2019 Prince William Sound Forage Fish Observations

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Executive Summary

This project provided funding for aerial surveys of forage fish in Prince William Sound (PWS). The project helps to identify areas where forage fish congregate. It builds upon previous aerial forage fish surveys conducted in PWS by Evelyn Brown (Brown and Moreland 2000) and Scott Pegau (Pegau 2018). The aerial surveys allow for identifying forage fish schools that are in water too shallow for a survey vessel. The data from this project also provides an index of age-1 Pacific herring (*Clupea pallasii*) for use in the population modeling effort within the Herring Research and Monitoring program to predict recruitment to the spawning stock.

Aerial surveys were conducted in June of 2019. Fish species, school size, and number of schools were recorded along with time and position electronically and on paper. The surveys followed the coastline throughout Prince William Sound and took approximately twelve flight days to complete. Surveys are only flown when weather permits so the survey period extended throughout the month of June.

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 along the coast. As often occurs, sand lance were concentrated on Middle Ground Shoal, Naked Island, and near Eaglek, with some schools observed in other areas (see map in Appendix for these locations). Juvenile herring were fairly uniform; however, there were concentrations along Hawkins Island and the northwest section of PWS. Relatively few whales were observed. A fin whale was observed much further into PWS than expected.

Validation occurred through June and into early July. Nineteen schools were validated by surface vessels. Eighteen of those were correctly identified with the misidentification being an age-0 herring school that was observed in early July. The difficulty associated with identification of age-0 herring and sand lance schools that appear in July is a major reason that the forage fish surveys occur in June.

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). Many of the forage fish can be found along the coasts in shallow water, which makes them susceptible to impacts from oil spills. 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, 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). Hydroacoustic assessment of fish biomass in the water column works particularly well in deep, open waters (Carscadden et al., 1994; Demer et al., 2011), but has several disadvantages when working in shallow coastal areas: 1) the transducer near-field and surface noise exclude detections shallower than 4-5 m, 2) the cone-shaped beam pattern covers a very narrow swath at shallow depths, 3) trawl-capable support vessels are unable to operate safely in shallow rocky coastal areas, and, 4) shallow fish schools may actively avoid vessels under way.

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. The high speeds of the plane allow a large area to be surveyed in a short period of time. They also allow us to determine the broad-scale distribution of schools visible from an airplane (Photo 1).

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. While both survey techniques are not funded by the Prince William Sound Regional Citizens' Advisory Council we were able to work with the forage fish project in the Gulf Watch Alaska program that provides information from acoustic surveys. The forage fish project collected fish from schools identified from the air to provide validation of the aerial observations.

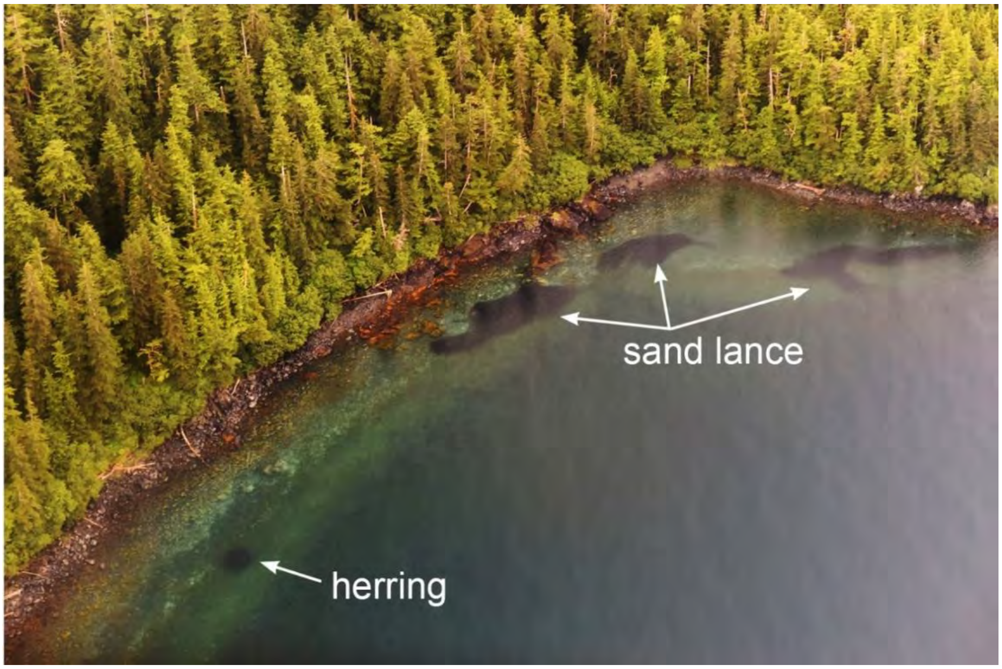

Photo 1. Aerial photograph of typical Pacific herring (n = 1) and Pacific sand lance schools (n = 3) along shorelines in Prince William Sound, AK. Herring schools are typically round or oval and sand lance schools are darker and irregularly shaped.

In this report we describe the current distribution of coastal forage schools in Prince William Sound as observed during the June 2019 aerial surveys and provide some historic distributions for comparison. 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 (2010-2018) surveys were again conducted under auspices of the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC). We also report on 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.

Scope of Work

The objective of the work is to provide an aerial survey of forage fish schools in Prince William Sound during June to allow prioritization of their protection during a spill response. The two deliverables were to conduct aerial surveys and to provide a report on the observations.

Methods

Aerial shoreline census survey methods followed those established during the Sound Ecosystem Assessment (SEA) and Alaska Predator Ecosystem Experiment (APEX) (Brown and Moreland, 2000; Norcross et al., 1999). Aerial surveys are conducted from a Cessna 185 float plane traveling at speeds of 200-240 km/h and a target altitude of 300 m. Surveys are flown parallel to shore, but we occasionally circled back to verify observations when school densities are high. The entire coastline of Prince William Sound is flown. It normally takes twelve to fourteen days, flying four to five hours in a day, to complete a survey of the entire Sound. The section of the

Sound flown on any particular day depends on the weather and aircraft schedule. The completed sections are mapped on the aircraft's GPS and on a paper map to ensure there are no gaps in coverage. The survey was flown in the month of June to reduce identification errors caused when age-0 herring and sand lance become visible, typically in July. This year we did not survey the Copper River Delta and Kayak Island area. We only survey those areas if time allows after completion of Prince William Sound.

There were two observers in the aircraft on each flight. The primary observer counts and identifies the schools while the secondary observer records the observations and looks for schools on the other side of the plane. The primary observer is the one on the shoreline side of the plane where most schools are observed. The primary observer has at least two years of aerial survey experience. Observations during flights are collected on the location, altitude, number and size of schools of forage fish. A GPS is used to provide position information to an electronic recording platform and paper logs are kept as a backup record. Norcross et al. (1999) contains a detailed description of the survey design and analysis of errors associated with observations.

The schools are identified by species (Pacific herring, Pacific sand lance, capelin, and eulachon and unknown forage fish) and herring are classified by age (1 or 2+). Age-1 herring are just over a year old in June and age-2+ herring are any herring older than one year old. Species identification was based on characteristics of the school including color, shape, location and of "flashing." Herring schools tend to be round (Photo 1) and the tendency of individuals within schools to roll creates a telltale flash of light. Younger (smaller) herring show a finer pattern of flashing compared to older fish. Adult herring (age 2+) tend to form larger schools in deeper water than age-1 herring. Sand lance schools tend to be darker in color, irregularly shaped and in shallow areas with sand and gravel habitats (Photo 1, Norcross et al., 1999; Ostrand et al., 2005). Capelin tend to form large, cresent-shaped schools, whereas eulachon form very large shoals primarily associated with offshore waters and the Copper River Delta.

The size of schools are estimated using a sighting tube constructed of PVC pipe with a grid drawn on mylar on the far end (see Norcross et al. 1999 for details). The focal length (F) of the tube is 210 mm, and a full tick mark on the grid is 1 cm. School size is 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 < 75 m^2 for small schools, 75 – 300 m^2 for a medium school and > 300 m^2 for a large school.

The species, number, and size information is mapped to show the locations of forage fish. The number of schools of age-1 herring are counted each year to provide an estimate of future recruitment.

Findings

Forage fish school observations are mapped in Figure 1. Larger versions of the maps provided in Figure 1 and a map with the locations identified are provided as an appendix. In general, few schools were observed in 2019 compared to previous surveys (Pegau 2018). Age-1 herring make up the majority of forage fish schools observed each year. They are followed by sand lance and age-2+ herring. The smaller number of forage fish schools observed in 2019 was driven by the number of age-1 herring schools that were moderate in number compared to other years (Figure 2). As often occurs, sand lance were concentrated on Middle Ground Shoal, Naked Island, and near Eaglek with some schools observed in other areas. The distribution of juvenile herring was fairly uniform; however, there were concentrations along Hawkins Island and the northwest section of PWS. Adult herring tend to migrate out of Prince William Sound by June and therefore we expect to find most of the age-2+ herring near the entrances or outside of the Sound. There are always some age-2+ herring that remain in PWS. Relatively few whales were observed. A fin whale was observed much further into PWS than expected.

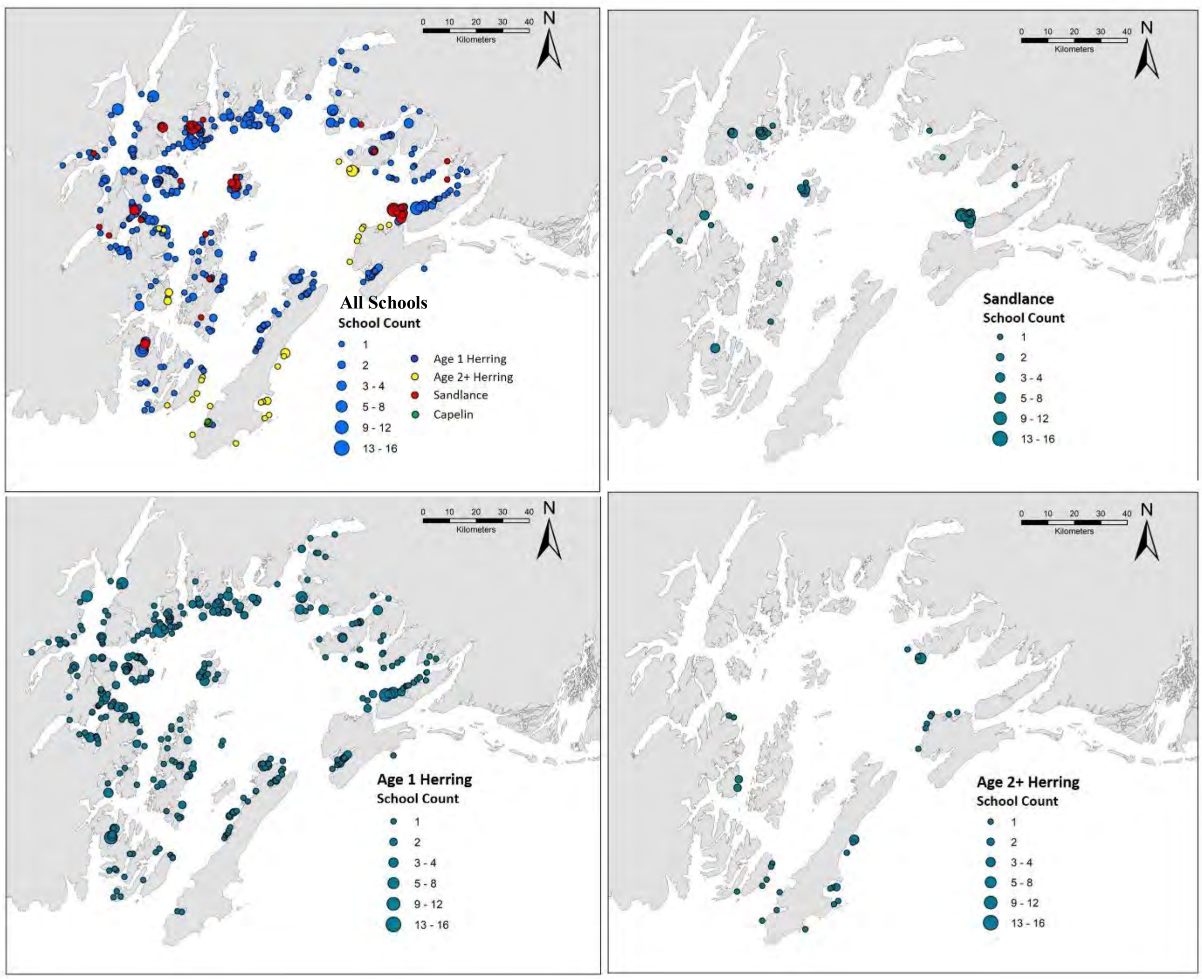

Figure 1. Observations of the number of schools for all forage fish (a), sand lance (b), age-1 herring (c), and age-2+ herring (d). Only one school of capelin was seen so they were not mapped separately.

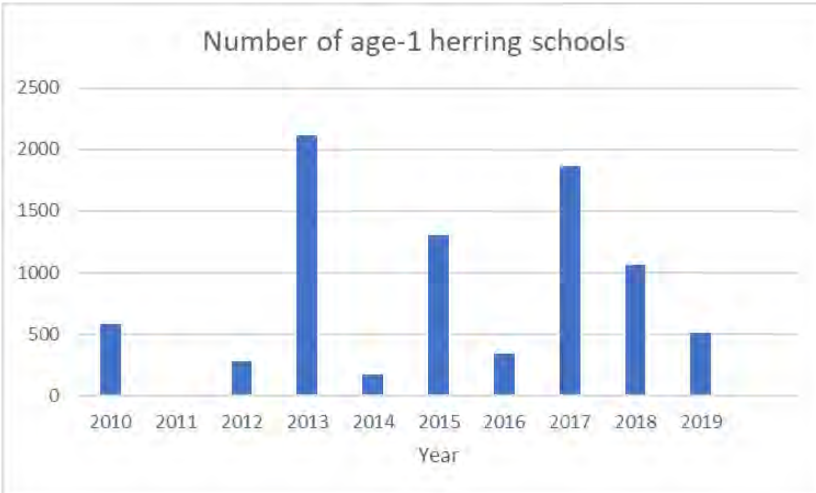

Figure 2. Number of age-1 herring schools by year. Data from 2011 is not presented because the survey did not cover the entire Sound.

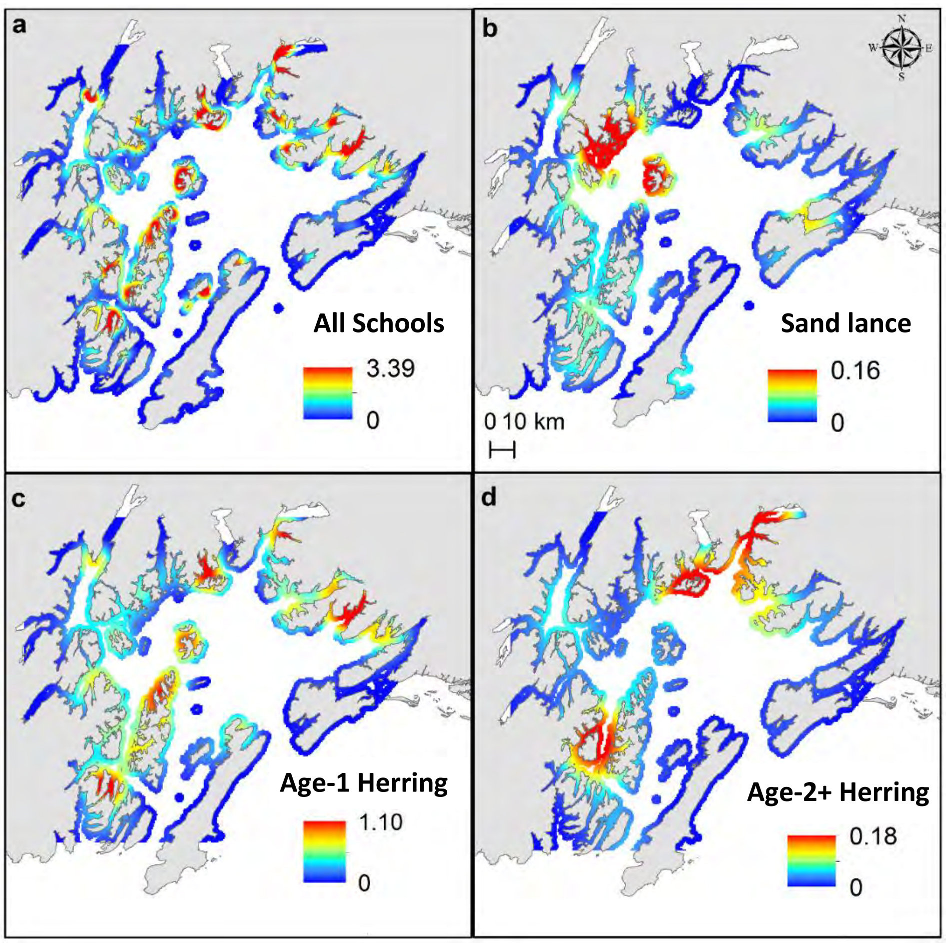

Figure 3. Relative distribution of forage fish schools (Kernel density, Km^{-2}) observed during June 2010-2016. The panels match those in Figure 1.

For comparison the kernel density of the forage fish populations are provided in Figure 3. The distribution of sand lance from 2010-2016 is similar to what we observed in 2019 with the exception of more sand lance observed near Middle Ground Shoal. Other notable differences are the increase in age-1 herring schools along Hawkins Island and the lack of age-2+ herring in the Valdez Arm.

Observations of whales also are collected during the surveys. A map of their 2019 distribution is provided in Figure 4. The general feeling is that the number of humpback whales is significantly lower than 3 to 4 years ago.

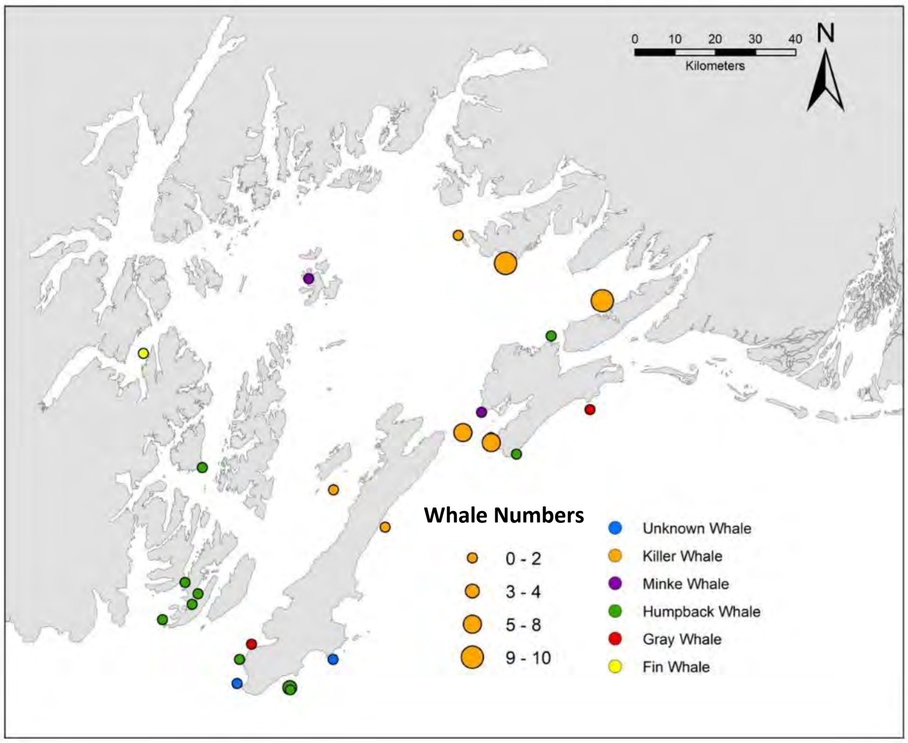

Figure 4. Type and number of individual of whales observed during the 2019 forage fish surveys.

The 2019 aerial survey data has been made available through the AOOS data portal at https://portal.aoos.org/gulf-of-alaska#metadata/2f2367fa-6f4c-44e6-9c7a-150dc156154c/project. Video was collected during many portions of the aerial survey and is available from Scott Pegau.

Validation of the aerial-survey school identification is possible through shipboard collection of fish from schools identified from the air. We worked with two vessels this year to obtain validations on nineteen schools. Three herring schools age-2+, three herring schools age-1+, and eleven sand lance schools were correctly identified. The lone misidentification was of an age-0 herring school that was called a sand lance school. This occurred in early July as the age-0 herring and sand lance were first becoming visible.

Discussion

While the PWS herring populations remain low, they still represent the largest number of schools of forage fish observed. The number of age-1 herring schools in 2019 was low, but within the observed range. The largest difference in the age-1 herring distribution in 2019 compared to previous years is the number of schools along the coast of Hawkins Island. This is possibly a result of the use of Canoe Pass on Hawkins Island as a spawning area in 2018.

The second most common forage fish schools observed were of sand lance. They were predominately located over Middle Ground Shoal, around the western side of Naked Island, and the northwest section of PWS (Eaglek). We have not seen many capelin over the past four years. More schools were observed last year and they were near Latouche Island. There was some evidence that capelin may have been at the southern end of Latouche this year; however, they were not aggregated in dense enough schools to be observed from the air. The presence of capelin was inferred from the behavior of the whales and seabirds in the area.

It is important to validate the aerial identification by capture of fish from known schools. This is accomplished by the aerial observers identifying a school of fish and then guiding a capture vessel to that particular school. The capture vessel is told what the aerial observer classified the school as and then the capture vessel lets the aerial observer know what they actually were.

The 2019 validation results were consistent with previous validation efforts. From 2014–2016 we validated 34 schools in the month of July. During that period 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 fish capture vessel. 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.

Even earlier school identification validation efforts were conducted in the late 1990s. Norcross et al. (1999) provided an analysis of 419 validation observations in PWS. 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.

Similar to Norcross et al. (1999), the 2014-2019 validations efforts found that most of the identification errors involved age-0 herring or age-0 sand lance, probably because these fish occur in overlapping regions and do not have as well-defined schooling characteristics. From the combination of all 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 hypothesize that identification errors by aerial observers would be lower in June when age-0 herring and sand lance are not visible from the air. This is consistent with our efforts in 2019 when all schools validated in June were found to have been correctly identified. However, there have not been enough validations in June to provide the statistics necessary to determine the identification accuracy in June.

A simple measure of the size of the herring population is mile-days-milt. This is just the miles of herring milt observed by air summed over all days of the survey. This year the mile-days-milt nearly tripled from 2018 and this appears to be a result of a large recruitment of age-3 fish. This is consistent with the large number of age-1 fish observed in 2017. This provides hope that the surveys are able to provide an early indication of the future of the herring population in Prince William Sound.

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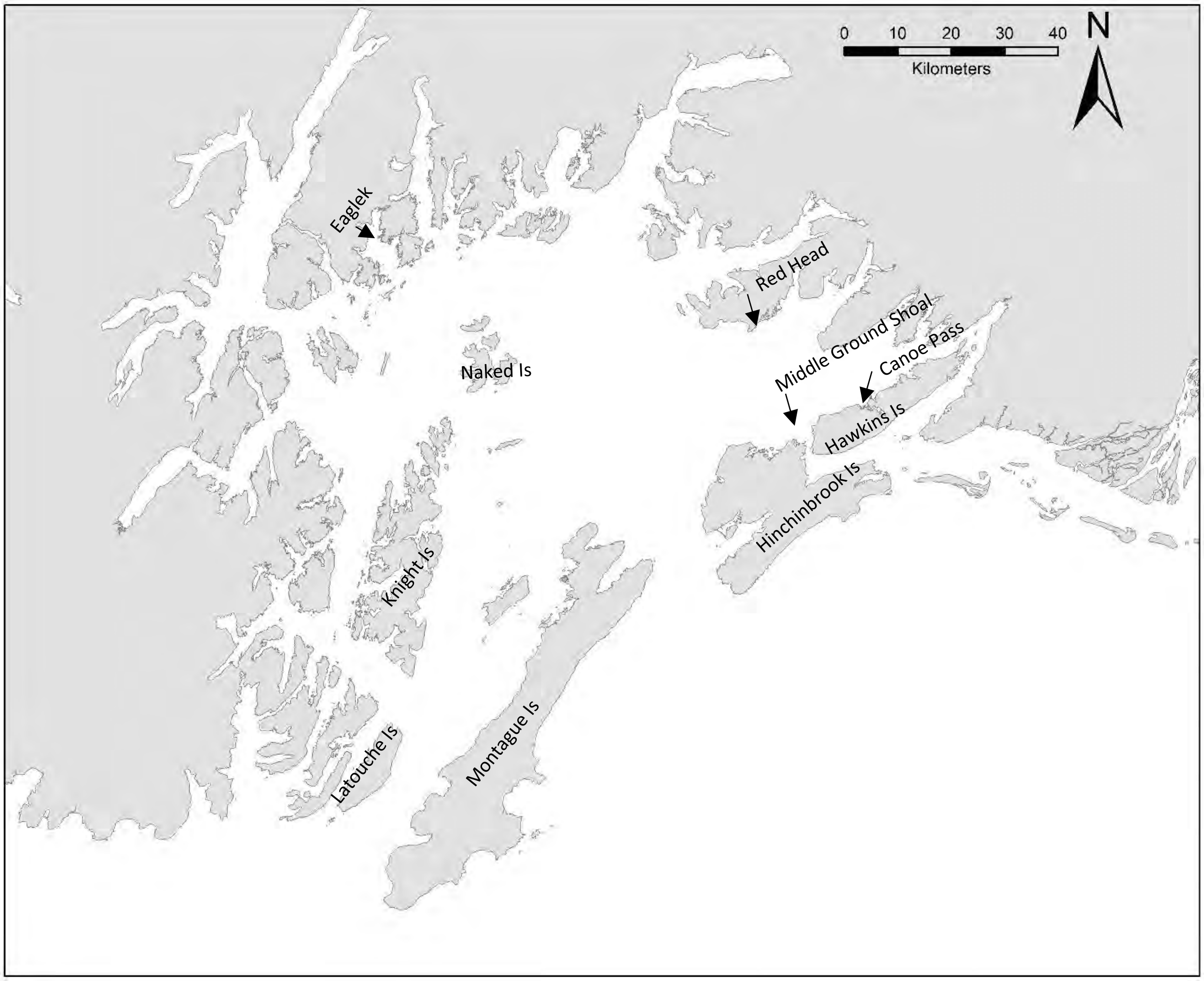
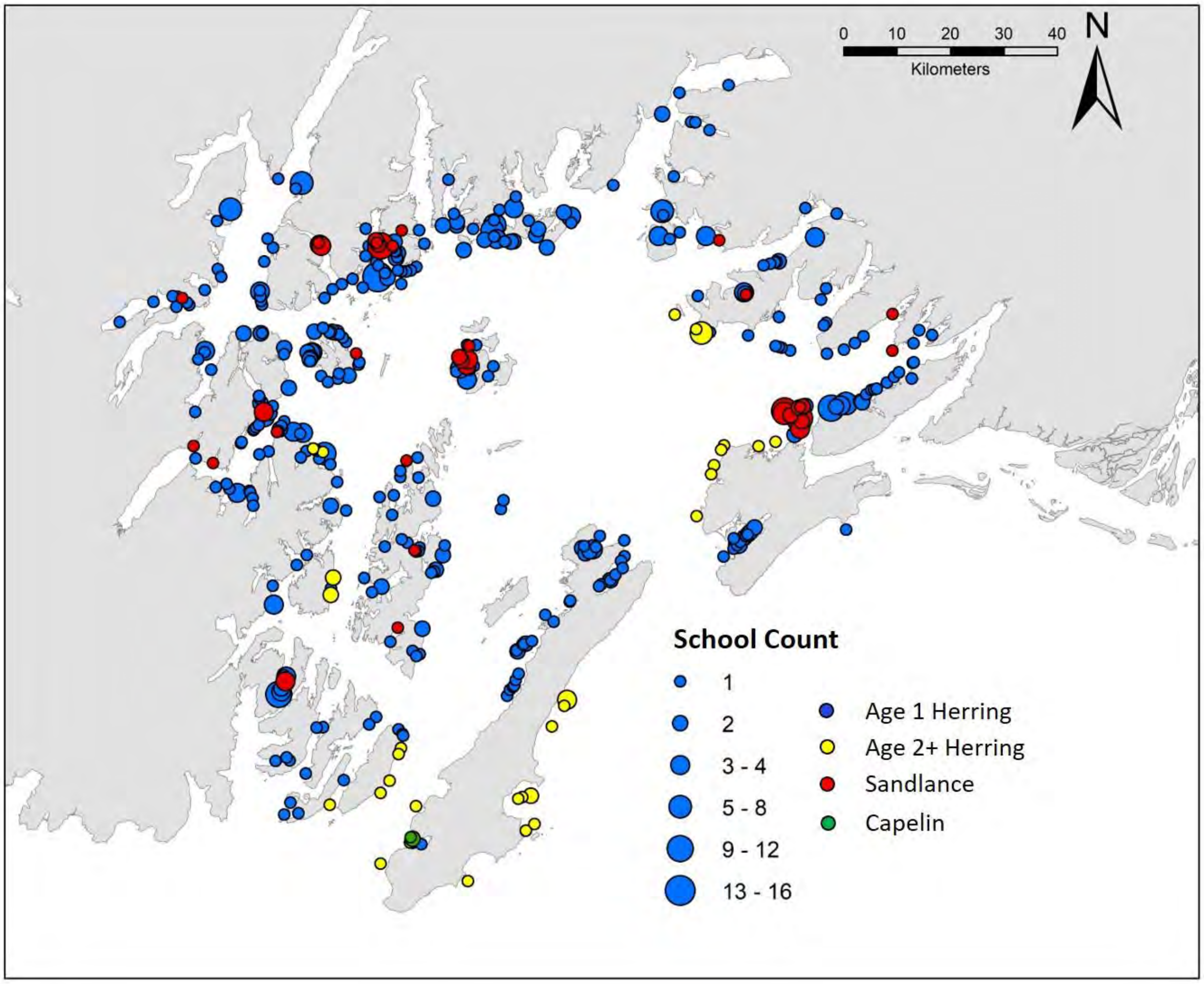
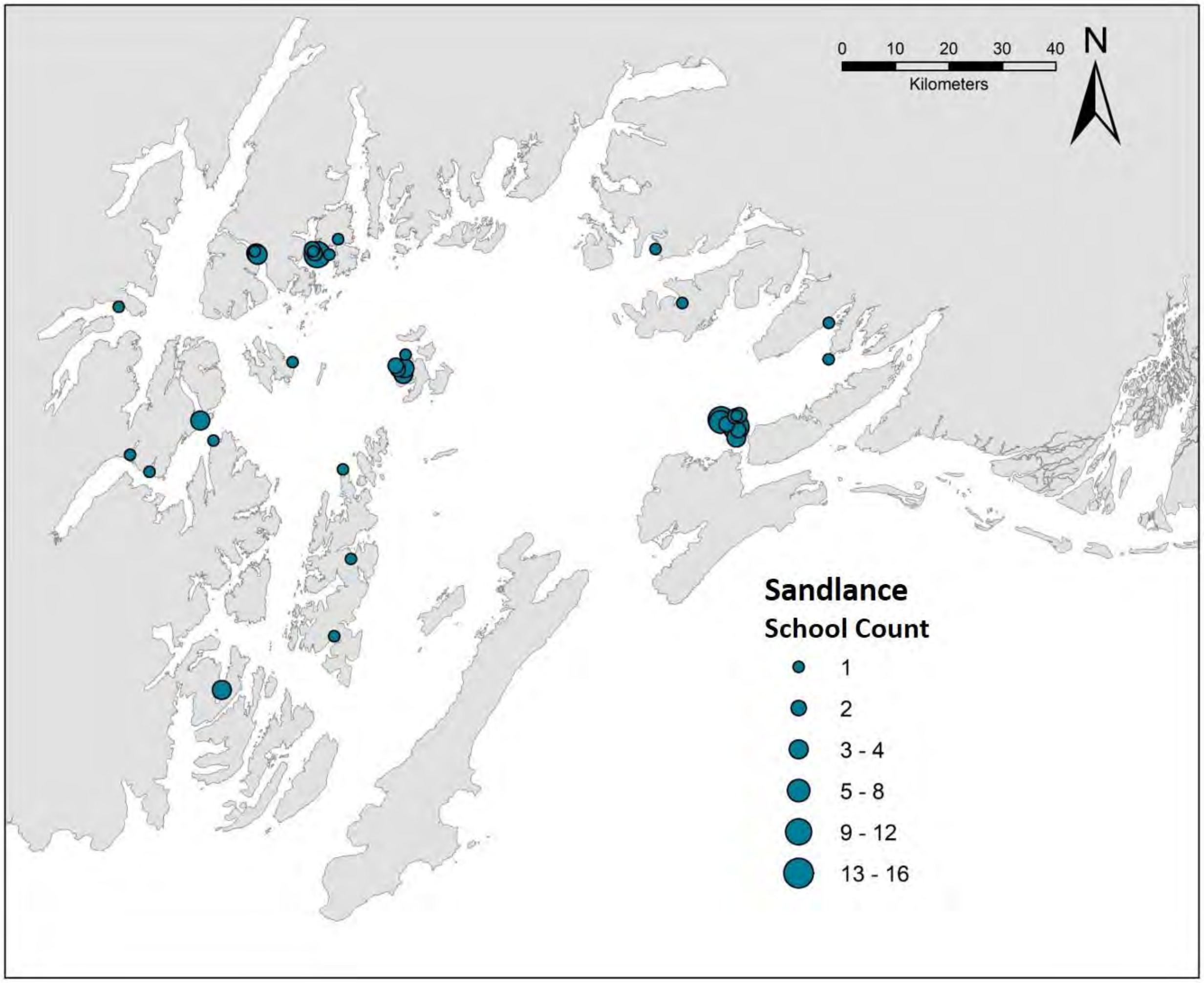
Appendix



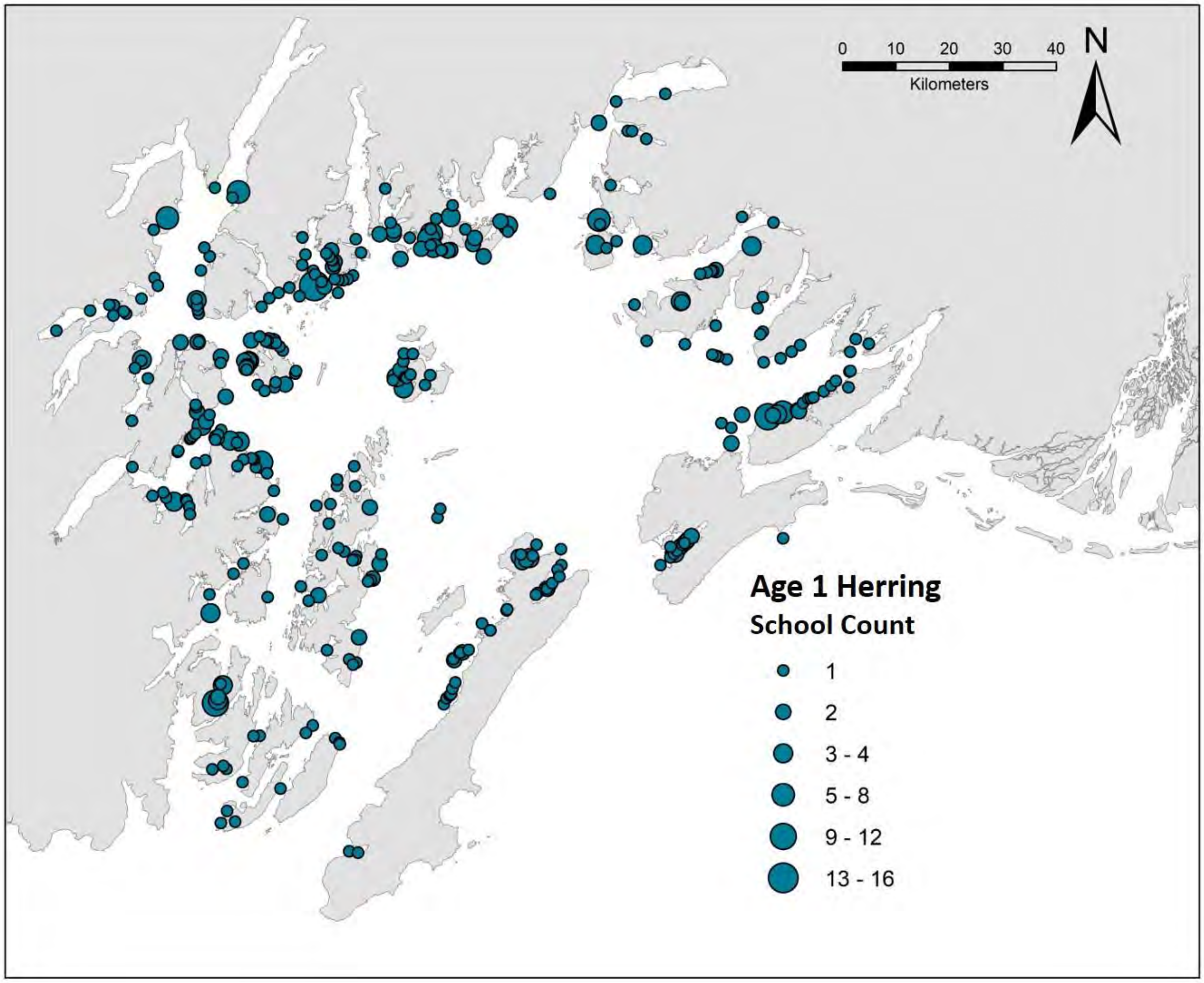
Map of locations in Prince William Sound.



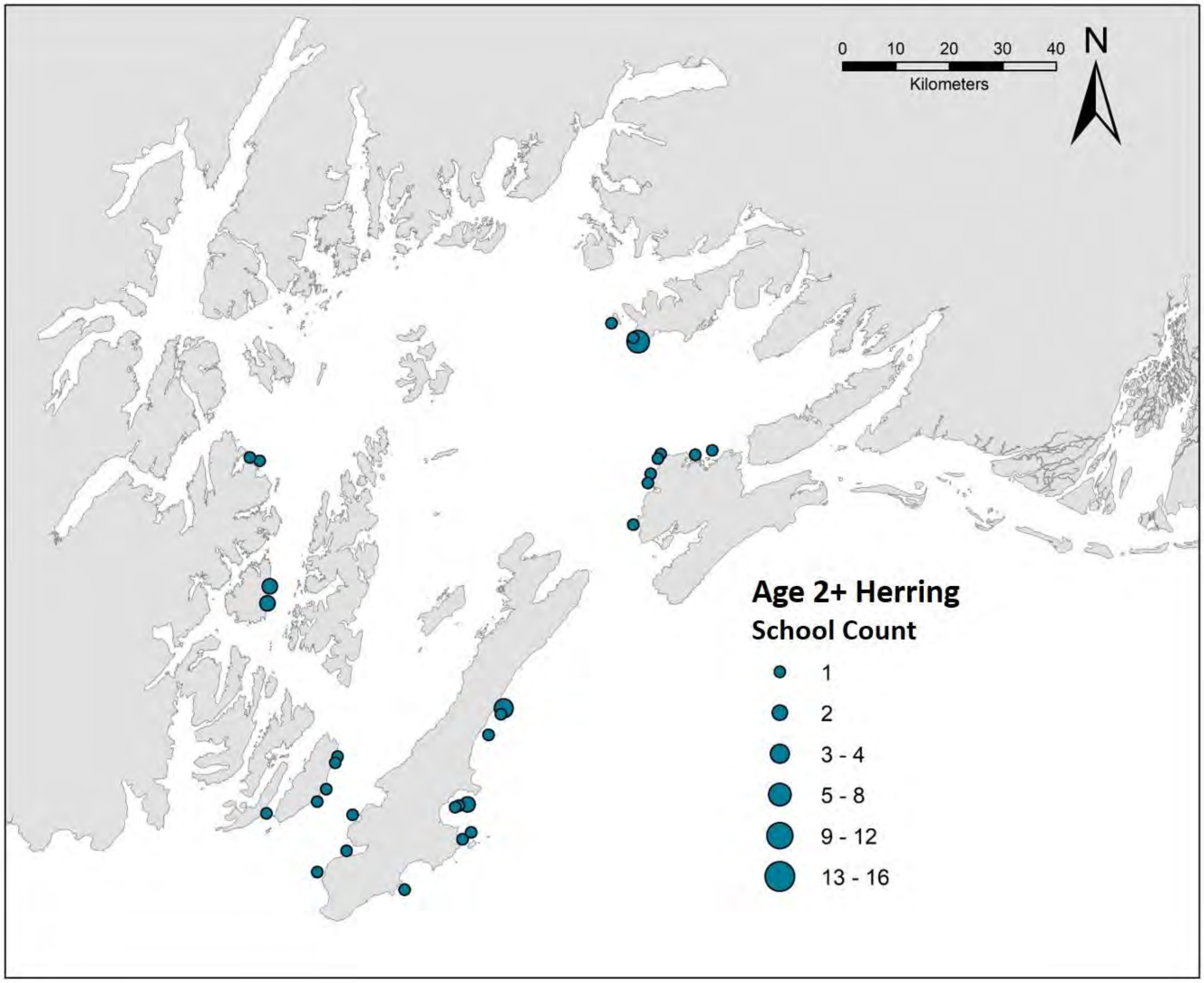
June 2019 Forage Fish Distribution



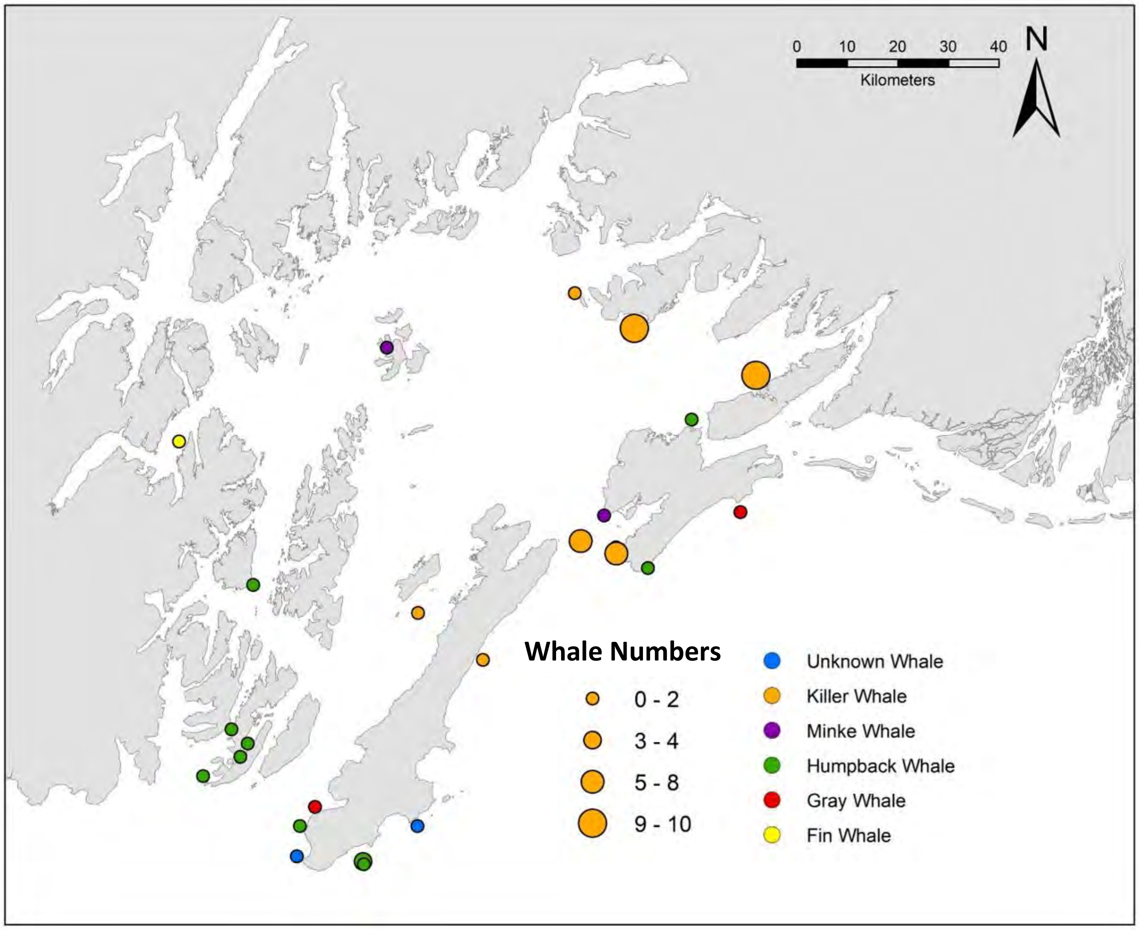
June 2019 Sand lance distribution



June 2019 Age-1 Herring distribution



June 2019 Age-2+ Herring distribution



June 2019 Number and type of whales observed