 (2-2003) was 11 m above the seafloor at a water depth of 18.6 m. The maximum detection range to the acoustic tag physically attached to buoy 1 was 151.8 m, whereas that of buoy 2 was 259.7 m (Table 6). The average of the maximum detection ranges in 2003 was 206 m. All distances in 2003 were calculated from the NOAA ship *John N. Cobb* shipboard satellite location fix with ARPA DGPS-corrected locations. As a result, the average maximum detection range of 206 m determined in 2003 was considered the best estimate of acoustic tag detection range in St. John Baptist Bay.

In 2004, the maximum detection range was calculated to a tag physically attached to a drifting buoy. The acoustic tag was attached at a depth of 12.2 m at a water depth of approximately 24 m. The maximum detection range to the tag was 201 m (Table 6), which was consistent with the average maximum detection range (206 m) determined in 2003 (Table 6). In 2004, the maximum intermittent detection range to the tag attached to the drifting buoy was considerably farther (256.0 m) (Table 6). However, the drifting buoy was too small for the NOAA ship *John N. Cobb* ship to obtain an accurate ARPA DGPS fix and the geographic position of the drifting buoy had to be approximated. As a result, acoustic tag detection limits in 2004 were approximate.

Data Analysis

A detailed analysis of pressure and temperature records was conducted for 2003 remotely deployed hydrophone buoy data (MAP-SDL). Juvenile sablefish depth and temperature were recovered from a total of 230,887 acoustic transmission records for buoy 1 (buoy 1-2003) and 226,183 acoustic transmission records for buoy 2 (buoy 2 -2003) (Table 7). Acoustic records of depth and temperature were recovered from every tag released (minimum 60, maximum 47,781) from 1 October 2003 to 14 November 2003 (GMT; Table 7).

A condition factor (1, 2, or 3) was assigned to each tagged fish based on a graphical examination of the depth and temperature time series data: condition factor 1 – Movement (changes in depth or temperature) and remained in range; condition factor 2 – Movement but appeared to leave the area; condition factor 3 – No movement and remained in range. Movement was identified by depth or temperature changes through time other than those associated with changes in the tide. Fish with a condition factor of 1 were assumed to be healthy and to have remained within the detection range of the remotely deployed hydrophone buoys. Fish with a condition factor of 2 were assumed to be healthy, but to have left the detection range of the buoys. Fish with a condition factor of 3 remained within the detection range of the remotely deployed hydrophone buoys, but were assumed to have died (mortality) as a result of tagging.

Of the 13 acoustically tagged sablefish in 2003, 6 appeared to be a healthy fish that remained within the detection range of the buoys (condition factor 1), five appeared to be a healthy fish that left the detection range of the buoys (condition factor 2), and two appeared to be mortalities (condition factor 3) (Table 7).

Juvenile sablefish depth and temperature preferences in St. John Baptist Bay were determined from the combined records of buoy 1 and buoy 2 recovered from the six apparently healthy (condition factor-1) fish that remained within the detection range of the buoys from 1 October 2003 to 14 November 2003 (Table 7). For these six fish, depth was recorded from a total of 294,418 unique acoustic transmission records and temperature was recorded from a total of 34,143 unique acoustic transmission records (Table 8). Average tag depth was 23.6 m and average temperature was 10° C (Table 9). The time series plot of depth was informative and revealed frequent excursions to the surface from depth (Fig. 4). The histogram plot of depth revealed that tagged fish spent most of their time at depths assumed to be near the bottom (Fig. 4). Time series plots of temperature were less informative and revealed very little variation around the mean temperature of 10° C (Fig. 5). The lack of variation in temperature over time may have been an artifact of the low precision of the temperature measurements which were recorded to the nearest 0.5° C.

DISCUSSION

All acoustically tagged juvenile sablefish were relocated at least once, and multiple records were available for most tagged fish (Tables 1 and 2). A detailed analysis of tag records from remotely deployed hydrophone buoys in 2003, indicated that 54% (6 of 11) of the apparently healthy age-0 juvenile sablefish remained within range of the remotely deployed hydrophone buoys for the duration of the study (1 October – 14 November) (Table 7). Two of the 13 acoustically tagged age-0 juvenile sablefish appeared to have died as a result of tagging, or to have expelled their tags (Table 7).

During the period 3 – 4 October 2003, acoustic tag records from manual relocation indicated that acoustically tagged age-0 juvenile sablefish utilized the inner St. John Baptist Bay (Table 3, Fig. 1). Average water depth from the five sampling locations with relocated juvenile sablefish in the inner bay was 18.6 m (Table 3, Fig. 1). In contrast, during 12 – 14 May 2004, acoustic tag records from manual relocation indicated that acoustically tagged age-1 juvenile sablefish utilized the outer St. John Baptist Bay and Salisbury Sound (Table 4, Fig. 2). Average water depth from the 45 sampling locations in the outer bay was 58.9 m (Table 4, Fig. 2).

During 1 October 2003 – 14 November 2003, acoustic tag records recovered from the remotely deployed hydrophone buoys indicated that tagged age-0 juvenile sablefish were predominantly near the bottom (Table 9, Fig. 4). Average tag recovery depth was 23.6 m and average depth of the inner channel of St. John Baptist Bay was between 16.5 and 27 m (Figs. 1 and 3). Tagged age-0 juvenile sablefish also utilized the entire water column of St. John Baptist Bay, making frequent excursions to the surface (Fig. 4).

CONCLUSIONS

Acoustic tagging was an efficient method for determining habitat utilization of juvenile sablefish (age-0 and age-1) in St. John Baptist Bay. All acoustically tagged juvenile sablefish were relocated at least once, and multiple records were available from most acoustically tagged juvenile sablefish. Acoustic tagging results indicated that age-0 juvenile sablefish utilized the relatively shallow waters of inner St. John Baptist Bay (average relocation water depth 18.6 m), while age-1 juvenile sablefish utilized the relatively deeper waters of outer St. John Baptist Bay and Salisbury Sound (average relocation water depth 58.9 m). Detailed analysis of acoustic tag records recovered from remote hydrophone buoys during 1 October 2003 – 14 November 2003 indicated that age-0 juvenile sablefish were predominantly found near the bottom, but also utilized the entire water column, making frequent excursions to the surface.

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Table 1. --Year 2003 juvenile sablefish (age-0) acoustic tag releases in St. John Baptist Bay.

Tag number	Tag date	Fork length (mm)	Manual relocations[1] 3 – 4 October 2003	Buoy records[2] 2 October 2003 – 14 November 2003
29500	1 October	245	-	120
29700	2 October	260	2	86,300
29800	1 October	245	3	77,762
29900	1 October	240	3	54,019
30000	1 October	230	3	56,232
30100	1 October	250	4	20,372
30200	1 October	240	2	19,176
30300	1 October	245	-	272
30500	1 October	230	4	72,288
30600	1 October	225	3	34,357
30700	1 October	240	-	538
30800	1 October	245	3	16,255
30900	2 October	250	3	19,379

[1] The number of locations where acoustic tags were manually relocated.
[2] The number of records for each acoustic tag from remotely deployed hydrophone buoys.

Table 2. --Year 2004 juvenile sablefish (age-1) acoustic tag releases in St. John Baptist Bay.

Tag number	Tag date	Fork length (mm)	Manual relocations[1] 12 – 14 May 2004	Buoy records[2] 12 May 2004 – 7 September 2004
29800	12 May	320	1	288
29900	12 May	320	7	172,595
30500	12 May	325	9	8,464
30700	12 May	330	-	74
35300	12 May	340	5	346
38000	12 May	350	7	169
48200	12 May	320	3	49,896
53700	12 May	330	5	187,726
58296	12 May	300	5	432,156
58348	12 May	310	8	17,598
58608	12 May	315	5	605,494
58868	12 May	310	-	255
59024	12 May	330	4	202,680
59232	12 May	320	9	153,582
59284	12 May	335	6	-
59336	12 May	300	8	232,889
59388	12 May	320	7	57,492

[1] The number of locations where acoustic tags were manually relocated.
[2] The number of records for each acoustic tag recovered from remotely deployed hydrophone buoys.

Table 3. --Year 2003 manual acoustic tag re-sampling in St. John Baptist Bay, 3 – 4 October.

Sample	Relocated tags	Water depth (m)	Sample date beginning	Sample time beginning	Sample duration (hr:min)	Latitude	Longitude	Platform
1[1]	7	21.3	3 October	14:53	0:22	57° 17.178 N	135° 33.723 W	*John N. Cobb*
2	5	21.3	3 October	15:24	0:08	57° 17.308 N	135° 34.292 W	Skiff
3	2	21.3	3 October	15:36	0:06	57° 17.364 N	135° 34.464 W	Skiff
4	0	35.1	3 October	15:47	0:02	57° 17.454 N	135° 34.677 W	Skiff
5	0	22.9	3 October	15:58	0:03	57° 17.539 N	135° 34.427 W	Skiff
6	6	7.6	3 October	16:10	0:09	57° 17.113 N	135° 33.47 W	Skiff
7[1]	12	21.3	3 October	16:46	22:46	57° 17.178 N	135° 33.723 W	*John N. Cobb*

[1] The NOAA ship *John N. Cobb* anchorage in October 2003 was located at 57° 17.178 N by 135° 33.723 W at water depth 21.3 m.

Table 4. -- Year 2004 manual acoustic tag re-sampling in St. John Baptist Bay, 12 – 14 May.

Sample	Relocated tags	Water depth (m)	Sample date beginning	Sample time beginning	Sample duration (hr:min)	Latitude	Longitude	Platform
1[1]	0	22.9	12 May	18:00	18:00	57° 17.21 N	135° 33.98 W	*John N. Cobb*
2	0	9.2	13 May	12:47	< 0:05	57° 17.13 N	135° 33.357 W	Skiff
3	0	15.0	13 May	12:51	< 0:05	57° 17.131 N	135° 33.5 W	Skiff
4	0	17.2	13 May	12:53	< 0:05	57° 17.131 N	135° 33.573 W	Skiff
5	0	19.3	13 May	12:56	< 0:05	57° 17.153 N	135° 33.676 W	Skiff
6	0	22.5	13 May	13:00	< 0:05	57° 17.177 N	135° 33.841 W	Skiff
7	0	21.8	13 May	13:04	< 0:05	57° 17.224 N	135° 33.85 W	Skiff
8	0	23.9	13 May	13:09	< 0:05	57° 17.169 N	135° 33.962 W	Skiff
9	1	26.0	13 May	13:15	< 0:05	57° 17.207 N	135° 33.988 W	Skiff
10	1	14.4	13 May	13:18	< 0:05	57° 17.274 N	135° 34.031 W	Skiff
11	1	26.1	13 May	13:23	< 0:05	57° 17.238 N	135° 34.188 W	Skiff
12	1	28.7	13 May	13:28	< 0:05	57° 17.279 N	135° 34.357 W	Skiff
13	0	24.8	13 May	13:34	< 0:05	57° 17.376 N	135° 34.537 W	Skiff
14	1	32.5	13 May	13:39	< 0:05	57° 17.413 N	135° 34.743 W	Skiff
15	2	36.0	13 May	13:45	< 0:05	57° 17.542 N	135° 34.658 W	Skiff
16	2	49.5	13 May	13:55	< 0:05	57° 17.505 N	135° 34.908 W	Skiff
17	4	61.0	13 May	14:08	< 0:05	57° 17.55 N	135° 35.21 W	Skiff
18	3	47.6	13 May	14:19	< 0:05	57 °17.664 N	135° 35.342 W	Skiff
19	2	53.2	13 May	14:27	< 0:05	57 °17.742 N	135° 35.521 W	Skiff
20	2	59.4	13 May	14:32	< 0:05	57° 17.8 N	135° 35.693 W	Skiff
21	3	59.6	13 May	14:38	< 0:05	57° 17.889 N	135° 35.977 W	Skiff
22	2	61.0	13 May	14:42	< 0:05	57° 17.733 N	135° 35.185 W	Skiff
23	1	NA	13 May	14:46	< 0:05	57° 17.624 N	135° 35.854 W	Skiff
24	3	58.8	13 May	14:49	< 0:05	57° 17.54 N	135° 35.427 W	Skiff
25[1]	0	22.9	13 May	15:00	3:00	57° 17.21 N	135° 33.98 W	*John N. Cobb*
26	3	36.6	13 May	NA	< 0:05	57° 18.048 N	135° 36.334 W	Skiff
27	2	61.0	13 May	18:51	< 0:05	57° 18.038 N	135° 36.49 W	Skiff
28	4	77.4	13 May	18:56	< 0:05	57° 18.08 N	135° 36.694 W	Skiff
29	3	78.0	13 May	19:01	< 0:05	57° 18.128 N	135° 36.846 W	Skiff
30	2	79.2	13 May	19:06	< 0:05	57° 18.178 N	135° 36.954 W	Skiff
31	1	91.4	13 May	19:11	< 0:05	57° 18.27 N	135° 37.212 W	Skiff
32	1	87.8	13 May	19:15	< 0:05	57° 18.363 N	135° 37.378 W	Skiff
33	1	82.9	13 May	19:21	< 0:05	57° 18.492 N	135° 37.701 W	Skiff
34	2	81.4	13 May	19:26	< 0:05	57° 18.679 N	135° 37.897 W	Skiff
35	1	86.6	13 May	19:32	< 0:05	57° 18.606 N	135° 38.407 W	Skiff
36	1	82.9	13 May	19:40	< 0:05	57° 18.309 N	135° 37.944 W	Skiff
37	2	91.4	13 May	19:44	< 0:05	57° 17.916 N	135° 37.082 W	Skiff
38	1	31.1	13 May	19:47	< 0:05	57° 17.463 N	135° 36.653 W	Skiff
39	0	25.0	13 May	19:50	< 0:05	57° 17.128 N	135° 36.429 W	Skiff

[1] The NOAA ship *John N. Cobb* anchorage in May 2004 was located at 57° 17.21 N by 135° 33.98 W at water depth 22.9 m.

Table 4. -- Continued.

Sample	Relocated tags	Water depth (m)	Sample date beginning	Sample time beginning	Sample duration (hr:min)	Latitude	Longitude	Platform
40	2	81.7	13 May	19:54	< 0:05	57° 17.629 N	135° 35.97 W	Skiff
41	3	54.9	13 May	19:58	< 0:05	57° 17.523 N	135° 35.016 W	Skiff
42	1	29.7	13 May	20:02	< 0:05	57° 17.278 N	135° 34.319 W	Skiff
43	0	21.3	13 May	20:05	< 0:05	57° 17.171 N	135° 33.759 W	Skiff
44[1]	0	22.9	13 May	20:30	9:00	57° 17.21 N	135° 33.98 W	*John N. Cobb*
45	0	82.0	14 May	8:39	< 0:05	57° 18.898 N	135° 38.62 W	Skiff
46	0	82.3	14 May	8:45	< 0:05	57° 19.28 N	135° 38.978 W	Skiff
47	0	64.0	14 May	8:55	< 0:05	57° 19.93 N	135° 40.683 W	Skiff
48	0	45.1	14 May	9:03	< 0:05	57° 18.922 N	135° 41.765 W	Skiff
49	0	64.6	14 May	9:09	< 0:05	57° 19.466 N	135° 41.413 W	Skiff
50	0	76.8	14 May	9:15	< 0:05	57° 19.008 N	135° 39.569 W	Skiff
51	3	84.4	14 May	9:21	< 0:05	57° 18.561 N	135° 38.675 W	Skiff
52	0	68.0	14 May	9:27	< 0:05	57° 18.303 N	135° 38.49 W	Skiff
53	0	36.6	14 May	9:42	< 0:05	57° 18.191 N	135° 38.258 W	Skiff
54	1	87.8	14 May	9:45	< 0:05	57° 18.506 N	135° 38.014 W	Skiff
55	2	85.6	14 May	9:48	< 0:05	57° 18.781 N	135° 38.359 W	Skiff
56	0	86.9	14 May	9:53	< 0:05	57° 18.439 N	135° 37.601 W	Skiff
57	1	91.4	14 May	9:56	< 0:05	57° 18.216 N	135° 37.17 W	Skiff
58	2	83.5	14 May	10:01	< 0:05	57° 18.137 N	135° 36.972 W	Skiff
59	2	85.6	14 May	10:05	< 0:05	57° 17.918 N	135° 36.834 W	Skiff
60	2	81.7	14 May	10:10	< 0:05	57° 17.7 N	135° 36.696 W	Skiff
61	0	31.7	14 May	10:14	< 0:05	57° 17.364 N	135° 36.635 W	Skiff
62	3	66.8	14 May	10:19	< 0:05	57° 17.774 N	135° 35.905 W	Skiff
63	4	60.3	14 May	10:22	< 0:05	57° 17.642 N	135° 35.398 W	Skiff
64	3	52.7	14 May	10:26	< 0:05	57° 17.522 N	135° 34.96 W	Skiff
65	1	26.5	14 May	10:30	< 0:05	57° 17.361 N	135° 34.531 W	Skiff
66	2	26.8	14 May	10:33	< 0:05	57° 17.227 N	135° 34.174 W	Skiff
67	1	26.2	14 May	10:40	< 0:05	57° 17.182 N	135° 33.965 W	Skiff
68	1	18.9	14 May	10:45	< 0:05	57° 17.144 N	135° 33.65 W	Skiff
69	0	4.9	14 May	10:51	< 0:05	57° 17.087 N	135° 33.424 W	Skiff
73	2	25.0	14 May	12:31	< 0:05	57° 17.26 N	135° 34.182 W	Skiff

[1] The NOAA ship *John N. Cobb* anchorage in May 2004 was located at 57° 17.21 N by 135° 33.98 W at water depth 22.9 m.

Table 5.--Years 2003 and 2004 remote hydrophone buoy locations in St. John Baptist Bay.

Buoy	Deployment date	Recovery date	Latitude	Longitude	Depth (m)
1-2003	2 October 2003	18 November 2003	57° 17.2 N	135° 33.659 W	20.2
2-2003	2 October 2003	18 November 2003	57° 17.12 N	135° 33.648 W	18.6
1-2004	12 May 2004	7 September 2004	57° 17.293 N	135° 34.21 W	21.6
2-2004	12 May 2004	7 September 2004	57° 17.198 N	135° 34.143 W	23.2

Table 6. -- Years 2003 and 2004 maximum and intermittent acoustic range of test tags in St. John Baptist Bay.

Sample	Range (m)	Sample date	Sample time	Sample water depth (m)	Range latitude	Range longitude
2003[1] Max range to buoy 1	151.8	3 October	15:18	21.3	57° 17.197 N	135° 33.812 W
2003[1] Max range to buoy 2	259.7	3 October	15:22	21.3	57° 17.196 N	135° 33.87 W
2003[1] Average of buoys 1 and 2	205.7					
2004[2] Max range to a drifting buoy	201.2	14 May	12:20	24.4	57° 17.296 N	135° 34.365 W
2004[2] Intermittent detection range to a drifting buoy	256.0	14 May	12:30	24.4	57° 17.314 N	135° 34.413 W

[1] Year 2003 positions were provided by the NOAA Ship *John N. Cobb* ship board fix with ARPA DGPS-corrected locations.
[2] Year 2004 drifting buoy latitude (57° 17.2595 N), longitude (135° 34.178 W), water depth (22.9 m), and acoustic tag depth on the drifting buoy (12.2 m) were approximate.

Table 7. -- Year 2003 juvenile sablefish acoustic tag records recovered from remotely deployed hydrophone buoys in St. John Baptist Bay, 1 October – 14 November.

	Buoy 1			Buoy 2			
		Date			Date		
Tag number	Buoy records[1]	Min.	Max.	Buoy records[1]	Min.	Max.	Condition factor
29500	60	1 Oct.	1 Oct.	60	1 Oct.	1 Oct.	2[2]
29700	47,781	2 Oct.	10 Nov.	38,519	2 Oct.	11 Nov.	1[3]
29800	29,913	1 Oct.	5 Nov.	47,849	1 Oct.	5 Nov.	1[3]
29900	28,742	1 Oct.	14 Nov.	25,277	1 Oct.	11 Nov.	1[3]
30000	32,219	1 Oct.	7 Nov.	24,013	1 Oct.	7 Nov.	1[3]
30100	10,806	1 Oct.	8 Nov.	9,566	1 Oct.	11 Nov.	1[3]
30200	7,668	1 Oct.	5 Oct.	11,508	1 Oct.	5 Oct.	2[2]
30300	127	1 Oct.	1 Oct.	145	1 Oct.	2 Oct.	2[2]
30500	39,522	1 Oct.	8 Nov.	32,766	1 Oct.	8 Nov.	1[3]
30600	19,524	1 Oct.	27 Oct.	14,833	1 Oct.	27 Oct.	3[4]
30700	269	1 Oct.	1 Oct.	269	1 Oct.	1 Oct.	2[2]
30800	3,092	2 Oct.	13 Oct.	13,163	2 Oct.	13 Oct.	2[2]
30900	11,164	2 Oct.	9 Oct.	8,215	2 Oct.	9 Oct.	3[4]
Total	230,887			226,183			

[1] The number of records for each acoustic tag recovered from remotely deployed hydrophone buoys.
[2] Changes in depth and temperature (movement) but appeared to leave the area.
[3] Changes in depth and temperature (movement) and remained in range.
[4] No movement and remained in range.

Table 8. -- Year 2003 depth and temperature records used for analysis; Juvenile sablefish acoustic tag records recovered from remotely deployed hydrophone buoys in St. John Baptist Bay, 1 October – 14 November, and condition factor 1.

Tag number	Buoy records[1]	Unique records for depth[2]	Unique records for temperature[2]
29700	86,300	70,945	7,944
29800	77,762	49,250	4,219
29900	54,019	44,162	6,557
30000	56,232	46,880	8,232
30100	20,372	18,424	751
30500	72,288	64,757	6,440
Total	366,973	294,418	34,143

[1] The number of records for each acoustic tag recovered from remotely deployed hydrophone buoys.
[2] Duplicate depth and temperature records from buoy 1 and buoy 2 removed.

Table 9.-- Year 2003 summary of depth and temperature records used for analysis; Juvenile sablefish acoustic tag records recovered from remotely deployed hydrophone buoys in St. John Baptist Bay, 1 October – 14 November, and condition factor 1.

	Depth data		Temperature data	
Summary	Date	Depth (m)	Date	Temp. (°C)
Minimum	1 October	0	1 October	3.6
1st Quartile	6 October	22.7	6 October	10.0
Median	10 October	24.7	11 October	10.0
Mean	14 October	23.6	14 October	10.0
3rd Quartile	19 October	26.8	20 October	10.1
Maximum	14 November	33.0	13 November	11.6

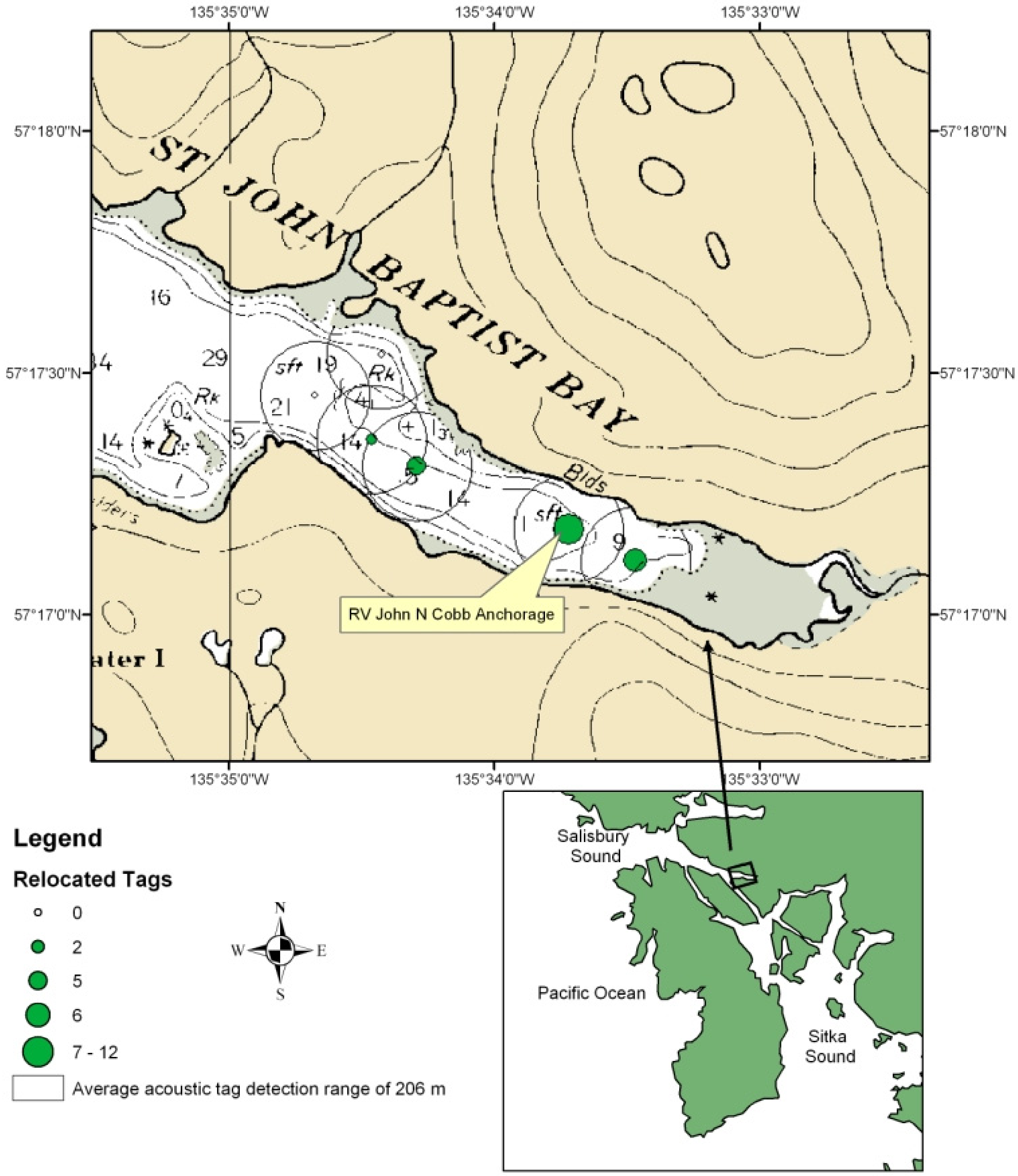


Figure 1.-- Year 2003 acoustic sampling locations in St. John Baptist Bay, 3 and 4 October 2003 (small circles), in relation to the acoustic tag release location (NOAA ship *John N. Cobb* anchorage) and the average acoustic tag detection range of 206 m (large circles).

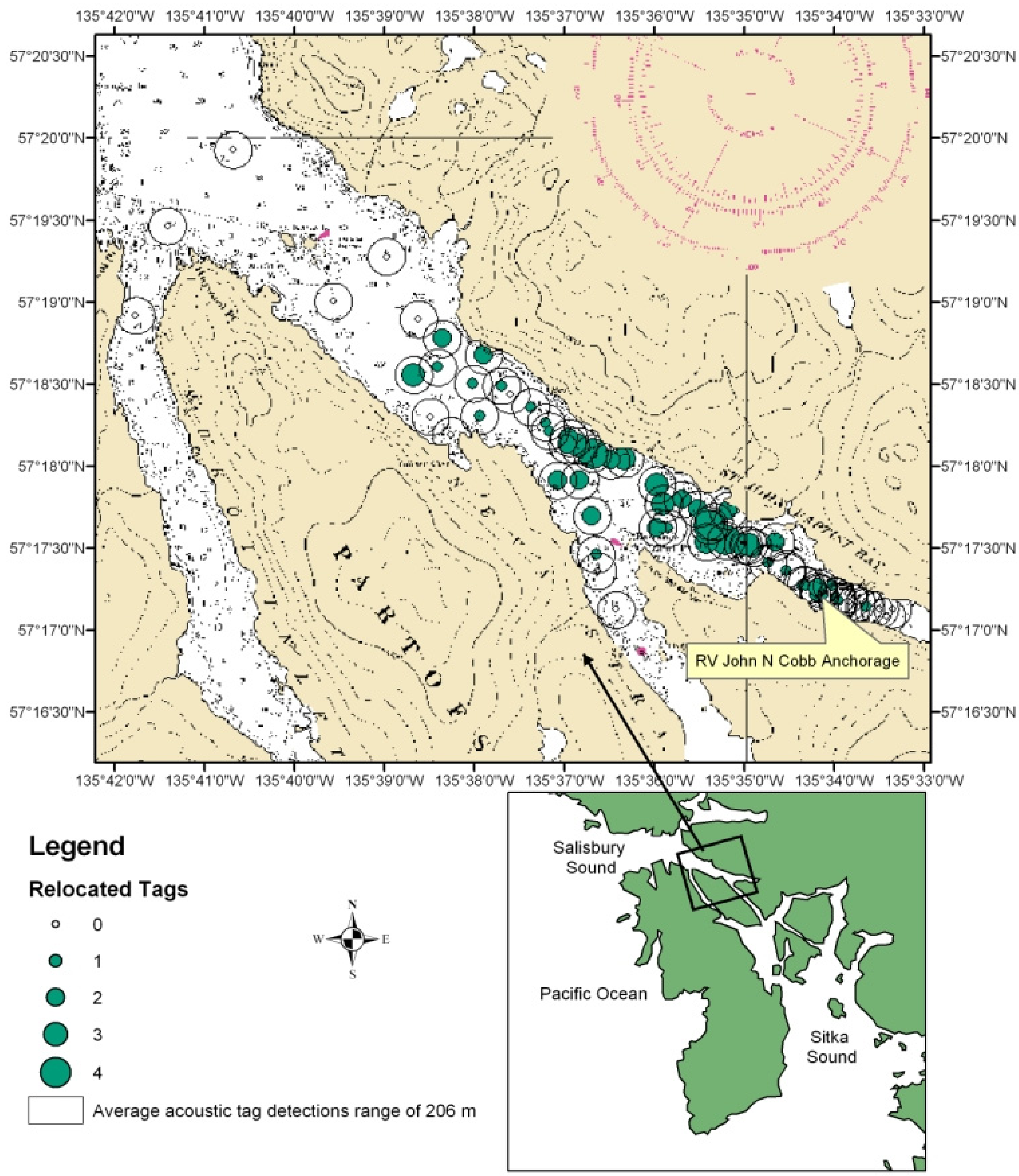


Figure 2.-- Year 2004 acoustic sampling locations in St. John Baptist Bay, 12 – 14 May 2004 (small circles), in relation to the acoustic tag release location (NOAA ship *John N. Cobb* anchorage) and the average acoustic tag detection range of 206 m (large circles).

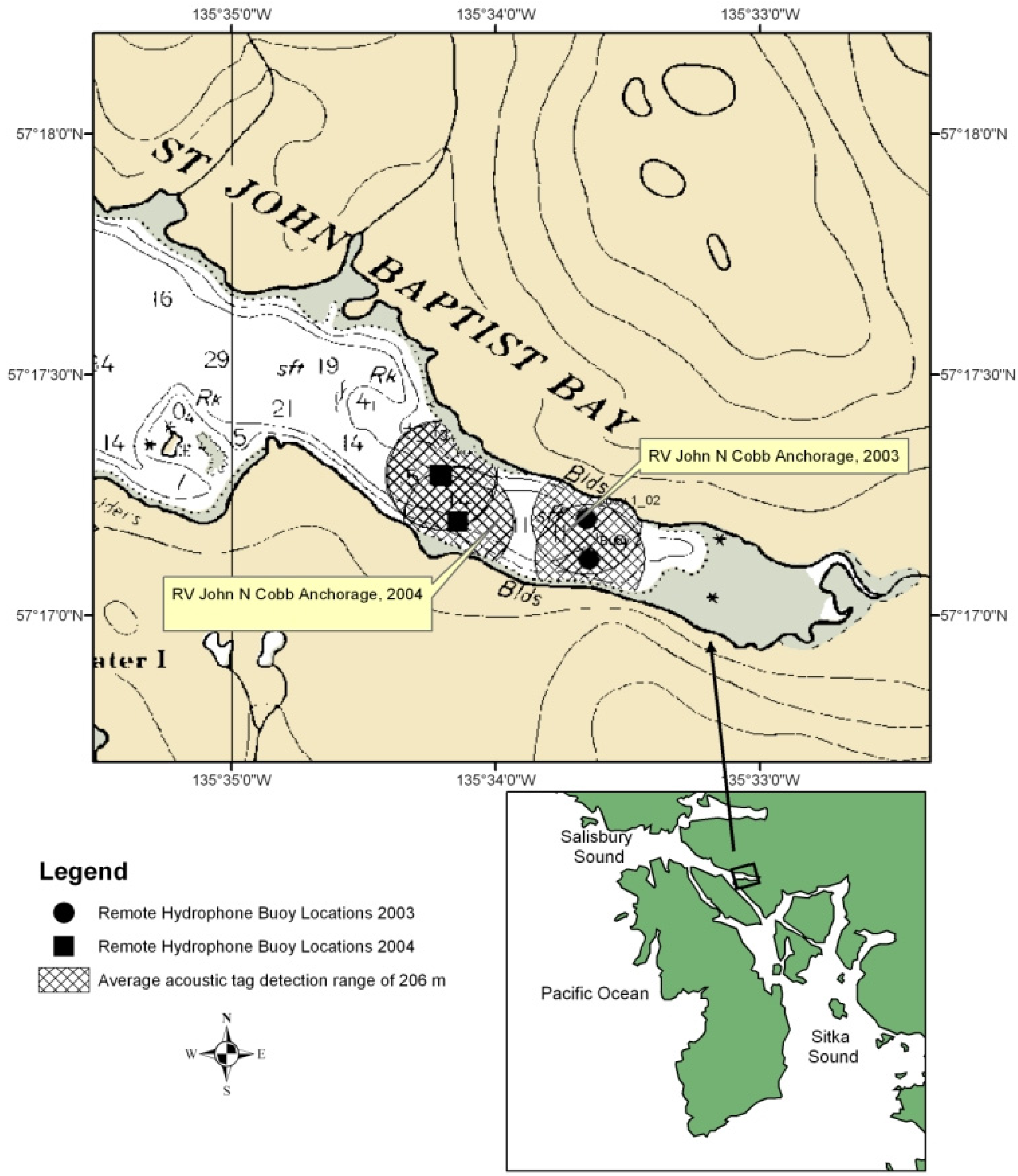


Figure 3.-- Remote hydrophone buoy locations in St. John Baptist Bay in year 2003, 2 October – 18 November (small solid circles) and year 2004, 12 May – 7 September (small solid squares), in relation to the NOAA ship *John N. Cobb* anchorages in 2003 and 2004 and to the average acoustic tag detection range of 206 m (large hatched circles).

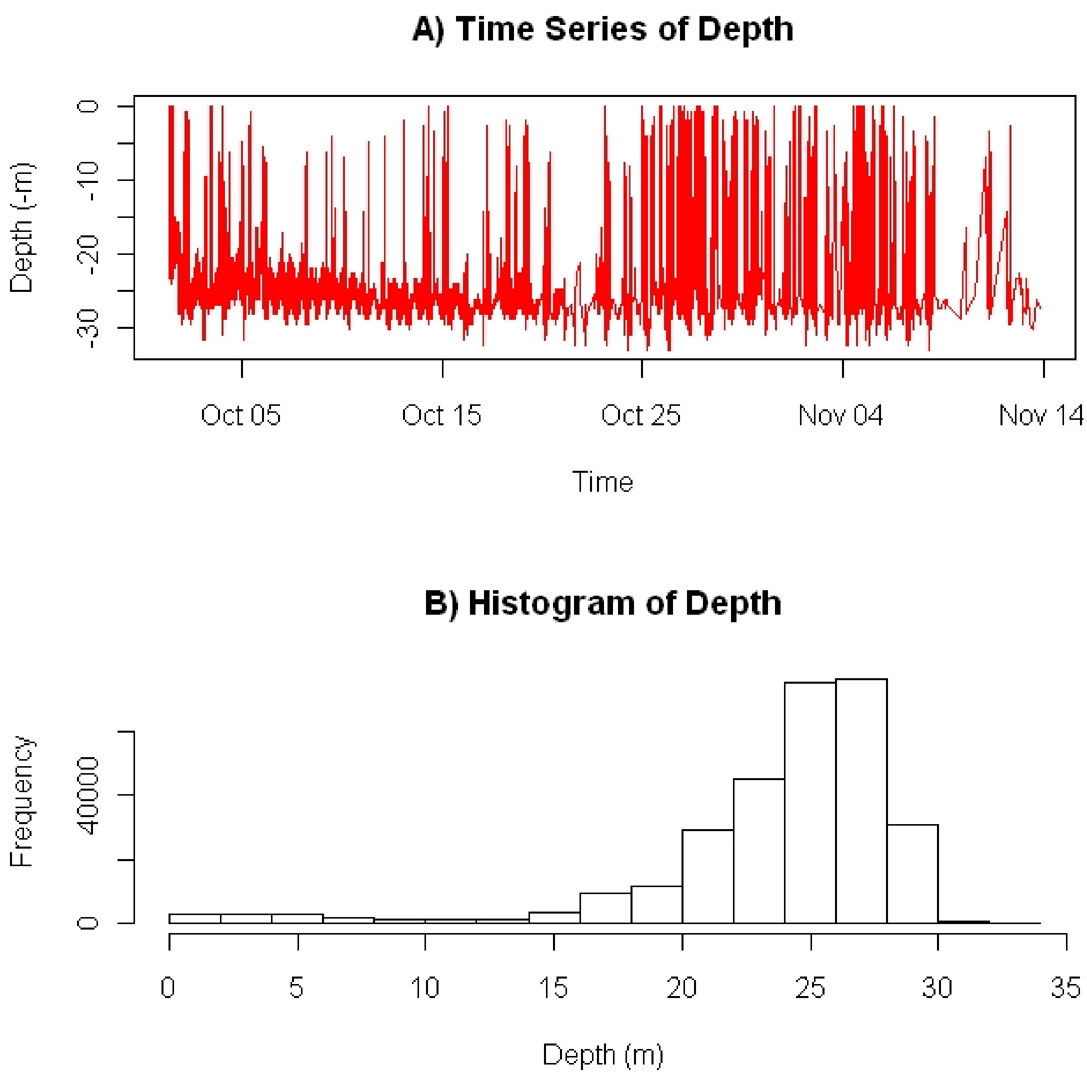
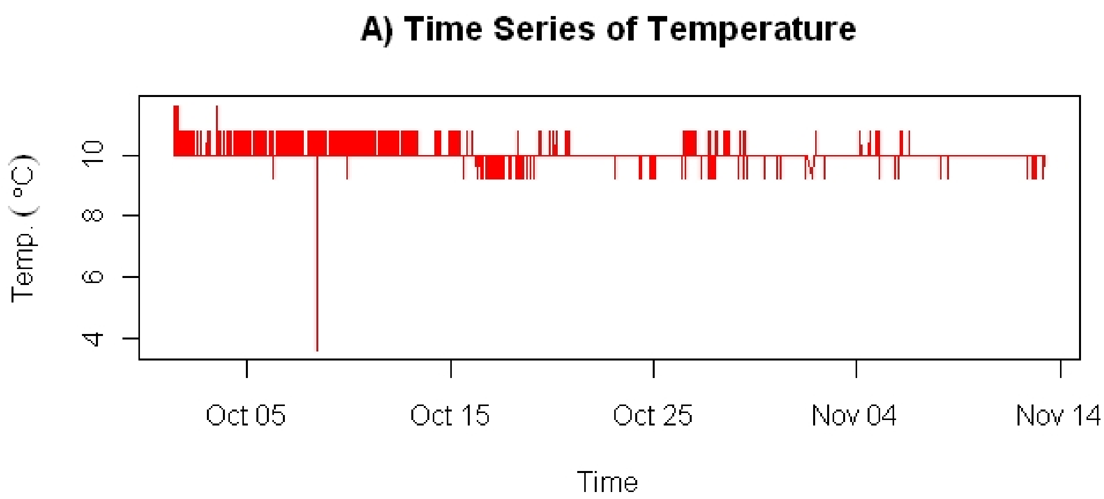


Figure 4.-- Depth (m) time series (Panel A) and histogram (Panel B) of acoustically tagged juvenile sablefish in St. John Baptist Bay, 1 October – 14 November 2003, recovered from remotely deployed hydrophone buoys.



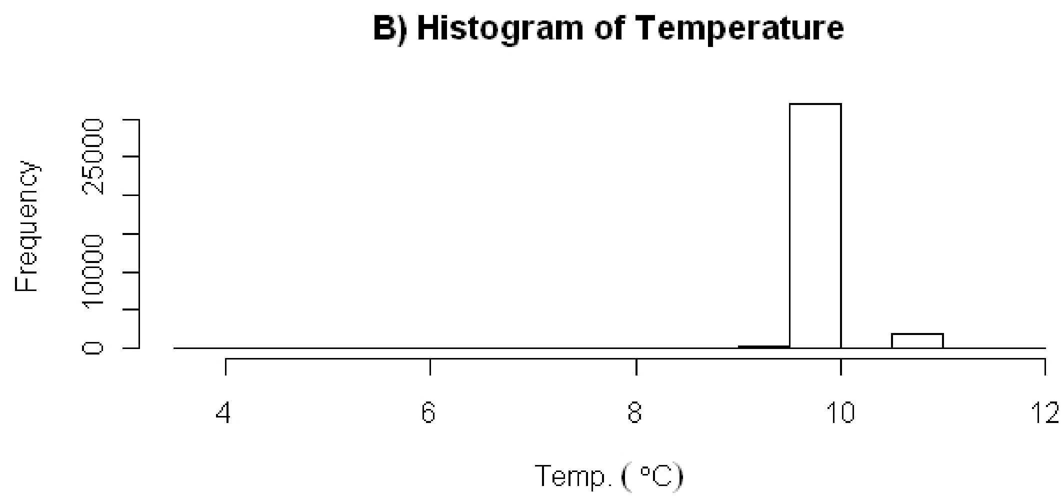


Figure 5.-- Temperature (°C) time series (Panel A) and histogram (Panel B) of acoustically tagged juvenile sablefish in St. John Baptist Bay, 1 October – 14 November 2003, recovered from remotely deployed hydrophone buoys.

APPENDIX A

Captive Sablefish Pilot Tagging Study

A captive juvenile sablefish pilot tagging project was conducted from 4 August 1999 to 1 December 1999 (119 days) at the Auke Bay Laboratories, Juneau, Alaska. On 4 August 1999 experimental surgery was conducted on five age-1+ sablefish (*Anoplopoma fimbria*). Mean fork length (FL) was 310 mm. Four of the fish received a dummy electronic tag measuring approximately 11 by 35 mm. The fifth fish was a control and was incised but did not receive a tag. Surgical methods were similar to those used in this study, except that the wounds were closed with 3 – 4 interrupted sutures of 6 – 10 lb monofilament rather than surgical staples.

The five fish were examined on 10 October 1999, 67 days after surgery. All five fish were alive and appeared to be in good health. An inspection of the holding tank showed that none of the dummy tags had been expelled. Only one suture remained in any of the fish, the rest of the sutures had either dissolved or had been expelled. An inspection of the wounds showed that three wounds were completely healed and two wounds were not completely healed. The worst case of incomplete healing was on the largest fish which had a partially open incision (90% closed) with a small red membrane-finger-like protrusion extending from the wound. No viscera were showing from the incision, which indicated visceral closure. The second fish with incomplete healing showed ripped skin by each suture, but a completely closed wound. The three remaining fish (including the control without a tag) showed no skin ripping by the sutures, no redness, and complete closure of the incision.

The five fish were re-examined again on 11 November 1999, 99 days after surgery. All five fish were alive and appeared to be in good health. An inspection of the tank showed that none of the dummy tags had been expelled. An inspection of the wounds showed that all five wounds had completely healed (no evidence of sutures, complete closure of wounds).

The growth rate of the five surgically altered fish was compared to the growth rate of nine captive sablefish (control group) held under similar conditions without surgery (Fig. A.1). At the beginning of the experiment (4 August 1999), the average fork length (FL) of the control group (309 mm FL), was similar to the average size of the experimental group (310 mm FL). The growth rate of the surgery group (0.4 mm/day) was lower but comparable to the growth rate of sablefish held without surgery (0.5 mm/day). Length was not measured from all fish during the study which may have biased the results, and as a result, growth rates were not compared statistically.

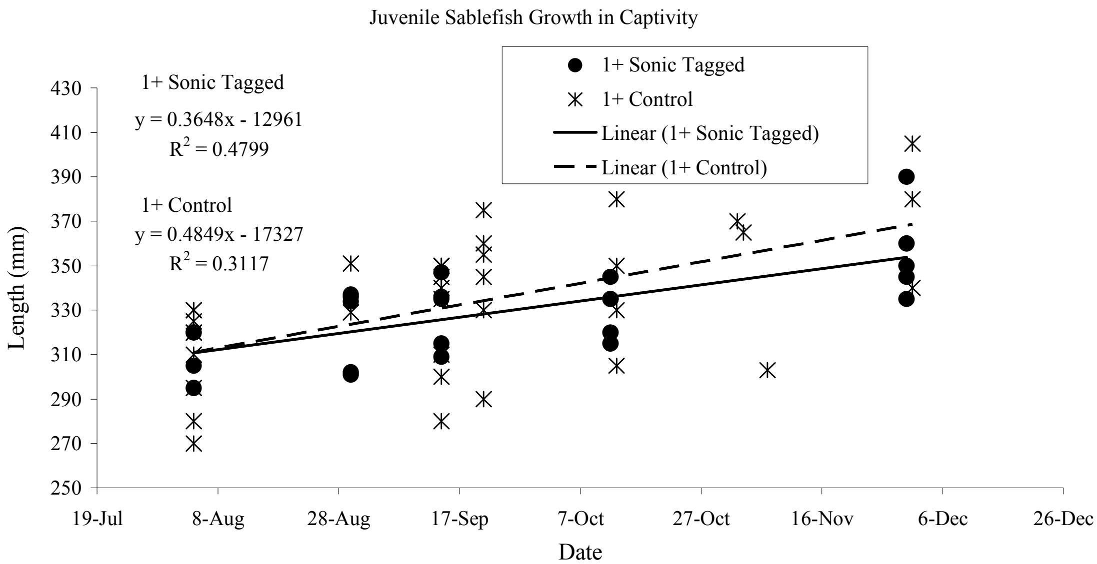


Figure A.1.-- Captive juvenile (age-1+) sablefish linear growth rates (y = slope*x + intercept) of the five surgically altered (1+ Sonic Tagged; solid line) and nine unaltered (1+ Control; stippled line) fish held under similar conditions.

APPENDIX B

Juvenile Sablefish Pilot Tagging Project in St. John Baptist Bay

In 2002, a pilot acoustic tagging project was conducted on juvenile sablefish in St. John Baptist Bay. The study location and methods were similar to those used in our present study except that LOTEK CAFT series coded acoustic transmitters and LOTEK SRX-400 receivers were utilized in 2002 rather than the LOTEK MAP digital encoded telemetry system which was utilized in 2003 and 2004.

In the 2002 study, acoustic tags were surgically implanted in 10 juvenile sablefish (300 – 320 mm FL) during 1 – 6 June 2002 on board the NOAA ship *John N. Cobb* and released in St. John Baptist Bay. During release, a SRX-400 receiver with one hydrophone was used to detect the acoustic tags. The acoustic signal of each released fish was monitored manually on the SRX-400 receiver. The real time pressure and temperature data transmitted from each tagged fish appeared to be consistent with the temperature and water depth in St. John Baptist Bay. After release, each tagged fish appeared to swim actively to the bottom and then to swim actively out of range of the acoustic receivers within seconds, suggesting that any adverse effects from the tagging were minimal.

Additional monitoring for acoustic tag transmissions was conducted with a remotely deployed hydrophone buoy during 1 – 6 June 2002 and during a return trip on board the MV *Chantrel* (10 m) during 30 June 2002 – 1 July 2002. The remote hydrophone buoy was attached to a VHF antenna buoy at the surface and anchored to the bottom along a corridor leading from the head of St. John Baptist Bay to the open ocean along Salisbury Sound. LOTEK suggests that under optimal conditions, the hydrophones used during 2002 were capable of detecting acoustic tag signals from a distance of 500 m. The wireless hydrophone is then capable of sending data to a receiver via VHF radio signal from a distance of 3 km or more depending upon the line of sight from the hydrophone to the receiver. The VHF antenna buoy has to remain above the water surface. Because of potential for interference with the acoustic equipment from vessel traffic in St. John Baptist Bay, the wireless hydrophone was only deployed during 1 – 6 June 2002, while VHF receiver was mounted on the NOAA ship *John N. Cobb* anchored in St. John Baptist Bay.

The SRX-400 receiver with one hydrophone was used to detect the acoustic tags during the return trip to St. John Baptist Bay on board the MV *Chantrel*, 30 June 2002 – 1 July 2002. Acoustic tag transmissions were recovered during the return trip. However, the acoustic records recovered during the additional monitoring included inaccurate acoustic tag IDs. We defined this problem of inaccurate acoustic tag IDs as a "false positive" tag identification. False positive tag identification confounded our ability to determine the number of tagged juvenile sablefish that remained in St. John Baptist Bay in 2002 because we could not be sure of the tag IDs. Acoustic records recovered during the additional monitoring also included temperatures and depths that were inconsistent with known temperatures and depths in St. John Baptist Bay. Because the temperatures and depths were inaccurate, and because of the potential for false positive IDs, the data were not analyzed further.

The 2002 pilot study was used to determine if the acoustic equipment was suitable to study movements of juvenile sablefish in St. John Baptist Bay. The results showed that the juvenile sablefish could survive in the wild after the tags were implanted, and that acoustic signals could be recovered in St. John Baptist Bay up to 1 month after tag release. The problems associated with the false positive tag IDs and inaccurate temperature and depth records were attributed to inaccurate calibration of the LOTEK CAFT series coded acoustic transmitters and LOTEK SRX-400 receivers in the acoustically “noisy” waters of inner St. John Baptist Bay. Our study in 2003 and 2004 utilized LOTEK MAP digital encoded telemetry system, a newer technology designed to overcome some of the technical problems encountered in the 2002 pilot project.