Project Title: Use of bottom-moored echosounders and commercial fishing vessels to improve spawning stock surveys: walleye pollock in Sanak Trough, Gulf of Alaska

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Background and Justification: Acoustic-trawl (AT) surveys provide critical input to stock assessment models and other management needs throughout NOAA. Researchers at AFSC, for example, have provided AT survey estimates of the pre-spawning pollock biomass for over three decades for use in the Gulf of Alaska (GOA) pollock stock assessment (Dorn et al. 2014). Survey timing is critical for spawning stock surveys as it can be the largest source of uncertainty in the abundance estimates (O'Driscoll 2004). It is essential that the surveys are timed to coincide with peak spawning so that survey-based abundance estimates represent the total numbers of spawning fish for the area and not some fraction of the total. The time of peak spawning can be estimated by conducting multiple survey passes over the duration of the spawning season, but this is extremely costly, and is often not possible due to vessel scheduling conflicts.

A better approach to obtain peak spawning information is now possible using recently developed autonomous echosounder technology. That is, trawl-resistant bottom moorings with next-generation upward-directed echosounders (TRBM) can be deployed on the spawning grounds over the entire spawning season to develop a time-series of spawner abundance indices to identify the time of peak spawning. Previous fieldwork has demonstrated that the moorings can be easily and cost-effectively deployed and recovered from small commercial fishing vessels (Fig. 1). The mooring data can provide invaluable information on spawning pollock distribution and abundance. For example, an array of 3 TRBMs successfully collected data over the entire 2015 pollock spawning season in Shelikof Strait in the GOA. The moorings were deployed in the southern, middle, and northern Strait areas (Fig. 2). Time-series plots of the mooring backscatter suggested a northward migration of pre-spawning fish into the Strait based on the relative increase in pollock backscatter at the middle mooring, which was quickly followed by a rapid increase in backscatter at the north mooring as the fish entered and formed pre-spawning

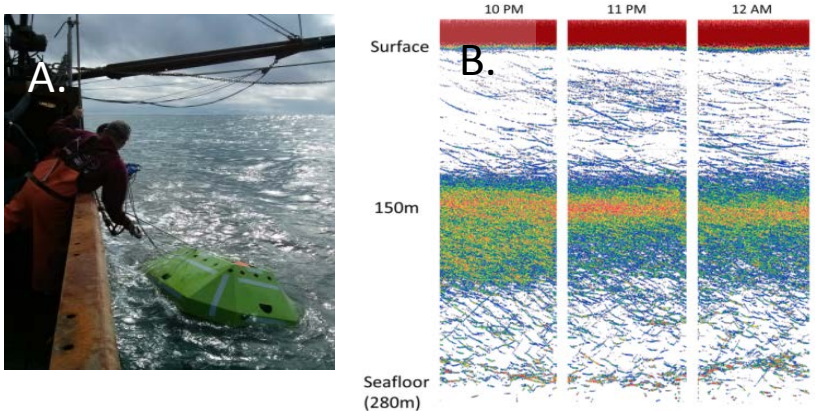

Figure 1. Moored echosounder technology to be used in this project. A) Recovery of trawl-resistant mooring from a fishing vessel. B) Echograms of pre-spawning pollock aggregations observed in Shelikof Strait with the moored echosounder.

aggregations in the Strait. This was followed by a southward-directed emigration of post-spawning fish from the Strait in early April as documented by the increase in pollock backscatter at the south mooring and decline in backscatter at the other moorings. These data allow one to conclude that timing of peak spawning occurs over several weeks in mid-March.

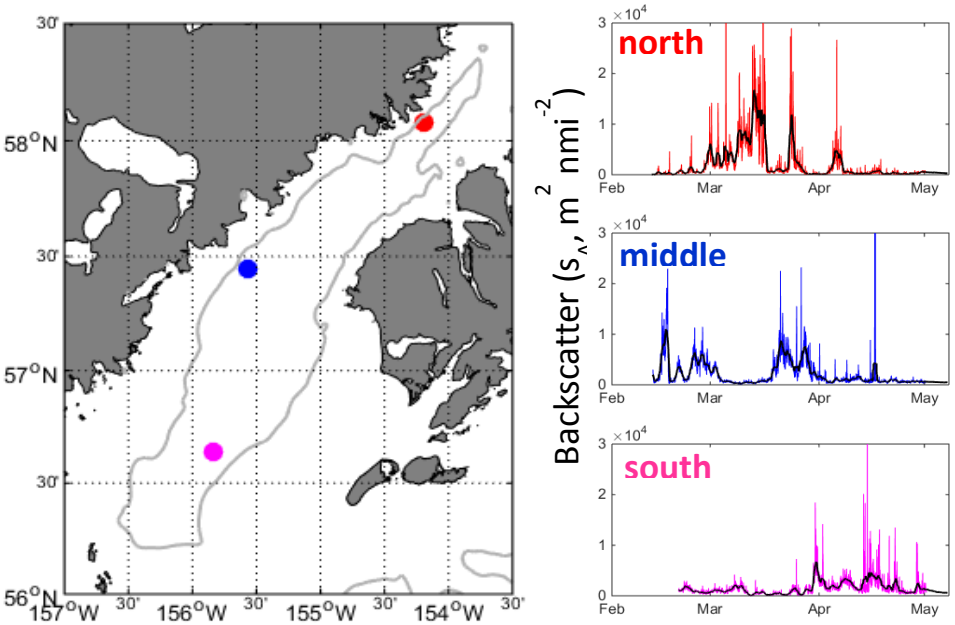

Figure 2. Map of Shelikof Strait showing locations of the three echosounder moorings and 200 m bottom contour (left panel), and mooring time series of pollock backscatter from each mooring (right panel). The hourly backscatter data are plotted with a 1-day moving average shown in black. These results show that pre-spawning pollock have moved into the Strait proper (i.e., middle and north moorings) during March, and thus a ship-based spawning stock survey of the area would be appropriate within this time period. The mooring data in April suggest emigration of post-spawning fish from the Strait proper based on the relative increase in abundance at the south mooring and the decreasing abundance at the north and middle moorings. A shoaling in the pollock vertical distribution (not shown) in April compared to Feb-March is also indicative of post-spawning pollock.

Additional insights into the spatio-temporal aspects of the spawning process are also possible with the mooring data. For example, a time-series of pollock vertical distribution patterns can be generated over the spawning season. Based on earlier survey work, post-spawning pollock are generally found shallower in the water column than pre-spawners, and this information can be used to help confirm that the relatively shallow pollock backscatter detected at the south mooring in April represents emigration of post-spawners from Shelikof Strait (along with the very low backscatter levels at the other moorings). We are also characterizing the swimming behavior of individual fish detected in the beam, which suggests that fish at the middle mooring in late Feb - early March exhibit relatively rapid, directed movements, unlike the fish observed at the north mooring in late March, which exhibit less directed and reduced speeds typical of undirected milling behavior. These patterns may be indicative of fish moving to the north Strait area to spawn. It may be possible to use these types of small-scale pre-

spawning fish movement patterns to predict when spawning may actually occur, and thus align ship-based surveys more closely with the timing of peak spawning.

A similar mooring-based project is proposed here to determine the time of peak spawning of walleye pollock in Sanak Trough in the Gulf of Alaska. Sanak Trough, which is located about 90 nmi west of the Shumagin Islands has been surveyed annually by AFSC using the NOAA ship, *Oscar Dyson* since 2003 (Fig. 3). The abundance estimates are currently used in the assessment to regionally apportion the total GOA pollock quota. Plans are also being considered to use the Sanak time-series as a tuning index for the GOA assessment. Spawning pollock abundance estimates from the acoustic-trawl (AT) surveys in Sanak have ranged from 7,000 to 127,000 tons. However, there are problems with the estimates. Pollock typically spawn much earlier in Sanak than in the Shumagin Islands, yet the survey of this area is timed to coincide with peak spawning of fish in the Shumagins (Feb) and not Sanak. This mismatch between the timing of peak spawning of Sanak pollock and the survey exists primarily for two reasons. More fish are thought to spawn in the vicinity of the Shumagin Islands so this survey timing takes precedence over Sanak and secondly, the time of Sanak peak spawning consistently occurs at some time well before the NOAA survey vessel is available at the beginning of the year. The specific time of peak spawning for Sanak is unknown.

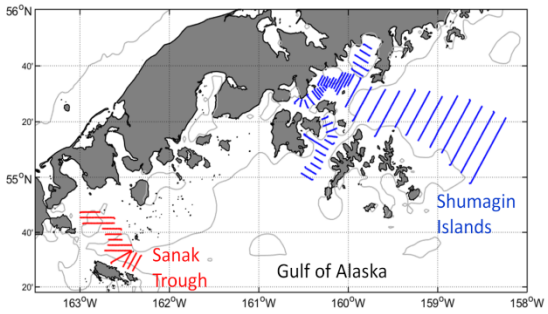

Figure 3. Map of study area with AT survey transects in Sanak Trough (red) and transects in the Shumagin Islands (blue). Sanak Trough is surveyed after peak spawning occurs.

The relative proportion of pre-spawning females in later stages of gonad maturity (Williams, 2007) is currently used as indirect evidence for assessing the timing of peak spawning. The 1994 Shelikof AT survey revealed that pollock biomass declined as the proportion of adult females in the spawning and spent stages of maturity increased (Wilson 1994). This suggested that substantial emigration of adults from the surveyed area occurred soon after peak spawning and could potentially result in a negative bias to the abundance estimate. In practice, when the proportion of adult females in the spawning/spent stage of maturity is less than ~10%, survey timing is considered appropriate to assess the spawning stock. The mean proportion (range) of adult females in the spawning/spent stage of maturity for Sanak was 35% (range 13-65%) compared to 9% for Shumagin (2-28%) for surveys since 2003. Because the time of Sanak peak spawning consistently occurs well before the Shumagin survey, we propose to deploy TRBM echosounders in Sanak Trough over the entire suspected spawning season. The TRBM data will be used to develop a time-series of spawner abundance to identify the time of peak spawning in Sanak and thus determine optimal survey timing and potentially correct the February *Oscar Dyson* AT survey-based pollock abundance estimates for Sanak.

Methodology: The major objective of this proposal is to quantify the timing of the pollock spawning migration into and out of Sanak Trough, Alaska. We propose to use long-term continuous acoustic measurements from stationary bottom moored echosounders in conjunction with 3 acoustic surveys (in December, February, May) to quantify changes in pollock abundance, distribution, and behavior in this spawning area. Stationary echosounders are ideal for this application as they provide high temporal resolution compared to ship-based surveys at low cost. This information will be used to 1) provide recommendations for the optimal time to conduct this survey, 2) evaluate the potential errors introduced into the Sanak Trough AT survey due to imperfect survey timing, and 3) provide adjustment for bias introduced if the Sanak AT survey is not conducted during the time of peak spawning.

Approach: We propose to deploy two trawl-resistant bottom moorings equipped with upward-directed echosounders to generate an index of pollock abundance in Sanak Trough during the winter 2017 spawning season. The moorings will be deployed in November well before spawning begins and will be recovered in May, well after spawning has ended. The acoustic observations from the moorings will be supplemented with an AT survey conducted during each expedition: the mooring deployment (November), the annual *Dyson* AT survey (February), and the mooring recovery (May). Earlier work comparing ship-based AT surveys and mooring observations in Shelikof Strait has shown that the time-averaged mooring information represents pollock abundance over a much broader area than the relatively small sampling volume of the stationary instrument.

The mooring locations will be determined by a retrospective analysis of the 2003-2015 Sanak AT survey data. This analysis will consist of gridding the survey area into 5×5 km blocks, and computing the mean backscatter within the block for surveys. We will partition the survey data into two geographic strata, and will identify potential mooring locations in each stratum by selecting locations with higher-than-average abundance as well as consistent pollock abundance (i.e., low variance-to-mean ratio). Several candidate sites for mooring locations will be selected in this manner. Final selections will be made based on input from our fishing industry partners (i.e., selection of suitable locations and risk to the mooring from trawling activity). This approach will optimize mooring placement, as the moorings will be spatially separated in areas of consistently high pollock abundance, and will incorporate industry expertise of the study area.

Instrumentation: In collaboration with Kongsberg Underwater Technology, we have developed and tested a new high-performance autonomous echosounder that is equivalent to the echosounders used on NOAA AT surveys (and the TRBM deployment package – used in the Shelikof 2015 fieldwork described below). The moorings will be deployed in areas with an active trawl fishery. To minimize the probability of damage or disturbance by trawls, the autonomous echosounder will be placed into a trawl-resistant bottom mooring package equipped with an acoustic release, floatation, and a dual-axis transducer gimbal (Fig. 1). A passive acoustic recorder may be incorporated into the mooring, based on results of a 2015 pollock vocalization study to investigate whether pollock

vocalizations occur in spawning aggregations as this may offer a complementary method to develop an index of spawning activity.

The moorings will be lowered to near the seafloor and then released to ensure that they are deployed at the selected location. A magnetometer will determine the orientation of the transducer on the seafloor so that the movement of fishes observed in the acoustic beam can be determined relative to earth coordinates.

The three ship-based AT surveys conducted as part of this study will follow the same survey track and use the standard methods of the annual AT surveys (McCarthy 2015, NMFS 2013) to ensure that the results are directly comparable. The NOAA ship *Oscar Dyson*, which is used for virtually all AFSC AT survey work, will not be available for the mooring deployment and recovery work, so a commercial trawler with a split-beam 38 kHz echosounder will be chartered to conduct the AT survey and mooring work in November and May.

Field deployments and expected results: The mooring system will be deployed in November 2016 and recovered in May 2017 with a chartered commercial vessel. We will leverage the captain's fishing experience to streamline the mooring deployment and recovery process. Three full-scale Sanak AT surveys will be conducted while the moorings are deployed (Nov - *Charter;* Feb - *Dyson*; May - Charter). Small-scale (~8 h) AT surveys (i.e. acoustic measurements and trawl hauls) will also be conducted in the vicinity of the mooring sites during each visit.

The increase and decline of pollock abundance at the index sites will be estimated from the mooring data over the spawning season in Sanak Trough. This will provide an understanding of the formation, duration, and dispersal of pollock spawning aggregations, and how survey timing impacts ship-based survey biomass estimates in this area. We will compare the results of the AT surveys to those from the moorings to confirm that time-averaged mooring estimates provide an index of abundance in Sanak Trough as a whole. Efforts will be made to use the mooring-based time-series of abundance indices to adjust the potential bias in the Dyson-based (Feb) abundance estimate.

The behavior of pollock during the spawning season will also be characterized based on the mooring data. The split-beam echosounders allow the vertical distribution and schooling behavior of the fish to be studied. Individual fish can also be tracked through the acoustic beam to estimate their swimming velocity (speed, direction), and to make inferences on the direction of spawning migrations and other behavioral activities. For example, over 300,000 individual pollock were tracked for > 3 months at the Shelikof Strait north mooring (Fig. 2). These fish targets periodically displayed similar trajectories and other attributes over portions of the mooring time-series, which were consistent with migratory movements to and from the area. Trawl hauls conducted during the proposed study will also provide information such as pollock body size, sex and maturity state from three periods during the project (Nov, Feb, May) to help in interpreting the mooring data.

This work will 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 (O'Driscoll 2014), 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 a ~2 week period during the spawning period (Wilson, 1994)

Anticipated probability of success: Sanak Trough is well-suited for autonomous acoustic measurements as pollock dominates the backscatter, so species identification is not a major concern (e.g., pollock accounted for an average of 94.8 % of trawl catch weight since 2007). The results from the proposed work will lead to clear recommendations to improve AT survey timing, and will provide an indication of the biases introduced by survey timing in this area. The PIs have substantial experience with AT surveys and innovative sampling technologies including moored echosounders.

The 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 to establish the appropriate timing of AT surveys for fisheries management. The products will include: 1) a scientific paper describing the formation and dispersal of spawning aggregations of walleye pollock in Sanak Trough, 2) guidance for appropriate timing for an established NOAA AT survey of Sanak for use in the stock assessment, and 3) an estimate to adjust the bias that may be introduced to the Dyson-based AT survey abundance estimate for Sanak, if the Sanak AT survey continues to be conducted at the time considered appropriate for conducting the Shumagin AT survey (as is current practice).

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. However, many other species aggregate in predictable and restricted parts of their habitat (e.g. Atlantic herring, reef fishes), and an autonomous echosounder approach could be used in those situations to augment ship-based assessment surveys. The techniques developed in this study could potentially be implemented in many other areas in Alaska and elsewhere to describe the temporal dynamics of fish aggregations.

Industry participation in this proposal: This proposal involves significant collaboration with central Gulf of Alaska fishing industry, and fisheries managers. We have contacted the Peninsula Fishermen's Coalition (PFC), an industry association to discuss the merits of the proposed work with them and have received their strong support (see attached letter). We also contacted fishing industry representatives to help identify trawlers and vessel owner/operators in Sand Point, Shumagin Islands who would be suitable for this work. Vessels were identified that have appropriate trawling and

acoustics equipment (Simrad ES60). Knowledgeable vessel operators were also identified who currently work both in the Shumagins and Sanak areas in the winter and have collaborated on AFSC fisheries projects in the past. These individuals can provide valuable advice on potential mooring site selections, and implement methods to safely and quickly deploy and recover the moorings from commercial fishing vessels, based on referrals from AFSC researchers who have worked with them on previous charters.

There is a clear pathway for results of the proposed study to benefit the GOA pollock stock assessment process. This is evident by the fact that the lead assessment author for GOA pollock (M. Dorn) is also a co-PI on this proposal. Dorn was successfully funded to conduct AT surveys to assess pre-spawning pollock in Sanak in the past. However, logistical challenges prevented his survey from taking place at the appropriate time during the spawning season.

It is noteworthy that similar mooring work in Shelikof Strait in 2015 has been well received by fishing industry representatives and the public in Kodiak during two community outreach presentations. The Shelikof work has also been recently featured as a NOAA press release and in an industry trade magazine (Press, 2015) based on its potential value to NOAA and the fishing industry.

We continue to reach out to industry to keep them informed of our activities. If funded, we will provide 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 and the public. We will also present the results of this work to the GOA pollock Plan Team and as a public outreach briefing in Sand Point, Shumagins.

Deliverables:

1) Metadata delivered to NMFS Data catalog and Metadata Repository
2) Analysis of acoustic-trawl surveys (Dec. 2016, March and May 2017) and documentation of biomass estimates.
3) Analysis of moored echosounder acoustic abundance time series.
4) Quantification of uncertainty in spawning surveys in Sanak Trough due to survey timing, formulation of recommendations for optimal survey timing, and adjustment for survey timing bias in the abundance estimate.
5) Scientific publication describing items 3 and 4.
6) Presentation of the results of this study at the GOA pollock Plan Team meeting.
7) Community outreach post-survey presentation of study results to public and industry representatives in Sand Point, Shumagins.

Budget and Justification:

Item	unit price	units	Total cost
5-day vessel charter (mooring deployment/AT survey)	7000	5	35000
5-day vessel charter (mooring recovery/AT survey)	7000	5	35000

Shipping (to/from Sand Point, Alaska field location)	3500	2	7000
Travel for PIs to charter vessel	3000	4	12000
Overtime for field crew	1500	4	6000
Field supplies (e.g., echosounder/acoustic release battery packs, release links, mooring anchors)	10000	2	20000
Acoustic release transponder deck unit	9000	1	9000
Outreach presentation Sand Point, Shumagins	2500	1	2500
Echoview tracking, maintenance module cost	950	1	950
Total			127,450

The majority of the requested funds will be dedicated to contracting vessels to deploy and recover the moorings and conduct acoustic-trawl surveys in Sanak Trough. Two 5- day vessel charters on a commercial fishing vessel are requested to deploy the moorings in December 2016 and recover them in May 2017. Funds are requested for AFSC scientists to participate on these surveys and ship gear to and from the field location. We also request funds to assemble the moorings (floatation, drop weights, hardware). Funds are needed to purchase a transponder to release the moorings from the charter vessel and service the acoustic releases and purchase consumables used during the deployments and testing cruises (e.g. release links, battery packs for the moored devices), and for licensing costs of the Echoview tracking software needed for the project.

This proposal leverages substantial resources and knowledge in the development and operation of the TRBM autonomous echosounder instrumentation at AFSC. Development of the mooring packages (echosounders, acoustic releases, trawl-resistant bottom-mounts), as well as the techniques to efficiently process these data has been largely funded by a previous grant from the OST Advanced Sampling Technology Working Group. The project will also benefit from customized software that has been developed at AFSC to post-process the TRBM echosounder data. The PIs will conduct the work at no cost to the proposal. Although charters are proposed for the first and third Sanak trips, the second trip when the moorings will be visited and the Sanak AT survey conducted during the annual *Oscar Dyson* AT survey of the Shumagin Islands and vicinity will occur at no cost to the project.

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