Development and Testing of Methods for Determining Lake Ozette Sockeye Salmon Beach Spawning Abundance and Distribution

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FIGURES

1 INTRODUCTION

In 2009, NMFS adopted the Lake Ozette Sockeye Salmon Recovery Plan (NMFS 2009) which identifies a broad range of actions needed to recover this ESA-listed species. The Recovery Plan and 2011 five-year status review for Lake Ozette sockeye (NMFS 2011) identify the current lack of sufficient data regarding abundance and distribution of the beach spawning portion of this population as a critical uncertainty preventing NMFS from fully understanding the viability status of the species.

Estimates of sockeye returning to Lake Ozette each year are generally made based on May-July weir counts (the weir is located at the outlet of the lake in the Ozette River) and represent the total number of beach and tributary-origin adults migrating into the lake. Fish counted at the weir subsequently hold in Lake Ozette up to six months prior to occupying beaches or entering tributaries in the fall and winter to spawn. The number of sockeye that die each year before spawning in the lake due to natural causes or predation is unknown. Identifying the abundance and distribution of the beach-spawning component of the population has been especially problematic due to adverse lake visibility and weather conditions that disrupt and often prevent stock assessment surveys based on visual observations of fish. The lack of reliable spawning estimates makes it difficult to assess current beach spawner status, or any changes in status that might be occurring over time for this population.

The purpose of this project is to help develop methods that can be used to enumerate Lake Ozette sockeye on the spawning beaches. This was accomplished by field testing dual frequency identification sonar (DIDSON) along the shorelines of Lake Ozette during the sockeye salmon spawning period. DIDSON technology uses sound pulses and converts the returning echoes into digital images, similar to the technology used in ultrasounds (Sound Metrics 2011). DIDSON does not use or need light to "see" and therefore can be used in dark and turbid water with limited or no visibility.

2 BACKGROUND

There are two known active beach spawning sites along the shores of Lake Ozette: Allen's Beach and Olsen's Beach (Figure 2.1). Beach spawning sockeye stage offshore of the spawning beaches in mid- to late-October and begin spawning as early as November 1 (MFM unpublished spawning ground surveys). Sockeye continue to aggregate in deeper water just off-shore of spawning beaches until maturation, then move onto the beaches to commence spawning.

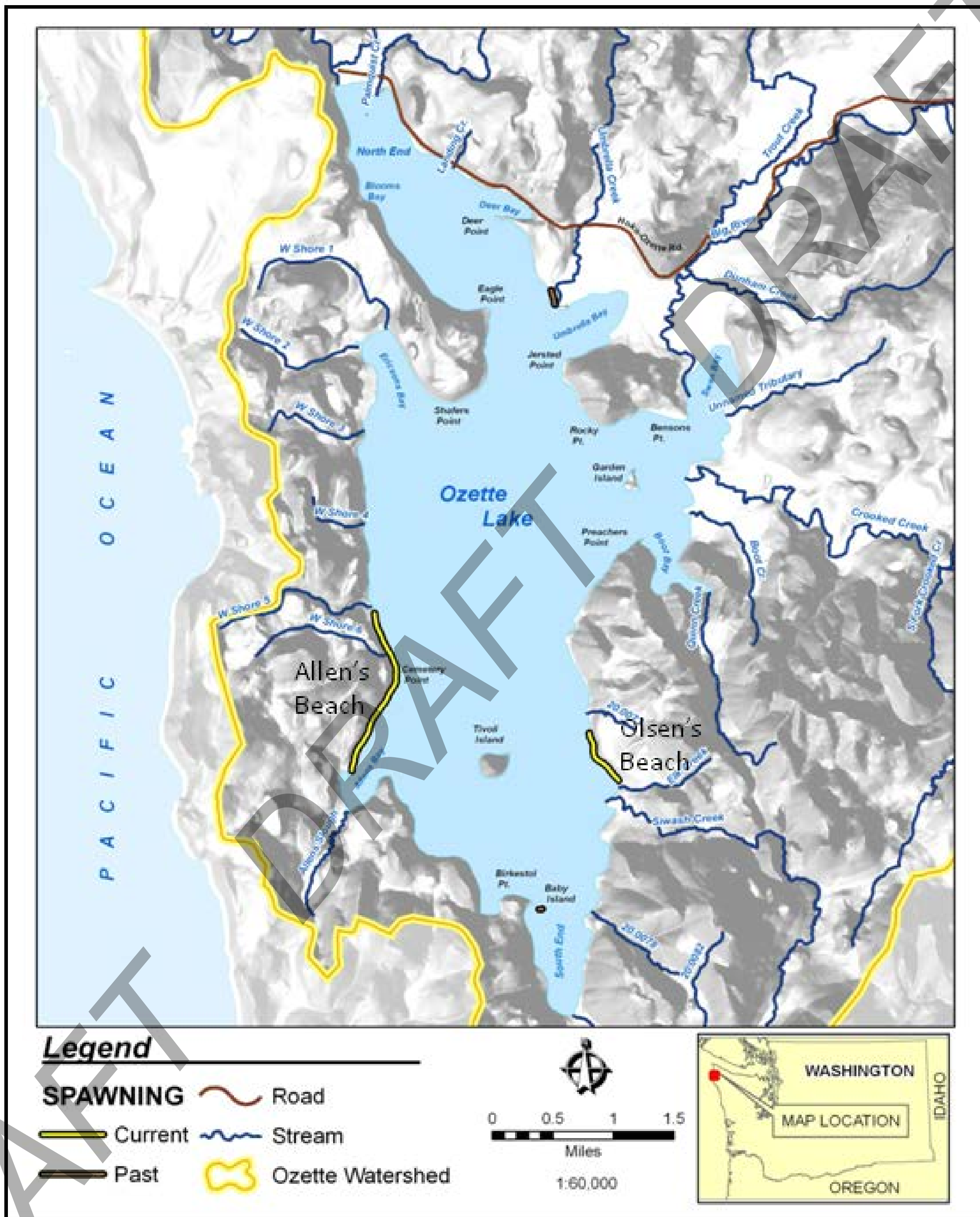

Figure 2.1. Current and historical Lake Ozette sockeye beach spawning locations (source: Haggerty et al. 2009)

2.1 Olsen's Beach Description

At Olsen's Beach the core spawning area is centered on a relatively small upwelling zone (spring) and encompasses approximately 6,400 ft^2 (600 m^2) of beach. Substrate conditions along the entire spawning beach grade from small cobble/large gravel to coarse sand and silt. Haggerty et al. (2009) characterized suitable spawning habitat in three utilization categories: core, concentrated, and dispersed. The core habitat is approximately 100 feet (30 m) in length and 66 feet (20 m) in width. The concentrated spawning use occurs for about 115 feet (35 m) on either side of the core area, as well as a zone approximately 425 feet (130 m) long at the northern tip of Olsen's Beach (Figure 2.2).

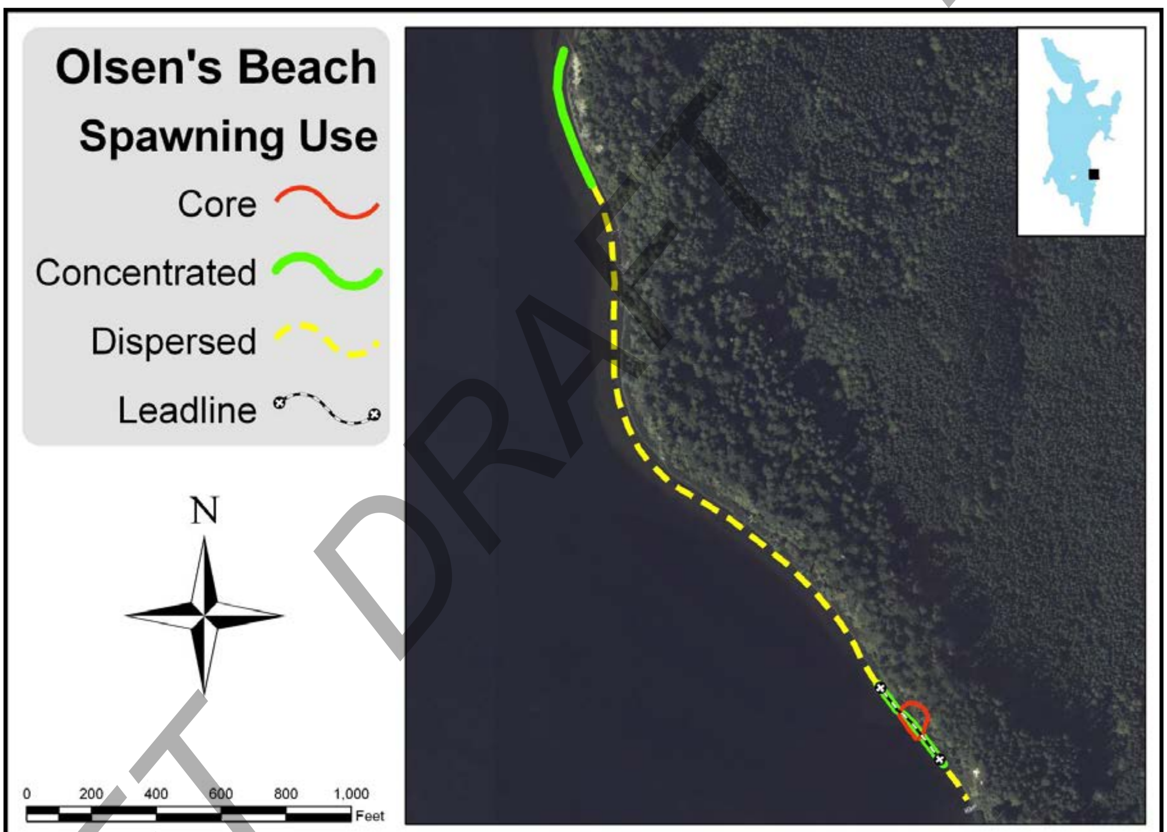

Figure 2.2. Current Olsen's Beach sockeye spawning use categorized as concentrated, core, and dispersed (From: Haggerty et al. 2009). Note: the lead line in the figure was used for snorkel and scuba surveys conducted 1999, 2000, and 2001.

Haggerty et al. (2009) described three discrete beach zones within the core spawning area at Olsen's Beach. These zones included the following: the upper beach, middle beach, and lower beach. Beach slope, substrate, and vegetation conditions vary between each zone. The highest spawning concentrations have been observed in the middle beach zone. The core area within the middle beach is approximately 26 feet (8 m) wide and 100 feet (30 m) in length, and has a slope of 2.7% (Figure 2.3). The core area upper and lower beaches have slopes of 11% and 12% gradient respectively. The spawning areas to the south of the core area have a more uniform beach slope. The spawning areas to the north have a slope similar to the core area, with the exception being that the low gradient beach sections occur at an elevation 3.3 feet (1 m) higher.

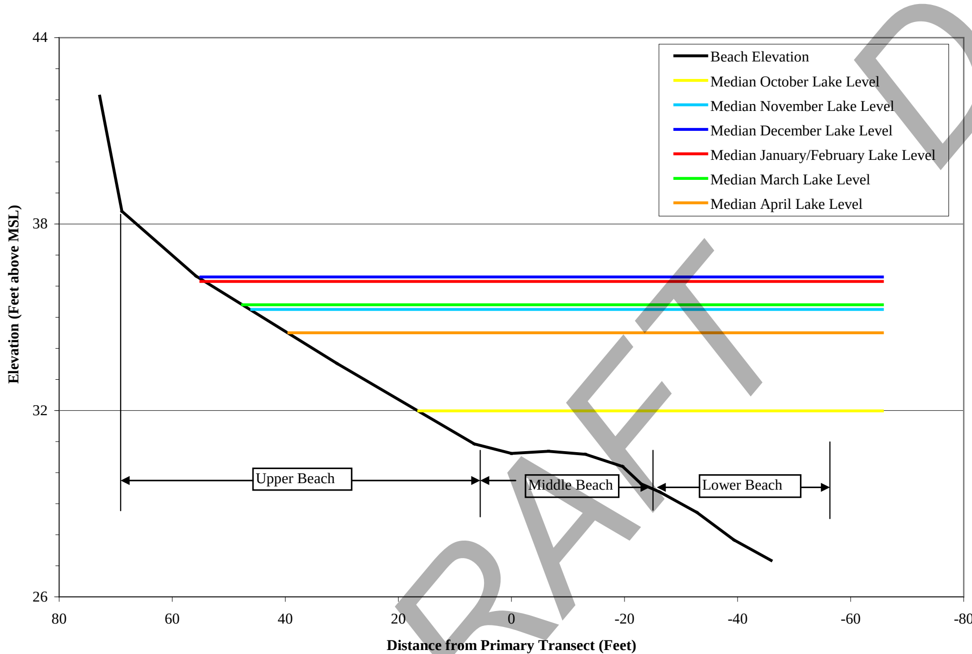

Figure 2.3. Cross-section of upper, middle, and lower beaches within the core spawning area at Olsen's Beach contrasted with median monthly lake level data from water years 1981 through 2004 (From: Haggerty et al. 2009).

2.2 Allen's Beach Description

Allen’s Beach sockeye salmon spawning is much more dispersed than at Olsen’s Beach. Based on spawning ground surveys conducted from 1999 through 2004 one area was classified as having concentrated spawning use (Figure 2.4). There may be other small areas with concentrated spawning use that have not yet been detected by surveys (such as Cemetery Point). The spawning area at Allen's Beach is approximately 1.4 miles long (2.2 km).

Substrate size and condition is variable along Allen's Beach. Substrate along the southwest end of the beach is composed primarily of fine sand, silt, mud, and organic detritus. Substrate size quickly grades into a matrix of coarse sand, pebbles, and gravel in the northeast direction. This area is sometimes referred to as South Allen’s.

Moving north-northeast from South Allen’s Beach, substrate size generally increases, with cobbles becoming a dominant component near Cemetery Point. Moving in the offshore direction, the substrate grades to sand and the bottom gently slopes to a depth of about 4 meters (13 ft) (relative to winter lake levels), where a distinct slope break occurs between about 4 and 6 meters (13 to 20 ft). Below about 6 meters (20 ft), the slope decreases again, and in some areas gravel can be found. Sockeye salmon have been observed spawning on this lower “shelf” at Allen’s Beach to depths of approximately 10 meters (32 ft). At least some spawning site selection appears to be associated with numerous seeps and springs along the shoreline, which were mapped during the summer of 1999 (See Haggerty et al. 2009).

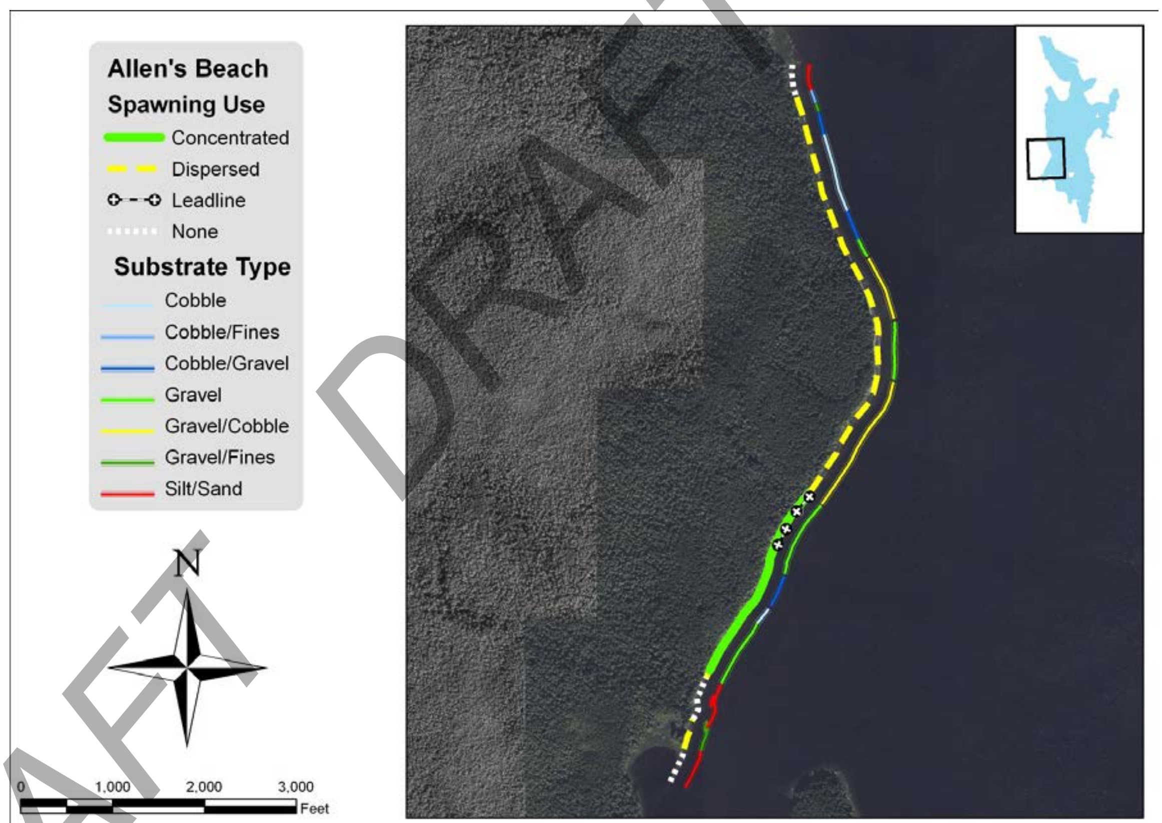

Figure 2.4. Allen's Beach spawning use classification and dominant substrate size (From: Haggerty et al. 2009).

Beach slope at Allen's Beach ranges from 8% to 9% gradient. Figure 2.5 depicts the differences in beach slope between Olsen's and Allen's beaches based upon typical cross-sections from the core and concentrated spawning areas.

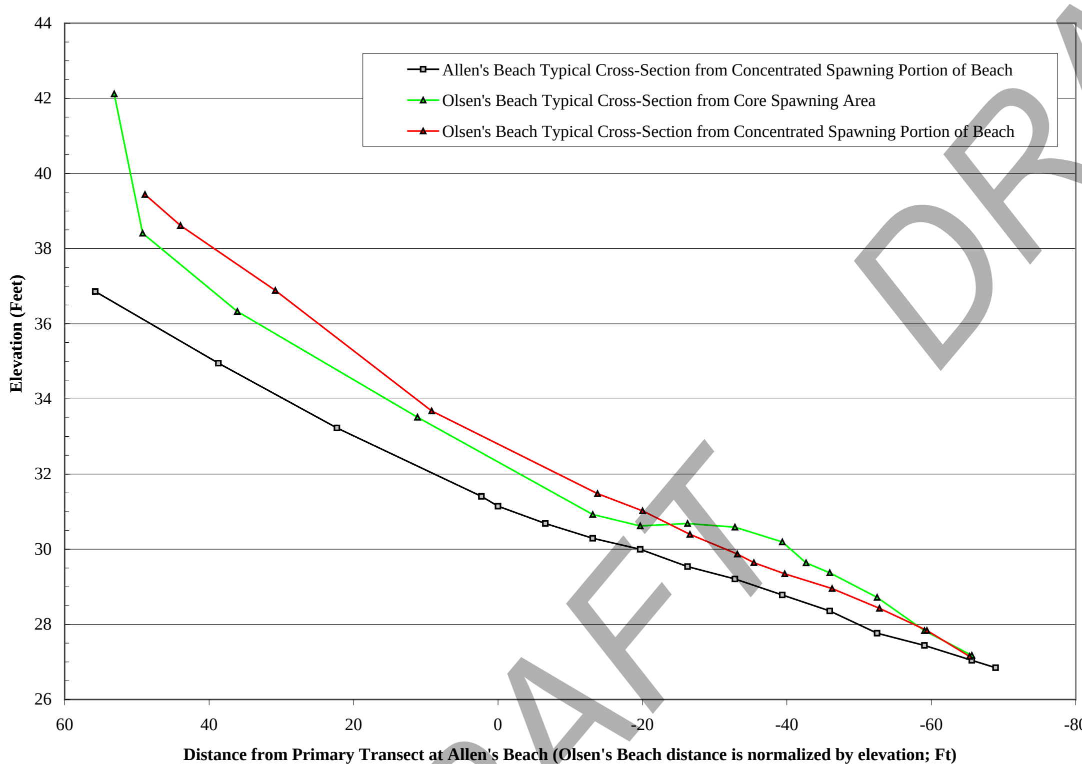

Figure 2.5. Comparison of beach profiles from Olsen's Beach core and concentrated spawning areas and Allen's Beach concentrated spawning use area. (From: Haggerty et al. 2009).

2.3 Recent and Past Methods used to Enumerate Beach Spawning Sockeye

Various methods have been used to count the number of spawning sockeye along the shorelines of Lake Ozette. The first fully documented surveys took place in 1973. Since then several different survey methods have been used. No systematic method for counting beach spawning sockeye has been developed. Past methods used to count spawning sockeye have included: seine and gill netting (mostly for broodstock collection, but also used to retrieve tissue samples for various genetic collections), foot, snorkel, scuba, and boat surveys. A detailed summary of past methods and results is included in Haggerty et al. (2009).

In 1999, lead line survey transects were established along the spawning beaches. These transects have been used for snorkel and scuba surveys where the number of sockeye are counted by divers. In addition divers have also collected data on the number, size, and position of redds along the lead lines. Boat surveys have been used to supplement dive surveys. These efforts have resulted in annual estimates of the minimum number of sockeye observed spawning, as well as detailed information on the location and characteristics of redds. Dive, snorkel, and boat surveys can be difficult during periods of high lake level, poor water visibility, and inclement weather conditions.

3 METHODS

3.1 Development of Beach Spawning Ground Survey Methods

During the sockeye salmon spawning period Lake Ozette often has poor visibility making counting fish from the surface difficult or impossible. Dive surveys are also limited by viewing conditions and are labor intensive, which limits the amount of area than can be surveyed. Since the fish are listed under the ESA standard mark and recapture techniques to assess the population have been discouraged by fishery managers and are unlikely to be permitted.

Over the course of the last several years the idea of using DIDSON (dual-frequency identification sonar) to count sockeye along the spawning beaches has been discussed by co-managers and stakeholders. The purpose of this project is to help advance those discussions into a field tested set of methods that can be used to enumerate sockeye on the spawning beaches. A thorough review of the literature yielded no examples of a DIDSON used for counting beach spawning sockeye salmon. We attempted to locate other sources of information related to this specific use of a DIDSON by contacting experts throughout the Pacific Northwest and Alaska. We were unable to find a single example of a DIDSON used for counting spawning sockeye on lake beaches. However, we did get recommendations for attempting the use of a DIDSON to enumerate beach spawning sockeye. The input from various experts and stakeholders was incorporated into the development field methods (see Section 3.2) used to test DIDSON technology at Lake Ozette.

3.2 Field Methods

Equipment Used

An 18 ft fiberglass boat with small cabin was used during the field surveys. The boat was equipped with a 90hp outboard motor, an 8hp motor, and smaller electric motor. A DIDSON Model 300 LR was used for data acquisition (Figure 3.1). When operating in identification mode the instrument operates at 1.2 Mhz. The DIDSON utilizes 96 beams spaced at 0.3 degrees. Beam width is 0.3° in the horizontal plane and 14° in the vertical plane.

Source: Sound Metrics 2011. Accessed via internet- http://www.soundmetrics.com

Figure 3.1. Photo of a DIDSON Model 300 LR.

The DIDSON was attached to an adjustable pole mount (Figure 3.2). The adjustable pole mount was mounted the boat's gunnel and clamped tight. A 3/8 inch rope was tied to the mounting system near the locking pin and to the boat in case the pole mount became disconnected from the boat's gunnel. The DIDSON transducer was mounted to the transducer mount using four factory supplied screws. The DIDSON was lowered and raised vertically along the main vertical pole using the locking sleeve to adjust postion. The DIDSON can be moved left or right using the aiming bars located at the top of the main pole. The DIDSON can be tilted vertically up and down using the tilt adjustment crank. The DIDSON unit measures view direction (magnetic azimuth) and vertical tilt with each image captured.

The DIDSON was power by a small 1 kilowatt gas powered generator. The power was fed into a Sound Metrics power supply box where the DIDSON cable was also attached. The DIDSON signal was delivered to a Panasonic Toughbook computer where data files were stored using DIDSON software. A handheld GPS unit (Garmin GPSmap 76Cx) was also attached to the computer with its signal interfaced with the DIDSON software so that the unit's position could be recorded on each image.

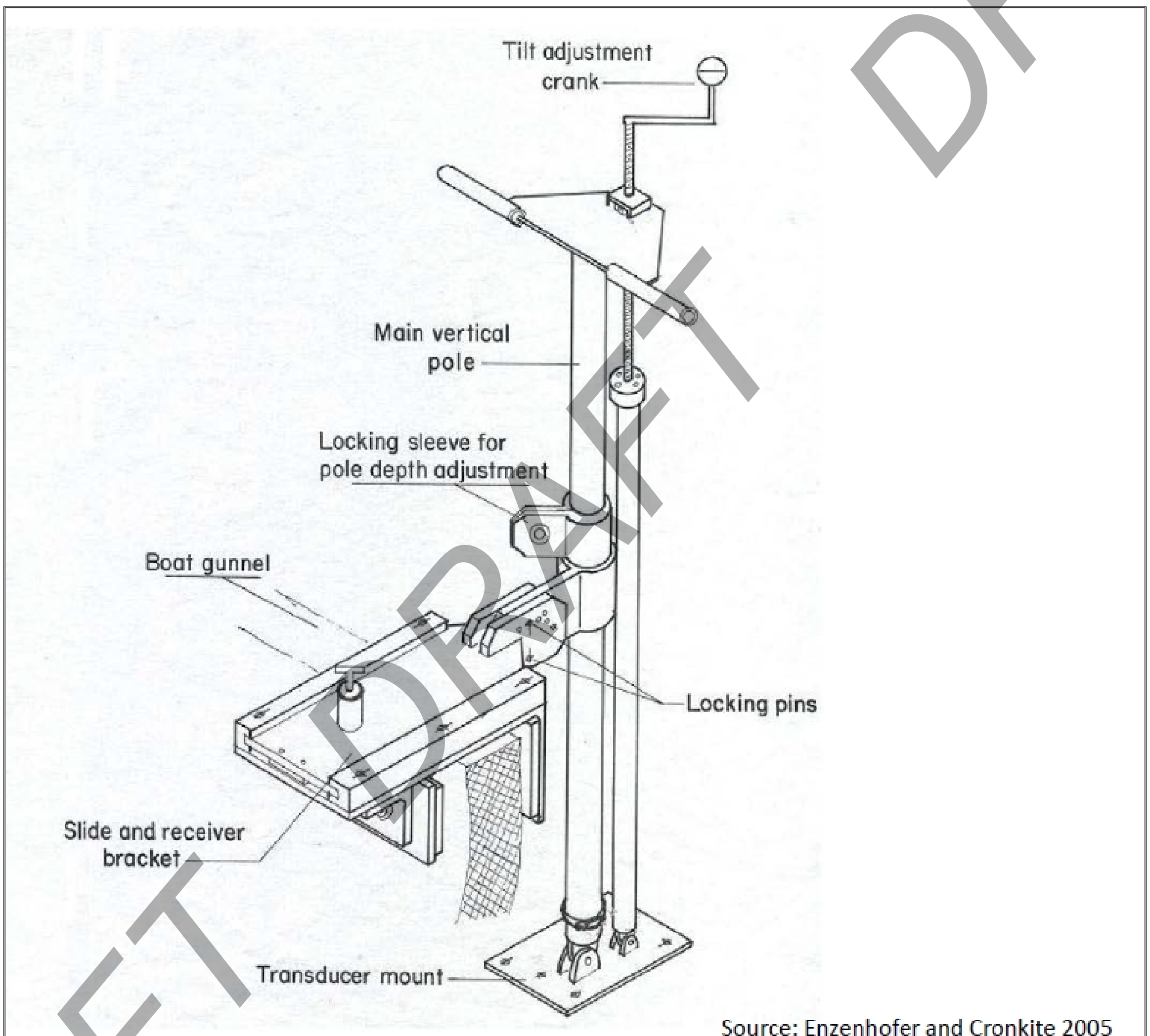

Figure 3.2. Diagram showing the adjustable pole mount used for mounting the DIDSON unit to a boat (Source: Enzenhofer and Cronkite 2005).

Survey Methods

All surveys were conducted on December 14, 2012. Surveys utilized a boat mounted DIDSON at Olsen's and Allen's beaches to count spawning sockeye salmon. Two survey methods were used: station and slow pass survey methods. The DIDSON was mounted along the side of the boat (as described above) in such a way that it can look "sideways" on the spawning grounds. The station method used multiple fixed stations. The boat was held in position and DIDSON images were recorded for 1 to 5 minutes. The total number of sockeye salmon observed at each station was recorded (see conceptual example in Figure 3.3).

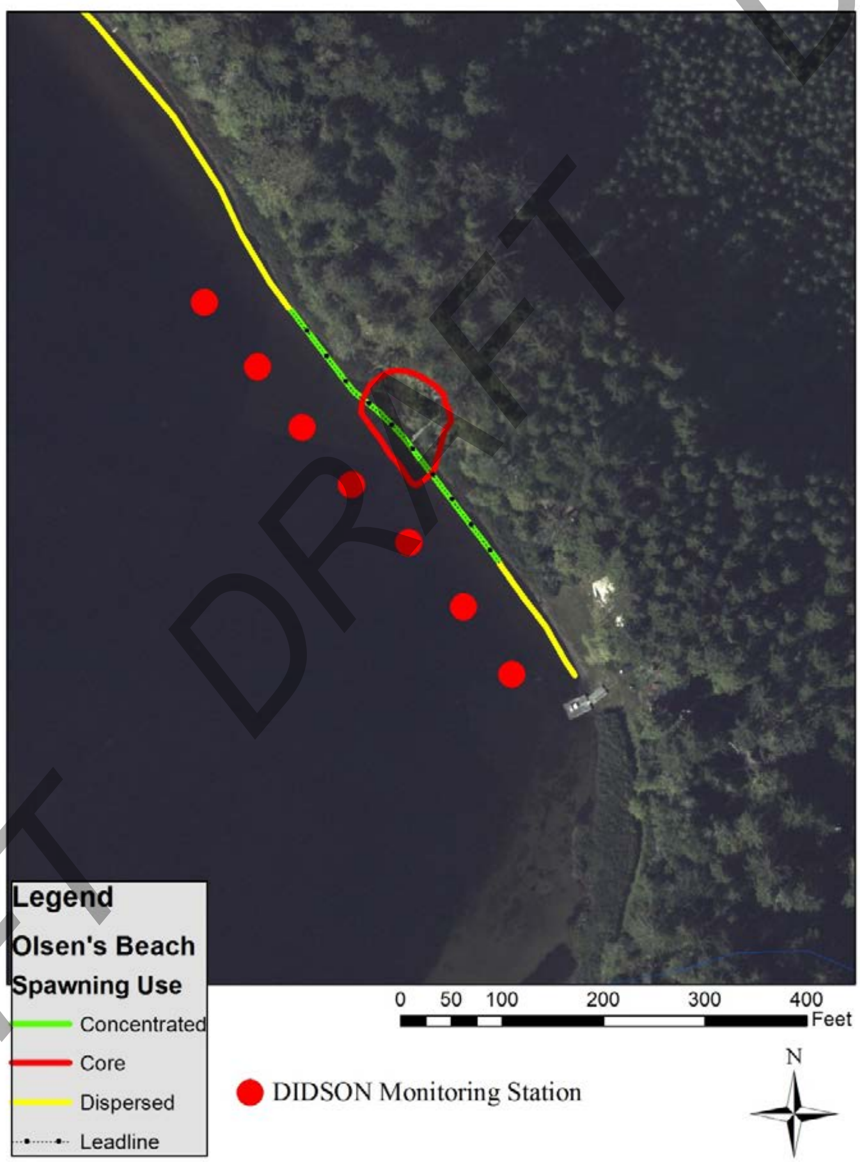

Figure 3.3. Diagram depicting conceptual DIDSON monitoring station locations at Olsen's Beach.

The slow pass method used a slowly moving boat. The DIDSON was pointed at the spawning beaches and the boat was driven very slowly past the targeted areas. Speeds were typically between 0.5 and 1.5 miles per hour. In order to travel at this slow of a speed, a small electric motor had to be used. Distance from spawning grounds varied from 10 to 25 meters. Only areas lake-ward of the low water vegetation line were targeted. The DIDSON was set to record 6 to 10 images per second. Sockeye were counted only if the their direction of travel through the image screen was opposite of the direction of the pass. This reduced or eliminated double counting sockeye that passed through the image frame more than once.

4 RESULTS and DISCUSSION

4.1 Olsen's Beach

Station Method Results

The station method was used at Olsen's Beach with the DIDSON set to ranges of 20 and 10 meters. When set to the 20 meter range the DIDSON was recording images from 3 to 23 meters away from the instrument. The DIDSON was used to target the middle beach of the core spawning area where high densities of sockeye could visually be seen. Lake level at the time of the survey was 35.2 ft (based on Olympic National Park staff gauge at the lake's outlet). At the 20 meter range the DIDSON was difficult to aim without getting interference from the surface and lake bottom. Images were quite grainy and difficult to interpret. Sockeye were detected intermittently making counting and individual fish identification difficult. The sockeye within the target area were also milling around further complicating the counting of individual fish.

At the 10 meter range DIDSON images were recorded at 3 to 13 meters away from the instrument. The DIDSON was easier to aim without getting interference and the images were clearer than those from the 20 meter setting. The field of view significantly limits the area surveyed from a single monitoring station. Multiple settings were used at the 10 meter range, varying from 1 to 11 meters to 5 to 15 meters. At the 10 meter range set to detect from 3 to 13 meters, the horizontal field of view is 6.7 meters and the vertical field is 3.3 meters. Figure 4.1 depicts the cross-sectional field of view of the DIDSON when set to record from 1 to 11 meters. Individual fish were much easier to identify when using the DIDSON at the 10 meter range as compared to the 20 meter range. Figure 4.2 depicts the Olsen's Beach spawning area ensonified by DIDSON at Station A and B. The small lines below polygons in Figure 4.2 represent the position of the DIDSON during the station surveys. Station A and B were 112 and 133 square meters respectively. The similar size between the two areas was due to the length of time surveyed, differences in drifting during image capture, and frame geometry. Sockeye density at station A was 15.2 sockeye per 100 sq meters. Sockeye density could not be measured at station B.

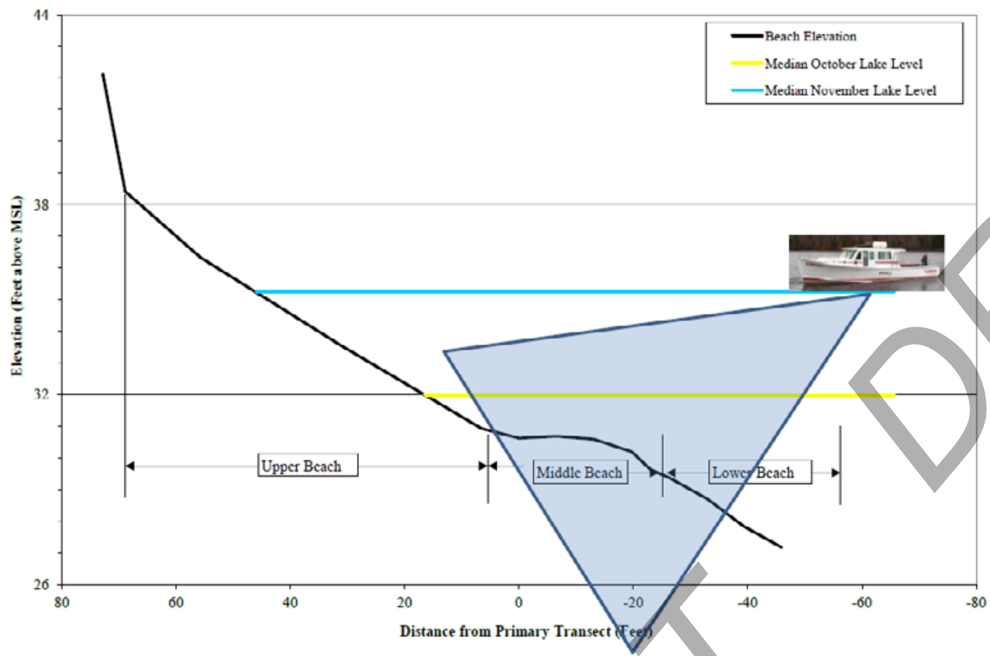

Figure 4.1. Cartoon depicting the cross-sectional field of view of the DIDSON when set to detect from 1 to 11 meters aimed at the middle beach.

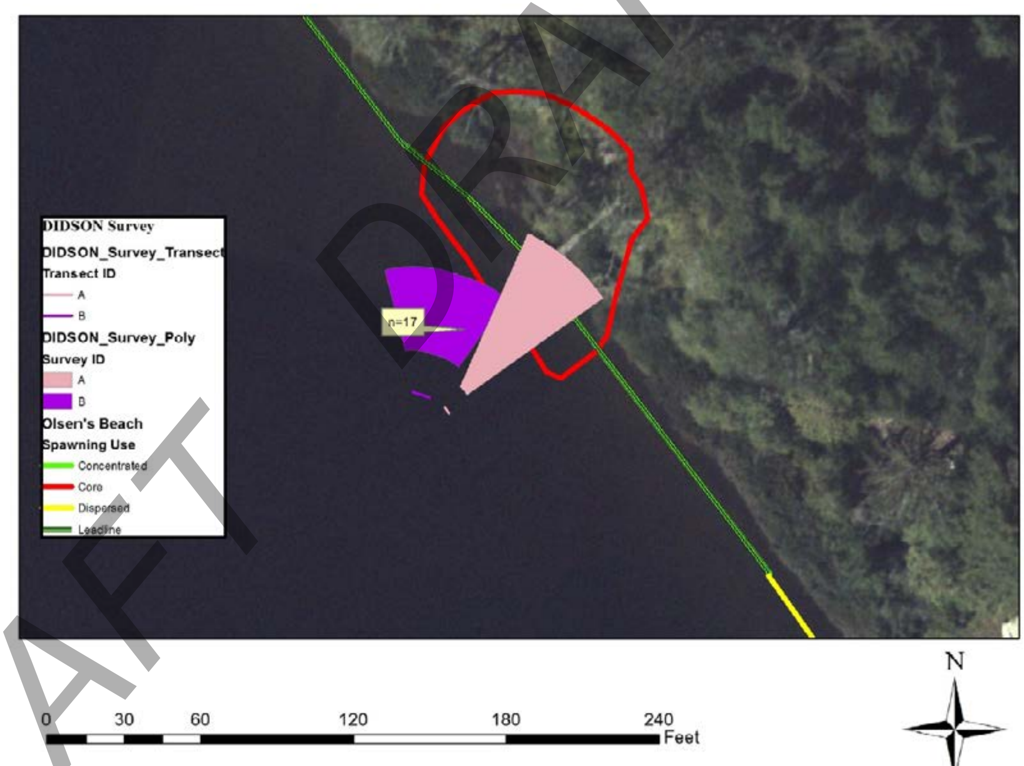

Figure 4.2. Map depicting Olsen's Beach spawning area ensonified by DIDSON at Station A and B.

Slow Pass Method Results

The first slow pass test at Olsen's Beach was recorded as transect 1a and 1b (Figure 4.3). The slow pass transects were run with the boat slowly moving to the northwest directly along the low water vegetation line. The DIDSON unit was aimed down the beach slope. A few large downed trees created obstacles that the boat had to maneuver around (see Figure 4.3). In these cases the survey was not directly parallel to the low water vegetation line. Transect 1a images were recorded from 5 to 15 meters (first half of survey) and 1 to 11 meters (second half of survey). Image recording rate was 7 frames per second. Each sockeye salmon captured in the DIDSON imagery was given a unique identification. GPS coordinates and distance from the DIDSON unit were recorded for each unique target. DIDSON software was used to measure the length of each sockeye. An example of the results from individual fish plotting is included in Figure 4.4. Average total sockeye length was 62 cm.

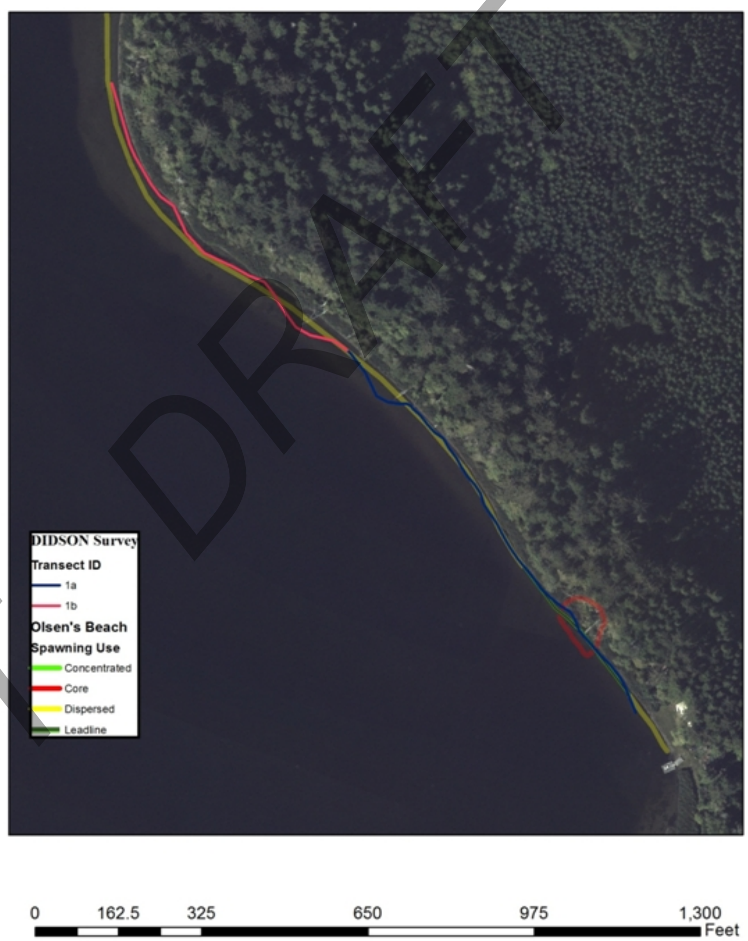

Figure 4.3. Map depicting the location of Transect 1a and 1b at Olsen's Beach contrasted with Olsen's Beach classified spawning use (source: Haggerty et al. 2009).

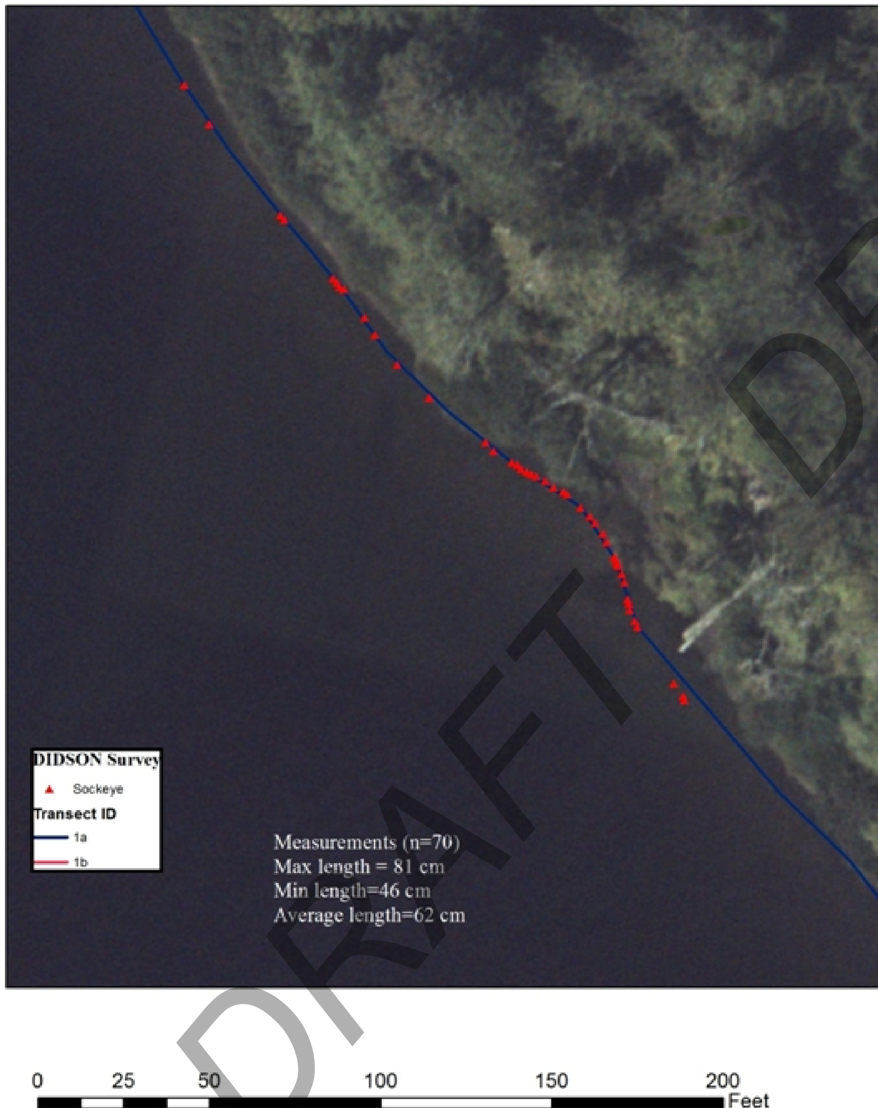

Figure 4.4. Example of results from Olsen's Beach Transect 1a showing the location of each sockeye salmon documented in DIDSON images.

Survey transects were further split into sub-transects based on sockeye salmon densities. The sub-transects were then plotted in ArcMap 10 based on DIDSON image size (image window length) and position relative to the transect (distance from DIDSON that image capture was set to). Sockeye salmon densities ranged from 0.2 to 20.9 sockeye per 100 sq. meters (Figure 4.5). Sockeye salmon densities were lowest in areas previously classified as having dispersed spawning use (range 0.2 to 0.35 sockeye per 100 sq. meters). Sockeye salmon densities were highest in the core spawning area. Sockeye salmon densities were intermediate within the areas classified as having concentrated spawning use (range 0.9 to 2.9 sockeye per 100 sq. meters).

Figure 4.5. DIDSON recorded sockeye salmon densities for Olsen's Beach Transect 1a and 1b.

The second slow pass test at Olsen's Beach was recorded as transects 2a through 2e (Figure 4.6). The slow pass transects were run with the boat slowly moving to the south and southeast approximately 10 to 15 meters lakeward of the low water vegetation line. The DIDSON unit was aimed up the beach slope. Transect 2a images were recorded from 3 to 13 meters (first half of survey) and 5 to 15 meters (second half of survey). Image recording rate was 8 frames per second. Transect 2b images were recorded from 5 to 15 meters (first 20-percent of survey), image recording rate was 10 frames per second. For the remainder of Transect 2b images were recorded from 6 to 26 meters at 7 frames per second. Transect 2c images were recorded from 4 to 24 meters at 7 frames per second. Transect 2d images were recorded from 4 to 24 meters at 7 frames per second and 5 to 15 meters at 10 frames per second. Transect 2e images were recorded from 3 to 13 meters at 10 frames per second.

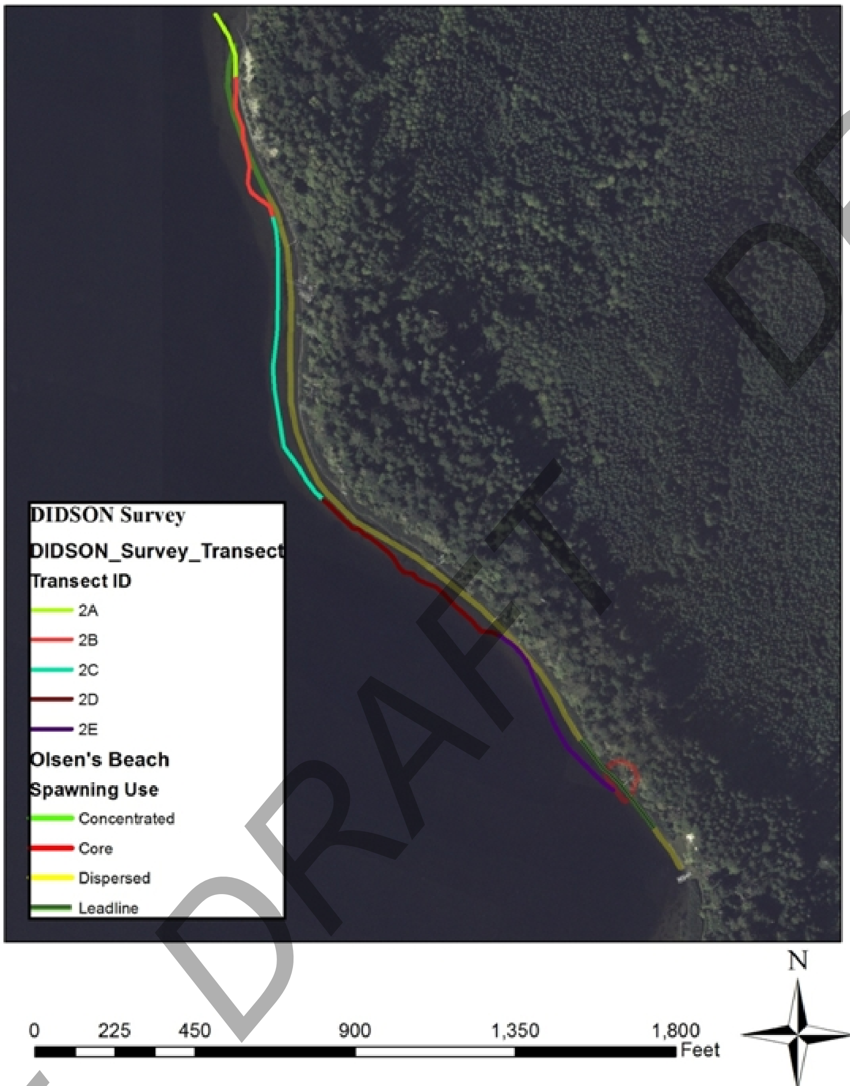

Figure 4.6. Map depicting the location of Transects 2a through 2e at Olsen's Beach contrasted with Olsen's Beach classified spawning use (source: Haggerty et al. 2009).

Survey transects were further split into sub-transects based on sockeye salmon densities. The sub-transects were then plotted in ArcMap 10 based on DIDSON image size and position relative to the transect. Sockeye salmon densities ranged from 0.0 to 5.9 sockeye per 100 sq. meters (Figure 4.7). Sockeye salmon densities were lowest in areas previously classified as having dispersed spawning use. Sockeye salmon densities were highest in the core spawning area.

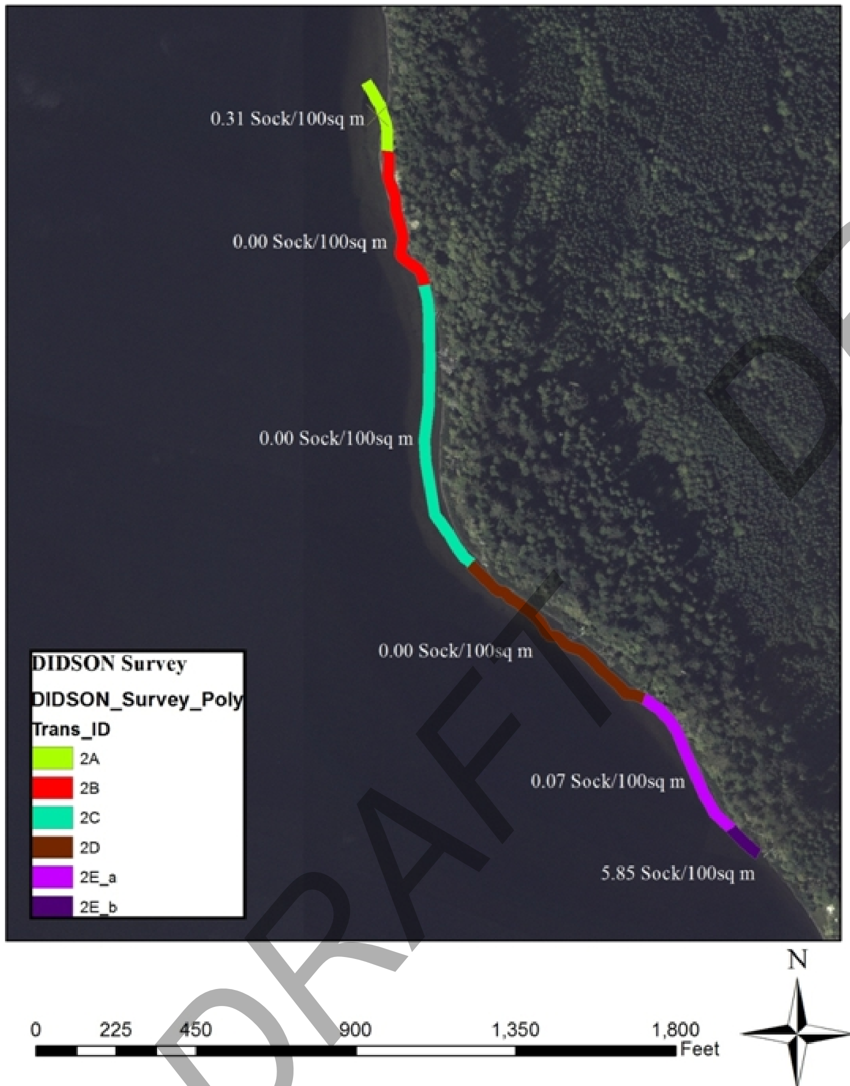

Figure 4.7. DIDSON recorded sockeye salmon densities for Olsen's Beach Transect 2a through 2e.

Slow Pass Observations

The best results came from transects looking lakeward from the brush line. However, many of the targets were visually seen directly below the boat and shoreward of the boat and therefore could not be detected with the DIDSON unit. Image quality was better looking down the beach slope versus looking up the beach. When looking up the beach the DIDSON images became less and less clear despite high target density. Brush and shallow water prevented sockeye detection in the upper portion of the beach where high sockeye salmon densities could be seen visually (Figure 4.8). At North Olsen's Beach visual observations yielded an estimated sockeye salmon density of 14.8 sockeye per 100 sq. meters. The same area surveyed with the DIDSON yielded estimates of 0 to 0.3 sockeye per 100 sq. meters.

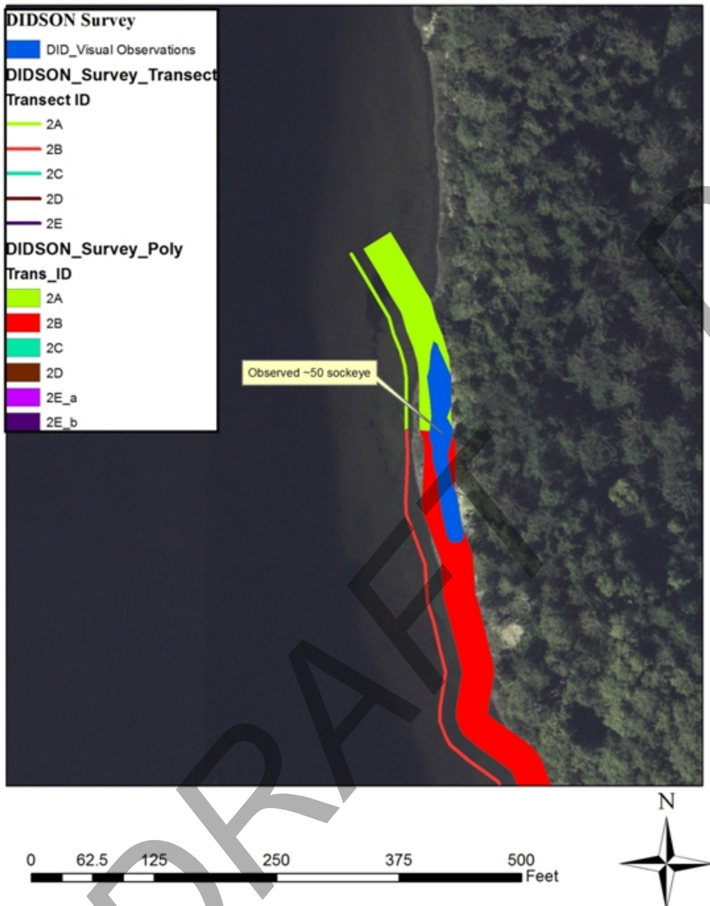

Figure 4.8. Map depicting DIDSON survey transects 2a and 2b and visual sockeye observations at North Olsen's Beach.

4.2 Allen's Beach

Slow Pass Method Results

The first slow pass test at Allen's Beach included Transects 3a and 3b. The slow pass transects were run with the boat slowly moving to the south, approximately 15 to 20 meters lakeward of the low water vegetation line. The DIDSON unit was aimed down the beach slope towards the center of the lake. The survey was targeting known deeper spawning sockeye salmon habitat within this portion of Allen's Beach. Transect 3a images were recorded from 3 to 23 meters (first half of survey) and 2 to 12 meters (second half of survey). Image recording rate was 7 frames per second. Transect 3b images were recorded from 2 to 12 meters. Image recording rate was 7 frames per second.

Survey transects were further split into sub-transects based on sockeye salmon densities. The sub-transects were then plotted in ArcMap 10 based on DIDSON image size and position relative to the transect. Sockeye salmon densities ranged from 0.0 to 3.8 sockeye per 100 sq. meters (Figure 4.9). Sockeye salmon densities were lowest in areas previously classified as having dispersed or no spawning use.

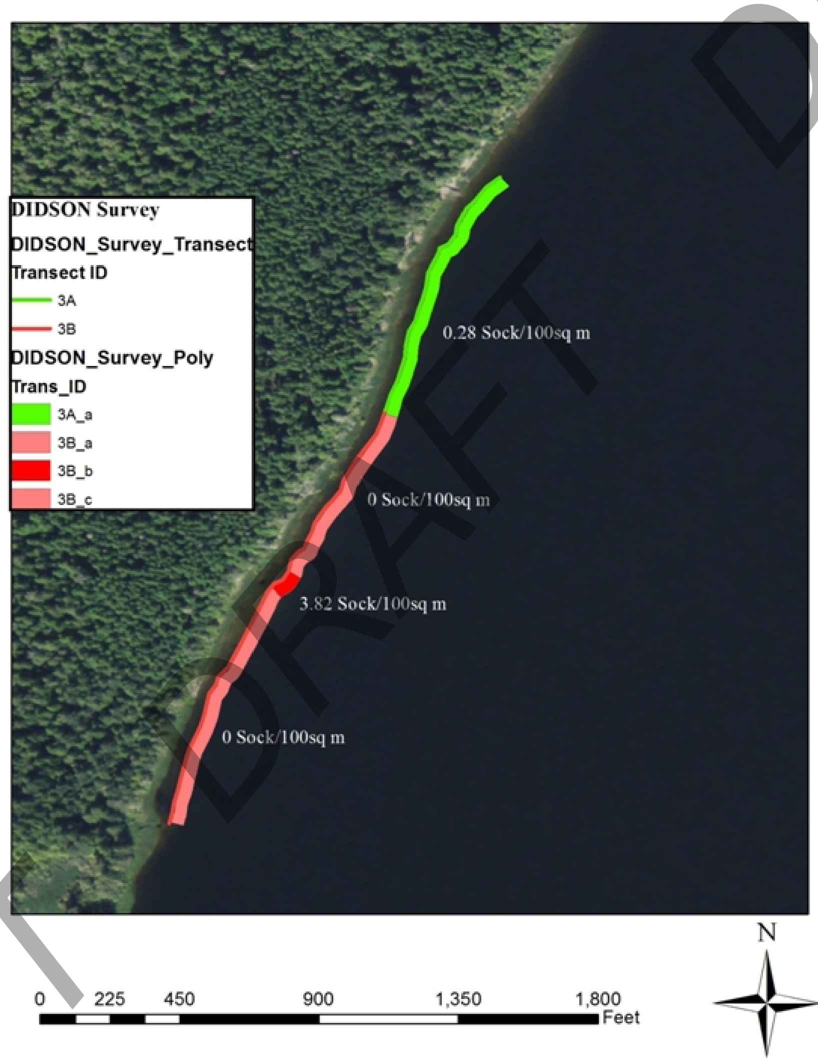

Figure 4.9. DIDSON recorded sockeye salmon densities for Allen's Beach Transects 3A through 3B_c.

The second slow pass test at Allen's Beach included Transects 4a and 4b. The slow pass transects were run with the boat slowly moving to the north, approximately 15 to 20 meters lakeward of the low water vegetation line. The DIDSON unit was aimed up the beach slope. Transect 4a and 4b images were recorded from 2 to 12 meters. Image recording rate was 7 frames per second. Survey transects were further split into sub-transects based on sockeye salmon densities. The sub-transects were then plotted in ArcMap 10 based on DIDSON image size and position relative to the transect. Sockeye salmon densities ranged from 0.0 to 2.1 sockeye per 100 sq. meters (Figure 4.10). DIDSON based sockeye salmon densities were low at Cemetery Point despite high numbers of fish which could be visually seen spawning in less than 1 meter of water.

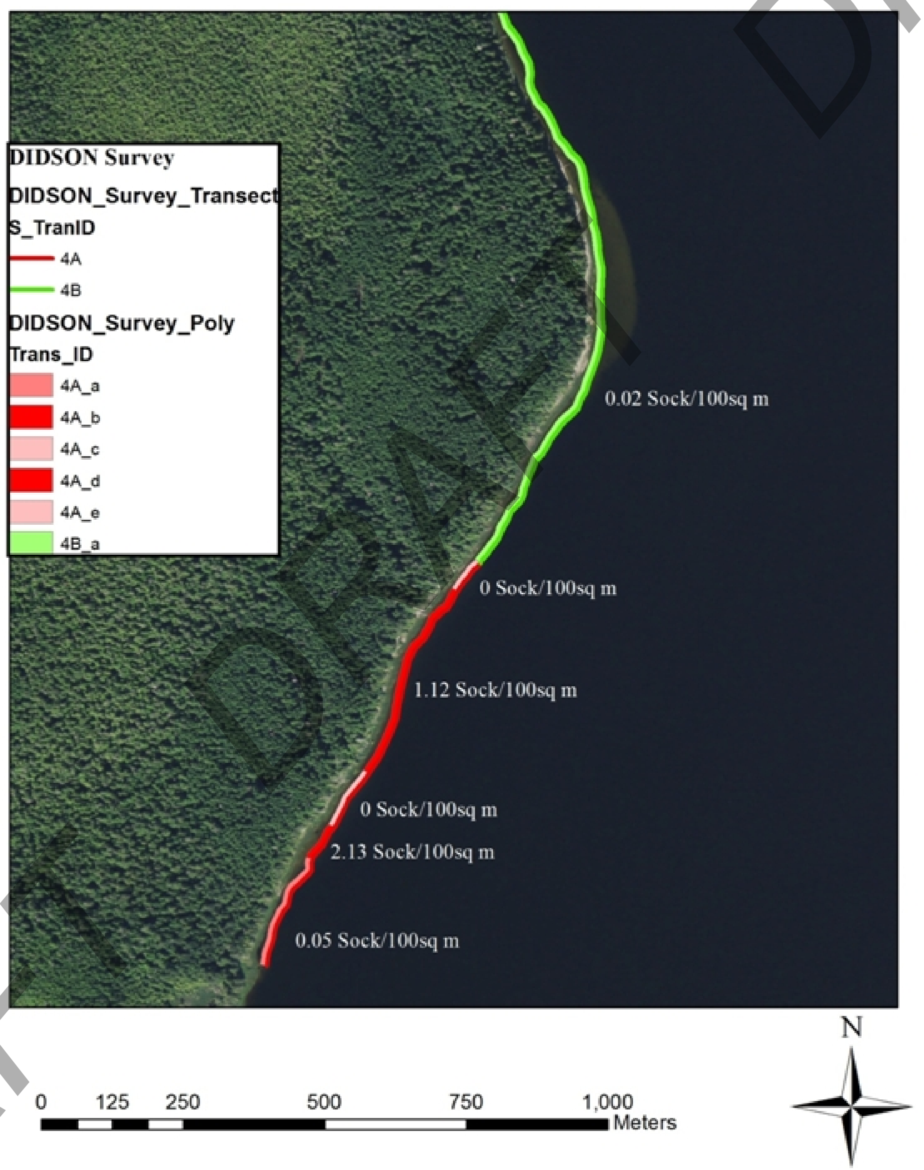

Figure 4.10. DIDSON recorded sockeye salmon densities for Allen's Beach Transects 4A_a through 4B_a.

Slow Pass Observations

The DIDSON detected sockeye salmon spawning or staging more than 30 meters lakeward of the low water vegetation line. Sockeye salmon in these areas were previously very difficult and/or impossible to detect. Depths in this area ranged from 5 to 15 meters.

Rough water conditions limited our ability to visually observe sockeye at depths greater than one or two meters. The DIDSON looking up the beach did well relative to our ability to visually observe sockeye at the south end of Allen's Beach. At north Allen's and Cemetery Point the wind was stronger, which made it difficult to control the boat at slow speeds. Higher travelling speeds and big wind waves yielded low quality DIDSON images. We visually observed approximately 40 sockeye salmon spawning high on Cemetery Point. The DIDSON was unable to detect a single one of these sockeye salmon.

4.3 Additional Observations

The slow pass method was used to survey two additional beaches. The first survey (Transect 5) was conducted around the southwest, west, and east perimeter of Garden Island. No sockeye size targets were detected at Garden Island. The second survey (Transect 6) was conducted along the west side of Umbrella Beach. No sockeye size targets were detected at Umbrella Beach. The DIDSON survey only detected sockeye salmon size targets at Olsen's and Allen's Beaches.

The six DIDSON survey transects and one stationary count yielded 187 targets identified as sockeye salmon. In addition, a total of 190 live sockeye salmon were visually observed in three high density concentrations (Olsen's Beach core area, Olsen's North, and Cemetery Point). Dozens of additional live sockeye salmon were visually observed at lower densities scattered along Olsen's and Allen's Beaches. During the DIDSON surveys Makah Fisheries Management were conducting a sockeye salmon carcass survey. They identified 192 dead sockeye salmon. Nearly all of the dead sockeye salmon observed were spawned out. The vast majority of dead sockeye sampled had no evidence of predator related wounds or injuries.

5 RECOMMENDATIONS

Included below is a brief list of recommendations that will help improve enumeration methods for beach spawning sockeye salmon in Lake Ozette.

- Continue testing and developing DIDSON survey methods on lake beaches during the 2012/2013 spawning season.
    - Conduct surveys throughout the spawning season; weekly during the peak spawning period(s).
    - Surveys should focus on using the slow pass method. Effort should include looking both lakeward and shoreward. Very slow speeds appear to be especially important for capturing high quality images.
    - Surveys should target weather windows where wind waves will not negatively affect image quality. If not possible consider testing the use of stabilizers on the boat used for surveying.
    - Include survey staff on boat that can visually count sockeye salmon high on the beach (that are outside of the DIDSON imaging range).
    - When time permits conduct surveys along habitats that may be utilized by sockeye salmon but are currently not known to be utilized (e.g., Umbrella Beach).
- Use the standard DIDSON 300 unit- compare image quality between the standard 300 and the 300LR.
- Document results and refine methodologies as appropriate.

6 CITATIONS

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