Project Title: Acoustic Habitat Classification to Improve the Aleutian Islands Bottom Trawl Biomass Indices for Stock Assessments

Principal Investigators: Steven J. Barbeaux (AFSC), John Horne (University of Washington), Chris Rooper (AFSC), and Paul von Szalay (AFSC)

Background

The Aleutian Island (AI) archipelago is a volcanic island chain stretching over 1,900 km east to west. The bathymetry of this region is fragmented, diverse habitat mosaic characterized by a patchwork of canyons, pinnacles, reefs, plateaus, passes, and knolls. Much of this area is rocky and rugged making commercial fishing and surveying challenging. Stock assessments of AI groundfish largely rely on a biennial summer bottom trawl survey (e.g. NPFMC 2013) that uses a depth-stratified random sampling design within large longitudinal areas that are intersected by the islands in eastern strata (von Szalay et al. 2011). Even though the bottom trawl survey gear used in the AI survey is limited to relatively smooth, soft bottom where a trawl can be set without damage, catch per unit effort (CPUE) values are extrapolated to each strata using area swept to obtain a biomass index. This index does not include considerations of bottom type or habitat preferences of the surveyed species (von Szalay et al. 2011, Jones et al. 2012). Extrapolating data collected over a patchwork of habitats likely results in a biased biomass index for many species and prevents the ability to quantify uncertainty of biomass indices for all species. The overall objective of this study is to acoustically classify Aleutian Islands benthic habitat using split-beam acoustic data collected during the biennial AI bottom trawl survey and use these classifications to develop acoustic habitat-based biomass indices. This effort will improve both Tier 5 and Tier 3 stock assessments for the AI region through improved estimates of biomass and estimates of variance for the key indices used in AI stock assessments.

Approach

Year 1

In 2004, side-scan sonar (SSS), multi-beam acoustic (MBA), underwater video (UV), and splitbeam acoustic (SBA) data were collected in an area north of Umnak Island (cf. Figure 1, Rooper and Zimmerman 2007). The area was chosen because it contains a wide variety of bottom features and seabed types. Since 2006 all AI bottom trawl vessels have surveyed a standard transect (known as the Rooper Line) collecting 38 kHz acoustic data at the beginning and end of each survey (eight transects in total). Previous efforts have used SBA data for sea-bed and fish habitat classification (e.g. Ellingsen et al. 2002, Simard and Stepnowski 2007, Anderson et al. 2008, McConnaughey and Syrjala 2009). Even though resulting classifications have not always matched physical sediment grabs (e.g. Ellingsen et al. 2002), MBA, or SSS characterizations (e.g. Schimel et al. 2010), seabed classifications from SBA systems have provided useful information on gross bottom structure. Gross bottom structure classification has allowed delineation of acoustic habitat types which have then been correlated with specific fish habitat types (e.g. Cutter and Demer 2014). In 2012 Myriax released a Habitat Classification (MHC) module for their acoustic data processing software Echoview (Myriax Software Pty. Ltd;

www.echoview.com), which facilitates the use of SBA data to classify acoustic bottom types. The MHC module now makes it feasible for processing large acoustic datasets using unsupervised classification to characterize bottom features and to define fish habitat types.

In this project we propose to have a Master's candidate, supervised by Dr. John Horne of the University of Washington School of Aquatic and Fisheries Sciences, process the SBA data from each of the Rooper Line transects using SBA data and the MHC module in Echoview to quantitatively compare acoustic bottom features with those extracted from SSS, MBA, and UV data following Schimel et al. (2010). The Master's candidate will screen the data from each source for data quality, process the SBA data using the MHC module, export the MHC bottom echo features: mean depth, hardness, roughness, bottom length, rise time, kurtosis, skewness, and maximum acoustic backscatter; and investigate additional bottom echo features that could prove useful for identifying acoustic habitat types. Principle component analysis (PCA) and K-means clustering will be used with the SBA echo features to characterize acoustic habitat types. The SBA-based acoustic habitat types will also be compared to those derived using SSS, MBA, and UV data. The Master's candidate will produce a report on the consistency of MHC derived bottom echo features from among the multiple SBA collections, potential additional bottom echo features from SBA data , and comparability between the MHC-derived features and acoustic habitat types and those derived from the SSS, MBA, and UV methods by Rooper and Zimmerman (2007).

<u>Year 2</u>

Since 2006, SBA data have been collected during the biennial AI bottom trawl survey and since 2013 during normal fishing operations on board longline fishing vessels operating in the Aleutian Islands. These data are acquired using calibrated, hull-mounted 38 kHz SIMRAD ES60 echosounders, which have been shown to collect data at a precision comparable to scientific grade systems (e.g. Barbeaux and Fraser 2009, Barbeaux et al. 2013, Barbeaux et al. 2014). During this phase of the project, the Master's candidate will initially pre-process (i.e. bottom definition, transect definition) and quality check (i.e. noise filtering) all of the AI bottom trawl survey SBA data and opportunistically collected fishing vessel data. The candidate will then process the data in MHC for sea-bed classification following methods refined in the first year of the study. All bottom echo features will be exported from Echoview and then combined in a geo-referenced, relational database on the AFSC ORACLE server. This exercise will result in a comprehensive database of bottom echo features for the Aleutian Islands shelf area. Because survey and fishery data have been collected over multiple years for the same areas, bottom echo features will be evaluated for consistency among years using techniques describe in Schimel et al. (2010) to enable geo-referenced, temporal comparisons. As in year 1 of this study, PCA and K-means clustering will be used to evaluate and categorize the bottom echo data into acoustic habitat types for the entire dataset. Geostatistical methods (nearest neighbor, ordinary Kriging, or co-Kriging) will be explored to predict bottom echo features and project bottom types at un-sampled regions and a N-fold cross-validation used to evaluate the predictive performance (cf. Isaaks and Srivastava 1989, Cressie 1993). The Master's candidate will produce a report on data

quality of the Aleutian Islands-wide SBA data, performance of the MHC and alternative features in categorizing acoustic habitat types, a geo-referenced database of bottom echo features from the Aleutian Islands SBA where data quality was deemed sufficient, and a summary of Aleutian Islands acoustic habitat types.

Where AI bottom trawl survey trawl data are available, the Principle Investigators will then evaluate relationships between bottom echo features, acoustic habitat types, and species occupations. At locations where bottom trawls have been conducted and acoustic data collected, correlations between species-specific probability of occurrence and/or densities and acoustic bottom classification, as well as other environmental covariates will be evaluated using a random forest approach (Breiman 2001, Baker and Hollowed 2014). Likely species to be examined in this exercise include: Atka mackerel (*Pleurogrammus monopterygius*), Pacific ocean perch (*Sebastes alutus*), rougheye rockfish (*Sebastes aleutianus*), black spotted rockfish (*Sebastes melanostictus*), northern rockfish (*Sebastes polyspinis*), Pacific cod (*Gadus macrocephalus*), walleye pollock (*Gadus chalcogrammus*), northern rocksole (*Lepidopsetta polyxystra*), southern rocksole (*Lepidopsetta bilineata*), arrowtooth flounder(*Atheresthes stomias*), Kamchatka flounder (*Atheresthes evermanni*), Brown king crab (*Lithodes auquispinus*), and Pacific halibut (*Hippoglossus stenolepis*). Where a high correlation between bottom type and probability of occurrence and/or density are determined, a biomass index and its variance, and size and age composition distributions for that species will be calculated for each survey year using the stratification of the Aleutian Islands bottom trawl survey area, SBA-derived acoustic habitat types, and currently used survey location and depth stratums. For Tier 3 (age- or length-based assessment model) managed species the effects of habitat variability on population estimates and uncertainty of the estimates will be evaluated by substituting habitat-based biomass indices, variance of the indices, and length or age composition distributions in current age and length-based stock assessment models. For Tier 5 managed species for which the survey biomass estimates are used as absolute values the habitat-based biomass estimates and variance will be contrasted with the current time series.

Benefits

Work in the first year of this project will evaluate the utility of the MHC module for use with SBA data, and potentially develop alternative bottom echo features for classifying acoustic habitat types. This project will result in the first quantitative comparison of Aleutian Island SBA derived acoustic habitat types with bottom classifications derived from SSS, MBS, and UV methods. The Master's candidate report will also constitute a chapter in their Master's thesis and is expected to result in at least one peer-reviewed publication.

The second phase of this project will result in the development of databases on bottom echo features and acoustic habitat types for the Aleutian Islands which can then be augmented by opportunistically collected acoustic data from commercial longliners and biennially with each additional Aleutian Islands bottom trawl survey. With increased data, bottom classifications will increase the range and precision of geostatistical predictions. This component of the project will also be used as the second chapter in the Master's thesis and is expected to result in at least one,

peer-reviewed publication. Additional collaborative publications by the co-PIs are expected (see Year 2 deliverables below).

Data collection for this project is supplementary to survey or fishing efforts and cost of data collection is minor (i.e. less than $60 per survey/season for a 500GB external hard drive). Once the database has been created and protocols developed for data collection and processing, it will take little effort to expand this program to other surveyed regions and species.

In species for which bottom echo features and/or acoustic habitat types prove useful in projecting the probability of occurrence and/or density, this project will increase the accuracy of abundance indices. The project will also improve the understanding of uncertainty in survey indices due to acoustic habitat spatial variability and is expected to increase precision of survey index variance. Besides improving accuracy of stock assessments, understanding the effects of habitat variability on abundance indices used in stock assessments would improve our understanding of stock distribution in the Aleutian Islands, and provide insight on potential sample design improvements to the biennial AI bottom trawl survey.

Deliverables

Year 1

1. Final report on the consistency of MHC derived bottom echo features, alternative bottom echo features from SBA data for deriving acoustic habitat types, and comparability between the MHC derived features and acoustic habitat types and those derived from the SSS, MBS, and UV methods.
2. 1 peer-reviewed publication from the above report.
3. Presentation of work at an appropriate fisheries science conference

Year 2

1. Completed Master's thesis at the University of Washington School of Aquatic and Fisheries Sciences advised by Dr. John Horne
2. Aleutian Islands bottom echo features relational database housed on the AFSC Oracle server.
3. Aleutian Islands acoustic habitat type relational database housed on the AFSC Oracle server.
4. Four publications:
    a. "Classification of the Aleutian Islands bottom type based on bottom echo features and archived smooth sheet data," Target Journal: ICES Journal of Marine Science
    b. "Species association with bottom classification types in the Aleutian Islands," Target Journal: ICES Journal of Marine Science
    c. "Species-specific stratification of bottom trawl surveys based on acoustic bottom classification ," Target Journal(s): Canadian Journal of Fisheries and Aquatic Science or Fisheries Research
    d. "Re-evaluation of indices of abundance for key species in the Aleutian Islands based on acoustic bottom classification" Target Journal(s): Canadian Journal of Fisheries and Aquatic Science or Fisheries Research

5. Two presentations at internationally recognized scientific conferences, e.g. ICES or PICES Annual Science Meetings, AFS Annual Meeting , Alaska Marine Science Symposium etc..

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Itemized Total Budget

Item	Cost per unit	Units	Cost
1. Personnel			
Year 1:			
Master's Student – Stipend	$ 22,987.58 per year	1 year	$ 22,987.58
Master's Student – Tuition	$ 16,792.90 per year	1 year	$ 16,792.90
Dr. John Horne – Salary	$ 11,228.00 per month	1 month	$ 11,228.00
Year 2:			
Master's Student – Stipend	$ 23,079.53 per year	1 year	$ 23,079.53
Master's Student – Tuition	$ 16,860.08 per year	1 year	$ 16,860.08
Dr. John Horne – Salary	$ 11,677.00 per month	1 month	$ 11,228.00
2. Fringe Benefits			
Year 1:			
Master's Student Benefits (20.6%)	$ 4,734.86 per year	1 year	$ 4,734.86
Dr. John Horne Benefits (22.7%)	$ 2,549.00 per month	1 month	$ 2,549.00
Year 2:			
Master's Student Benefits (20.6%)	$ 4,753.80 per year	1 year	$ 4,753.80
Dr. John Horne Benefits (22.7%)	$ 2,650.96 per month	1 month	$ 2,650.96
3. Travel			
Airfare to conferences	$ 1,200.00 per flight	3	$ 3,600.00
Food and lodging during conferences	$ 1,500.00 per trip	3	$ 4,500.00
4. Equipment	None		
5. Supplies			
Desktop computer	$ 2,200.00 each	1	$ 2,200.00
Echoview Habitat Classification Module	$ 3,220.00 per year	2 years	$ 6,440.00
1TB external hard drive	$ 120.00 each	2	$ 240.00
6. Contractual	None		$ 0.00
7. Other			
Publication costs	$ 800.00 per paper	5 papers	$ 4,000.00
8. Total Direct Charges			$138,281.16
9. Indirect Charges			
Year 1:			
Master's Student – Off campus rate	$ 7,208.72 per year	1 year	$ 7,208.72
Dr. John Horne – Off campus rate	$ 3,582.00 per month	1 month	$ 3,582.00
Year 2:			
Master's Student – Off campus rate	$ 7,237.55 per year	1 year	$ 7,237.55
Dr. John Horne – Off campus rate	$ 3,722.00 per month	1 month	$ 3,722.00
10. Total			$160,031.43

Itemized Budget Year 1:

Item	Cost per unit	Units	Cost
1. Personnel			
Master's Student – Stipend	$ 22,987.58 per year	1 year	$ 22,987.58
Master's Student – Tuition	$ 16,792.90 per year	1 year	$ 16,792.90
Dr. John Horne – Salary	$ 11,228.00 per month	1 month	$ 11,228.00
2. Fringe Benefits			
Master's Student Benefits (20.6%)	$ 4,734.86 per year	1 year	$ 4,734.86
Dr. John Horne Benefits (22.7%)	$ 2,549.00 per month	1 month	$ 2,549.00
3. Travel			
Airfare to conferences	$ 1,200.00 per flight	1	$ 1,200.00
Food and lodging during conferences	$ 1,500.00 per trip	1	$ 1,500.00
4. Equipment	None		$ 0.00
5. Supplies			
Desktop computer	$ 2,200.00 each	1	$ 2,200.00
Echoview Habitat Classification Module	$ 3,220.00 per year	1 years	$ 3,220.00
1TB external hard drive	$ 120.00 each	2	$ 240.00
6. Contractual			$ 0.00
7. Other			
Publication costs	$ 800.00 per paper	1 paper	$ 800.00
8. Total Direct Charges			$ 67,452.34
9. Indirect Charges			
Master's Student – Off campus rate	$ 7,208.72 per year	1 year	$ 7,208.72
Dr. John Horne – Off campus rate	$ 3,582.00 per month	1 month	$ 3,582.00
10. Total			$ 78,243.06

Itemized Budget Year 2:

Item	Cost per unit	Units	Cost
1. Personnel			
Master's Student – Stipend	$ 23,079.53 per year	1 year	$ 23,079.53
Master's Student – Tuition	$ 16,860.08 per year	1 year	$ 16,860.08
Dr. John Horne – Salary	$ 11,667.00 per month	1 month	$ 11,667.00
2. Fringe Benefits			
Master's Student Benefits (20.6%)	$ 4,753.80 per year	1 year	$ 4,753.80
Dr. John Horne Benefits (22.7%)			
3. Travel			
Airfare to conferences	$ 1,200.00 per flight	2	$ 2,400.00
Food and lodging during conferences	$ 1,500.00 per trip	2	$ 3,000.00
4. Equipment	None		
5. Supplies			
Echoview Habitat Classification Module	$ 3,220.00 per year	1 year	$ 3,220.00
6. Contractual			$ 0.00
7. Other			
Publication costs	$ 800.00 per paper	4 papers	$ 3,200.00
8. Total Direct Charges			$ 70,828.82
9. Indirect Charges			
Master's Student– Off campus rate	$ 7,237.55 per year	1 year	$ 7,237.55
Dr. John Horne – Off campus rate	$ 3,722.00 per month	1 month	$ 3,722.00
10. Total			$ 81,788.37

Budget Justification

Because the data used in this study have already been collected for this project, most costs are associated with processing and analyzing data. The main cost of this project is for a Masters student ($103,655.02 or 64.8% of total project costs). Although the cost of supporting a master's student is more than hiring a contractor directly to conduct this work, the benefits go beyond this project. Currently in the Alaska region there is a lack of qualified acousticians to process acoustic data, training a Masters student adds another experienced acoustician to the work force. In addition to the time and effort of a young enthusiastic student, we also are able to leverage this with the expertise and time of a world renowned acoustics expert (Dr. John Horne, see CV below) who will mentor the student and review all work conducted by the student to ensure that the work meets the exacting standards of the University of Washington Masters degree program. To this end the second largest budget item is the salary and benefits for one month per year for Dr. John Horne ($35,396.41 or 22.1% of total project costs) to supervise the Masters student and participate in this project. Tuition, stipend (2014 rates Year I, 4% increase included for Year II), health benefits (26.7%), and University indirect costs (26% off campus rate) are included in the budget for the Masters student. Dr. John Horne's salary, health benefits (22.7%), and University indirect costs (26% off campus rate) are included in the budget. All University of Washington (UW) funds will be routed through the NOAA-UW's Joint Institute for the Study of the Atmosphere and Ocean (JISAO).

Travel costs for trips to conferences are next highest budget costs at $8,100.00 or 5.1% of total project costs. The Masters student will be required to present their methodology and results at a nationally or internationally recognized scientific conference. The PIs will make two presentations at internationally recognized scientific conferences. Presentations at scientific conferences not only allow the dissemination of scientific findings but also allow a thorough review of methodology by a wide variety of scientific experts knowledgeable in the field.

Costs for supplies are limited to a computer to be used by the Masters student ($2,200), two 1TB external hard drives ($240.00) which will be used to store data locally, and license for the Echoview HCM for two years ($6,440.00). The PI Steven Barbeaux currently holds an Echoview base license funded separately which will be used by the Masters student for this project. This limits costs for this project for software to the HCM.

The remaining budget item is publishing costs for the expected five peer reviewed journal articles estimated at $800.00 on average for each for a total of $4,000.00. This is expected to pay page costs and color graphics charges. This number is based on previous publication costs experienced by the PIs.

Assessment Author Recommendation – Dr. Steven Jon Barbeaux

I am the Principal Investigator on this study and a stock assessment author for Aleutian Islands walleye pollock (*Gadus chalcogrammus*) and Bering Sea and Aleutian Islands Greenland turbot (*Reinhardtius hippoglossoides*) stocks. This project was developed in response to my evaluation of the deficiencies in the Aleutian Islands (AI) bottom trawl survey design that I witnessed as a participant in the 2014 summer bottom trawl survey. Currently the point estimates of abundance for AI species derived from area swept extrapolations are likely biased, the degree of which depending on the habitat preference of the assessed species. Further, abundance estimates based on area swept extrapolations to strata are likely less precise than currently calculated because current strata delineations do not take into account patchy distributions of species in response to the high variability in AI habitat types. Many of our AI species are managed as Tier 5 or Tier 3. Tier 5 management assumes that the AI summer bottom trawl survey provides an absolute abundance estimate with an availability and catchability of 1.0, and not simply an index of abundance. Tier 3 management which relies on an age or length based model can treat the survey as an index of abundance with selectivity and availability different from 1, but is reliant on an accurate assessment of survey variance to determine model fit.

The first step in understanding the degree to which patchiness of habitat types affects survey estimates will be to classify and map AI habitats. The AI fisheries management region is remote and covers an immense area (1.0 million km^2) and submersible and towed underwater cameras can only cover small areas, leaving large parts of the region unclassified. Further because the AI bottom bathymetry is highly fragmented, fine resolution surveys are required to adequately characterize the bathymetry and bottom type. It is therefore necessary to investigate alternative means of classifying AI habitat diversity. The proposed project relies on data that has already been collected and will continue to be collected biennially during each AI bottom trawl survey. It is therefore potentially a low-cost alternative for developing a high resolution map of habitat types throughout the AI region. Once these habitat maps have been developed, if models can be developed to better quantify species biomass and variability with good predictive capabilities, then our assessment models, both Tier 5 and Tier 3, will be greatly improved for the AI region through the improvement of biomass indices. This project is well designed to accomplish these objectives.

The project team members are recognized experts at the top of their field and well suited to successfully carry out this project. Steve Barbeaux is a lead stock assessment author for AI species and has multiple publications on the use of acoustic data from commercial fishing vessels. Dr. John Horne is a renowned expert in the field of acoustics and has successfully managed several PhD and Masters students on acoustic related projects. Dr. Chris Rooper is a published expert on the use of submarine video, side-scan sonar, and multi-beam acoustic data specifically from the Aleutian Islands area and habitat classification. Paul von Szalay has published on seabed classification using single beam acoustic data and has been a field party chief on Gulf of Alaska and AI bottom trawl surveys since 2002 and therefore an expert on the data and techniques to be used in this project.