2020 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. The aerial surveys allow for identifying forage fish schools that are in water too shallow for a survey vessel. The objective of the work is to provide an aerial survey of forage fish schools in PWS during June to allow prioritization of their protection during a spill response. The data from this project also provides an index of age-1 Pacific herring (*Clupea pallasii*) that is used by the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) sponsored Herring Research and Monitoring (HRM) program to predict recruitment to the spawning stock. The HRM program conducts aerial and acoustic surveys of the herring spawning stock within PWS and works to understand changes in the herring population. These aerial forage fish surveys are the only indication of the population levels and distribution of juvenile herring.

Aerial surveys were conducted in June and early July of 2020. Fish species, school size, and number of schools were recorded along with time and position electronically and on paper. Observations of whale numbers, species, date, and time are also logged. The surveys followed the coastline throughout Prince William Sound and took approximately 12 flight days to complete. Surveys are only flown when weather permits so the survey period extended throughout the month of June. This year we were not able to complete the surveys until early July, although most of the survey effort occurred in mid-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. Sand lance were relatively rare this year with only a few schools seen in normal areas such as Middle Ground Shoal and Naked Island (see map in Appendix for these locations). Juvenile herring were fairly uniform; however, there were concentrations in Port Etches and the northwest section of PWS. Whale numbers remain low. A pod of fin whales was observed in the southwest passages. A pod of fin whales was also seen in Hinchinbrook Entrance but it was off transect and they were not recorded.

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 PWS 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 PWS 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 meters (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 PWS, 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 (GWA) program that provides information from acoustic surveys. The GWA forage fish project collected fish from schools identified from the air to provide validation of the aerial observations. While the normal GWA forage fish surveys had to be canceled due to COVID-19, they did contract with a vessel to provide validation observations of this project's aerial survey work.

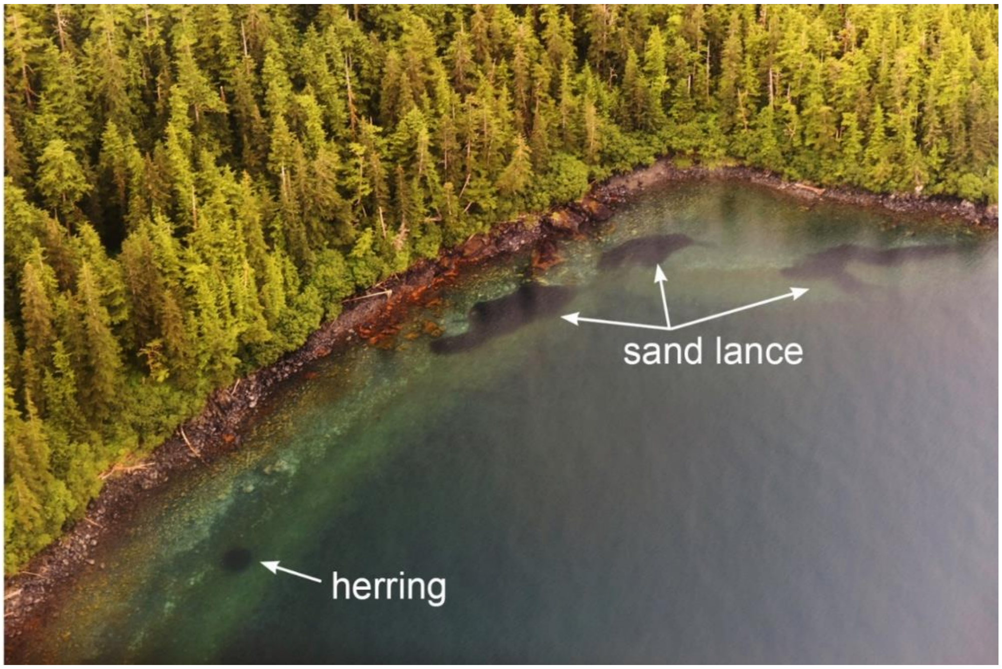

Photo 1. Aerial photograph of typical Pacific herring (n = 1) and Pacific sand lance schools (n = 3) along shorelines in Prince William Sound, Alaska. Herring schools are typically round or oval and sand lance schools are darker and irregularly shaped.

In this report we describe the current distribution of coastal forage fish schools in PWS as observed during the June 2020 aerial surveys and provide some historic distributions for comparison. Aerial shoreline census surveys of forage fish schools in PWS occurred in the late 1990s (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). Beginning in 2019, the surveys were conducted with funding from the Prince William Sound Regional Citizens' Advisory Council.

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 kilometers per hour 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 PWS is flown. It normally takes 12 to 14 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.

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. A video camera is placed in a rear window to provide an additional record of the flight. Normally the video only covers a section of the flight because the video camera batteries do not last the entire flight time. 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 as well as unknown forage fish) and herring are classified by age (0, 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 “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 millimeters and a full tick mark on the grid is 1 centimeter. 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.

Whales are identified to species and the number observed is logged into the same software used for the forage fish observations. The species of whale is identified by a four-letter code. The code starts with the first two letters of the common name of the whale and ends with “wh.” For instance, a humpback whale is logged as “huwh.”

Validation of aerial observations are conducted by having the aircraft guide a vessel to a forage fish school. The aerial observers radio their species/age identification to the vessel. The vessel then attempts to sample the school using jigs, seine nets, cast nets, underwater cameras, and other gear that allows sampling from the school. The vessel records what the aerial observers indicated and what was determined from vessel sampling. At the end of the season the validation observations are provided to the aerial survey project.

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 & Discussion

This year, ten days were spent surveying. Most of the flights were conducted in June, but weather and other scheduling caused the last flights to occur in early July. All of PWS, including the outsides of Montague and Hinchinbrook islands as well as the islands in southwest PWS were flown (Figure 1).

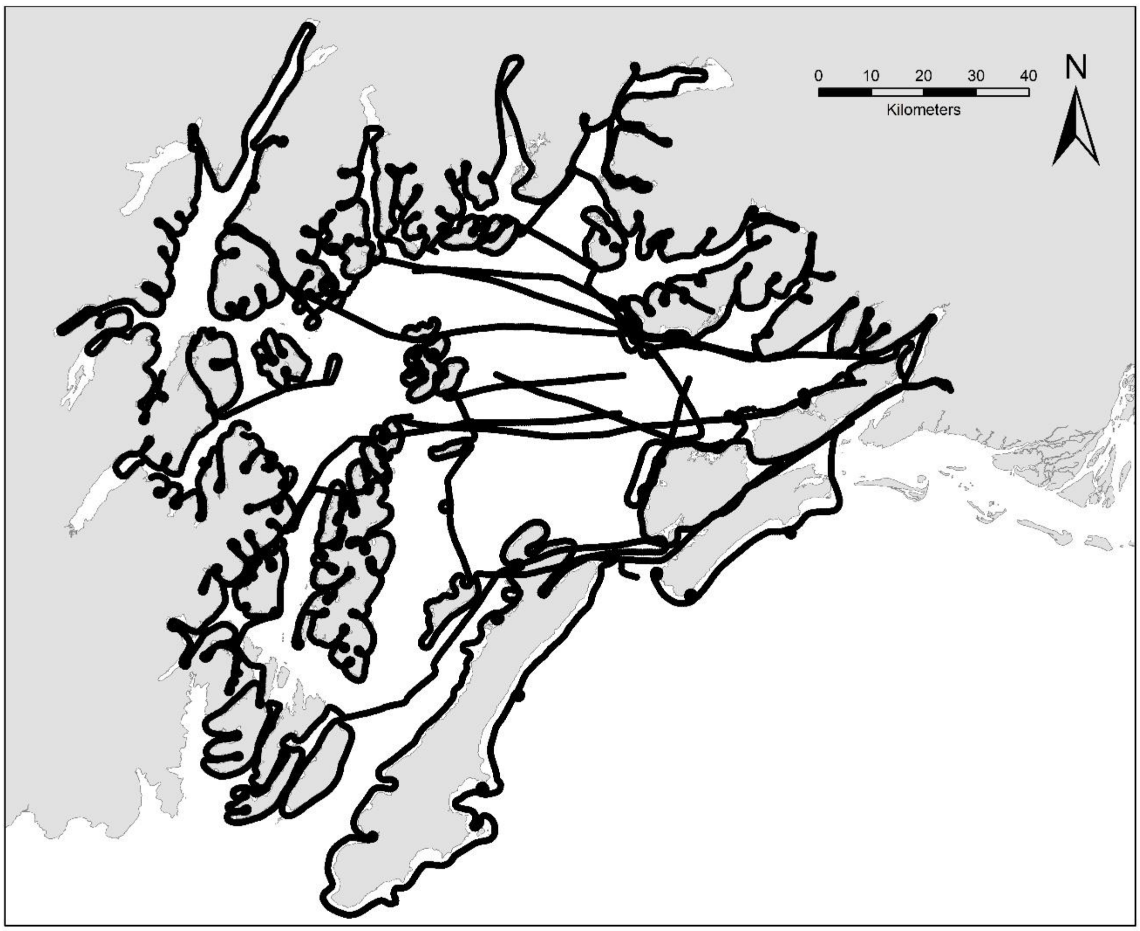

Figure 1. The 2019 survey flight tracks, which were essentially the same as the 2020 tracks. The 2020 survey flight tracks are not shown because there was a day when the primary GPS failed to record and fish school location had to be determined from flight video. The apparent gaps in the survey flight tracks from 2019 are due to issues with the GPS recording device, but they were flown and recorded on the backup paper logs.

Forage fish school observations are mapped in Figure 2. Larger versions of the maps provided in Figure 2 and a map with the locations identified are provided as an appendix. Age-1 herring make up the majority of the observed forage fish schools. They are followed by age-2+ herring and sand lance. In 2020, there were relatively few sand lance and a moderate number of age-1 herring. As often occurs, sand lance were concentrated on Middle Ground Shoal with some schools observed in other areas. The distribution of age-1 herring was fairly uniform; however, there were concentrations at Port Etches and near Whittier. Adult herring tend to migrate out of PWS by June and therefore we expect that we only see a small portion of the total adult population. There are always some age-2+ herring that remain in PWS. These may be fish that are not mature yet or ones that choose to feed within PWS instead of migrating into the Gulf of Alaska. With the final flights not occurring until the beginning of July, we began to observe age-0 herring. Since age-0 herring only become visible in July, we only observed them on the last two flights and we do not know what their full eventual distribution was. The observations on age-0 herring should not be considered representative of the entire population.

In general, the number of schools observed this year was similar to that observed in 2019 (Figure 3) and relatively fewer schools compared to previous surveys (Pegau 2018). This is not surprising given that the 2016 year class (fish born in 2016 and observed from air in 2017) was extremely large and it is unusual to get large year classes in the three years following an extremely large year class. The 2016 year class, was the most successful year class on record throughout the Gulf of Alaska as measured by the number of recruits per spawner.

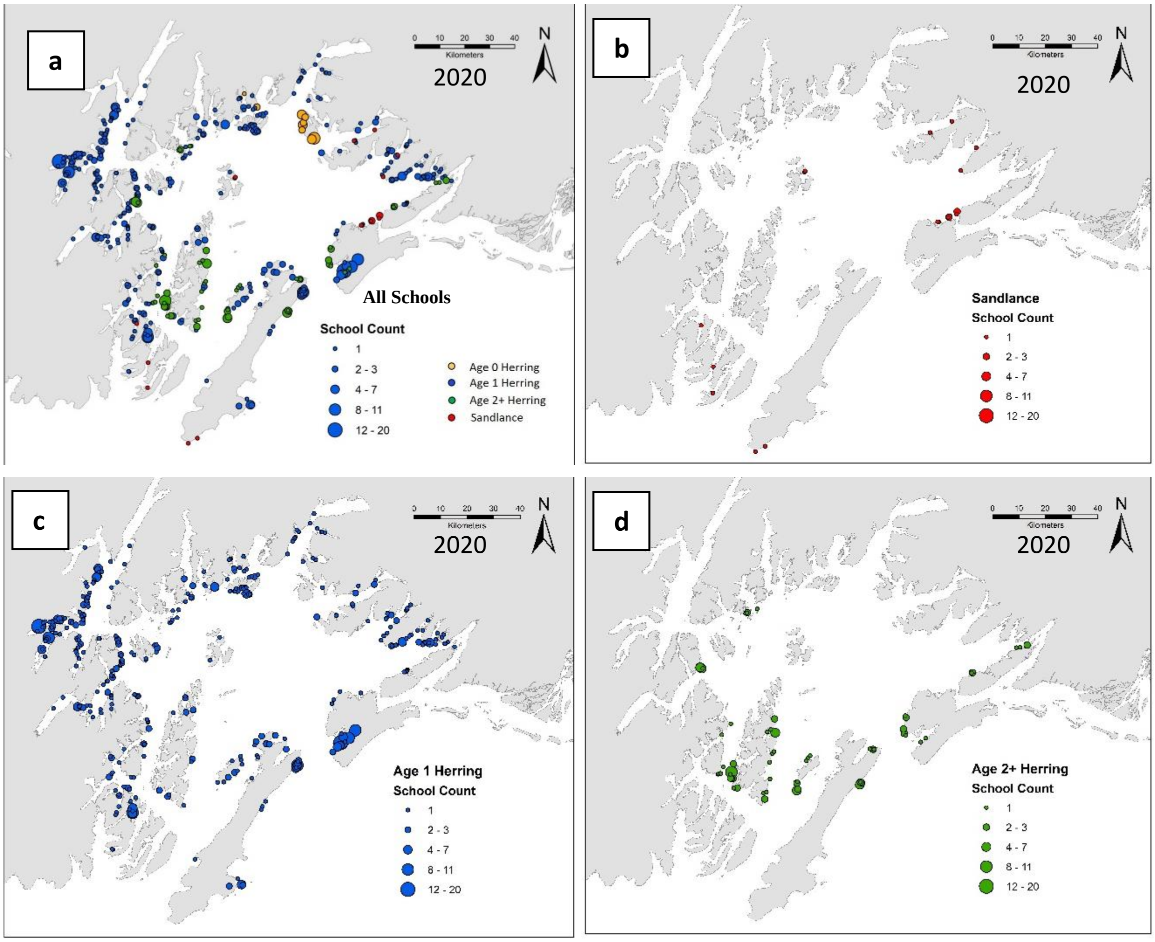

Figure 2 Observations of the number of schools for all forage fish (a), sand lance (b), age-1 herring (c), and age-2+ herring (d) in 2020. No capelin were seen this year.

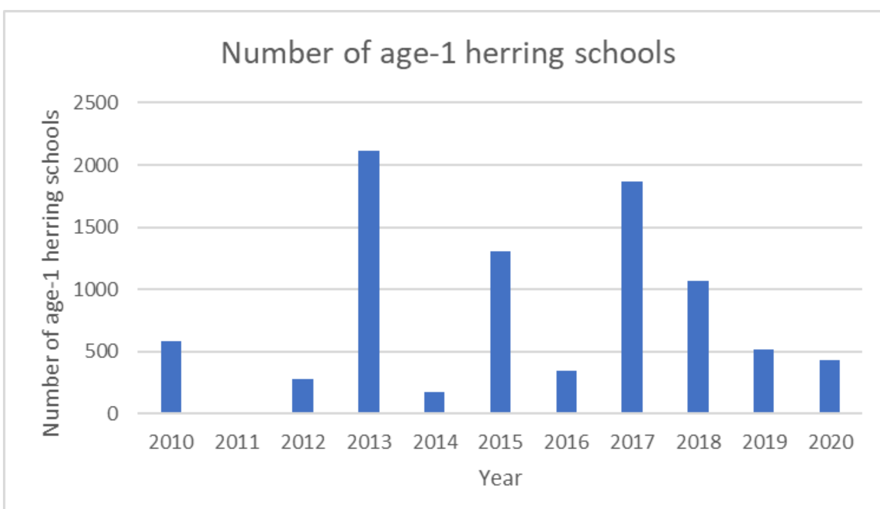

Figure 3. Number of age-1 herring schools by year. Data is not presented from 2011, because the survey did not cover the entire Sound.

For comparison among years, the distribution of age-1 herring schools in the past four years are provided in Figure 4. It should be noted that the highest count of schools was in 2017. In 2017 and 2018, the schools were concentrated in the eastern bays, near the spawning grounds, and around Knight Island. In 2019 and 2020, the distribution of age-1 schools has favored the northwest part of PWS. The change in distribution may be partially related to changes in the primary spawning areas but would also require changes in the ocean circulation to account for the age-1 herring being observed in northwest PWS.

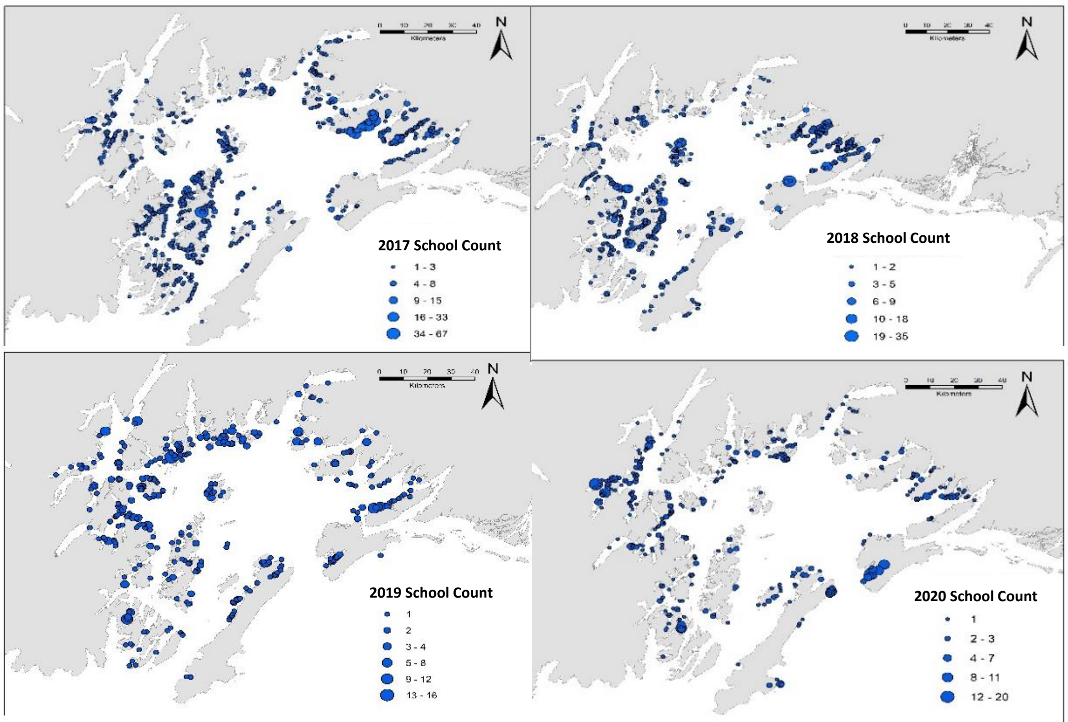

Figure 4. Distribution of age-1 herring schools in the last four years.

Observations of whales also are collected during the surveys. A map of their 2020 distribution is provided in Figure 5. There continue to be few humpback whales observed. This is the first year no humpback whales were observed inside PWS. This was the second year in a row that fin whales were seen in PWS.

The 2020 aerial survey data has been made available through the Alaska Ocean Observing System (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.

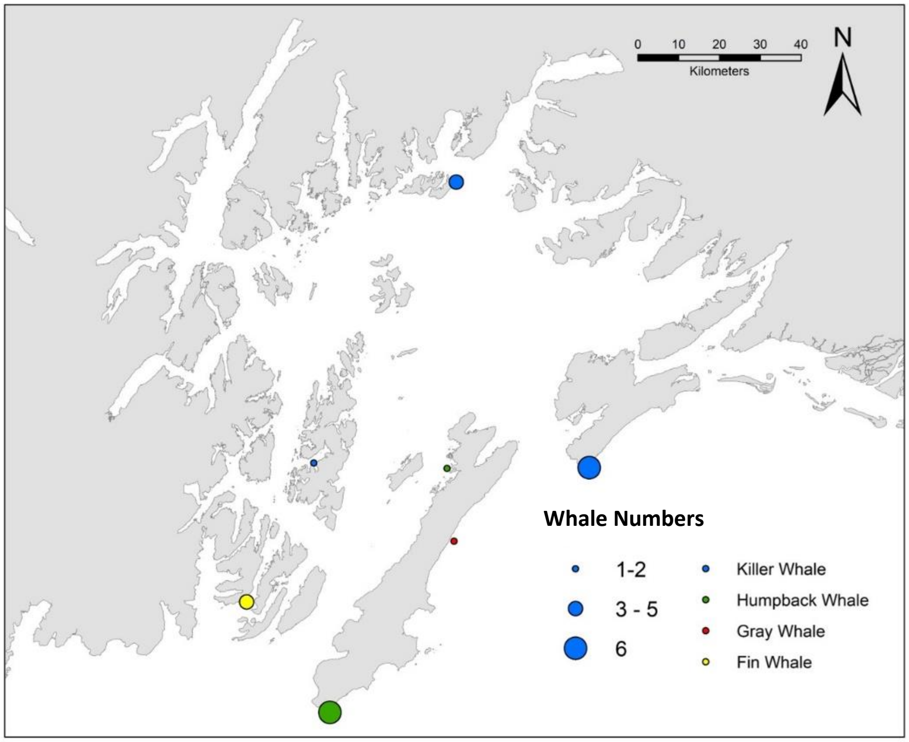

Figure 5. Type and number of individual of whales observed during the forage fish surveys in 2020. The size of the circle depicts the number of individual whales observed, while the color of the circle indicates whale type.

Validation efforts were limited due to COVID-19 concerns causing the primary effort to be canceled. Efforts to validate were hampered by a lack of fish near Naked Island, one of the areas pre-selected for validation effort, and fish avoidance of the larger vessel used in the validation effort this year. The vessel avoidance behavior is common and often limits the ability to conduct validation. This led to only two validations in 2020. Neither aerial observation was correct. One was a misidentification of the bottom as a school of fish. This is the first misidentification of bottom structure in over sixty validation efforts in recent years. The second was identified as sand lance but were actually age-1 herring.

The historic 2014-2019 validation 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 aerial survey 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. While the number of validation observations in June remain low, schools of sand lance and herring have been correctly identified over 90% of the time.

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 1990s, sand lance were correctly identified 80.4% of the time and the errors involved sand lance incorrectly identified as age-0 herring.

Conclusions and Recommendations

While the PWS herring populations remain low, they still represent the largest number of schools of forage fish observed. In 2020, the number of age-1 herring schools was moderate to low. The largest difference in the age-1 herring distribution in 2020, compared to previous years, is the large number of schools observed in Port Etches. There were few forage fish observed in the Naked Island group compared to any of the previous surveys.

There were few observations of sand lance this year. Middle Ground Shoal was the only area with multiple schools observed. Capelin were not seen during the survey period but were caught outside of Port Etches in early July 2020. For the last few years capelin have spawned off the beach between Nuchek and Bear Cape.

The surveys have been completed over enough years that we will be able to examine changes in the distributions over time. For instance, in 2017 and 2018, shown in Figure 4, it appears that the schools were primarily in the east and around Knight Island. However, in the last two years most of the schools have been in the north and northwest sections of PWS with few schools around Knight Island. This may be a result of different conditions during the larval drift of herring or a result of different spawning locations. As additional surveys become available, we anticipate being able to start to tease out the causes of the observed distributions. This is work that is underway in collaboration with the forage fish project within the EVOSTC sponsored GWA program. If we can identify the conditions that lead to a particular distribution, we would have a better idea of where these forage fish might be if a spill were to occur.

Data from this project is also being used by the modeling project within the HRM program to predict recruitment to the spawning stock. By working with the HRM and GWA programs we are able to build a better understanding of the conditions that lead to the success and distributions of forage fish. That information is then used to predict changes in the herring populations and impacts to marine birds and mammals.

We recommend continuing these surveys for two additional years to build up a time series that is better suited for determining the likely locations of forage fish and the potential connections to environmental variables. The extended survey duration would also capture a second large recruit class if herring are back in a four-year recruitment cycle, which there is some evidence for in other herring stocks in the Gulf of Alaska.

Acknowledgements

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Appendix

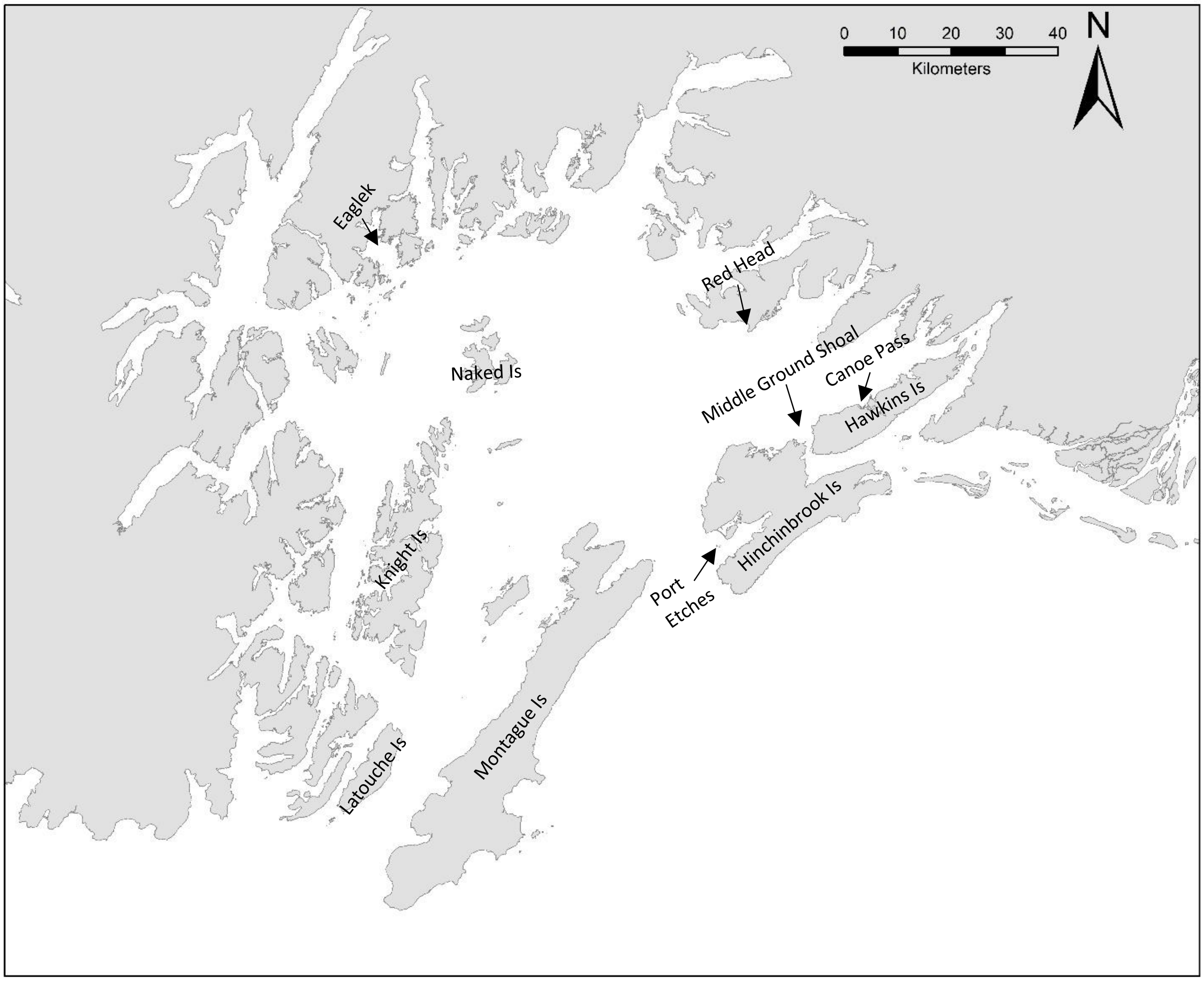

Figure 6. Map of locations in Prince William Sound.

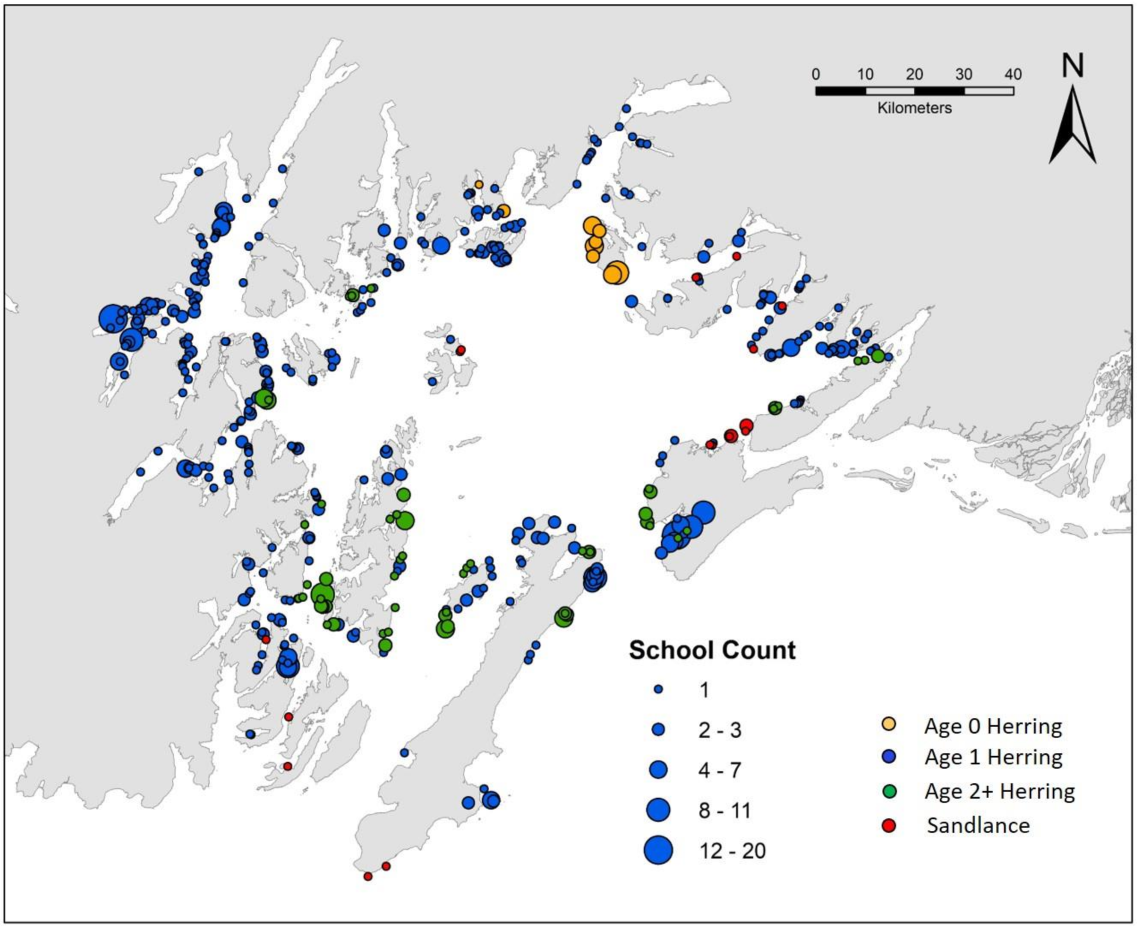

Figure 7. June 2020 forage fish distribution

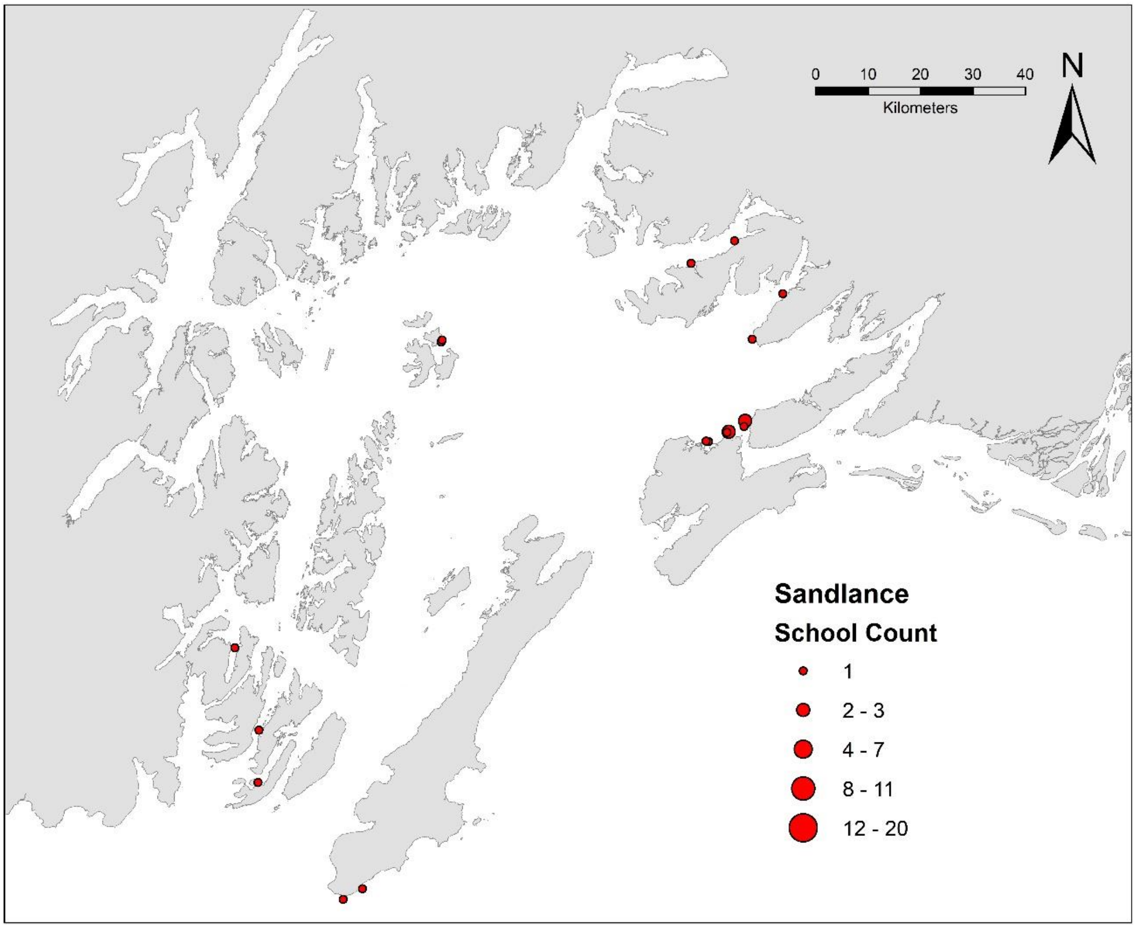

Figure 8. June 2020 sand lance distribution

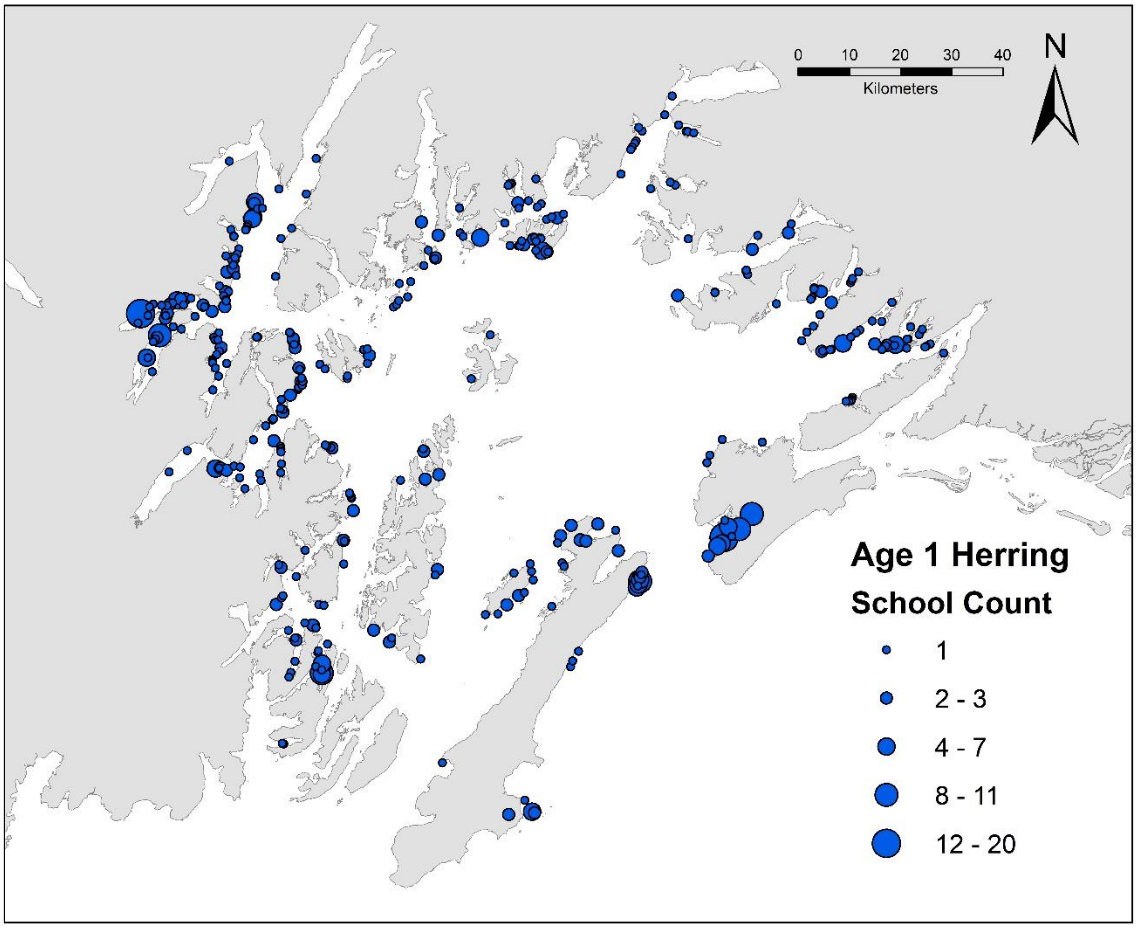

Figure 9. June 2020 age-1 herring distribution

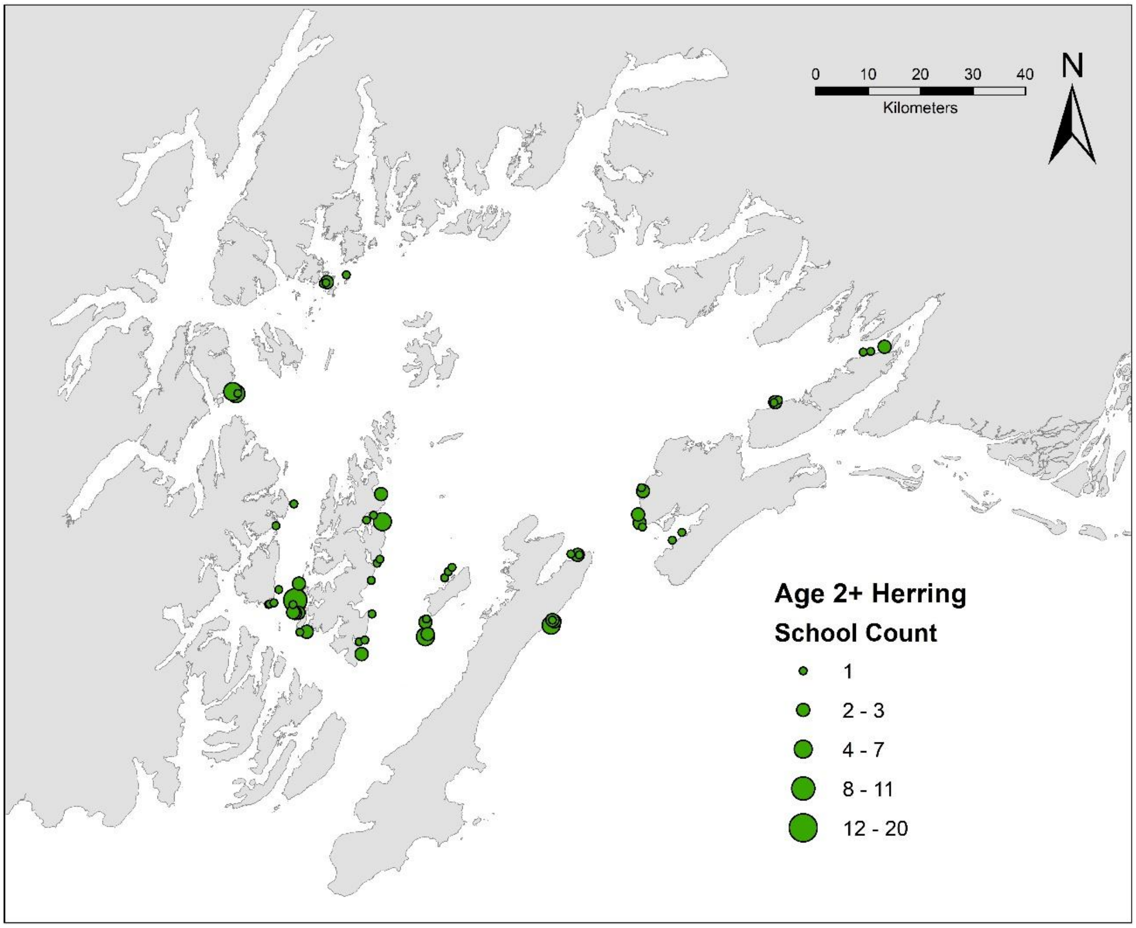

Figure 10. June 2020 age-2+ herring distribution

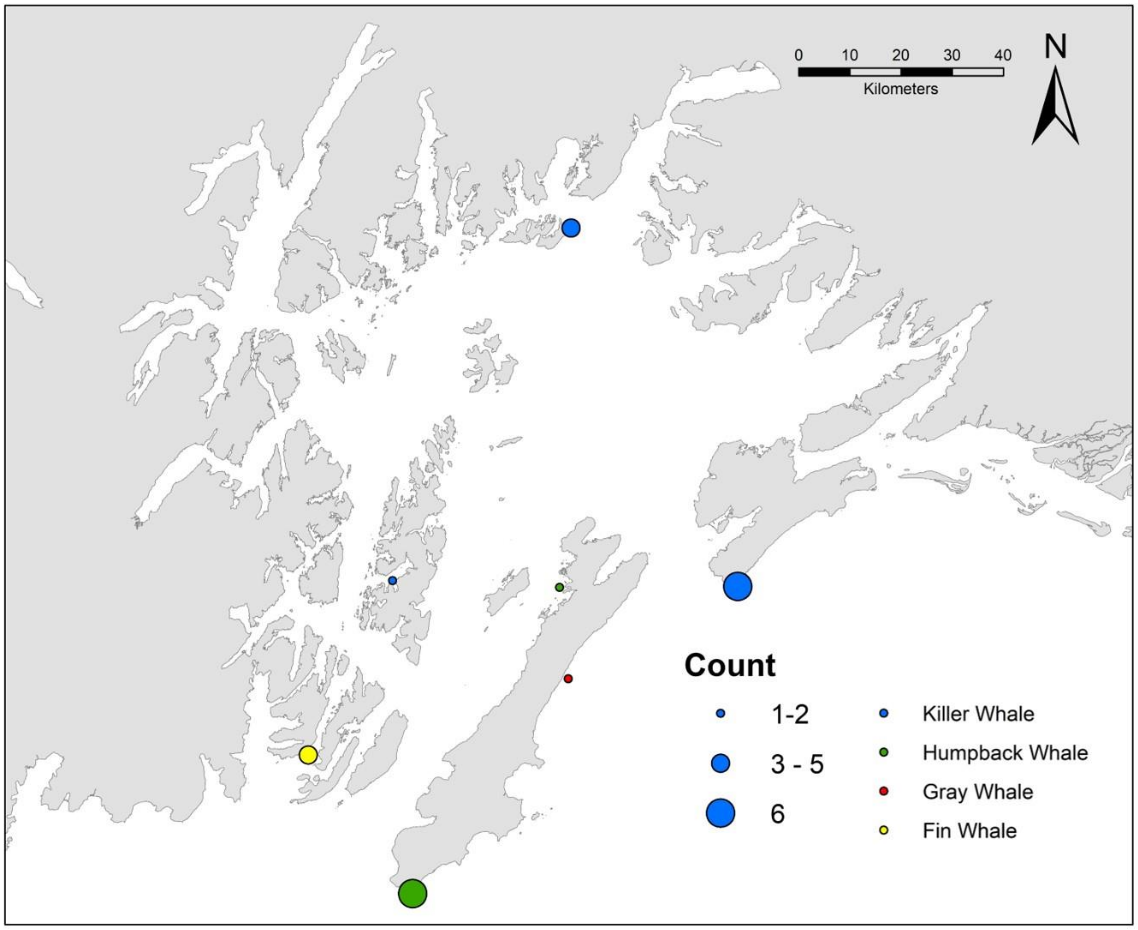

Figure 11. June 2020 number and type of whales observed. The size of the circle depicts the number of individual whales observed, while the color of the circle indicates whale type.