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

Adult Pacific Herring Acoustic Surveys in Prince William Sound

Exxon Valdez Oil Spill Trustee Council Project 21120111-G
Final Report

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PO Box 705
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Study History: This project is a continuation of an earlier project focused on monitoring abundance of adult Pacific herring in Prince William Sound (project 16120111-F). Annual reports submitted from 2018 through 2021 contributed to this final report. This project has resulted in one publication (Rand 2018) and has contributed annual monitoring data in support of the stock assessment model (project 21120111-C).

Abstract:

During the grant period herring biomass estimates during the spring spawning period in Prince William Sound ranged from a low of 3,646 metric tons (2018) to a high of 18,245 metric tons (2020). While biomass was generally greatest in Port Gravina over the grant period, we observed a more even distribution of biomass across regions in two years in the study period (2019 and 2020). We completed the last acoustic survey during March-April 2021. The greatest biomass was observed in Port Gravina during daylight hours on 29 March (4,536 metric tons). We quantified biomass in Stockdale Harbor during nighttime hours on 16-17 April (819 metric tons over survey area of 1.8 km^2). We provided these estimates to Herring Research and Monitoring principal investigators for input in the age-structured assessment and Bayesian stock assessment models to meet the objective of supporting on-going stock assessment work. The aerial survey results during the grant period were generally coherent with this acoustic survey with the exception of the surveys in 2021. The aerial survey in that year documented an increase in biomass from the 2020 field year, while the acoustic survey documented a reduction. Understanding how these survey results diverged in 2021 warrants further investigation.

Key words: Acoustic methodology, Alaska, *Clupea pallasii*, long-term monitoring of abundance, Pacific herring, Prince William Sound, spawning biomass

Project Data: Raw acoustic data (digital transducer output files) are archived in Biosonics format (*.dt4), intermediary acoustic summary files are archived in CSV format, echointegration files produced by Echoview software), and final biomass estimates are archived in CSV format. These files were uploaded on 27 April 2022, and the final biomass estimate was added to the time series (CSV file) and made public on 27 April 2022. Raw and processed data, along with metadata, from 1993 to 2021 acoustic surveys are available on the Gulf of Alaska data portal at the link below:

https://gulf-of-alaska.portal.aoos.org/#metadata/f83732b1-f95b-40c8-bd96-7f216e08a756/project

The data custodian is Carol Janzen, Director of Operations and Development, Alaska Ocean Observing System, 1007 W. 3rd Ave. #100, Anchorage, AK 99501, 907-644-6703. janzen@aoos.org.

Data are archived by Axiom Data Science, a Tetra Tech Company, 1016 W. 6th Ave., Anchorage, AK 99501.

Citation:

Rand, P. S. 2022. Adult Pacific herring acoustic surveys in Prince William Sound. Long-Term Herring Research and Monitoring Final Report (*Exxon Valdez* Oil Spill Trustee Council Project 21120111-G), *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

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EXECUTIVE SUMMARY

We continued a long-term hydroacoustic survey to provide estimates of pre-spawning biomass of Pacific herring in Prince William Sound (PWS) for the Bayesian age-structured assessment model. Since 1993, the Prince William Sound Science Center has been carrying out acoustic surveys as a cost-effective approach to estimate pre-spawning biomass of adult Pacific herring just prior to the spawning period. Here we report on observed patterns during the entire grant period (2017-2021) and provide more detailed description of the results generated from field surveys conducted during March-April of 2021.

A retrospective summary of results over the grant period (2017-2021) indicated that acoustic biomass ranged from a low of 3,646 MT (2018) to a high of 18,245 MT (2020). The majority of the biomass was measured in Port Gravina in all years except 2019, a year when biomass measured at Hawkins Island (near Canoe Pass) exceeded that measured in Port Gravina. The proportion of the total biomass attributed to Port Gravina ranged from a low of 21% (2019) to a high of 97.5% (2017). We observed herring aggregations in six separate regions over the course of this study (Port Gravina, Hawkins, Double Bay, Rocky Bay, Zaikof Bay, and Stockdale Harbor). The survey years of 2019 and 2020 were marked by a more even distribution of biomass across the regions (particularly 2019), whereas the other survey years were dominated by estimates in Port Gravina. Results here indicate that the spawning abundance during the period (2017-2021) remains highest in the eastern portion of PWS.

We completed four separate surveys during 29 March – 16 April 2021 within two regions in PWS: 1) Port Gravina in eastern PWS, and 2) Stockdale Harbor in the northeast region of Montague Island in PWS. All surveys were conducted off a chartered vessel (*M/V Auklet*). The greatest biomass was observed in Port Gravina during daylight hours on 29 March (4,536 metric tons over a survey area of 7.3 km^2). In addition, we quantified biomass in Stockdale Harbor during nighttime hours on 16-17 April (819 metric tons over survey area of 1.8 km^2). Our cruise track included other regions that contained aggregations in the past, including Port Fidalgo, Windy Bay and Canoe Pass on Hawkins Island, Double Bay and Port Etches on Hinchinbrook Island, and Zaikof and Rocky Bay on Montague Island. No aggregations were noted in these locations. We provided the total biomass estimate (5,355 mt) to Herring Research and Monitoring principal investigators for input in the age-structured assessment and Bayesian stock assessment models to meet the objective of supporting on-going stock assessment work.

We note that 2021 is unique given the disparity in measures of abundance based on aerial surveys and acoustics. Results of the aerial survey in 2021 indicated a relatively high abundance of spawning herring based on mile-days of milt. We note that the acoustic biomass estimate for 2021 is likely biased low given observations of many adult herring close to shore in shallow water in Port Gravina and we were unable to survey in these areas near shore.

INTRODUCTION

We continued a long-term hydroacoustic survey to provide estimates of pre-spawning biomass of Pacific herring (*Clupea pallasii*) in Prince William Sound (PWS) for the Bayesian age-structured assessment model (BASA). Since 1993, the Prince William Sound Science Center (PWSSC) has been carrying out acoustic surveys as a cost-effective approach to estimate pre-spawning biomass of adult Pacific herring just prior to the spawning period. We provide an overall summary of the survey results during the grant period (2017-2021) and we report on results generated from field surveys conducted during the spring of 2021.

OBJECTIVES

The objective of this project is to produce a reliable estimate of pre-spawning biomass of the population of Pacific herring through acoustic monitoring in support of the BASA stock assessment model.

METHODS

Hydroacoustic survey methods are well documented and well established in fisheries (Thorne 1983a,b; Simmonds and MacLennon 2005). They have been applied to Pacific herring for over forty years (Thorne 1977a,b; Trumble et al. 1983). The specific methods used in PWS are well documented (Thomas et al. 1997, Thomas et al. 2002, Thomas and Thorne 2003, Thorne and Thomas 2008). Below we provide a summary of the general methods applied for analysis of acoustic data collected during springs 2017-2021.

A three-stage sampling design (Cochran 1977) is used for the acoustic surveys in PWS. Adult herring during the extended winter period in PWS are typically located in a few select bays and inlets and are distributed primarily in large, midwater schools or dense layers at night. Since 1995, survey efforts have focused on the late winter/early spring prespawning distribution when the herring are most concentrated. The initial survey stage focuses on locating adult herring aggregations within PWS. As in years past, we primarily relied on aerial surveys of foraging marine mammals, especially Steller sea lions and humpback whales, to determine general location of spawning aggregations.

After the herring are located, the second stage consists of echo integration surveys over the areas occupied by the herring schools (Thorne 1971, 1983a,b; MacLennan and Simmonds 1992; Simmonds and MacLennon 2005). To collect acoustic data, a BioSonics 120 kHz digital single-beam transducer was mounted down-looking on a 30 cm long aluminum towfin and deployed off the *M/V Auklet*. The echosounder was configured to transmit 1 ping s-1 with a pulse duration of 0.4 ms. Transects were conducted after sunset, and the deck lights were extinguished to avoid responses of herring to light. Tow speeds were maintained at approximately 2-3 knots and the transducer was positioned approximately 1-2 m below the surface. Position of the vessel along the transect was recorded with a Garmin 17x NMEA 0183 high-sensitivity global positioning

system (GPS; accuracy rating under typical conditions < 10 m) connected via a power/data cable to the BioSonics DT-X top box so GPS coordinates were integrated as a cruise track into the *.DT4 data files. The majority of the surveys during the grant period were conducted during nighttime hours, but under some situations we carried out surveys during daylight hours. Times of all surveys are documented in the data. When feasible, the surveys were repeated several times to develop multiple estimates of the biomass of specific fish aggregations. We obtained herring size information from the Alaska Department of Fish and Game (ADF&G) for use in our biomass calculations.

The size composition of the herring in the net catches were used to estimate target strengths for converting backscatter to biomass. The general target strength equation used in PWS is:

$$TS_w = -5.98\text{Log}(L) - 24.23$$

Where TS_w is the target strength (decibels) per unit weight, w is weight in kg and L is standard length in cm. We applied the mean lengths of herring captured by ADF&G. Fish were typically captured by purse seines and cast nets.

This equation applies to the typical nighttime depths of herring during the late winter/early spring period (specifically 40 m). No alterations were made for different depths in this data series (Thomas et al. 2002) – in some past years, adjustments were made if herring occupied depths much greater than 40 m. We have not observed deep schools of herring in the surveys conducted during this grant period. Dates of the surveys are provided in Table 1, in the Results section.

The acoustic surveys during the grant period were carried out during cruises on the *M/V Auklet.* We focused on surveys in the eastern PWS during the early part of the season. We than transited to Montague Island to carry out surveys during the latter part of the season. We relied on reports from ADF&G aerial surveys to plan surveys. We also relied on our own observations (visual or observations using the ship's sonar) to determine locations of surveys and configure transects to effectively survey the encountered aggregations. A more thorough description of the sampling approach used in these surveys can be found in Rand (2019). We were unable to replicate surveys in a given location in a way that would provide an estimate of variance, thus no error estimates were produced for this survey.

RESULTS

Retrospective summary of past surveys, 2017-2021

The biomass estimates over the course of the study (2017-2021) ranged from a low of 3,646 mt (2018) to a high of 18,245 mt (2020, Fig. 1). The majority of the biomass was measured in Port

Gravina in all years except 2019, a year when biomass measured at Hawkins Island (near Canoe Pass) exceeded that measured in Port Gravina (Fig. 2). The proportion of the total biomass attributed to Port Gravina ranged from a low of 21% (2019) to a high of 97.5% (2017, Fig. 2). We observed herring aggregations in six separate regions over the course of this study (Port Gravina, Hawkins, Double Bay, Rocky Bay, Zaikof Bay, and Stockdale Harbor). The survey years of 2019 and 2020 were marked by a more even distribution of biomass across the regions (particularly 2019), whereas the other survey years were dominated by estimates in Port Gravina (Fig. 2). The tendency for the spawn distribution to be centered in the eastern part of PWS is consistent with the description by McGowan et al. (2021). These authors documented a spawn distribution that contracted away from historical aggregations in the western part of PWS following the collapse of herring abundance in the 1990s. Result here indicate that the spawning abundance during the period (2017-2021) remains highest in the eastern portion of PWS. We noted a disparity in abundance measures derived from the ADF&G aerial surveys and this acoustic survey conducted in 2021 that is described in more detail in the following section.

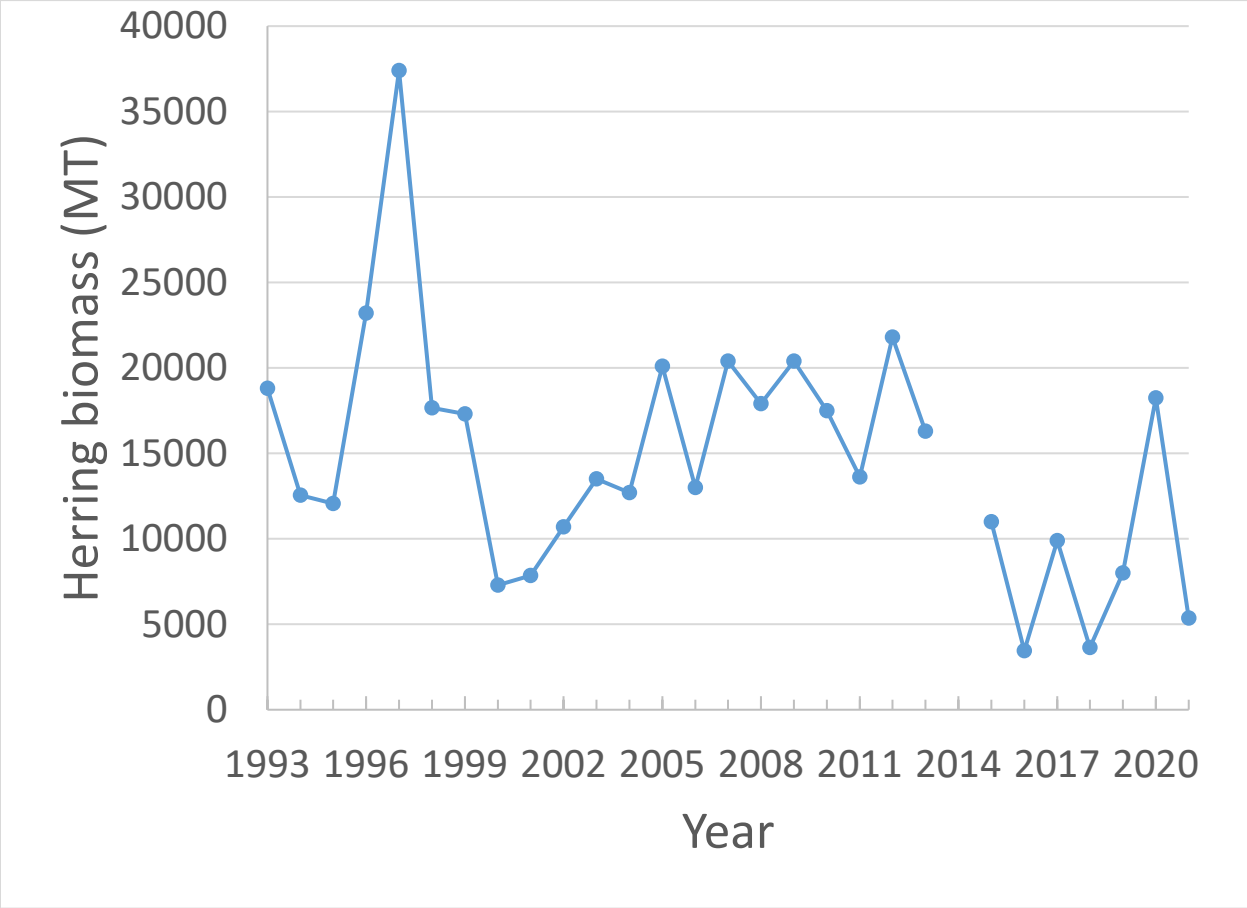

Figure 1. Herring biomass estimate in metric tons (MT) produced from Prince William Sound Science Center acoustic surveys during 1993-2021. Note that no estimate of herring biomass was produced in 2014 owing to an inability to survey fish that were very close to shore in water too shallow to survey.

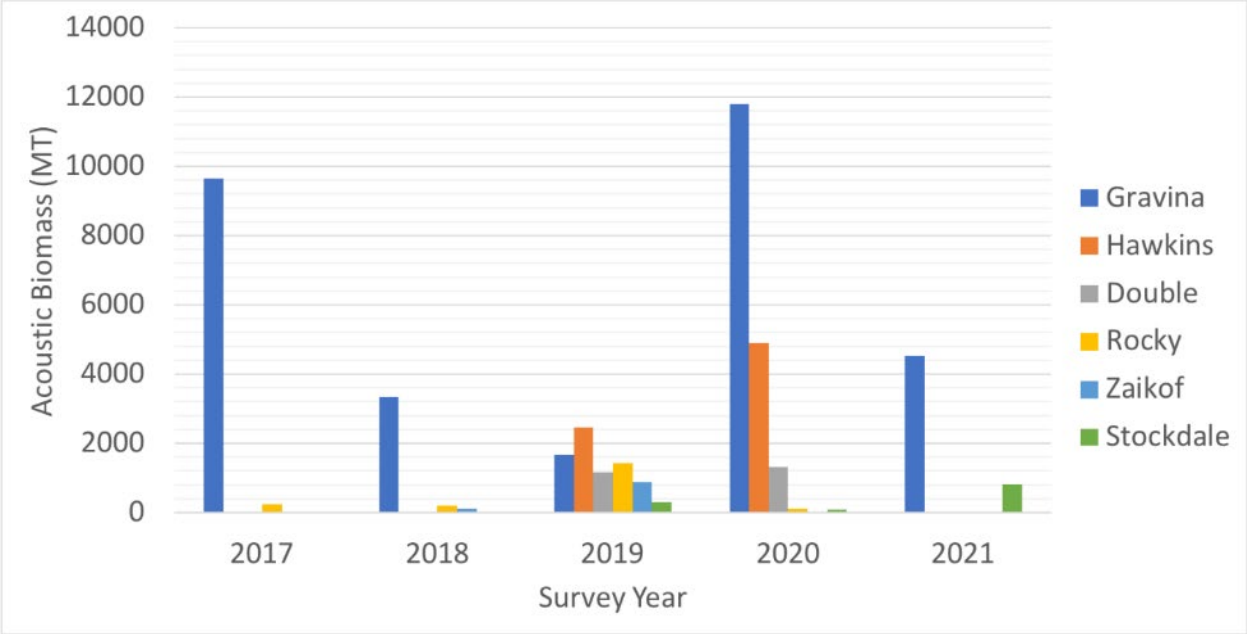

Figure 2. Acoustic biomass estimates in metric tons (MT) of Pacific herring during the study years, separated out by location.

2021 Survey Year

We successfully completed a total of four separate acoustic surveys in two different locations during the 2021 spring survey season in PWS. As in recent years, we observed an aggregation of herring in Port Gravina, a region which has typically supported the largest aggregations.

After getting reports from ADF&G on observations of milt near Hell's Hole in Port Gravina (Fig. 3), the chartered vessel departed Cordova at 13:30 on 28 March and headed to Port Gravina. We observed predators and milt very close to shore, in what appeared to be shallow water (~5-10 m depth). We prepared for survey that evening (21:30), but fish were generally in very shallow, and winds shifted to southeasterlies and rose to ~ 20 kts, making it unsafe for an acoustic survey. We anchored in St. Matthews Bay that night and returned to Hell's Hole the following morning. After surveying the area visually and with shipboard sonar, we carried out an initial survey during the day (during hours 13:23-16:12) on 29 March that generated the highest biomass estimate of all the surveys conducted (4,536 mt, Figs. 4 and 5, Table 1). Much of this survey was in the area of milt observed during the ADF&G survey the day prior (Fig. 3) and the majority of targets were very close to the bottom (Fig. 5). We observed several sea lions, one humpback whale, bald eagles in the trees along the shoreline, and hundreds of gulls. We finished in Knowles Bay and headed toward Port Fidalgo. We found no evidence of aggregations in Snug Corner Cove and Two Moon Bay. We anchored in Landlock Bay for the evening.

We departed from the anchorage at 06:30 on 30 March, and passed again through Knowles Bay and around Red Head, and noted the continued presence of milt and predators (including two humpback whales). That evening we conducted some transects near Windy Bay and Canoe Pass relying on the shipboard sonar but observed no evidence of a herring aggregation. We headed back to Port Gravina and conducted two additional surveys near Red Head (one during hours 00:25-02:37 on 31 March and other during hours 22:15-00:44 on 31 March – 1 April). Both of these surveys produced lower estimates of biomass compared to our first survey (Fig. 4, Table 1). After the Gravina surveys, we headed to Port Etches, arriving the evening of 2 April. There we conducted a visual survey and relied on shipboard sonar but found no evidence of aggregations there. No acoustic surveys were conducted in Port Etches. We returned to Cordova by early the next morning.

We departed on another cruise on 6 April (at 16:00) to Windy Bay and Canoe Pass on Hawkins Island. Conditions were choppy (20+ kt winds), so we decided to not conduct an acoustic survey, but we found no evidence of aggregations at this location based on shipboard sonar and visual observations. We returned to Cordova that same evening.

The third and final cruise took place during 15-18 April. Our cruise track included Windy Bay, Canoe Pass, Middle Ground Shoal, Anderson Bay, Double Bay, Port Etches, Zaikof Bay, Rocky Bay, Stockdale Harbor, Port Chalmers, and part of the southeast shore of Green Island. We followed transects (in a similar, sawtooth layout as used in previous years) at most of these locations, relying on visual observations and shipboard sonar. The only evidence of a spawning aggregation was observed at Stockdale Harbor on Montague Island. We carried out an acoustic survey there on the night of 16-17 April during the hours 23:43-00:34. The majority of herring appeared to be in the western portion of the survey area at depths between 10-20 m (Figs. 4 and 5). Our biomass estimate from this survey was 819 mt (Table 1). ADF&G noted the presence of milt in the same region during their aerial survey of 20 April (Fig. 6). The vessel retraced our cruise track during 17-18 April, visiting Port Etches, Double Bay, Anderson Bay, Middle Ground Shoal, Canoe Pass and Windy Bay. There was no evidence of aggregations at any of these locations. We returned to Cordova on 18 April.

Our overall biomass estimate (adding the 29 March survey in Port Gravina and the 16 April survey in Stockdale Harbor) of 5,355 mt is markedly lower than our estimate produced from the 2020 spring survey (over 18,000 mt, Fig. 1) and more comparable to the estimates produced during the prior years of this survey (2015-2019, Fig. 1).

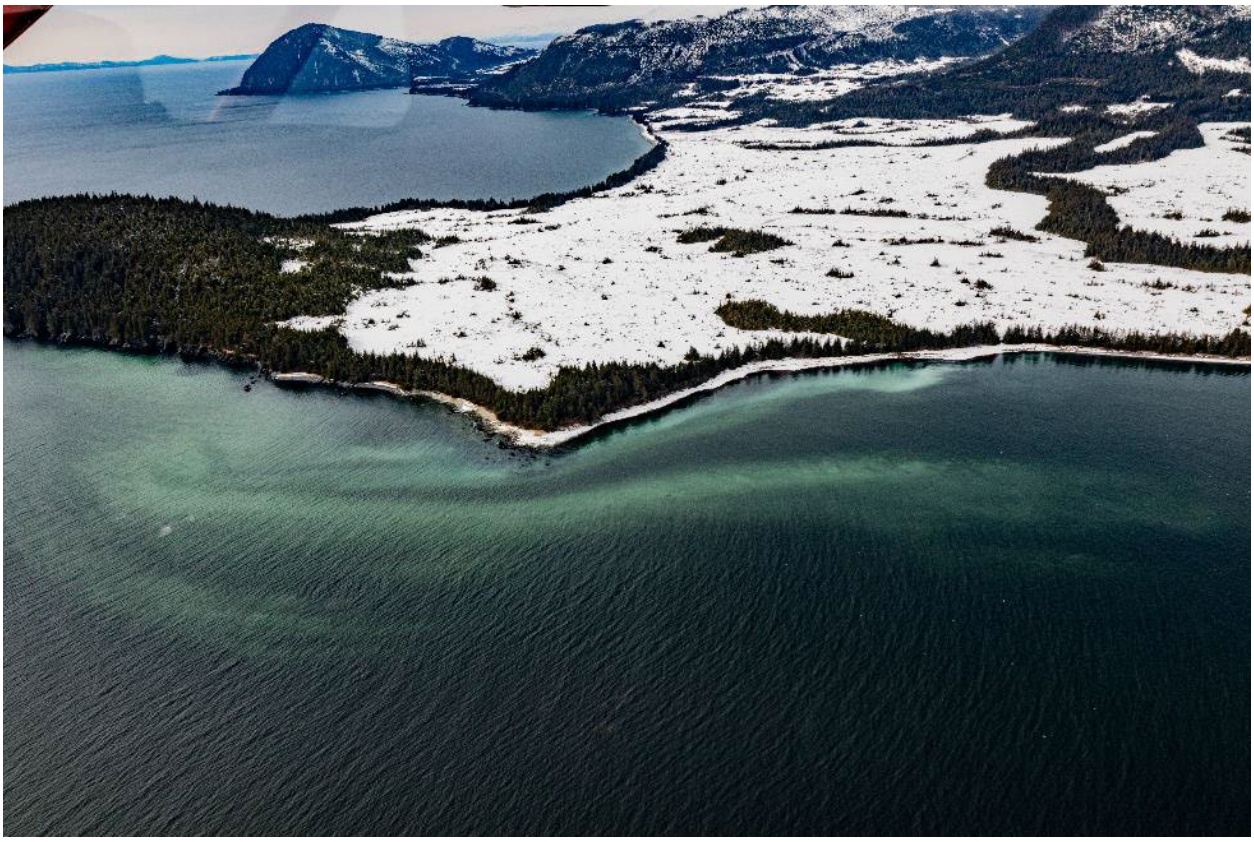

Figure 3. Image of spawn in Port Gravina, Hell's Hole on 28 March 2021, the same day of the Prince William Sound Science Center acoustic survey. Photo credit: Shane Shepard, Alaska Department of Fish and Game.

Table 1. Summary of acoustic surveys conducted during spring 2021 in Prince William Sound. The shaded rows are the surveys that contributed to the total biomass estimate for the survey.

Survey Location	Date	Time of Survey	Survey Area (km^2)	Biomass Estimate (mt)
Gravina	29 March	Day	7.3	4536
Gravina	31 March	Night	6.6	370
Gravina	1 April	Night	8.8	1083
Stockdale	16 April	Night	1.8	819

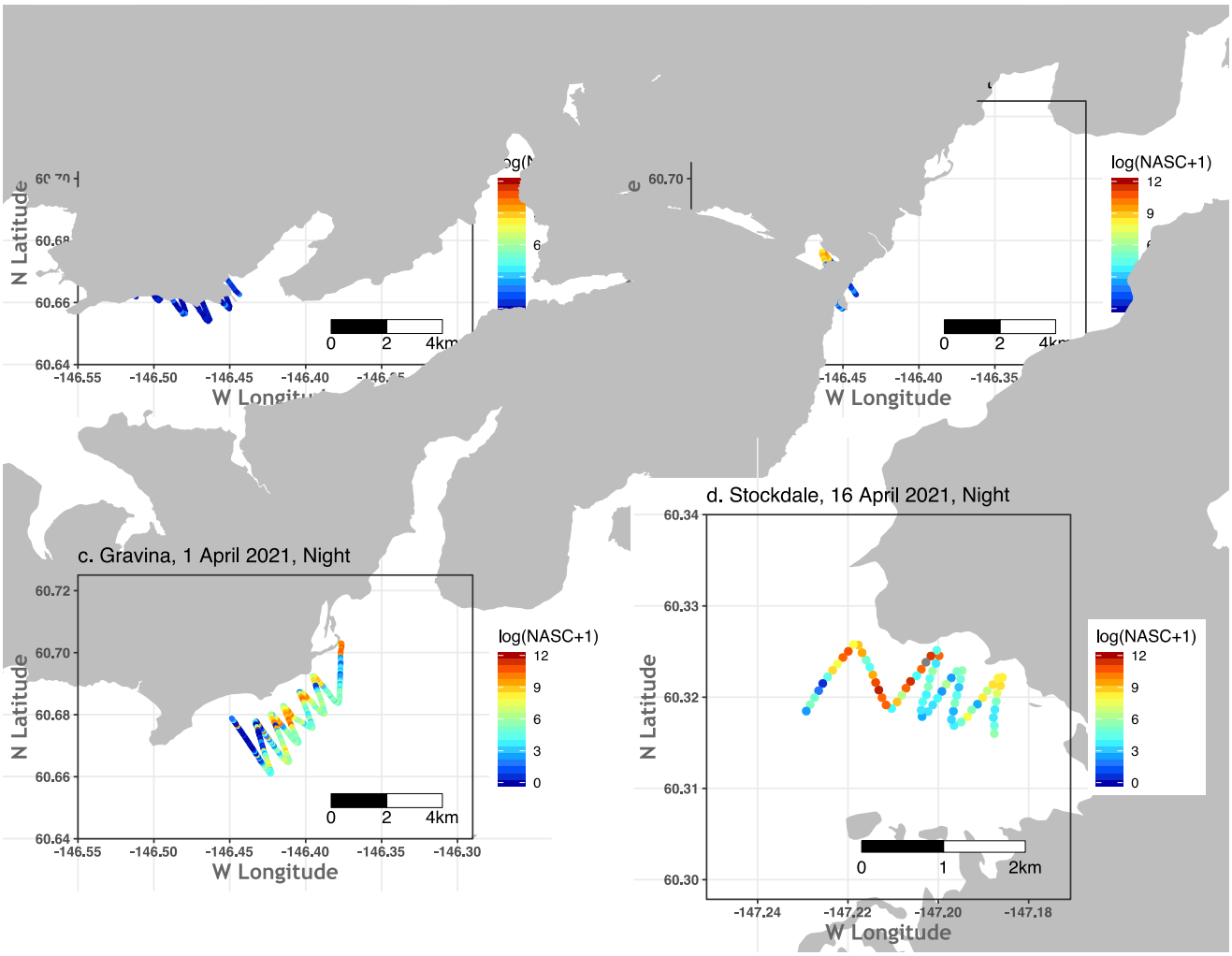

Figure 4. Cruise tracks and acoustic backscatter in nautical area scattering coefficient (NASC) for four separate acoustic surveys conducted during spring 2021 in Prince William Sound.

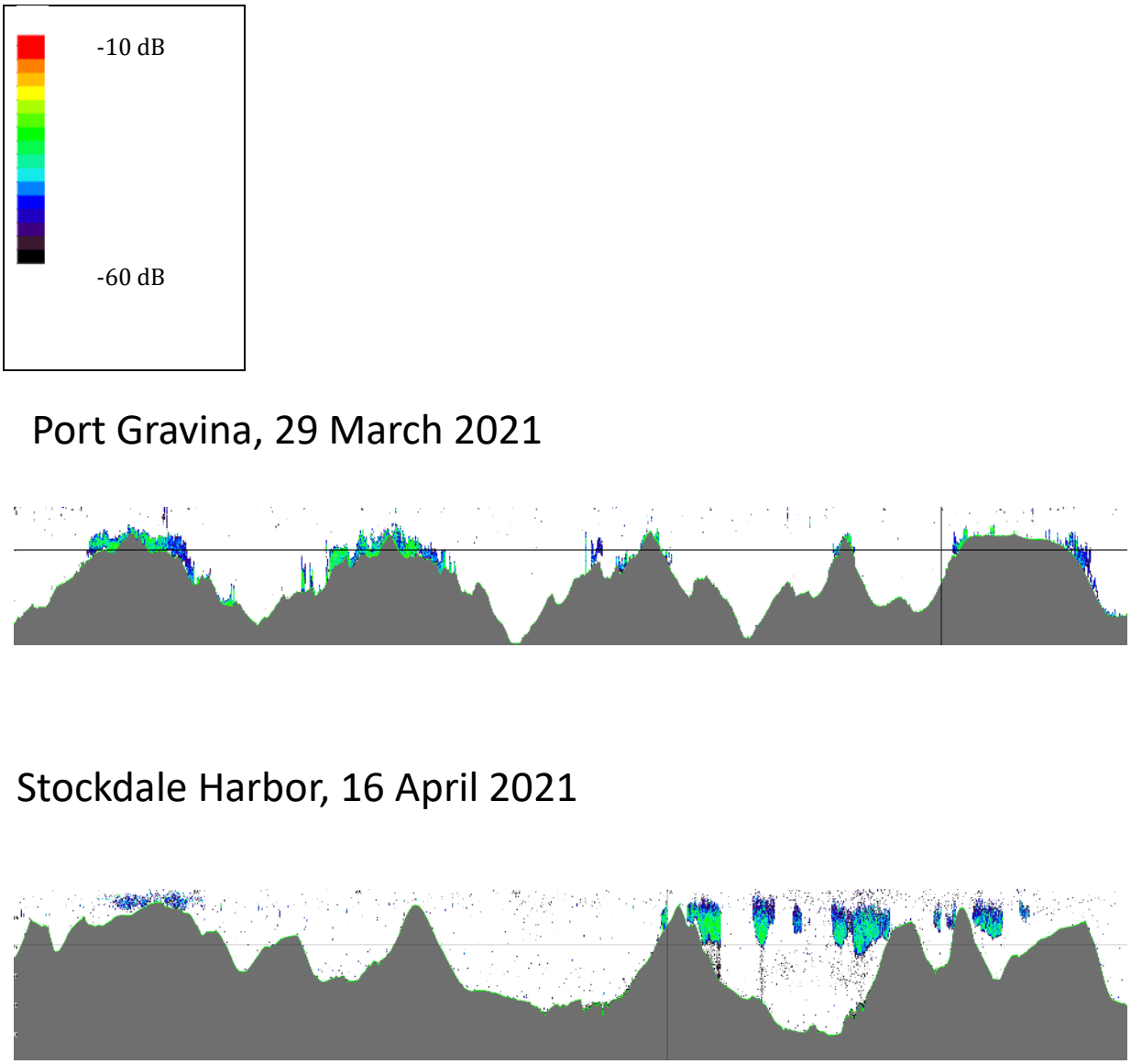

Figure 5. Echograms from the surveys that contributed to the total biomass estimate during spring 2021. The horizontal grid lines represent 10 m depth intervals, and the configurations of the transects are depicted upper echogram (Port Gravina survey) and lower echogram (Stockdale Harbor survey).

Figure 6. Image of spawn in Stockdale Harbor on 20 April 2021. Photo credit: Shane Shepard, Alaska Department of Fish and Game.

DISCUSSION

The past five years (2017-2021) of acoustic monitoring produced a range of total biomass estimates, from a low of 3,646 mt (2018) to a high of 18,245 mt (2020). While biomass was generally greatest in Gravina over the five-year period, we observed a more even distribution of biomass across regions in two years in the study period (2019 and 2020). As documented in other studies (McGowan et al. 2021), the majority of the herring biomass during the spring spawning period over this grant period was in the eastern region of PWS.

The biomass estimates from the acoustic survey reported in 2021 is markedly lower than that reported in 2020. Our estimate in 2021 was only 29% of the biomass value estimated during our 2020 acoustic survey. These results are inconsistent with the results from the aerial surveys carried out by ADF&G. Their estimate of mile-days of milt in 2021 (25.55) was higher than that estimated in 2020 (23.69), amounting to an increase of 8% (Morella 21160111-F). Prior to this year the two surveys were very consistent. The answer to why these two monitoring data series

diverged during 2021 is unclear at this time. Based on our visual observations and predator distributions and behavior during the spring 2021 cruises, our biomass estimate is likely biased low given our inability to survey herring in shallow water close to shore in Port Gravina, the location that tends to harbor the largest aggregation of adult herring. Further, we may have started our survey late and missed the peak abundance in the areas in which these fish are normally surveyed. We mobilized immediately after the ADF&G aerial survey revealed the presence of milt near Hell's Hole in Port Gravina. Typically, our survey is conducted prior to spawning when fish are staging farther offshore in deeper water. Earlier aerial surveys did not reveal the presence of herring schools or predators in these locations. We included these areas in our acoustic survey, but the majority of the herring were very close to shore in shallow water, as noted in our results. The *M/V Auklet* carried out a quick survey on 24-25 March just prior to our mobilization. Some isolated schools were observed in the area, but no whales or sea lions and very few birds were observed.

Earlier acoustic surveys noted a prolonged period of staging in deep water prior to spawning (Rand and Thorne 2018). At the time the current principal investigator took over this survey (2015-2016), Dick Thorne (PWSSC) noted how fish appeared to be migrating differently in those years and tended to occupy shallower water without staging first in deeper water, making it difficult to survey them. This was the reason reported on why there were no reliable surveys conducted in 2014 (there was no acoustic estimate produced for that year, Fig. 1). This phenomenon was noted for several years in the earlier report of Rand and Thorne (2018) and suggests the established monitoring protocol may need to be modified or changed to account for this different pattern of migration. Relying on shallower draft vessels or drones may expand the survey areas to shallower water, but traditional sonar surveys like the one described here (with a split, narrow beam) have clear limitations in surveying shallower waters. Fixed site, acoustic sampling over the season can provide some useful information about dynamics of herring during the spawning season (as described in Rand 2018). Better understanding of herring movement prior to spawning by tracking them with acoustic tags (as described in Bishop and Cypher 2021) could provide some additional insight into designing new methods of estimating biomass during this phase of their life history.

In an earlier era of acoustic monitoring, variance of biomass estimates was generated by repeating surveys of the spawning aggregation over multiple days to quantify precision (Thomas and Thorne 2003). This method of estimating uncertainty is predicated on the assumption that there is no net immigration or emigration from the survey era between the times of surveys (i.e., each survey provides an "independent" sample of the spawning aggregation). The observations over this grant period (2017-2021) from acoustic surveys and observations of predator distribution and behavior suggested that this assumption did not apply given the great disparity in conditions at aggregation sites over repeated surveys. These results suggest that the herring spawning aggregations were more ephemeral compared to the surveys conducted prior to 2014. Estimates of uncertainty using bootstrap methods were generated for the 2020 acoustic survey

(Rand 2021), but these are not comparable to those estimated in the earlier surveys described in Thomas and Thorne (2003). It would be worthwhile to investigate how herring spawning behavior may have shifted over the history of the monitoring effort and explore other methods (field survey and statistical methods) to quantify uncertainty in acoustic biomass estimates.

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These findings and conclusions presented by the author(s) are their own and do not necessarily reflect the views or position of the *Exxon Valdez* Oil Spill Trustee Council.

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