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

Expanded Adult Herring Surveys

Exxon Valdez Oil Spill Trustee Council Project 16120111-E
Final Report

Peter S. Rand
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Study History: This work is an extension and expansion on Restoration Project 070830 (Trends in Adult and Juvenile Herring Distribution and Abundance in Prince William Sound) initiated in 2007.

Abstract: The objective of this study was to increase the current survey area of adult spawning beyond the Port Gravina and Fidalgo areas to provide a more precise estimate of spawning biomass of herring in Prince William Sound. We proposed to extend the Prince William Sound Science Center acoustic surveys to help identify the relative contributions of additional spawning aggregations over temporal and spatial scales. This work was proposed to establish more accurate estimates of the total herring biomass in Prince William Sound and provide an alert to changes in biomass in different regions. Beginning in 2013 and continuing through 2016, hydroacoustic surveys were conducted in spring (March-April) to assess adult spawning biomass. The Alaska Department of Fish and Game continued to conduct direct sampling for age/length/weight during this period. Additional direct capture of adult herring was conducted by Prince William Sound Science Center at adult spawning sites. Estimates of mean length of captured, adult herring were used to estimate acoustic target strength (dB per unit weight) to generate estimates of biomass each year of the survey. Locations to be acoustically surveyed were determined using aerial reconnaissance by noting distribution of predators, including sea birds, sea lions and whales. The highest biomass estimate generated over the time period was in 2012 (21,800 mt). Our biomass estimate declined over the period to 3,453 mt in 2016, representing the lowest estimate since the survey began in 1993. Although effort was expended to survey the region in 2014, we were unable to obtain a reliable biomass during that year primarily because herring were in water too shallow to effectively survey. Through expanded surveys, we found a consistent pattern of greater spawning biomass in the Port Gravina and Port Fidalgo region, and less in the Montague Island region. Results of this survey indicate herring have continued to remain at low abundance since their dramatic decline in the early 1990s. Results of our surveys provide important data which is incorporated into the age-structured assessment and Bayesian stock assessment models of Prince William Sound herring.

Key words: Adult Pacific herring, *Clupea pallasii*, hydroacoustic survey, prespawning herring biomass, Prince William Sound.

Project Data: Acoustic data is in the form of *.DT4 files that contain the GPS cruise track and measures of acoustic backscatter collected on each research cruise. Data collected prior to 2016 was analyzed using Biosonic Analyzer software. Data from the 2016 survey were analyzed using Echoview 5.0, and echointegration results are exported in the form of *.CSV files.

Data collected for the Herring Research and Monitoring Program projects that contributed to this report are available through the Alaska Ocean Observing System (AOOS) Gulf of Alaska data portal.

The data may also be found through the DataONE earth and environmental data archive at https://search.dataone.org/#data and by selecting the Gulf of Alaska Data Portal under the Member Node filter.

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

Citation:

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EXECUTIVE SUMMARY

Robust Pacific herring (*Clupea pallasii*) populations, suitable for exploitation by commercial fisheries, are typically sustained by periodic recruitment of strong year classes into the adult spawning population. However, the Prince William Sound herring population has not had a strong recruitment class since 1989, when the *Exxon Valdez* Oil Spill occurred. In the *Exxon Valdez* Oil Spill settlement herring were identified as an injured resource and they remain listed as an unrecovered species by the *Exxon Valdez* Oil Spill Trustee Council. Understanding why herring have not recovered in Prince William Sound requires understanding potential bottlenecks in the herring life cycle. The identification of the limiting conditions to herring recovery requires a series of focused process studies combined with monitoring of the natural conditions that affect herring survival.

The current management of the Prince William Sound herring stock by the Alaska Department of Fish and Game includes information from hydroacoustic surveys. Biomass estimates from these surveys provide a direct measure of the herring stock abundance and are provided for input into the age-structured assessment model that is the primary forecasting tool. The hydroacoustic surveys were initiated in 1993 when fishers were unable to locate concentrations of herring despite a forecast for high abundance. Over time the hydroacoustic survey has shown to be an early and accurate measure of the herring stock abundance and compares well with the recent age-structured assessment model estimates that now can incorporate hydroacoustic survey information as well as an index of male spawning abundance.

Prior to 2001, the hydroacoustic surveys were conducted exclusively by the Prince William Sound Science Center. Since 2001, the effort has been shared between the Prince William Sound Science Center and the Alaska Department of Fish and Game in Cordova, Alaska. The cooperative effort has been critical since both the Prince William Sound Science Center and the Alaska Department of Fish and Game have limited resources for this effort. While the Alaska Department of Fish and Game considers the hydroacoustic surveys to be critical (Steve Moffitt, personal communication) the lack of a commercial herring fishery in Prince William Sound since 1998 has reduced management priorities for herring during a time of overall limited funding for the state agency. Thus the Prince William Sound Science Center contribution has become increasingly important for the long-term, especially if a future fishery appears only a remote possibility.

We report here on a continuing survey that allows us to track the status of the population. During this grant period (2012-2016), we expanded surveys in Prince William Sound to improve our estimates of adult biomass. There have been shifts in the sampling area over time as the main spawning population moved from Montague Island to Port Gravina. Similarly, there have been shifts in effort related to other observations such as the spawn surveys and sampling.

We report a decline in pre-spawning herring biomass during 2012-2016 as determined through hydroacoustic surveys. Our highest estimate of biomass (21,800 mt) documented during this grant period occurred in the first year (2012), and each subsequent year yielded a lower biomass estimate. Our 2016 biomass estimate (3,453 mt) was the lowest recorded since this survey began in 1993.

The overall distribution of pre-spawning, adult herring has shifted away from Montague Island since 2002, and we found this pattern persisted over the study period (2012-2016). We found the majority of spawning biomass continues to be centered in Port Fidalgo and Port Gravina, with only a minor component observed along the coastline of northeast Montague Island.

INTRODUCTION

Hydroacoustic surveys of Pacific herring (*Clupea pallasii*) in Prince William Sound (PWS) were initiated in fall 1993 after indications that the stock had collapsed. The surveys have now been conducted by the Prince William Sound Science Center (PWSSC) for 24 consecutive years since. PWS herring stock biomass estimates from hydroacoustic surveys provide a direct measure of the stock abundance for use in the age-structured assessment (ASA) model that is the forecasting tool used for management by the Alaska Department of Fish and Game (ADF&G). Prior to 2001, the hydroacoustic surveys were conducted exclusively by the PWSSC. Since 2001, the effort has been shared between the PWSSC and ADF&G in Cordova, Alaska. While the ADF&G considers the hydroacoustic surveys to be crucial (Steve Moffitt, personal communication), the lack of a commercial herring fishery in PWS since 1998 has reduced management priorities for herring. Thus the PWSSC contribution has become critically important for the long-term, especially if a future fishery appears only a remote possibility. With the level of effort available over the past several years, PWSSC and ADF&G individually have achieved herring biomass estimates with a precision of about ±30%, which is insufficient for management purposes. However, the combined effort currently meets management requirements for precision. Current stock assessment efforts by ADF&G resource managers in PWS focus on the largest spawning aggregations.

The objective of this study is to increase the current survey area of adult spawning beyond the Port Gravina and Fidalgo areas to provide a more precise estimate of spawning biomass. We proposed to extend the PWSSC acoustic surveys to help identify the relative contributions of additional spawning aggregations over temporal and spatial scales. This will help establish more accurate estimates of the total herring biomass in PWS and provide an alert to changes in biomass in different regions. Beginning in 2013 and continuing through 2016, hydroacoustic surveys were conducted in spring (March-April) to assess adult spawning biomass. ADF&G continued to conduct direct sampling for age/length/weight. Additional direct capture was conducted at adult spawning sites under a separate *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) funded project (16120111-E).

OBJECTIVES

The objective of this study is to increase the current survey area of adult spawning beyond the Port Gravina and Fidalgo areas to provide a more accurate estimate of spawning biomass.

METHODS

Hydroacoustic survey methods are extensively documented and well established in fisheries (Thorne 1983a; Simmonds and MacLennon 2005). They have been applied to Pacific herring for nearly forty years (Thorne 1977a,b). The specific methods used in PWS are well documented and have been demonstrated to be both accurate and precise (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 over the 2012-2016 grant period, but we include additional detail from our latest completed survey in 2016.

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 pre-spawning distribution when the herring are most concentrated. The initial survey stage focuses on locating adult herring aggregations within PWS. Approaches include aerial surveys of foraging marine mammals, especially Steller sea lions (*Eumetopias jubatus*) and humpback whales (*Megaptera novaeangliae*), sonar surveys and observations from fishers, hunters and others transiting PWS, as well as a detailed database of historic locations. This, along with some aerial surveys conducted by ADF&G, provided some early indications on location of aggregations and spawn timing.

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). Examples of cruise tracks during the survey during spring 2016 are provided in Figs. 1 and 2. To collect acoustic data, a BioSonics 70 kHz digital single-beam transducer was mounted down-looking on a 1.2 m 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 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. Our spring 2016 survey included some daytime transects to provide some contrast with our observations at night. If conditions allowed, the surveys were repeated several times to develop multiple estimates of the biomass of specific fish aggregations. The repeated estimates are used to determine the precision of the biomass estimates represented by the coefficient of variation of

estimated biomass (CV, standard deviation divided by the mean). After the echointegration surveys, the herring schools are sampled to provide biological information. During the spring 2016 survey, the crew of the M/V *Auklet* captured adult herring with an experimental gill net set at night in Gravina Bay, Rocky Bay and Stockdale Harbor. These samples augmented some cast net collections made by ADF&G personnel. No purse-seine collections were made during the spring 2016 field season.

The size compositions of the herring in the net catches are 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. Based on our gill net collections described above during 2016, we used 17.6 cm, 19.3 cm and 19.1 cm mean lengths to represent mean target strengths for herring in Port Gravina, Rocky Bay and Stockdale Harbor, respectively.

This equation applies to the typical night-time depths of herring during the late winter/early spring period (specifically 40 m). If observed aggregations diverged markedly from this in a given year, we applied a depth correction as described in Thomas et al. (2002). No alterations were made for different depths in the 2016 data set as most fish observed were occupying this depth stratum. Additional sampling was conducted with other hydroacoustic systems and other frequencies by Bree Zenone of Florida International University in 2015 and 2016. Only the data from the PWSSC system are reported here.

Based on estimates of mean sizes of captured adult herring, we applied the appropriate acoustic cross section (sigma) values to reflect the mean size of herring in the spawning population.

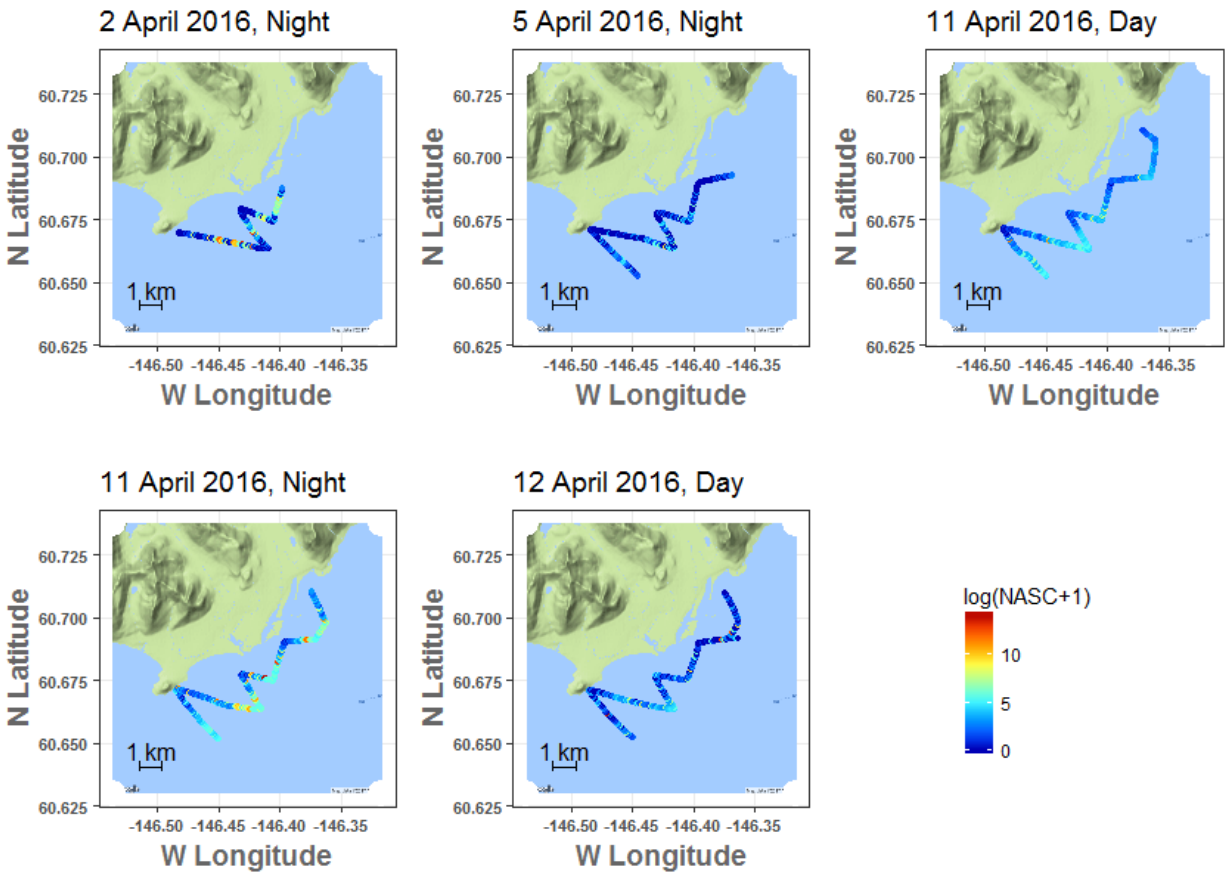


Figure 1. Cruise tracks during the spring 2016 adult herring biomass survey in Port Gravina, Prince William Sound. False color spectrum represents hydroacoustic backscatter measured along the transect (in NASC, m^2 nm^{-2}).

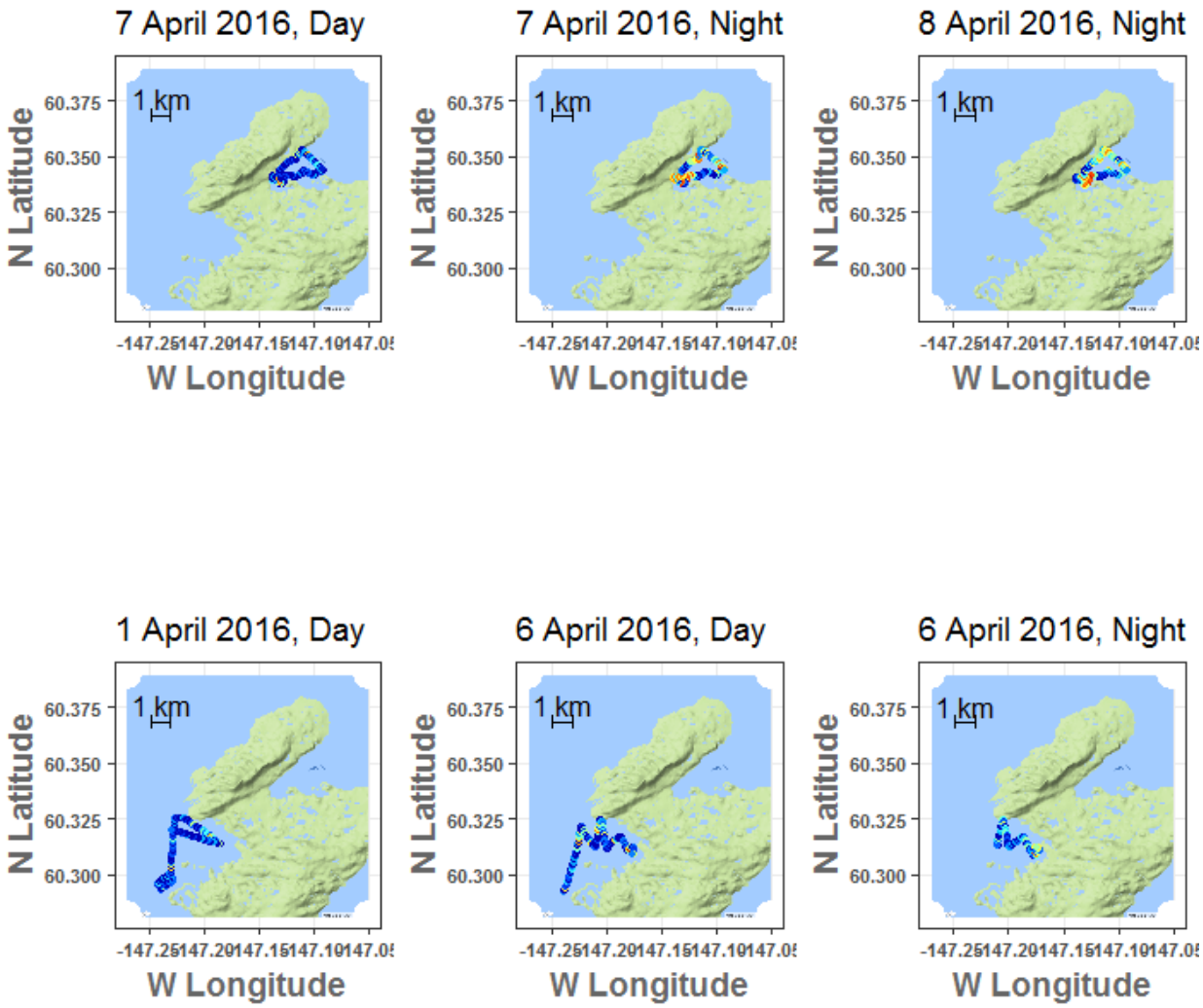


Figure 2. Cruise tracks that constitute the expanded survey in the northeast region of Montague Island, Prince William Sound. Shown in the top row are the Rocky Bay transects, and the lower row are the transects in Stockdale Harbor. False color spectrum represents hydroacoustic backscatter measured along the transect (in NASC, m^2 nm^{-2}, legend appears in Figure 1).

All data processing and plotting for the 2016 survey was carried out using Echoview 5.0 and R version 3.2.0 (2015-04-16). Acoustic data processing and plotting of echograms of surveys conducted during 2012-2015 were carried out using the BioSonics Visual Analyzer 4.0.

RESULTS

Below we provide a brief summary of each year's survey results, with a more detailed description of our latest survey during 2016.

2012

The 2012 survey was conducted from March 30 to April 3 aboard the *MV Auklet*. Acoustic transects were run in Port Gravina and Port Fidalgo. Additional searches were conducted in areas north and west of these two locations, including Galena Bay and west to Glacier Island and Columbia Bay, but no fish concentrations were located. A total of five series of transects were completed in Port Gravina and Port Fidalgo over four nights. Fish distribution was favorable for acoustic surveys on March 30 and 31, but then the fish moved rapidly inshore. The biomass estimate for the first two nights with favorable distribution was 21,800 mt with 95% confidence intervals of 15,500 to 28,100 mt.

2013

The 2013 hydroacoustic survey of adult herring in PWS was conducted between March 27 and April 5 aboard the *MV Auklet*. The first two days of the survey were focused on Port Gravina and Port Fidalgo, and included a survey over a substantial concentration of herring in Port Fidalgo the night of March 28. The next day was spent searching for herring in Tatitlek Narrows and Galena Bay, before returning to Port Fidalgo for a second night-time survey. Zaikof Bay and Rocky Bay were searched on March 30, and a survey was conducted on a small concentration of fish in Rocky Bay. The next two days included searches for herring off Montague Point, Stockdale, Chalmers, Green Island, Drier Bay, Herring Bay, Northwest Bay, around Naked Island and into Wells Inlet ending in a night survey on a small concentration of fish in Cedar Bay. On April 2, we returned to Port Fidalgo, but the herring concentrations observed previously were absent. The last two days of the survey focused in Port Gravina and included a broad-scale survey on April 3 and a more focused survey on April 4 of a large concentration of herring between Hells Hole and Redhead.

Despite the expanded survey effort, no appreciable adult herring were located outside of Port Gravina and Port Fidalgo. The two surveys each in those two areas did detect considerable movement from Port Fidalgo to Port Gravina, a pattern observed in previous years. The final, focused survey in Port Gravina on April 4 estimated a biomass of 16,300 mt with 95% confidence intervals of 13,700 to 18,800 mt.

2014

The effort during spring 2014 expanded in time as well as space. One survey took place March 25-28 and covered areas around Montague Island as well as Port Fidalgo and Port Gravina. A second cruise took place April 21-25, later than previous years, and focused around Montague Island.

The effort during March 25-28 could not locate any substantial biomass in Port Gravina and Port Fidalgo. Two large schools were detected in the vicinity of Port Fidalgo, both over 1000 mt, but the schools were migrating rapidly and were not successfully surveyed. Several whales were foraging on both schools. Some adult herring were detected and surveyed around Montague Island, but the biomass was relatively minor.

Many adult herring schools were detected around Montague Island during the April 21-25 period, extending from Chalmers to Rocky Bay. Although these herring schools were small compared to the massive schools typically seen in Port Fidalgo and Port Gravina, the densities of the herring in these schools were quite high, reaching 7 kg/m^2. The biomass of adult herring in the region was estimated to be in the range of 1-3 thousand mt. The schools were located close to shore, but were still targeted by several humpback whales. The whales could be seen as close as 10 m from shore. Despite the expanded effort in 2014, we were unable to obtain a reasonable estimate of the adult herring biomass.

2015

During the first cruise, the only appreciable abundance of adult herring was found in Port Fidalgo, and these were relatively small schools scattered primarily in deeper water from off Whalen Bay to off Two Moon Bay and Landlocked Bay. There were about 7 humpback whales within Port Fidalgo along with scattered groups of Steller sea lions. A single series of acoustic transects was run over this abundance the night of March 29. The survey covered a relatively large area (31.4 km^2) and encountered about 30 herring schools. These fish were deep in the water column (40-130 m) and the acoustic cross section (sigma) was adjusted for depth (depth-corrected sigma values were calculated for each transect). The estimate of total biomass was 9,240 mt.

Five acoustic surveys were conducted during the second cruise. Two were in Port Fidago: one in an area off Two Moon Bay, the second in the vicinity of Whalen Bay. Three surveys were conducted in Port Gravina, all between Red Head and St. Mathews Bay. The survey off Two Moon Bay was conducted at night in a limited area (5 km^2). Schools were similar to typical herring pre-spawning aggregations, although smaller in school size than normally observed in April. The estimated biomass was 2,130 mt. The survey of the fish in the vicinity of Whalen Bay was conducted during the daytime. The fish were atypical both in location (upper Port Fidalgo) and distribution (small, deep schools). They were clearly herring, and subject to predation by several humpback whales. The survey covered about 10 km^2 and the estimated biomass was 1,380 mt.

Fish abundance in Port Gravina varied dramatically during the short interval of the cruise. Herring were distributed near shore between Red Head and St. Mathews Bay the first night of the cruise (April 7) but weather conditions precluded a survey. The next morning the fish (and associated marine mammals) had vanished. A survey was conducted, but not analyzed because

of the low numbers. The night survey on April 10 encountered herring near shore, but primarily just off Red Head. More fish had clearly entered the area on April 11 and the distribution had shifted slightly northward. Most of the herring were very near shore. The estimated fish biomass was about 3,480 mt on April 10 and 5,240 mt on April 11. The fish were near surface (8-14 m), so the depth-corrected sigma was almost twice that of the normally assumed 40 m.

Additional fish were observed off Landlocked Bay during the second cruise, but not surveyed. It is unlikely these would amount to more than 2,000 mt. In summary, the first cruise could account for slightly over 9,000 mt. The second cruise could similarly account for between 9 and 12 thousand mt. Additional fish were probably still entering Port Gravina at the time of the last survey. Nevertheless, the amount of fish detected during the 2015 appears to be considerably less than anticipated. Variances and confidence intervals were not calculated for the 2015 surveys because of the relatively small sample size and limited replications.

2016

The survey in 2016 consisted of three separate cruises. The first cruise departed Cordova on 29 March and returned 3 April. The second cruise extended from 5 April to 8 April, and the final cruise was 12-13 April. The survey vessel was the M/V *Auklet*. The first two cruises consisted of surveys in Port Gravina and the northeastern end of Montague Island. The final cruise was limited to Port Gravina. We observed conditions in Port Fidalgo, but no acoustic surveys were conducted there because of a lack of evidence of herring presence.

We observed an aggregation of herring within the 30-50m depth contour along the coastline near Hell's Hole in Port Gravina. We completed five separate, acoustic surveys in this region during 2-12 April (Fig. 1). Two were conducted at night, and the other three were conducted during the day (Fig. 3, Table 1). Biomass estimates varied from 205 to 2,953 mt (CV = 56.7%, Table 1). The range for the two nighttime surveys was smaller, and yielded higher estimates (1,591-2,953 mt). The survey area ranged from 5.8 -18.7 km^2 (Table 1). We assumed the survey that yielded the lower biomass estimate (1,591 mt on 2 April) should be considered an early estimate before full recruitment of adults to the spawning aggregation site. We conclude that a more appropriate measure of spawning biomass was 2,953 mt measured during the night of 11 April. It should be noted that the early survey on 2 April only included a subset of the full survey transects and thus should not be considered a full survey (Fig. 1).

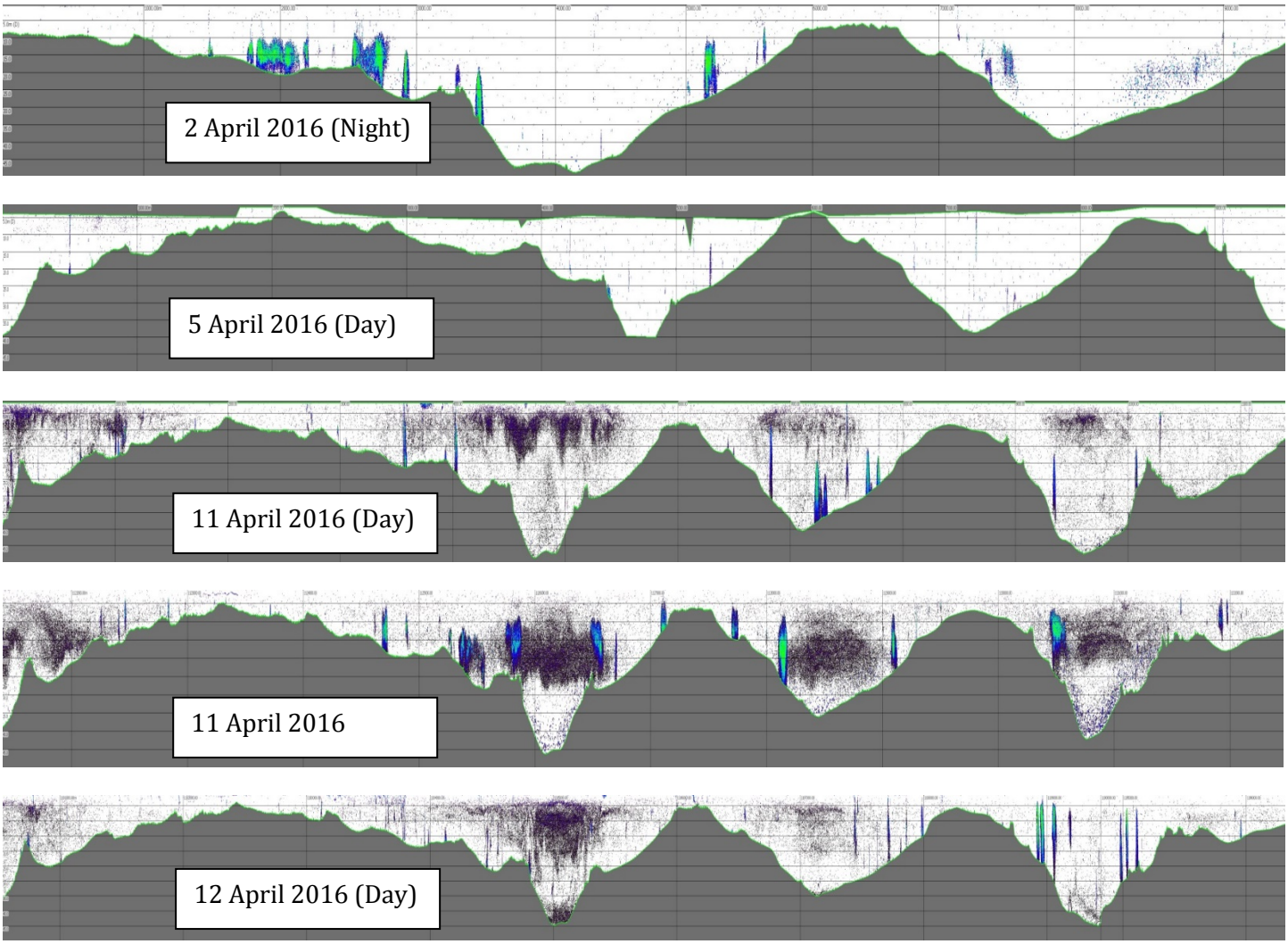
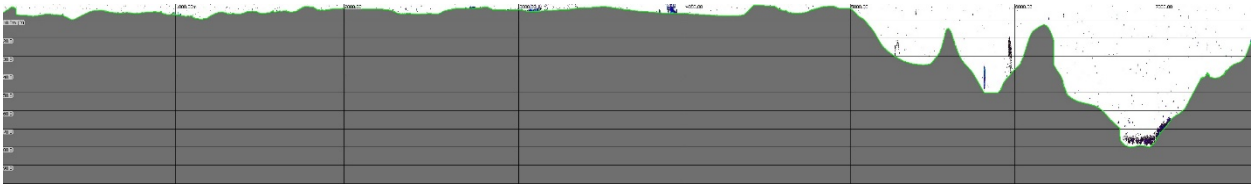
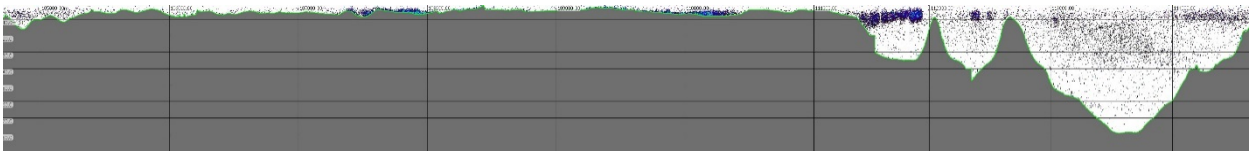


Figure 3. Echograms from transects conducted off of Hell's Hole in Gravina Bay, Prince William sound during 2-12 April 2016. Horizontal bars represent 10 m depth strata, and vertical bars represent 1 km intervals determined from GPS tracking of the vessel during the survey. Acoustic data shown are filtered by applying a minimum threshold of -60 dB.

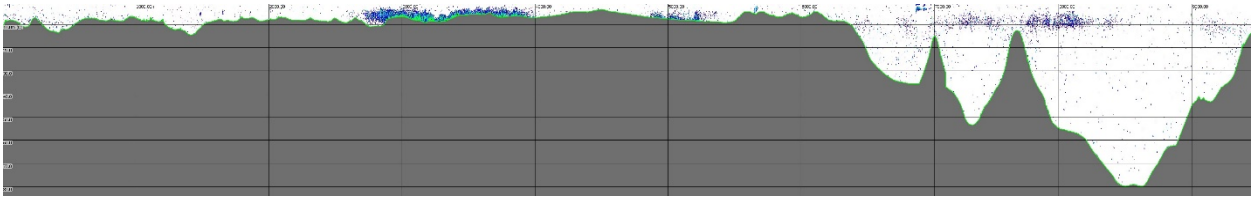
Rocky Bay, Montague Island, 7 April, Day Transect:



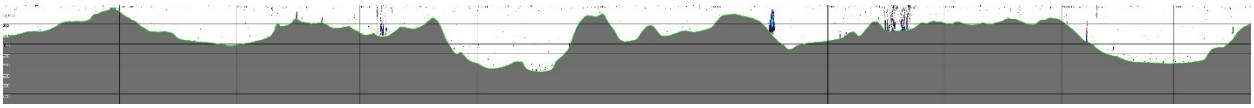
Rocky Bay, Montague Island, 7 April, Night Transect:



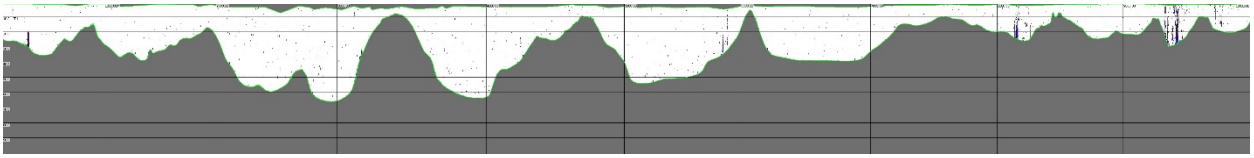
Rocky Bay, Montague Island, 8 April, Night Transect:



Stockdale Harbor, Montague Island, 1 April, Day Transect:



Stockdale Harbor, Montague Island, 6 April, Day Transect:



Stockdale Harbor, Montague Island, 6 April, Night Transect:

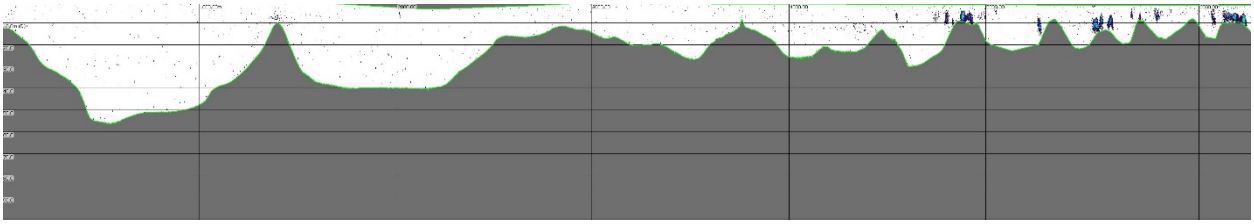


Figure 4. Echograms from transects conducted in Rocky Bay and Stockdale Harbor on Montague Island, Prince William Sound during 1-8 April 2016. Horizontal bars represent 10 m depth strata, and vertical bars represent 1 km intervals determined from GPS tracking of the vessel during the survey. Acoustic data shown are filtered by applying a minimum threshold of -60 dB.

We conducted an early survey (1 April) at Stockdale Harbor that yielded a biomass estimate of 268 mt (Figs. 2, 4; Table 1). During 6-8 April, an additional five surveys were conducted (three at the head of Rocky Bay, and two additional surveys in Stockdale Harbor). The range of biomass estimates was 64-389 mt (Table 1). The largest amount of biomass (389 mt) was detected at the head of Rocky Bay during the night of 8 April, with herring in relatively shallow water (~10 m depth, Fig. 4). The coefficients of variation for these two surveys were higher than that reported for Port Gravina (Rocky Bay CV = 71%, Stockdale Harbor CV = 73%). These values should be considered high given this includes surveys from both day and night. We conclude that the most reliable biomass estimates are 389 mt measured in Rocky Bay during the night of 8 April, and 111 mt measured in Stockdale Harbor during the night of 6 April. These estimates, combined (400 mt), represent the spawning biomass estimates for this region during 2016. Variances and confidence intervals were not calculated for the 2016 surveys because of the relatively small sample size and limited replications.

Table 1. Biomass estimates of adult Pacific herring during spring cruises, 2016. Shaded rows are the survey results used to estimate total herring biomass that appears in the bottom row (described more fully in the text).

Location	Date	Time of Survey	Survey Area (km^2)	Biomass Estimate (mt)
Gravina	2 April	Night	5.8	1591
Gravina	5 April	Day	11.1	205
Gravina	11 April	Day	18.7	2500
Gravina	11 April	Night	17.8	2953
Gravina	12 April	Day	18.3	2804
Rocky Bay	7 April	Day	2.3	88
Rocky Bay	7 April	Night	2.3	176
Rocky Bay	8 April	Night	2.3	389
Stockdale Harbor	1 April	Day	5.3	268
Stockdale Harbor	6 April	Day	6.4	64
Stockdale Harbor	6 April	Night	1.8	111
Total:				**3453**

After combining the biomass estimates for both surveyed regions, our effort yielded a biomass estimate of 3,453 mt, which is less than half of the biomass estimated during the spring 2015 survey (9,000 mt), and represents the lowest estimate since this survey was initiated in 1993 (Fig. 5).

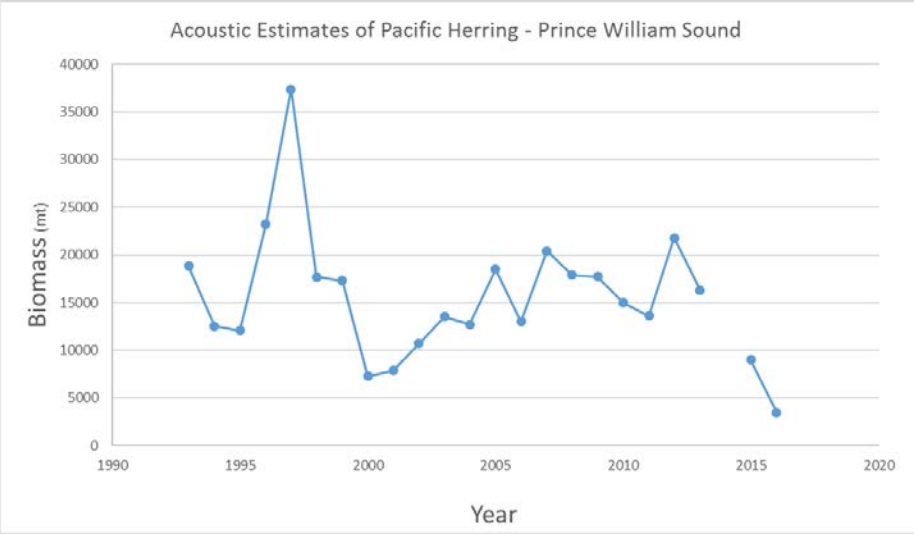


Figure 5. Time series of acoustic biomass estimates (metric tonnes) of Pacific herring in Prince William Sound. The survey conducted during 2014 did not yield a biomass estimate due to adult herring occupying water too shallow to survey effectively with hydroacoustics.

DISCUSSION

We report a decline in pre-spawning herring biomass during 2012-2016 as determined through hydroacoustic surveys. Our highest estimate of biomass (21,800 mt) documented during this grant period occurred in the first year (2012), and each subsequent year yielded a lower biomass estimate. Our 2016 biomass estimate (3,453 mt) was the lowest recorded since this survey began in 1993.

The distribution of pre-spawning herring in Prince William Sound changed dramatically after 1997. In 1997, distributions were centered around Montague Island. However, since 2002 most herring have been distributed in Port Fidalgo and Port Gravina prior to spawning, and this pattern remained consistent during the 2012-2016 survey period. The change in distribution to locations further from the Gulf of Alaska may have been caused by increasing predation by humpback whales. Vessel logs note large numbers of humpback whales around Montague Island in the mid-1990s, whereas the whales were virtually absent from Port Fidalgo and Port Gravina until 2006. Whales were observed to be present in Port Fidalgo and Port Gravina during all years in this grant period.

Associated with the change in distribution were more variable pre-spawning migrations. Prior distributions were relatively stable, with fish holding in pre-spawning locations for several weeks. Behavior in more recent years has been observed to be different, with rapid changes in distribution and variable timing that appears to be related to water temperatures (R. Thorne, PWSSC, personal observation). Many of the adult herring arrive in Port Fidalgo, remain for a variable period, then migrate around to Port Gravina. As spawning approaches, the fish move further inshore, but the timing of the movement has varied considerably among years. The more dramatic and variable movements greatly complicate acoustic surveys, which need a relatively stable, predictable behavior so that the limited available survey effort can be used efficiently. The fish biomass is underestimated when concentrations cannot be located or are not accessible to the survey. This was most dramatic during the spring of 2014 when we were unable to conduct a survey because fish were occupying very shallow water in Port Gravina. Uncertainty increases when the distribution is insufficiently stable for multiple surveys to be conducted.

CONCLUSIONS

We document a declining trend in pre-spawning, adult biomass of Pacific herring in Prince William Sound during 2012-2016. Our biomass estimate measured during spring 2016 is the lowest recorded estimates since the survey began in 1993. The overall distribution of spawners remains centered in Port Gravina and Port Fidalgo with only a minor contribution of herring biomass along the northeastern coastline of Montague Island. Recent survey years have noted smaller aggregations, and early migration of adult herring into shallow water that has made it difficult for us to accurately quantify biomass in our acoustic surveys. This project was funded for the second 5 year program (2017-2021, project 18120111-G) with the aim to continue to monitor the abundance of spawning herring in Prince William Sound.

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