ATTACHMENT C ***EVOSTC Annual Project Report Form***

Form Rev. 10.3.14

*Please refer to the Reporting Policy for all reporting due dates and requirements.

1. Program Number: *See*, Reporting Policy at III (C) (1).

15120111-E

2. Project Title: *See*, Reporting Policy at III (C) (2).

PWS Herring Program – Expanded Herring Surveys

3. Principal Investigator(s) Names: *See*, Reporting Policy at III (C) (3).

Richard Thorne, Pete Rand, PWSSC

4. Time Period Covered by the Report: *See*, Reporting Policy at III (C) (4).

1 February 2015 to 31 January 2016

5. Date of Report: *See*, Reporting Policy at III (C) (5).

February 2016

6. Project Website (if applicable): *See*, Reporting Policy at III (C) (6).

http://pwssc.org/research/fish/pacific-herring/

7. Summary of Work Performed: *See*, Reporting Policy at III (C) (7).

Project Summary – Overview

Introduction

Hydroacoustic surveys of Pacific herring in Prince William Sound 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 for 23 consecutive years. The survey in 2015 consisted of two cruises. The first cruise departed Cordova late afternoon on March 26 and returned March 30. The second cruise extended from April 7 to 12. The survey vessel was the Auklet, captained by David Janka. The first cruise covered Gravina Point, Port Gravina, Port Fidalgo, Tatitlek Narrows, Galena Bay, Glacier Island, Naked Island and the north edge of Hawkins Island (Fig. 1). The second cruise focused on Port Fidalgo and Port Gravina (Fig. 2).

Methods

Hydroacoustic survey methods are well documented and well established in fisheries (Thorne 1983; Simmonds and MacLennon 2005). They have been applied to Pacific herring for nearly forty years (Thorne 1977a,b; Trumble et al 1983). The specific methods used in PWS are well documented and have been demonstrated to be precise (Thomas et al. 1997, Thomas et al. 2002, Thomas and Thorne 2003, Thorne and Thomas 2008).

A three-stage sampling design (Cochran 1977) is used for the acoustic surveys in PWS rather than the systematic design more typically used in hydroacoustic surveys (MacLennan and Simmonds 1992; Simmonds and MacLennon 2005). 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 location of these adult herring aggregations within PWS. Approaches include aerial surveys of foraging marine mammals, especially Steller sea lions and humpback whales, sonar surveys and observations from fishers, hunters and others transiting PWS, as well as a detailed database of historic locations. 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). These surveys are generally conducted at night with a dark vessel since herring are further removed from bottom and surface boundaries at night, but are very light sensitive. The surveys are repeated several times to develop multiple, independent estimates of the biomass of specific fish aggregations. The repeated estimates are used to determine the precision of the biomass estimates (Scheaffer et al. 1986). After the echointegration surveys, the herring schools are subsampled for biological information, primarily with a commercial purse seine (McClatchie et al. 2000). The direct capture effort is conducted by the Alaska Department of Fish and Game.

Two separate echosounder systems operated during this cruise. We describe the systems and the analytical methodology applied to data generated by each system below. For both methodologies, we assume all targets are Pacific herring. Our objective during the spring 2015 cruise was to compare the measurements from these two systems so future work conducted by our contractor (FIU) could be calibrated to on-going survey efforts with the PWSSC system.

Biosonics 70 kHz Single Beam (PWSSC system)

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

$TS_w = -5.98Log(L) - 24.23$

Where TS_w is the target strength (decibels) per unit weight, w is weight in kg and L is standard length in cm.

This equation applies to the typical night-time depths of herring during the late winter/early spring period (specifically 40 m). Alterations are made for different depths and seasons based on Thomas et al. (2002). Hydroacoustic systems initially were BioSonics analog scientific echosounders (models 101. 102 and 105). However, for most years digital echosounders have been used (BioSonics DT and DX). System frequencies have usually been either 70 kHz or 120 kHz, although multi-frequency systems including 38 kHz have been applied. All the hydroacoustic systems are calibrated with standard targets following procedures of Foote et al. (1987). Calibration was not conducted during this cruise, however. The 2015 sampling during both 2015 cruises was done with the PWSSC BioSonics 70 kHz single beam system.

Additional sampling was conducted with other systems and other frequencies by Aubree Zenone from the Fisheries Ecology and Acoustics Laboratory at Florida International University. A full array of frequencies were deployed including an SIMRAD EK60 38 and 120 kHz split-beam transducer, and a SIMRAD EK80 70 kHz split-beam transducer operating through a wide-band transceiver. Due to transducer interference, the PWSSC BioSonics system and the FEAL system were used on alternating transects. Initial analyses with both data sets were concerned with ensuring consistency in results between the PWSSC systems and the new FEAL equipment.

There were insufficient direct capture samples during 2015 to accurately determine the mean size of the herring. Consequently, the historical average target strength (-32 db/kg) was used for the 2015 estimation. This corresponds to an acoustic cross section (sigma) of 0.00063 and a mean length of 20 cm.

SIMRAD EK60 & EK80 Echosounder (FIU)

In alternating transects, data were collected using the FEAL's SIMRAD EK60 38 and 120 kHz split-beam transducer, and a SIMRAD EK80 70 kHz split-beam transducer operating through a wide-band transceiver. This latter system emits and receives across a broad band of frequencies to allow for potential target discrimination, but when making direct comparisons we used data only from a single frequency (70 kHz) to make it directly comparable to the PWSSC system described above.

Acoustic data from the FIU echosounder were manually inspected and post-processed in Echoview 7.1 (Sonar Data Pty., Ltd.). An analysis threshold of -60.00 dB was applied to the volume backscattering (S_V) data in addition to a bottom detection algorithm to remove reverberation and unwanted acoustic backscatter (eg. benthic habitat, air bubbles, etc.). Additional manual inspections removed any remaining undesired data and the echograms were binned into 10m horizontal by 5m depth analysis cells.

Acoustic fish density estimates were calculated by using the backscattering cross-section ($\sigma_{bs;}$ MacLennan *et al.*, 2002) and Target Strength (TS) as calculated using standard linear regression equations for TS derived using average length of herring caught by trawling in each bay (Thomas *et al*, 2002). The area backscattering coefficient, s_a [$s_a = \int_{z1}^{z2} Sv * dz$], was then used to calculate fish densities (fish m^{-2}) in a transect as described in MacLennan *et al.,* 2002 (Eq.2).

$\sigma_{bs} = 10^{\wedge(TS/10)}$ (Eq. 1)

Fish $m^{-2} = s_a / \sigma_{bs}$ (Eq. 2)

Once density was derived, average herring length determined by average ADF&G trawl catch data was used to estimate herring weights as derived from a standard L/W relationship (Ostrand *et al*, 1998). Densities were then multiplied by average fish weight to obtain a biomass estimate for each analysis cell. Cells were then summed across a survey to result in total estimated acoustic biomass along the transect in each survey. Here we make the assumption that all backscatter in surveys were herring, as the threshold applied removes targets that lack a swimbladder, and schools likely to be herring were manually identified. Finally, we extrapolated out the results from the transects to the surface area of each bay. We did this by multiplying our estimates of density by the estimated surface area of the bay. We acknowledge this is a crude method of extrapolation. This simply represents a first step toward a more robust method accounting for other variables, particularly each bay's bathymetry.

Results

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 (Fig. 3). The survey covered a relatively large area (31.4 km^2) and encountered about 30 herring schools (Fig. 4). 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 derived from the Biosonics echosounder was 9,240 metric tons (Table 1).

Five acoustic surveys were conducted during the second cruise. Two were in Port Fidalgo: 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 (Fig. 5). The survey off Two Moon Bay was conducted at night in a limited area (5 km^2). Schools were similar to typical herring prespawning aggregations, although smaller in school size than normally observed in April. The estimated biomass with the Biosonics echosounder was 2,130 tons. 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-Fig. 6). They were clearly herring, and subject to predation by several humpback whales. The survey covered about 10 km^2 and the estimated biomass from the Biosonics echosounder was 1,380 tons.

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. The night survey on April 10 encountered herring near shore, but primarily just off Red Head (Fig. 7). 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 (Fig 8). The estimated fish biomass from the Biosonics echosounder was about 3,120 tons on April 10 and 5,850 tons on April 11 (Table 2). 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 tons. In summary, the first cruise could account for slightly over 9,000 tons using data from the Biosonics echosounder. The second cruise could similarly account for between 9 and 12 thousand tons. 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.

Acoustic density and biomass estimates from the SIMRAD echosounder were markedly lower than that generated from the Biosonics echosounder. The difference was particularly pronounced during three of the five days examined (Figure 9). The differences between the two systems appear to be related to differences in measures of acoustic backscatter (reflected here in our measures of acoustic density), but do not appear to be systematic given that on some days (e.g. 4 & 10 April 2015) the estimates from the two systems closely converged. One of the simplest explanations for the differences observed on those days was heterogeneity in the fish distribution across the transects. Because the two systems sampled alternating transects, it is conceivable that the transects run using the Biosonics echosounder on the days the estimates diverged were associated with a greater quantity of fish. Differences in post-processing between the systems may also have resulted in variable estimates of biomass. Biosonics data were analyzed with an automated program to detect potential fish targets. SIMRAD data were processed through Echoview, a program that can be used to manually excise unwanted data unlikely to be fish targets. It is possible this manual inspection and removal of non-herring targets resulted in lower estimates.

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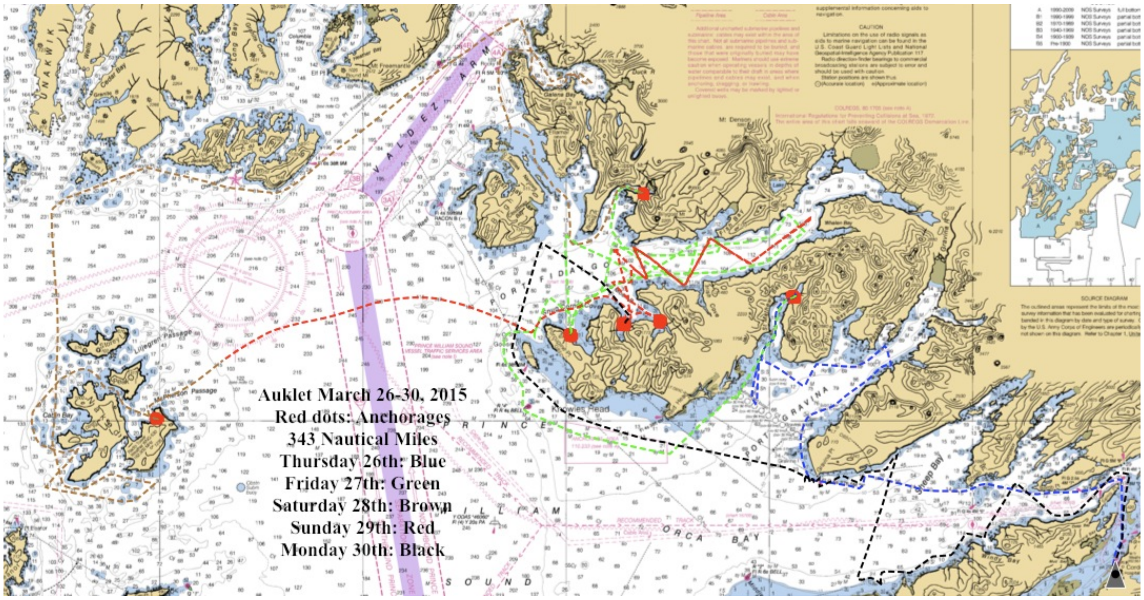

Fig. 1. Auklet vessel track for cruise #1, courtesy of David Janka

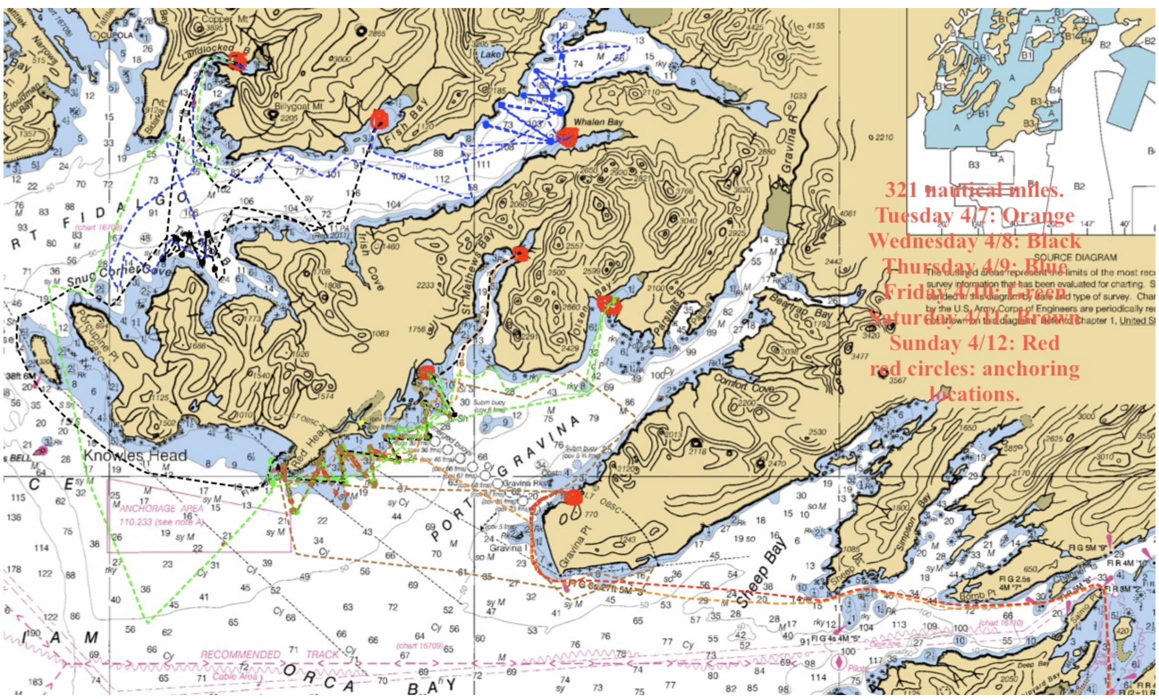

Fig. 2. Auklet vessel track for cruise #2, courtesy of David Ja

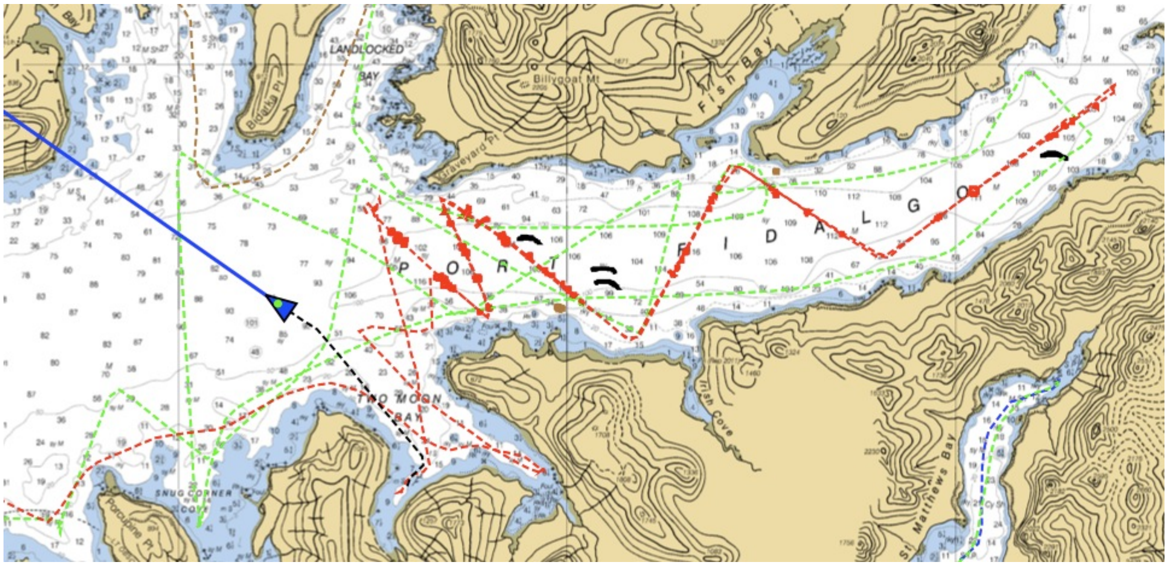

Fig. 3. Six-transect acoustic series conducted March 29, 2015. courtesy of David Janka.

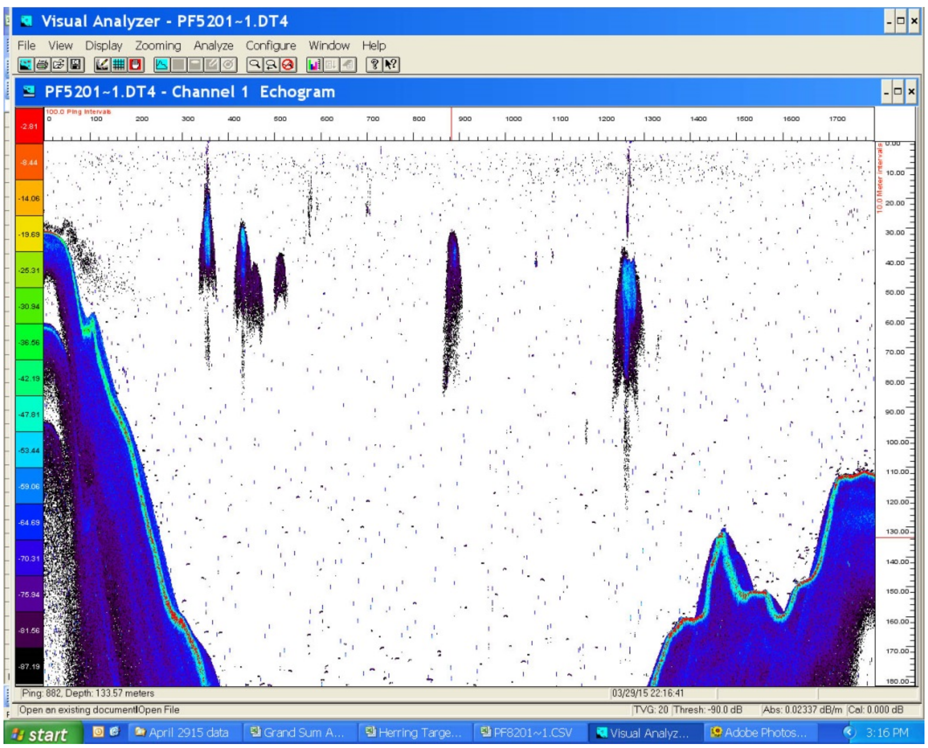

Fig. 4. Echogram from first 30 minutes of transect 3 from Fish Bay toward Irish Cove.

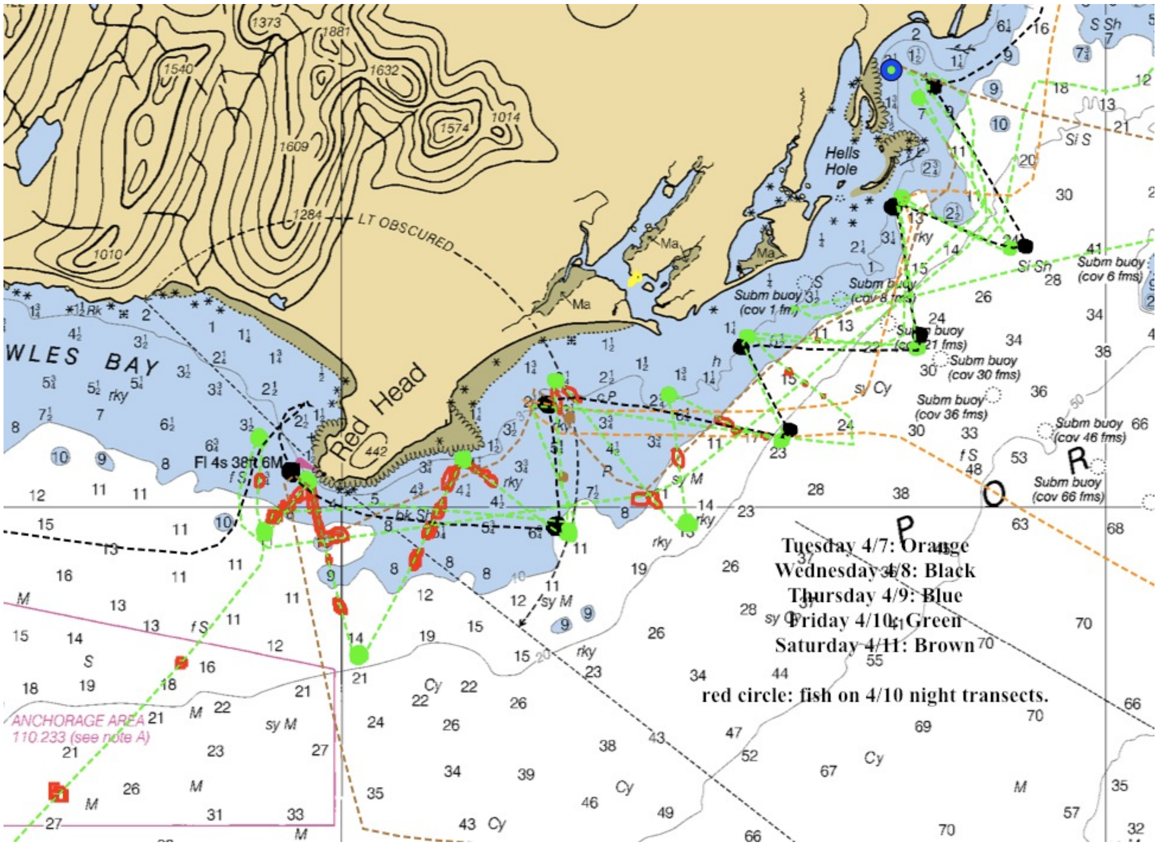

Figure 5. Surveyed area of Port Gravina, April 8, 10 and 11, 2015.

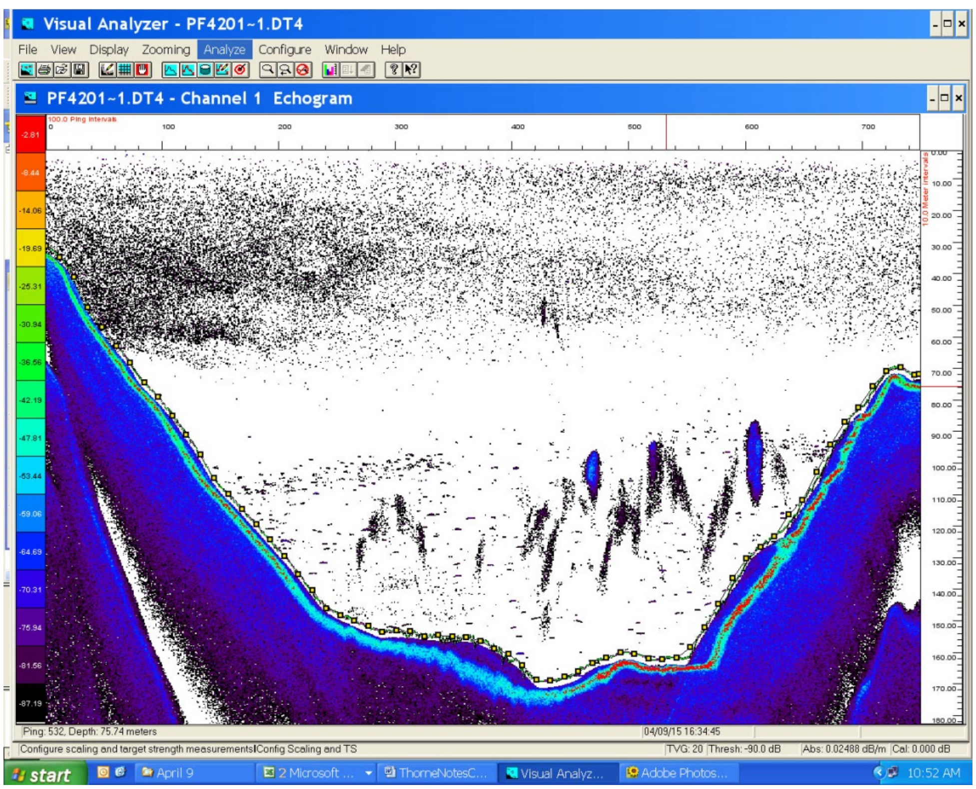

Fig. 6. Echogram from transect off Whalen Bay, Port Fidalgo, April 9, 2015.

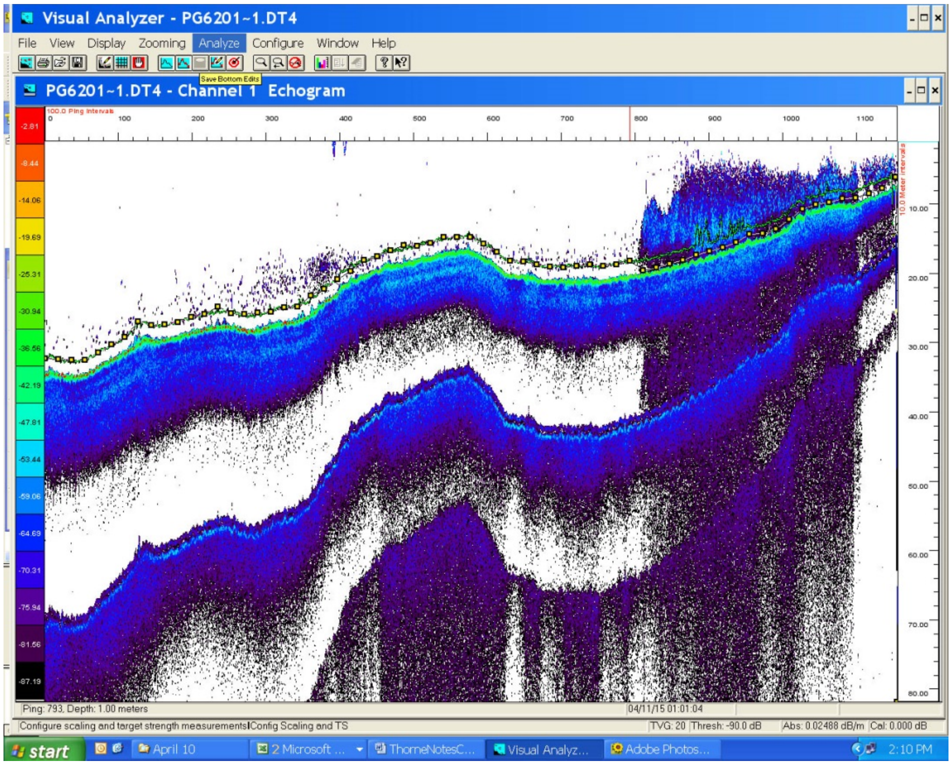

Fig. 7. Echogram of fish distribution just off Red Head

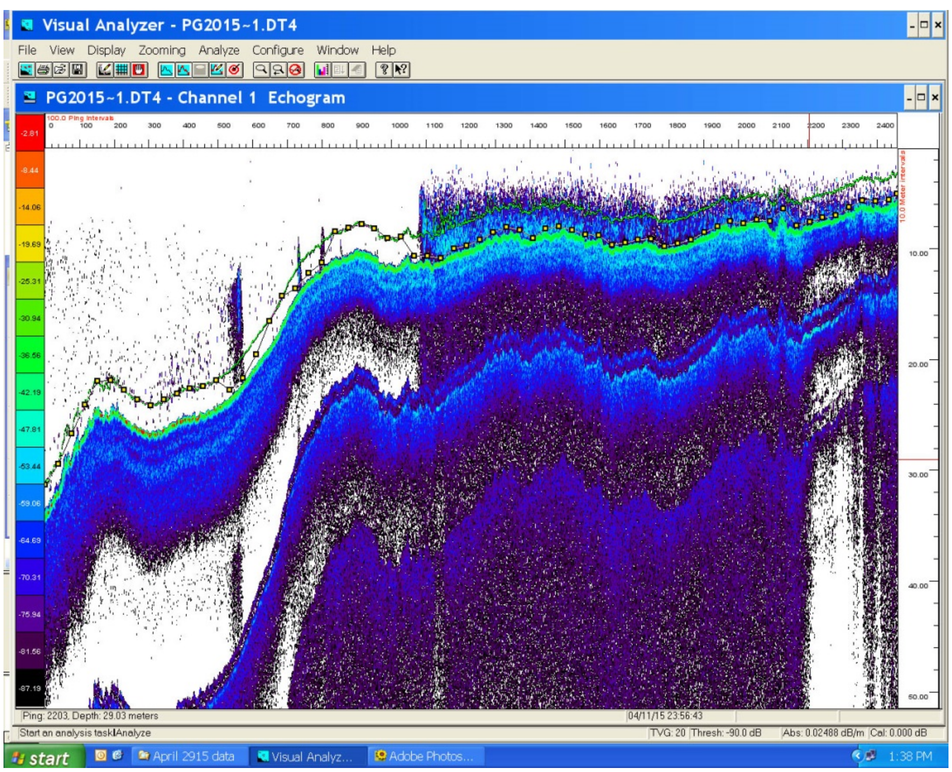

Fig. 8. Echogram from April 10 survey of Port Gravina showing inshore distribution

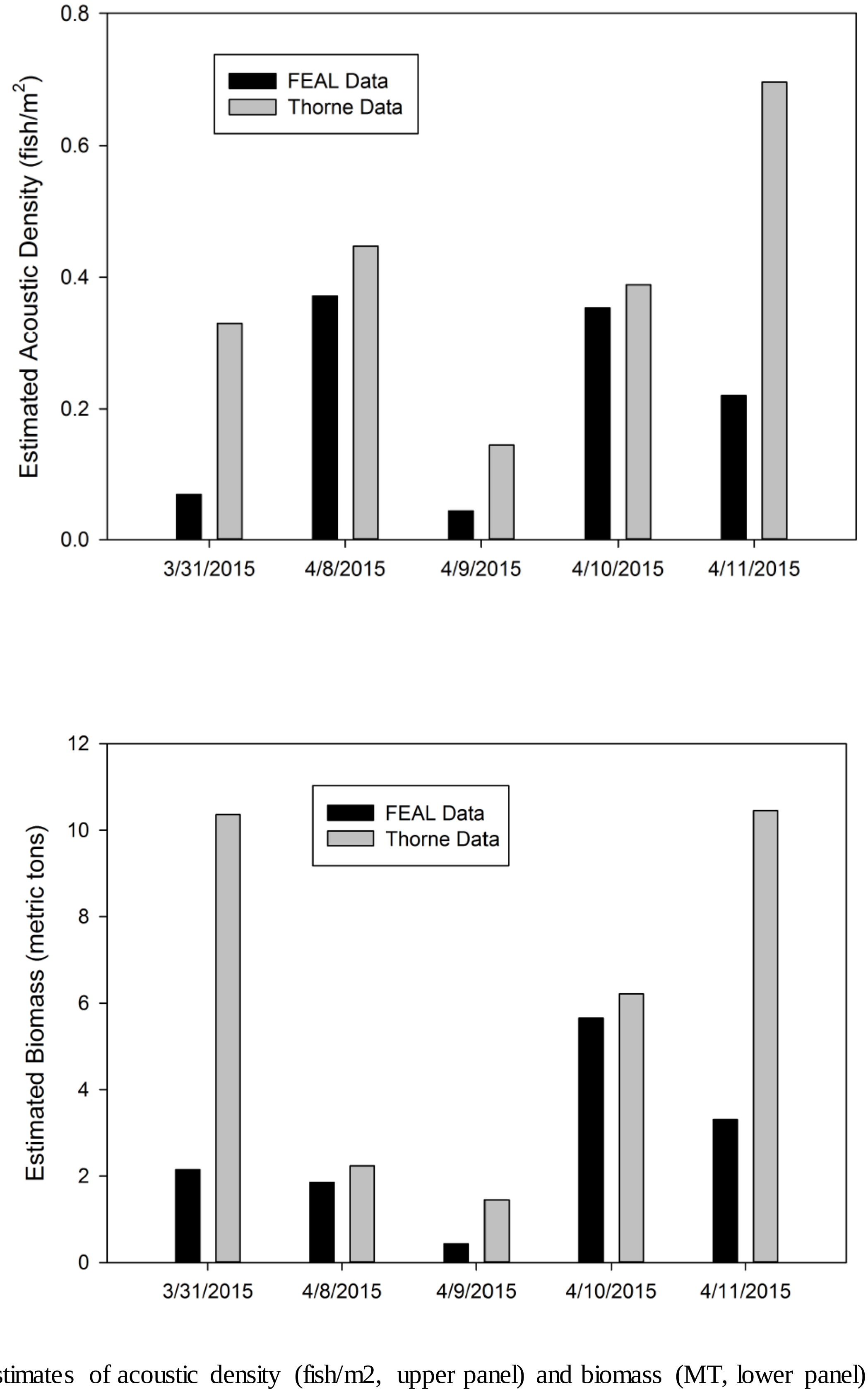

Figure 9. Estimates of acoustic density (fish/m2, upper panel) and biomass (MT, lower panel) for FIU SIMRAD systems (dark bars) and the PWSSC Biosonics echosounder (gray bars).

Table 1. Biomass Estimated from the PWSSC Biosonics echosounder from the March 29, 2015 Survey

Transect	Area (km^2)	Density (Kg/m^2)	Biomass (1000 mt)
1	8.96	0.097	0.87
2	5.12	0.051	0.26
3	5.76	0.573	3.30
4	7.68	0.489	3.75
5+6	3.84	0.275	1.06
Total	31.36		9.24

Table 2. Herring Biomass Estimates over the entire survey area during Spring 2015 from the PWSSC Biosonics echosounder

Location	Date	Density kg/m^2	Area km^2	Biomass 1000 mt
Port Fidalgo	29-Mar	0.29	31.4	9.24
	8-Apr	0.43	5	2.13
	9-Apr	0.14	10	1.38
Port Gravina	10-Apr	0.19	16	3.12
	11-Apr	0.39	15	5.85
Total For Port Gravina				9.4

8. Coordination/Collaboration: *See,* Reporting Policy at III (C) (8).

The inter-system comparison of density and biomass would not have been possible without the involvement of Aubree Zenone of FIU. This work was conducted through a contract to Kevin Boswell at FIU.

This project uses the size information collected by ADF&G during their spring surveys. Biomass estimates from the surveys are then provided to Steve Moffitt with ADF&G.

9. Information and Data Transfer: *See,* Reporting Policy at III (C) (9).

Data from these cruises have been uploaded to the AOOS website.

10. Response to EVOSTC Review, Recommendations and Comments: *See,* Reporting Policy at III (C) (10).

We were unable to address the issue of precision of the acoustic sampling brought up by the Science Panel in 2014. More ship time would be required to replicate transects to a sufficient degree to quantify the error associated with this sampling methodology. We are planning on doing this, at least for part of the survey area, during the Spring 2016 cruise. In addition, during this cruise we hope to generate estimates of herring size distribution and density using a multi-beam, imaging sonar system (DIDSON) mounted on an ROV. We hope this will provide another, independent measure of fish density to which we can compare with the more traditional, down-looking echosounders used in the present program.

11. Budget: *See,* Reporting Policy at III (C) (11).

Budget Category:	Proposed FY 12	Proposed FY 13	Proposed FY 14	Proposed FY 15	Proposed FY 16	TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel	$0.0	$49,900.0	$40,900.0	$55,300.0	$55,900.0	$202,000.0	$ 55,969
Travel	$0.0	$3,600.0	$3,600.0	$3,600.0	$3,600.0	$14,400.0	$ 11,532
Contractual	$0.0	$2,000.0	$3,600.0	$3,000.0	$0.0	$8,600.0	$ 12,184
Commodities	$0.0	$4,000.0	$0.0	$2,000.0	$0.0	$6,000.0	$ 531
Equipment	$6,000.0	$0.0	$0.0	$0.0	$0.0	$6,000.0	$ 6,000
Indirect Costs (*will vary by proposer*)	$0	$17,900	$14,400	$19,200	$17,900	$69,400.0	$ 24,065
SUBTOTAL	$6,000.0	$77,400.0	$62,500.0	$83,100.0	$77,400.0	$306,400.0	$110,281.0
General Administration (9% of	$540.0	$6,966.0	$5,625.0	$7,479.0	$6,966.0	$27,576.0	
PROJECT TOTAL	$6,540.0	$84,366.0	$68,125.0	$90,579.0	$84,366.0	$333,976.0	
Other Resources (Cost Share Funds)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	

Spending on personnel is behind because of a change in P.I. in 2015. Funding is being shifted from personnel to contractual to allow for contracting with Kevin Boswell at Florida International University to assist in data collection and processing.

We appreciate your prompt submission and thank you for your participation.