Exxon Valdez Oil Spill
Long-Term Herring Research and Monitoring Program Final Report

Aerial Survey Support

Exxon Valdez Oil Spill Trustee Council Project 15120111-R
Final Report

W. Scott Pegau

Prince William Sound Science Center
Box 705
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Study History:
This funding was for logistical support to continue aerial surveys of forage fish, particularly age-1 Pacific herring (*Clupea pallasii*) in Prince William Sound. The study follows the design set by Dr. Evelyn Brown in the *Exxon Valdez* Oil Spill Trustee Council project 10100132-F. It also builds on aerial survey work performed in the 1990s under projects 99320-T and 00163-T. Support for analysis of the observations collected was provided by Trustee Council projects 16120111-O and 16120114-O. Most of the analysis was completed by Mayumi Arimitsu with the forage fish project (16120114-O). While the analysis of the data was completed in other projects we present the aerial observations of forage fish in this report.

Abstract:
This project is for providing aerial survey support to the *Exxon Valdez* Oil Spill Trustee Council sponsored Herring Research and Monitoring and Gulf Watch Alaska programs. For the Herring Research and Monitoring program the aerial support was used to help collect Pacific herring (*Clupea pallasii*) samples for the genetics project and to provide an aerial index of age-1 herring abundance. For the Gulf Watch Alaska program, the aerial support supported the forage fish project. The desire was to provide an aerial index of forage fish abundance and guide the capture efforts of the vessel. The entire coastline of Prince William Sound was surveyed in June 2014, 2015, and 2016. The aircraft followed the shoreline and the number, species, and size of schools logged electronically and on paper. In July of those years grid pattern surveys were flown of randomly selected survey boxes. Validation of observations was also conducted by the forage fish project in the Gulf Watch Alaska program (16120114-O).

Key words: Aerial survey, *Ammodytes hexapterus*, capelin, *Clupea pallasii*, *Mallotus villosus*, Pacific herring, Pacific sand lance, Prince William Sound, *Thaleichthys pacificus*,

Project Data:
Description of data: Data collected includes time, location, school size, number of schools, species, and for herring an estimated age. Forage fish species include Pacific herring (*Clupea pallasii*), Pacific sand lance (*Ammodytes hexapterus*), capelin (*Mallotus villosus*), and eulachon (*Thaleichthys pacificus*). Observations of whales (orca, humpback, minke, grey, and fin) were also recorded.

Data format: Electronic and paper log data are available. The electronic data is in .csv files and paper logs as .pdf.

Data archive and custodians:
Carol Janzen
AOOS, 1007 W. 3rd Ave. #100,
Anchorage, AK 99501

907-644-6703
janzen@aoos.org
https://portal.aoos.org/gulf-of-alaska.php#metadata/2f2367fa-6f4c-44e6-9c7a-150dc156154c/project.

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There are no limitations on the use of the data, however, it is requested that the authors be cited for any subsequent publications that reference this dataset. It is strongly recommended that careful attention be paid to the contents of the metadata file associated with these data to evaluate data set limitations or intended use.

Citation:

Pegau, W.S. 2018. Aerial survey support. *Exxon Valdez* Oil Spill Long-Term Herring Research and Monitoring Final Report (*Exxon Valdez* Oil Spill Trustee Council Project 15120111-R), *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

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EXECUTIVE SUMMARY

This project provided funding for aerial survey support that was used in the Herring Research and Monitoring program and by the Forage Fish project in the Gulf Watch Alaska Long-Term Monitoring program. The aerial support provided a means for collecting additional samples for the herring genetics work, provided an index of age-1 Pacific herring (*Clupea Pallasii*) for use in population modeling, and observations of forage fish populations and distributions for comparison with vessel-based forage fish surveys.

Aerial surveys were conducted in June and July of 2014-2016. Fish species, school shape, and number of schools were recorded along with time and position electronically and on paper. The June surveys followed the coastline throughout Prince William Sound and were used primarily for the age-1 herring index. The July surveys were conducted in specified survey boxes, a portion of which were also surveyed by the forage fish vessel. During the July surveys the vessel provided validation of the aerial observations.

Pacific herring was the dominant species observed followed by Pacific sand lance (*Ammodytes hexapterus*). Based on historical surveys we expected to also observe capelin (*Mallotus villosus*) and eulachon (*Thaleichthys pacificus*). However, in recent years there have been very few observations of these latter two species. The relative proportion of herring and sand lance varied among years. The distribution of sand lance was fairly uniform among the years with the largest densities observed near the Dutch group and Naked Island areas. The distribution of age-1 herring was more variable through time, but tended to be higher near the spawning grounds and along the expected larval drift route.

The validation effort indicated that herring were correctly identified 84% of the time and sand lance 88% of the time. This is consistent with the much larger previous validation effort conducted during the Sound Ecosystem Assessment program (EVOSTC project 99320-T) that showed herring and sand lance to be correctly identified 95% and 80% of the time, respectively. In both this work and the previous effort, the majority of misidentified fish involved age-0 herring and sand lance. These fish do not generally become visible to aerial observation until sometime in July, therefore we expect that the identification error in June would be less than that observed in July.

Since herring begin recruiting to the spawning stock at age-3, we have a very limited number of data points to evaluate how well the age-1 surveys predict the incoming year class. There is some indication that larger number of observed schools leads to larger age-3 recruit classes, but there are not enough data points to provide a definitive answer.

INTRODUCTION

Forage fish are small, schooling pelagic fish important to marine ecosystems. They may be commercially harvested, or sustain a wide variety of large predatory fish which may in turn be commercially harvested (Pikitch et al., 2014). They also directly and indirectly support subsistence and recreational fisheries. Ecologically, they represent a vital trophic pathway between lower trophic level plankton and upper trophic level predators such as fish, seabirds and marine mammals (Cury et al., 2000). Common forage fish in the Gulf of Alaska are Pacific herring (*Clupea pallasii*), capelin (*Mallotus villosus*), Pacific sand lance (*Ammodytes personatus*), juvenile walleye pollock (*Gadus chalcogrammus*) and eulachon (*Thaleichthys pacificus*).

Despite their importance to marine ecosystems of the Gulf of Alaska, little is known about changes in forage fish distribution and abundance over time. They are difficult and expensive to monitor because they are patchy in their distribution, comprised of species with widely divergent life histories and habitats, and predisposed to experience large fluctuations in abundance. Much of what we know comes from surveys that target other species and were not designed for forage fish (Anderson and Piatt, 1999; Ormseth, 2014), or from studies of predator diets (Hatch and Sanger, 1992; Piatt and Anderson, 1996; Womble and Sigler, 2006; Yang et al., 2005). Fluctuations in the abundance of forage fish have been associated with highly variable recruitment of strong year classes over short time periods (Hay et al., 2001), and climate-mediated regime shifts over longer time periods (Anderson and Piatt, 1999). The coastal waters of Prince William Sound and other fjords and embayments in the Gulf of Alaska provide important nursery areas and spawning grounds for some forage fish species (Arimitsu et al., 2008; Brown, 2002; Robards, 1999). In these coastal areas, the distribution and abundance of forage fish are related to environmental gradients in temperature and freshwater inputs, as well as interactions with other organisms (e.g., zooplankton prey, gelatinous zooplankton competitors and marine predators) (Abookire and Piatt, 2005; Arimitsu et al., 2016; Speckman et al., 2005).

Past survey methods for estimating the abundance and distribution of forage fish in Prince William Sound have included hydroacoustic surveys coupled with trawl-sampling (Ostrand et al., 1998; Thedinga et al., 2000) and aerial surveys for surface-schooling fish (Brown and Moreland, 2000; Norcross et al., 1999). Aerial surveys are useful for counting near-surface fish schools (i.e., schools that may be visible from just below the surface to depths of 10-20 m depending on water clarity) in nearshore areas where it is normally difficult to conduct hydroacoustic surveys. They also allow us to determine the broad-scale distribution of schools visible from an airplane. However, precision and accuracy of aerial surveys are affected by variability in sighting conditions, water clarity, vertical distribution of fish in the water column, and observer bias (Norcross et al., 1999). Like all remote sensing techniques, aerial surveys benefit greatly from on-the-ground validation of species composition and age class. Indeed, noting a disparity between separate hydroacoustic and aerial survey efforts for forage fish in Prince William Sound, Brown and Moreland (2000) recommended the use of both survey methods.

In this analysis we use historic and recent aerial observations of coastal forage schools in Prince William Sound to examine variability in forage fish abundance and distribution. Aerial shoreline census surveys of forage fish schools in Prince William Sound occurred in the late 1990's (Brown et al., 1999; Brown and Moreland, 2000; Norcross et al., 2001; Suryan et al., 2002), and more recently (2010-2016) surveys were again conducted under auspices of the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC). We examined the ability of aerial observers to identify species composition of fish schools from the air, by contrasting aerial identifications with those obtained from contemporaneous vessel-based validation efforts conducted during both historical and recent time periods.

OBJECTIVES

The project objectives are to:

1) Provide aerial support for collection of samples for the genetics project (16120111-P).
2) Provide an index of abundance of age-1 herring.
3) Provide aerial support to the forage fish project of the Gulf Watch Alaska program.

METHODS

To achieve the first objective of providing aerial support for genetic sample collection, aircraft were used to identify when herring spawn was occurring in locations outside of the normal Alaska Department of Fish and Game (ADF&G) survey area. When feasible the aircraft would land and collect herring trapped in tide pools. ADF&G would also be informed of the spawn event and in some cases they were able to fly out and capture fish using cast nets.

Shoreline aerial surveys

This describes the approach used to achieve the objective 2, providing an index of abundance of age-1 herring. The general approach to the aerial shoreline census surveys followed those established by Dr. Evelyn Brown during the Sound Ecosystem Assessment (SEA) and Alaska Predator Ecosystem Experiment (APEX) (Brown and Moreland, 2000; Norcross et al., 1999). Norcross et al. (1999) contains a detailed description of the survey design and analysis of errors associated with the observations. It also follows the work by Dr. Brown in EVOSTC project 10100132-F. In June each year, aerial surveys were conducted from a Cessna 185 float plane traveling at speeds of 200 - 240 km/h and a target altitude of 305 m. Shoreline aerial census surveys were flown parallel to shore and occasionally the airplane would circle to ensure accurate observations when high densities of schools were present (Fig. 1). Observations were made from both sides of the airplane, but the primary observer was on the side with the coastline. While there were changes in observers over time, we maintained at least one experienced person as the primary observer. During flights observations were collected on the location, altitude, number and size of schools of forage fish. The schools were identified by species and herring were classified by age (0, 1, 2+).

Species were identified as Pacific herring, Pacific sand lance, capelin, and eulachon and unknown forage schools. Species identification was made based on several characteristics of the school. The color, shape of school, size, location, and evidence of light flashing off individual fish were used to provide identification (Fig. 2). Herring schools tend to be circular and a short distance off the beach. Herring tend to roll causing them to scatter light towards the observer that appears as flashes. The younger the fish the finer the pattern of flashes. In ageing herring the size of the flashes observed with the school is used. The age-0 fish don’t generally appear until sometime in July and greatly increases the number of schools compared to the observations in June. Mature herring (age 2+) tend to form larger schools in deeper water than the age-1 herring. Sand lance schools tend to be darker, strung out along the shore, and in areas with sand and gravel habitats. Capelin tend to form large, crescent-shaped schools and eulachon formed very large schools primarily associated with offshore waters and river systems. However, due to low frequency of occurrence of these species on aerial surveys and inability to adequately validate these observations we grouped capelin and eulachon observations in the unknown forage schools category in the analysis.

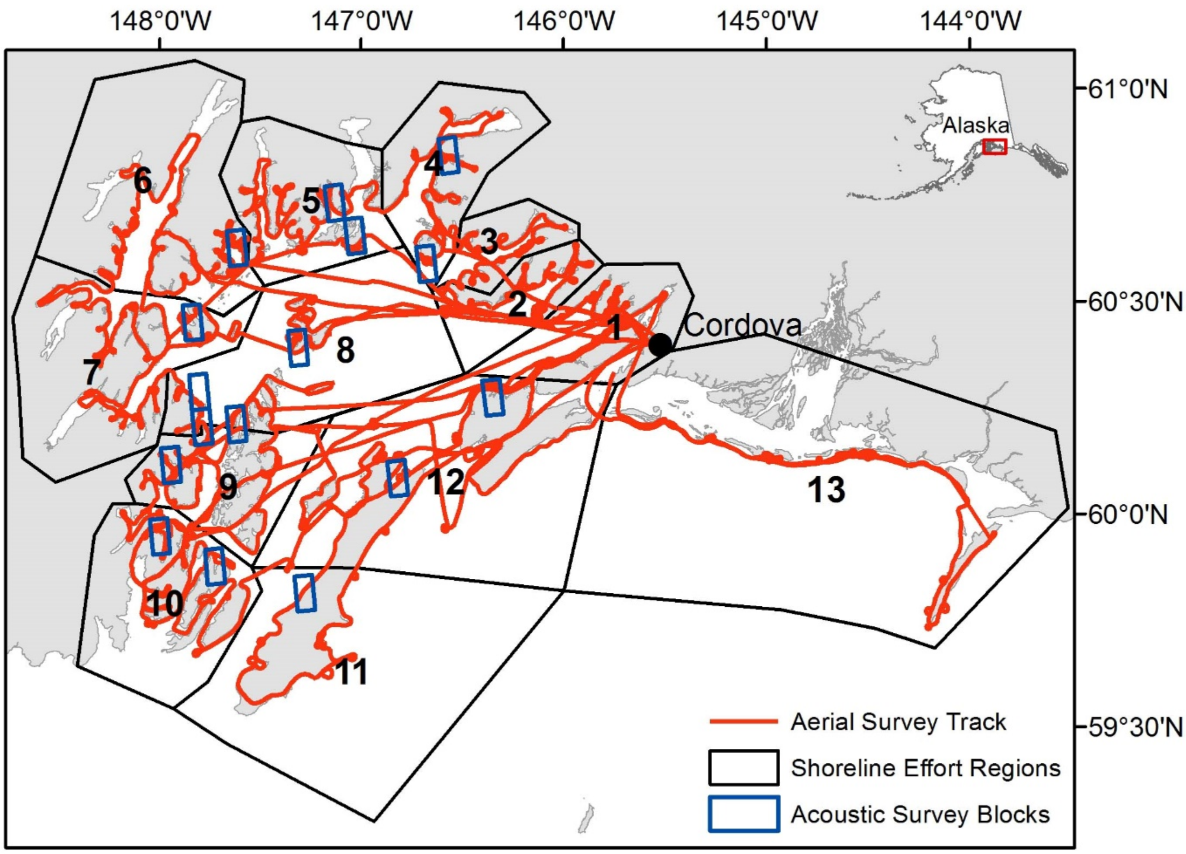

FIGURE 1. THE RED LINES SHOW THE AIRPLANE TRACK LINES IN JUNE 2012.

The size of schools was estimated using a sighting tube. The tube is constructed of PVC pipe with a grid drawn on mylar on the far end. The focal length (F) of the tube is 210 mm. A full tick mark on the grid is 1 cm. The ground distance can be determined from the number of grid points a school extends using: X=A(L/F) (Brady, 1987; Lebida and Whitmore, 1985), where X is the ground distance, A is the altitude, L is the distance on the grid, and F is the focal length of the sighting tube. From 2013 through 2016 school size was reported as small (diameter < 0.5 ticks), medium (> 0.5 ticks and < 1.0 ticks), and large (> 1.0 tick marks). From an observation height of 300 m this provides an equivalent surface area of < 93 m^2 for small schools, 93 – 374 m^2 for a medium school and > 374 m^2 for a large school.

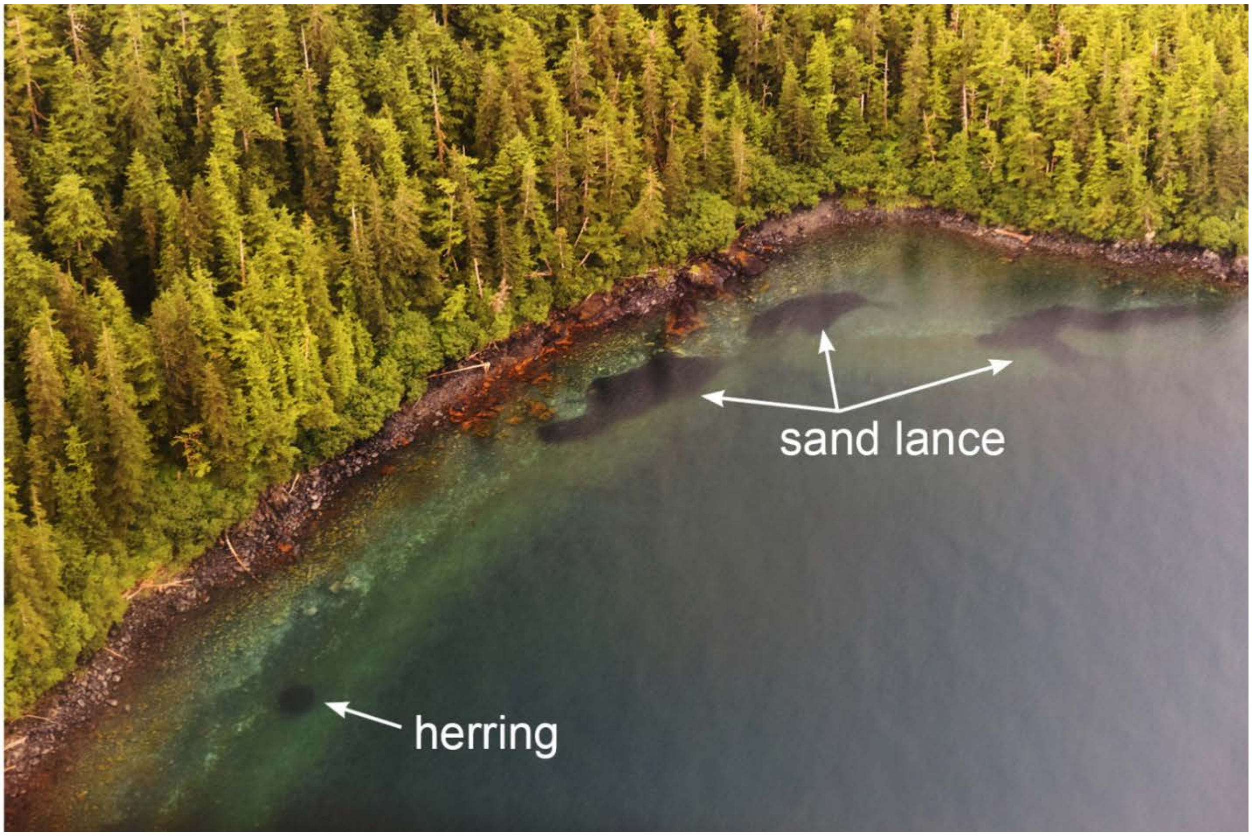

FIGURE 2. AERIAL PHOTOGRAPH OF TYPICAL PACIFIC HERRING AND PACIFIC SAND LANCE SCHOOLS ALONG THE SHORELINE OF PRINCE WILLIAM SOUND. HERRING SCHOOLS ARE TYPICALLY ROUND OR OVAL AND SAND LANCE SCHOOLS ARE DARKER AND IRREGULARLY SHAPED.

A GPS was used to provide position information to an electronic recording platform. Between 2010 and 2016 various data recording systems were used. In 2010 through 2012 an ArcPad mapping application was used to record observations by the primary observer (E. Brown, Flying Fish Ltd.); however, school count data were not recorded in 2011 and therefore we do not report those data in any analyses. In June 2013 observations were made by an experienced spotter pilot and schools observations within 13 regions were recorded on paper by a second observer. Paper logs included general description of the observation area, date and time, the species, number of schools, size of schools, comments, observer names, and several observation conditions. In July 2013 schools observations were recorded and time stamped with a digital voice recorder and then transcribed and georeferenced. In June and July of 2014, 2015 and 2016 – under this project - all schools observations were georeferenced in flight using dLOG software (dLOG-CE or dLOG for Windows 7, Glen Ford Consulting, Portland, Oregon) on a handheld data recorder or tablet connected to a handheld GPS.

Georeferenced flight paths and schools observations were mapped in GIS. For shoreline surveys, we estimated effort by calculating the length (km) of shoreline covered in each survey period. Some sections of shoreline were surveyed more than once in a given year. We used only the first survey of a section in the analysis described here.

To visualize the distribution of schools during June 2010 – 2016 shoreline survey periods we mapped the kernel density of schools counts within 2 km of shoreline covered at 500 m cell resolution. As an index of shoreline forage school density we first summed the effort (km of shoreline covered) and schools count observations within regions (Fig. 1) following Brown et al. (2002). We used a ratio estimator to estimate mean schools density and bootstrapped bias-corrected and accelerated (BC_a) 95% confidence intervals were calculated by resampling the density estimates 10000 times (DiCiccio and Efron, 1996).

Forage fish aerial surveys

Forage fish surveys in 2014-2016 were also conducted in July each year in partnership with the Gulf Watch Alaska Forage Fish project (EVOSTC project 16120114-O). These surveys followed the same methods as the shoreline aerial surveys described above, with one major difference. Aerial surveys were flown in survey boxes selected using a stratified-random design (Fig. 3). We used school counts on shoreline surveys from July 2010 – 2012 (Evelyn Brown, EVOSTC project 10130132-F, unpublished data) to identify low, medium and high density forage fish strata. A 5' latitude by 5' longitude grid (to facilitate navigation in the airplane) was overlaid on previous aerial track lines and observations in GIS. Grid cells encompassed 43 km^2 and varied in the area of water within them (mean ± 1SD = 25.85 ± 12.19 km^2). Using data from July 2010 – 2012, an index of school density (SI) was calculated for each grid cell (i) with the following equation: $SI_i = Y_i \sum \frac{S_i}{L_i}$, where the total number of schools observed (S) was standardized by the amount of effort (L, length in km of aerial survey flown) and weighted by persistence (Y, number of years schools were observed). A density index was computed from SI values were qualified as 'zero', 'low', 'medium' and 'high' for each cell by quantiles. Grid cells from high, medium and low density strata were randomly selected for sampling. The sample size in each stratum was chosen to minimize variance of the population mean using the following equation (Cochran, 1977): $u_i = \left(\frac{u_i \sigma_i}{\sum_{i=1}^{m} u_i \sigma_i}\right) u_T$, where u_i and σ_i is the sample size and standard deviation of the i^{th} stratum from i = 1 to m, and U_T is the fixed sample size of 109 sample blocks, or the number of blocks we could sample with the available resources. The final sample sizes were 72 high density, 21 medium density and 16 low density blocks.

Forage schools in each sampling block were counted by an experienced spotting pilot, a second observer and a third individual recorded observations. Flight pattern within each block included observations approximately parallel to the shoreline, and blocks that contain offshore area were surveyed with parallel transects at approximately 2 km intervals. Density D in each block was calculated by dividing the number of schools observed by the area of water in each survey block. We estimated forage school abundance using the following equation: $\hat{S} = \sum_v A_v \overline{D_v}$, where $\hat{S}$ is the estimated abundance of schools, V is the stratum from v = 1, …, V, A_v is the area of water in stratum v, and $\overline{D_v}$ is the mean school density in stratum v. Confidence intervals (± 95%) were calculated using bootstrapped BC_a confidence intervals. We also estimated size-weighted forage school abundance by multiplying the raw school counts by 1 for small schools, 2 for medium schools and 3 for large schools.

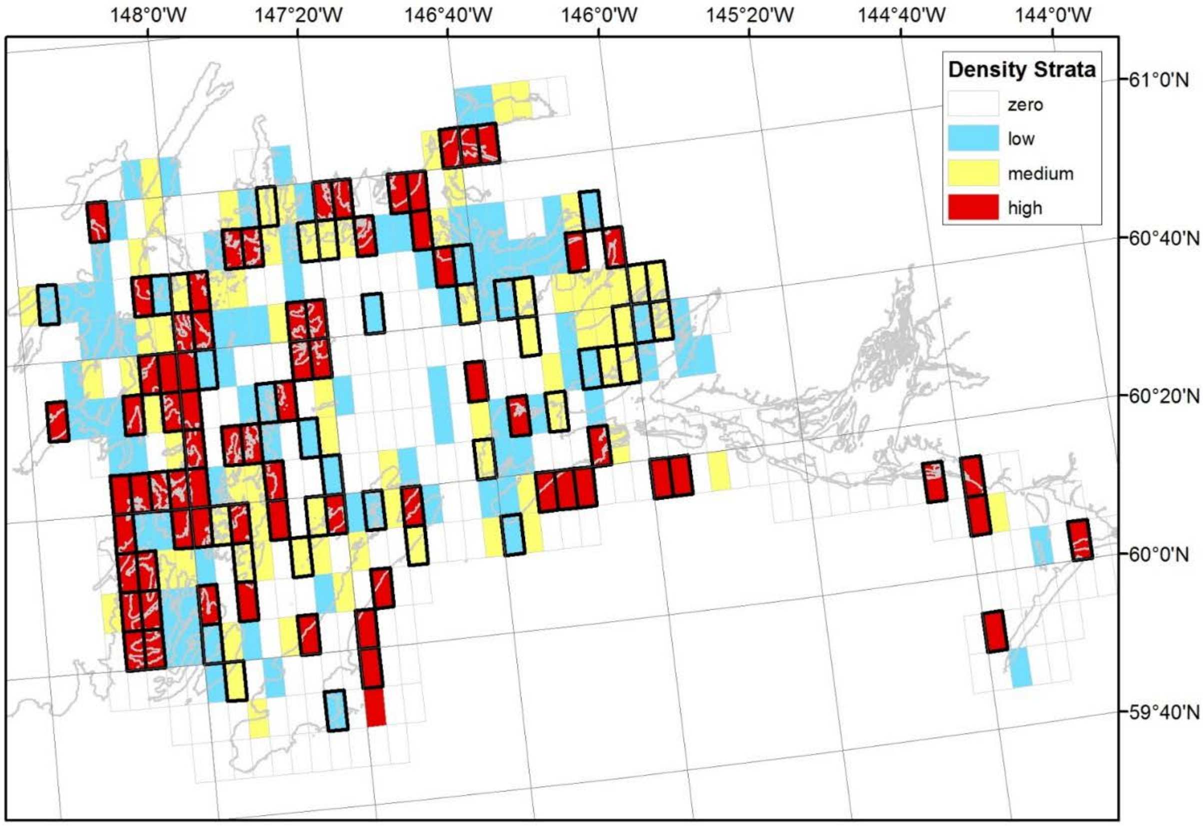

FIGURE 3. MAP OF SCHOOL DENSITY STRATA (COLOR) FROM 2010-2012. SURVEYS WERE USED TO SELECT AERIAL SURVEY BOXES (OUTLINED IN BLACK).

RESULTS

June shoreline surveys

A total of 9502 forage fish schools were counted during June aerial shoreline surveys including those conducted by Dr. Brown (Table 1). As a measure of effort, the length of shoreline searched ranged from a low of 1688 km in June 1996 to a high of 5902 km in June of 2010 (Table 1). The relative distribution of schools in 2010-2016 was patchy and differed by species (Fig. 4). The north end of Knight Island and Knight Island Passage had consistently high near-surface school density in June. High densities of forage schools were also observed in the eastern Sound (e.g., Port Fidalgo, Port Gravina or Sheep Bay) and the Naked Island complex.

During June 2013, mean school density was nearly four times higher than the next highest density (Table 1, Fig. 4). Fourth-root transformed density of schools was significantly different among years ($ANOVA_{[df:8,104;\ F = 5.858]}$, $p < 0.001$). A Tukey HSD test ($\alpha < 0.05$) indicated school density was significantly higher in 2013 compared to all other years. Additionally, school density was significantly higher in 2015 than 1995, but all other pairwise year combinations were not significantly different from one another ($p > 0.05$).

TABLE 1. SUMMARY OF JUNE AERIAL SHORELINE CENSUS DATA BY YEAR IN PRINCE WILLIAM SOUND, INCLUDING SCHOOL COUNTS, EFFORT (KM SHORELINE SEARCHED), MEAN DENSITY (SCHOOLS KM^{-1}) ACROSS REGIONS AND BOOTSTRAPPED 95% CONFIDENCE INTERVALS (CI). '-'INDICATES NO DATA.

			Mean (95% CI) Density			
Year	School Count	Effort (km)	All Schools	All Herring	Juvenile Herring	Sand lance
1995	261	2947	0.10 (0.06-0.17)	0.07 (0.04-0.16)	-	-
1996	377	1688	0.20 (0.11-0.36)	0.19 (0.1-0.35)	-	0.002 (0-0.01)
1997	600	4407	0.19 (0.08-0.56)	0.03 (0.02-0.06)	-	0.05 (0.01-0.09)
2010	1294	5902	0.22 (0.16-0.32)	0.16 (0.1-0.26)	0.10 (0.07-0.14)	0.02 (0.01-0.04)
2012	587	5287	0.30 (0.12-0.96)	0.10 (0.06-0.16)	0.08 (0.04-0.15)	0.002 (0-0.01)
2013	3582	4780	0.96 (0.59-1.53)	0.83 (0.46-1.46)	0.67 (0.31-1.34)	0.01 (0-0.02)
2014	762	4802	0.18 (0.10-0.32)	0.12 (0.06-0.2)	0.03 (0.02-0.05)	0.005 (0-0.01)
2015	1359	4610	0.38 (0.23-0.77)	0.37 (0.21-0.79)	0.35 (0.20-0.75)	0.01 (0-0.02)
2016	680	4328	0.16 (0.12-0.21)	0.12 (0.09-0.16)	0.09 (0.06-0.14)	0.01 (0-0.02)

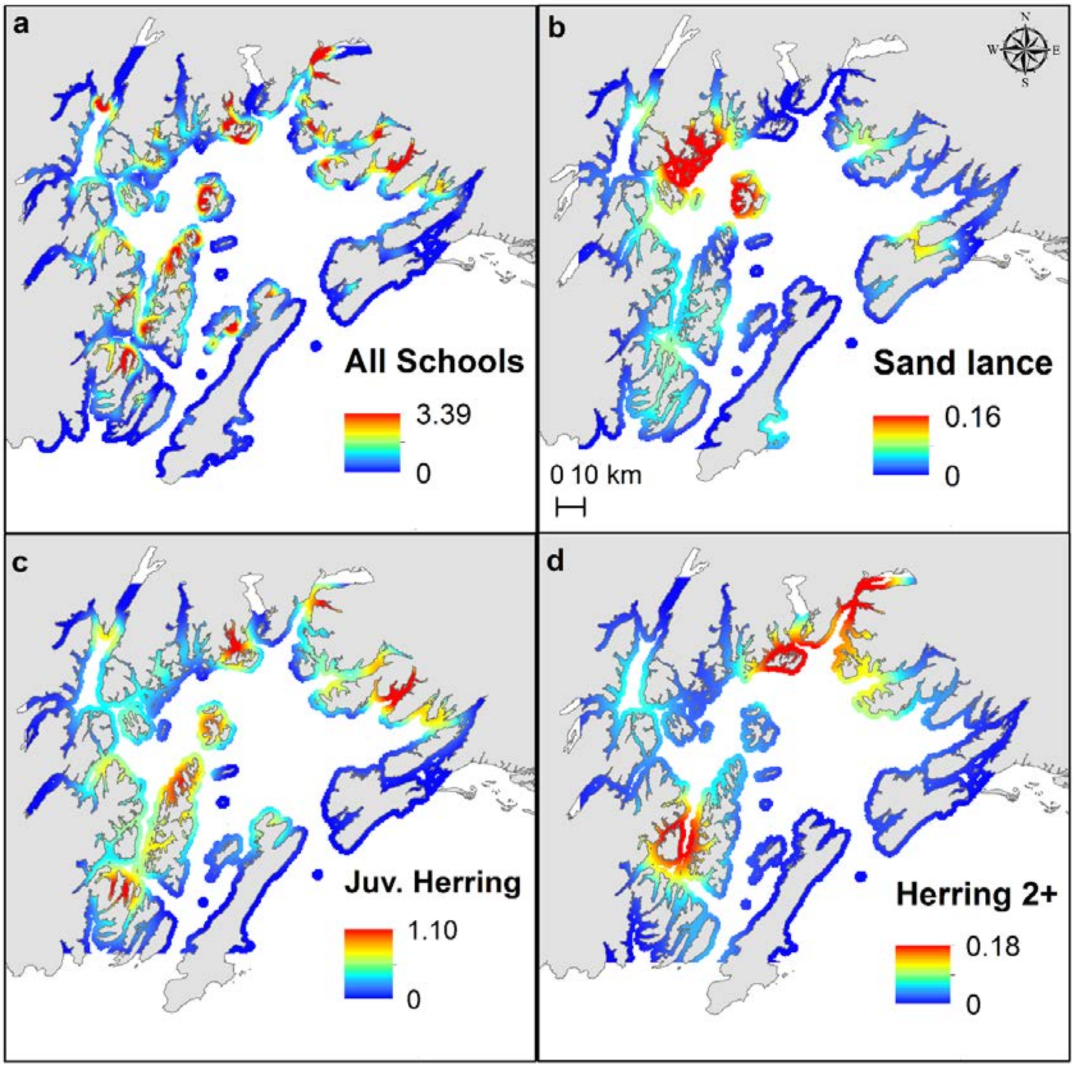

FIGURE 4. RELATIVE DISTRIBUTION OF FORAGE FISH SCHOOLS (KERNEL DENSITY, KM^{-2}) OBSERVED DURING JUNE 2010-2016 AERIAL SHORELINE CENSUS SURVEYS IN PRINCE WILLIAM SOUND, ALASKA. PANELS INCLUDE: A. ALL SPECIES COMBINED, B. SAND LANCE, C. JUVENILE HERRING, D. AGE 2+ HERRING.

Validation of aerial observations

In 2014–2016 we validated 34 schools in the month of July. The aerial observation identified one school as capelin, 25 schools as herring, and 8 schools as sand lance. The school identified by aerial observers as capelin was determined to be age-0 herring by the validation crew on the ground. Of the 25 schools identified by the aerial observers as herring, 21 (84%) were identified correctly, one was a mixed school of herring and sand lance, one was capelin, and two were sand lance. Sand lance were correctly identified 7 of the 8 (88%) times.

There were 15 herring observations where age was determined from both air and the vessel. Of those, six were identified by the aerial observers as age-2+, and all were correctly identified. Two were identified as age-0 and were validated as age-0. Of the seven aerial observations identified as age-1 herring, three were correct, three were age-0 herring, and one was a mixed school of age-1 and larger fish.

DISCUSSION

Validation

Norcross et al. (1999) provided an analysis of 419 validation observations. In their work, only herring (N= 310) and sand lance (N=109) schools were validated. They found that herring identifications from the aircraft were correct 96.1% of the time, and incorrect identifications from the air were generally associated with age-0 sand lance. In the validation dataset from the 1990's sand lance were correctly identified 80.4% of the time and the errors involve sand lance incorrectly identified as age-0 herring. Their analysis did not support the ability to reliably differentiate herring schools by age from aerial observations, primarily because of misidentification of age-0 fish in July.

Similar to Norcross et al. (1999), we found that most of the identification errors involved age-0 herring and sand lance, probably because these fish occur in overlapping regions and do not have as well-defined schooling characteristics. Furthermore, age-0 herring and age-0 sand lance sometimes occurred in overlapping aggregations. From the combined validation efforts, the July identification error of herring is between 5-10% and the error in identifying sand lance is approximately 20%. Because the transformation of these age-0 fish usually occurs sometime in July, we conclude that identification errors by aerial observers would be lower in June when age-0 herring and sand lance are not visible from the air.

Validation of herring age estimates were based on the length of fish captured. In July the age-0 fish are <80 mm, the age-1 fish are expected to be <140 mm, and age-2+ are >140 mm. The age-2+ herring schools were correctly identified each time, but the ability to separate age-0 and age-1 herring was not supported by our July validation effort.

June index

The purpose of conducting the June surveys was to develop an index to better be able to predict the strength of expected recruitment to the spawning population. The data collected in the 1990s did not separate out age-1 from age-2+ herring so we are not able to use it for evaluating the predictive capabilities of the aerial surveys. The fish observed in 2015 and 2016 have not recruited yet. That leaves only three years of data to use to evaluate the predictive capabilities. The moderately large number of schools observed in 2010 did correspond to a larger than normal year class being observed in the age-structure data. The low number of schools observed in 2012 corresponds to one of the smallest age-classes to recruit into the spawning population. The large number of schools observed in 2013 suggested that there might be a large age-3 year class recruiting to the spawning stock in 2015. Unfortunately, the 2015 age-structure sampling was unable to capture enough fish to determine if that was the case. The age-4 year class did make up a large portion of the spawning population in PWS in 2016. In 2015 and 2016 there was a large decline in the overall spawning population with a reduction in fish at all ages. This overall reduction makes it a bit difficult to evaluate how strong of a year class the fish observed in 2013 made up. Herring populations in Sitka and Kodiak were noted to have large numbers of age-3 fish joining the spawning population in 2015. Since large year classes in Sitka and PWS tend to coincide, it is likely that the 2013 observations are consistent with a large age class in the system. The observed age-1 herring school numbers appear to correspond to the strength of the incoming year class, but with so few data points the relationship cannot be determined.

Spatial and temporal variability

Examining all species observed in June we find that the majority of schools observed (77%) were identified as herring. There were changes in the proportions of herring and sand lance among the years. In 1997 sand lance made up the highest proportion of any year observed while 2013 was dominated by herring.

The distribution of forage schools throughout PWS was patchy, but some general patterns emerged. When observations from 2010–2016 were pooled, the highest densities sand lance schools were observed near the Naked Island complex in the central Sound and around the Dutch group in the northwest. A moderately high concentration was also observed at Middle Ground Shoal in the east. No area had consistently high age-1 herring school counts over time, suggesting that the distribution of age-1 fish is influenced by variability in recruitment and/or survival. However, the regions near the spawning grounds in the east, particularly Port Gravina, had higher school density than other areas, suggesting that larvae are retained locally. The expected circulation pattern from the spawning grounds is cyclonic, which is consistent with the higher age-1 herring school densities observed in the Naked Island group and Northwest Knight Island. The exposed waters in the Gulf of Alaska had the lowest density of age-1 herring schools.

Age-2+ herring comprised between 6% (81/1279 schools in 2015) and 69% (343/495 schools in 2014) of the herring school observations from 2010 – 2016. In June, age-2+ herring schools were most commonly encountered in the deep waters of the Valdez Arm and Glacier Island areas in the north, and in Knight Island Passage and around Chenega Island is the southwest. The peak in age-2+ herring schools occurred in 2014, which is consistent with the peak of age-1 schools in 2013 and a large herring year class in 2012. The decrease in age-2+ herring is 2015 is consistent with the 2012 brood year beginning to join the spawning population and moving out of PWS by the time of the June surveys.

CONCLUSIONS

Recent efforts to validate the aerial observations of forage fish schools are consistent with the larger efforts reported in Norcross et al. (1999). The most common misidentifications occurred when age-0 herring or sand lance were present. Since the validation work was conducted in conjunction with the vessel-based forage fish surveys all of the validation efforts occurred when age-0 fish were present and this should lead to the largest error in species identification. The June surveys should have smaller identification errors since there are not normally age-0 fish present during the survey period. With very few data points available, it is not possible to evaluate how well the aerial surveys predict the strength of a year class recruiting to the spawning population. We might not be able to evaluate the strength of the year class observed in 2013 because we did not get a sufficient age structure sample in 2015. However, it does appear that there was strong recruitment from that year class in other locations in the Gulf of Alaska.While sand lance observations tend to be observed in specific areas, the distribution of age-1 herring is more varied among years. This may be the result of the initial distribution being determined during the larval drift phase. Overall, locations near the spawning grounds and those closest to the expected larval drift route did tend to have higher numbers of herring schools.

ACKNOWLEDGEMENTS

We would like to acknowledge all the hard work by Dr. Evelyn Brown that we tried to build upon. The majority of the analysis of the aerial survey data was completed by Mayumi Arimitsu with the Forage Fish project in the Gulf Watch Alaska program. Mike Collins was the pilot and primary spotter throughout this work. Alexandra Wright flew surveys and transitioned the logging to a tablet. The views expressed here are our own and do not necessarily represent those of the *Exxon Valdez Oil* Spill Trustee Council.

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