Project Title: Evaluation of a bottom-moored echosounder array to provide a survey-comparable index of abundance: An alternative approach to NOAA ship-based acoustic surveys

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Overview: Evaluation of a bottom-moored echosounder array to provide a survey-comparable index of abundance: An alternative approach to NOAA ship-based acoustic surveys

Acoustic-trawl (AT) surveys provide critical input to stock assessment models and other management needs throughout NOAA. Researchers at AFSC, for example, provide AT survey estimates of the pre-spawning pollock biomass as well as indices of age-1 year class strength for use in the Gulf of Alaska (GOA) pollock stock assessment. There is a recognized need within the Agency and industry to develop innovative means to efficiently monitor the abundance of commercially important fishes.

Technological developments have reduced the cost and increased the endurance of autonomous (i.e., self-contained, moored) echosounders. Although these instruments have proven to be effective tools for studies of behavior, the development of more quantitative autonomous echosounders is needed to achieve the accuracy in abundance estimates required for stock assessment. Methods development is also needed to critically evaluate the number and the geographical placement of the moored echosounders necessary to provide a useful abundance index estimate over the area of interest (e.g., traditional AT survey area), given the target species local spatio-temporal patterns.

In a retrospective analysis, we have found that as few as three bottom-moored echosounders can provide an index of abundance comparable to that produced by an annual acoustic-trawl (AT) survey conducted for stock assessment purposes. We are thus developing a new trawl-resistant echosounder mooring package with funding from a NOAA Office of Science and Technology grant which will make autonomous measurements of pollock abundance that are equivalent to those made on AT surveys. The primary uncertainty in the moored echo-sounder approach is knowledge of the spatial-equivalent or spatial-representativeness of the mooring data, which is needed to design a mooring array (i.e., appropriate number and placement of moorings) capable of providing information suitable for stock assessments.

We are requesting funds here to partially support a field experiment (e.g., charter a commercial fishing vessel) to evaluate the use of the three newly-developed bottom-moored echosounder packages to provide a comparable abundance index to that produced by an annual AT survey conducted with a NOAA vessel. If successful, the moored echosounder approach will reduce the frequency that the AT vessel survey would need to be conducted. We anticipate that the moored echosounder approach could ultimately make NOAA ships available for other research and survey priorities. Additionally, this mooring assessment sampling approach could ultimately be implemented with industry vessels to produce abundance index estimates in other areas, which are currently under sampled.

Research Description:

Objectives of the work: The major outstanding question regarding the utility of moored echosounders for abundance estimation is the degree to which temporally averaged measurements from stationary instruments represent the density of fishes over a wider area. Specifically, stationary echosounders provide high temporal resolution at a single point in space compared to ship-based surveys, and the time-averaged measurements of fish movements past or around a stationary sensor represent the abundance over a broader area than the relatively small sampling volume of the stationary instrument. Thus, the primary objective of the proposed work is to establish the relationship (and associated uncertainty) between temporal averaging of the stationary measurements and the areal size of the local fish density estimates that the averaging represents. The GOA Shelikof Strait pre-spawning walleye pollock AT survey will be the test bed for the proposed work. The extensive annual survey data time series facilitates a retrospective analysis to initiate a mooring array design. Additionally, the importance of the survey to the GOA pollock stock assessment makes this survey ideally suited for the study as described in the next section.

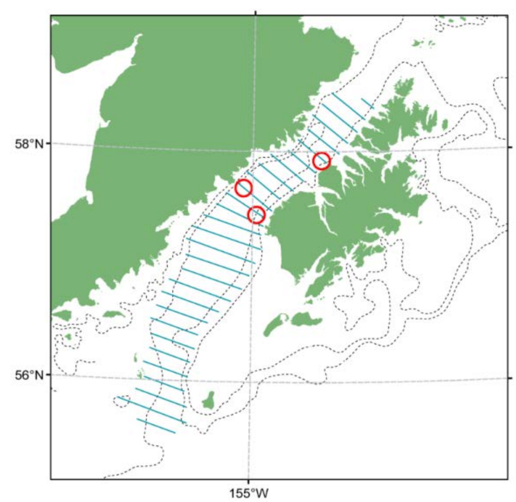

Fig. 1. Study area showing acoustic survey trackline and location of 3 proposed mooring sites at ~275 m bottom depths. The insert shows a typical pollock backscatter pattern observed in Shelikof Strait pre-spawning surveys.

*Technical approach, expected results and probability of success***:** We propose to deploy 3 trawl-resistant bottom moorings with upward-directed echosounders to generate a pollock index of abundance in Shelikof Strait during the spring spawning season (Fig. 1). The mooring locations were determined based on an analytical method we developed to optimize placements of moored echosounders by retrospective analysis of the AT survey data. This analysis consisted of gridding the survey area into 7×7 km blocks, and computing the mean backscatter within the block for surveys spanning 2003 to 2012 (data were readily available for this period). Backscatter values were normalized by dividing by the total backscatter within each survey year to prevent high abundance years from disproportionately influencing the spatial analysis. Blocks with consistently high abundance in the time series were identified by ranking them based on the among-survey mean divided by the among-survey standard deviation for each block. A time series based on AT survey data since 2003 from only the top 3 ranked blocks (locations in Fig. 1) was remarkably similar to the total AT survey estimates of pre-spawning pollock in Shelikof Strait (Fig. 2). About 94% of the variance in the AT survey time series would be captured by moorings in these 3 locations, assuming that the proposed mooring time-averaged data (e.g. over days to weeks) contained equivalent information as the length of AT track line contained with each block (~ 20 km; Fig. 2). Even if the equivalent content of the mooring were only 1 km of AT survey data (i.e., the closest 1 km to the mooring site is averaged rather than the 20 km in Fig. 2), ~ 50% of the variance is still explained.

The proposed work will essentially answer whether an actual mooring measurement is comparable to 1 km, 20 km, or some other amount of AT survey trackline. To determine the spatial sampling dimension of a moored echosounder in this environment, small-scale acoustic surveys will be repeated in the area of each mooring during the February-April spawning season. The April survey work will be conducted with a commercial vessel (see below).

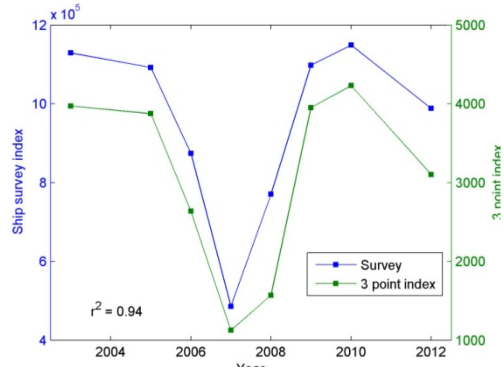

Fig. 2. Abundance indices from acoustic survey and three optimally chosen 7×7 km locations within the survey area, shown with circles in Fig. 1. Each location represents ~ 20 km of acoustic survey trackline.

Instrumentation: We examined existing echosounder designs, and concluded that there are no commercially available autonomous instruments suitable for collecting the high-quality data needed for generating estimates of fish biomass. Thus, we are developing an autonomous echosounder (and deployment package – see below) with NOAA Office of Science and Technology funds. The echosounder will be developed in collaboration with Simrad, the manufacturer whose scientific echosounders are used in most NMFS acoustic stock assessment work. The echosounder will be a high-quality, low-power, autonomous 70 kHz split-beam echosounder equipped with a relatively pressure insensitive transducer.

In Shelikof Strait, and other areas where fish stock assessments surveys are conducted, there is an active fishery. To minimize the probability of adverse impacts from the trawl fleet, the autonomous echosounder will be placed into a trawl-resistant bottom mooring equipped with an acoustic release, floatation, and a transducer dual-axis gimbal (Fig. 3). These low-profile packages will be lowered to the seafloor and released to ensure that they are deployed in the right orientation at a known location. To further minimize mooring damage or disturbance by commercial fishing operations, we will distribute a NOAA News Release to the commercial fishing industry through the Alaska NMFS Regional Office describing the project and mooring locations as well as provide this information during our AT survey briefings with industry representatives and the public.

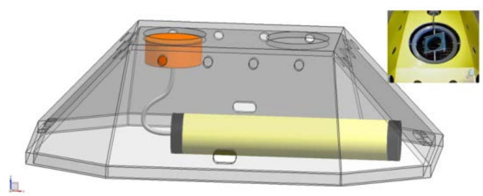

Figure 3. Trawl resistant mooring with installed echosounder. The transducer will be mounted in a gimbal similar to that shown (inset).

Field deployments and expected results: The three moorings will be deployed in February 2015 using the NOAA ship *Oscar Dyson* and recovered with a chartered fishing vessel 2.5 months later in mid April when the *Dyson* is unavailable for this project. Four small-scale (~8 h) acoustic-trawl surveys will be conducted in the vicinity of each mooring (*Dyson* Feb, Mar, Mar; *Charter* Apr).

From the backscatter measurements, we will compute the standardized mean error of mooring-based predictions of AT survey backscatter ($MPE_{S,T}$) as a function of how large an area of the AT survey is aggregated (S, i.e., km^2 surveyed), and duration (length of time) the mooring data are averaged (±T around ship survey), $MPE_{S,T} = \left|\left(\frac{AT_S - Mooring_T}{AT_S}\right)\right|$. The estimates of the prediction error as a function of spatial and temporal averaging, will allow us to incorporate the errors into our analysis (e.g., Fig. 2) by recomputing the retrospective analysis with bootstrap error estimates parameterized based on the mean prediction error from the surveys. We anticipate maximum agreement between the AT and mooring survey at 10s of km^2 with moderate temporal averaging of the mooring data (i.e., days to weeks, Fig. 4). We will determine the optimal averaging window (i.e., the minimum in Fig. 4) and use this information with realistic MPE estimates to refine the array design (i.e. number, placement) of moored echosounders to generate a pollock abundance index (Fig. 2).

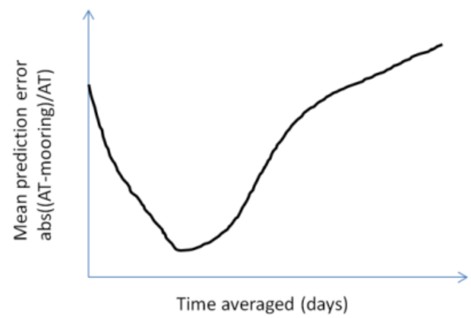

Figure 4. Hypothetical error in mooring and acoustic survey measurements. The lowest errors are predicted when the mooring is averaged over intermediate time scales (i.e., averaging over time is equivalent averaging over space to some degree due to fish movement over the stationary moored echosounder).

In addition to the spatial comparisons, we will conduct an analysis on the increase and decline of pollock abundance at the index sites over the spawning season in Shelikof Strait. This will help us understand how the timing in the formation, duration, and dispersal of pollock spawning aggregations impacts biomass estimates. This will also provide baseline information useful for designing additional experiments similar to those conducted on other species to evaluate impacts of spawning behavior on survey estimates of abundance. Survey timing has been demonstrated to be the major source of uncertainty in some surveys of spawning fish, and optimizing survey timing may be difficult because spawning timing can be variable. Repeated survey passes in Shelikof Strait, for example, have revealed that the pollock abundance and distribution can change substantially over ~2 weeks during the spawning period. Analysis of the time series from the autonomous echosounders will allow us to describe the temporal variability at the index sites, which can then be used to evaluate the effects of survey timing in the context of an overall survey error budget.

<u>*Anticipated probability of success*</u>: Shelikof Strait is well-suited for autonomous acoustic measurements as the backscatter is relatively homogenous, and backscatter is dominated by walleye pollock, so species identification is not a major concern. Our retrospective analysis suggests that only a few moorings will be needed to generate a pollock abundance index comparable to that generated by the acoustic-trawl survey for the GOA pollock stock assessment in this environment (Fig. 2). The results from our proposed work to evaluate the spatial extent of the mooring measurements will provide a definitive

answer for the location and number of the moorings that are needed. There is a clear pathway for using the results of this study to inform future stock assessments as the PI's conduct abundance surveys and stock assessments for GOA pollock. A presentation of this work to Kodiak fishing industry in spring 2013 resulted in substantial interest and support for this approach from industry representatives (see attached Alaska Groundfish Data Bank letter of support).

The technical challenges of our proposed work are minimal. Simrad has a proven track record of producing high quality acoustic systems, which are widely used by fisheries acousticians internationally and within NOAA. Trawl-resistant bottom moorings (e.g., Mooring Systems, Inc.) are commonly used for ADCP deployments, and we have been assured by MSI engineers that their use with echosounders should be straightforward. Expected products from the proposed work will facilitate the pathway for implementation to other areas/fisheries where moored echosounders can potentially be used in place of ship-based surveys. Products will include a scientific paper describing the methodology for mooring site selection, and the estimation of uncertainty in an abundance index as a function of number of moorings.

Performance Indicators:

This project has the potential to develop an innovative and efficient method to use autonomous echosounders to augment traditional ship-based acoustic surveys to assess aggregations of fish or other organisms in a wide variety of situations. Our particular application focuses on walleye pollock that periodically concentrate in a restricted part of their habitat for spawning purposes. Given that many other species aggregate in predictable and restricted parts of their habitat, other situations likely exist where an autonomous echosounder approach could be used to augment ship-based assessment surveys. In essence, the proposed work will establish a quantitative method to 1) determine the spatial sampling dimension of a moored echosounder, and 2) provide an estimate of uncertainty in the abundance index as a function of number of moorings.

The expansion of our proposed mooring sampling strategy into other areas can also serve as a gauge of the performance or value of this new method. We envision that this mooring approach can ultimately be employed in other AFSC survey areas including the Bering Sea (e.g., Bogoslof), and particularly the GOA (e.g., Kenai Bays, Prince William Sound) where substantial quantities of pre-spawning pollock have recently (i.e., 2010) been detected during GOA AT surveys. Because NOAA vessel time is unavailable to conduct annual AT surveys in these GOA areas, a moored echosounder approach similar to that proposed for the Shelikof Strait area, could potentially be implemented in these areas to describe the temporal patterns in the pollock spawning dynamics, and to generate pre-spawning abundance indices suitable for stock assessment needs. Commercial fishing vessels could easily be used to evaluate the feasibility of the approach in these areas, and subsequently, to routinely implement the moored echosounder approach.

Task	2014	2015
Trawl-Resistant Bottom Mooring (TRBM) field tests (Washington)	Sept	
TRBM and autonomous echosounder field tests (Washington)	Dec	Jan

Deploy moorings, small-scale *Oscar Dyson* surveys (n =3/mooring)		Feb-Mar
Recover moorings, small-scale *charter vessel* survey (n=1/mooring)		Apr
Data analysis, production of final report		Dec

Deliverables:

1) Standard sphere calibration of chartered fishing vessel
2) Development of methodology to establish the potential suitability of a moored approach based on retrospective analysis of surveys (i.e., Methods to guide mooring area(s) selection, and development of uncertainty estimate based on historical survey data).
3) Quantification of uncertainty in spawning surveys due to survey timing, which is often poorly known.
4) Scientific publication describing items 1 and 2.
5) Presentation of the results of this study at GOA pollock Plan Team meeting.
6) Community outreach post-survey presentation of study results to public and fishing industry representatives in Kodiak.

V. Budget and Justification:

Item	**unit price**	**units**	**Cost**
2 day vessel charter (Seattle)	1500	2	3000
6-day charter vessel(Kodiak)	9500	6	66500
Shipping (to/from Kodiak, Alaska field location)	3000	1	3000
Travel for PIs to charter vessel	2500	3	7500
Overtime for field crew	1000	3	3000
3 Radio beacons for moorings and 1 radio direction finder	10000	1	10000
Field supplies (echosounder/acoustic release battery packs, release links)	6500	1	6500
Total			99500

The majority of the requested funds will be dedicated to conducting the initial field tests in Seattle, and the final “mooring recovery” phase of the Shelikof field experiment (i.e., final 6-day mini-AT April survey, mooring recoveries) with a chartered industry vessel. The 2-day charter of a small vessel in Seattle is for initial equipment testing in Lake Washington and Puget Sound. Although the moorings will be deployed and visited on 3 occasions during traditional AT *Oscar Dyson* surveys, the charter is required as the *Dyson* will be unavailable to recover the mooring in April 2015. Development of the mooring packages (echosounders, acoustic releases, trawl-resistant bottom-mounts) is funded by the Office of Science and Technology, although we are requesting funds for consumables used during the testing and Alaska deployment cruises (e.g. release links, battery packs for the moored devices) and 3 submersible Novatech radio beacons with a handheld radio direction finder to locate the moorings at the sea surface during recovery.

Alaska Groundfish Data Bank

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AGDB Statement of Support: Shelikof Echosounder Project

July 25, 2013

To: Doug DeMaster
Re: Cooperative Research: AGDB statement of support MACE Shelikof Strait echosounder project

Alaska Groundfish Data Bank, Inc. (AGDB) is a trade organization comprised of Gulf of Alaska shoreside trawlers and processors. My company, AGDB, and its members advocate sound scientific research essential for proper management of our fisheries. AGDB as it members heartily support the proposed AFSC bottom-mounted echosounder project planned for March-April 2015 in Shelikof Strait by MACE Program staff.

During a briefing in Kodiak to members of the fishing industry in March 2013, Chris Wilson presented the idea (with copies of original proposal) for using upward-looking bottom-mounted echosounders to produce pollock abundance estimates under certain situations (e.g., areas where/when spawning pollock aggregate) in the Gulf of Alaska. Chris made the argument that these moored sounders could likely provide spawning pollock abundance estimates which would be comparable to the traditional survey estimates generated using the *Dyson*. He and his co-workers hoped to get funds to conduct an experiment during March-April 2015 in Shelikof Strait to compare spawning pollock abundances between the mooring array and the standard *Dyson* survey estimate. If these two methods provide similar estimates, the *Dyson* would not need to conduct the Shelikof spawning pollock survey each year but could conduct other important survey work with the available (and valuable) ship time. For example, during the March meeting, we had discussed the possibility of using the *Dyson* to survey other areas within the GOA where substantial pollock spawning aggregations have been found (e.g., Prince William Sound, Kenai Bays, Shelf break).

I understand from Chris that he and his colleagues received funding for their first proposal (NOAA Advanced Sampling Technology), and are submitting a second proposal for NOAA Cooperative Research funds to mainly cover the cost of chartering a fishing vessel to complete the proposed Shelikof fieldwork described above. We strongly encourage that NOAA support this innovative work to help make the most efficient use of NOAA resources such as the *Dyson* for addressing stock assessment needs in the GOA.

We look forward to seeing this project advance and are willing to help out in any way we can.

Sincerely,

Julie Bonney
Executive Director,
Alaska Groundfish Data Bank, Inc.