PROJECT TITLE: Seabed mapping to develop a habitat-based catchability function for the Bristol Bay red king crab (*Paralithodes camtschatica*) stock assessment $115K

INVESTIGATORS AND AFFILIATIONS:
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BACKGROUND: Stock assessment models use simplifying assumptions to account for complex and poorly understood phenomena, thereby introducing error into the fishery management process. For example, estimates of abundance are commonly based on bottom-trawl surveys where the catchability is assumed to be 1.0, meaning the entire population is sampled (availability) and all fish and crabs in the path of the net are captured (capture efficiency). However, catchability is often <1.0 due to escapement under the footrope or may exceed 1.0 due to horizontal herding (Dickson 1993). The common practice of using a single value of catchability for an entire survey compounds the estimation problem, if environmental factors cause significant spatial or temporal variability in survey-trawl performance (Weinberg *et al.* 2002; Dawe *et al.* 2010; Stewart *et al.* 2010; Wilderbuer *et al.* 2014). Biased and inconsistent data from the fishery-independent survey are used in the stock assessment, if these effects are not removed.

Crab populations support extremely valuable fisheries on the Alaska continental shelf, but are characterized by sizable fluctuations in abundance and occasional stock collapses (Orensanz *et al.* 1998; Dew and McConnaughey 2005). The NMFS assessment survey in the eastern Bering Sea (EBS) is a generalized bottom trawl survey that provides abundance and biomass estimates for crab, demersal and semi-demersal fish species alike, thus it is not optimized for assessment of crab. Management of the crab stocks is further complicated by estimates that are inherently imprecise because of the characteristic over-dispersion (aggregation) of individuals (Elliott 1977; Dew 1990; McConnaughey and Conquest 1993). Perhaps more importantly, field studies have shown that survey-trawl capture efficiency may be low and spatially variable. In particular, the overall catchability for EBS snow crab (*Chionoecetes opilio*) in the NMFS survey with an 83-112 trawl can be as low as 60% of that for an alternative net (*Nephrops* trawl; S. Goodman, unpub. data). Catchability also varies for different sexes and size classes according to sediment texture and depth (Somerton *et al.* 2013). The capture efficiency of the 83-112 reportedly decreases with depth and increases with grain size, likely due to differences in the height of the footrope above the substrate (Weinberg and Kotwicki 2008). To account for this effect, Somerton *et al.* (2013) modeled the 83-112 efficiency as a function of crab size, sex, depth, and sediment type. The model was used to predict efficiency at every station and the estimates were ultimately combined to produce a survey-catch weighted mean. This mean was used to construct Bayesian priors for the trawl survey, producing a 64% increase in the Over Fishing Limit (OFL) for snow crab (maximum survey selectivity estimated at 0.61; Turnock and Rugolo 2011).

In general, development of sediment-based catchability functions is limited by the availability of data collected with traditional (inefficient) point sampling gears, such as grabs and

corers. An alternative is to use acoustic methods to map and quantify seafloor properties, as was successfully done for EBS species-distribution models using backscatter from various sonar types (Yeung and McConnaughey 2008; McConnaughey and Syrjala 2009). These findings prompted a project to evaluate the use of single-beam-echosounder data to quantify seabed-related effects on survey-trawl performance and to develop new Bayesian priors for use in the EBS snow crab assessment models (**HAIP study #13-016, McConnaughey and Somerton**). Preliminary results indicate the acoustic data outperformed the broadly interpolated sediment data used in the previous study (Somerton *et al.* 2013), based on the amounts of spatial variation explained by the respective trawl-efficiency models (D. Somerton, pers. comm.; Fig. 1). It is anticipated that processed data from more sophisticated classes of sonars will be even more informative to this (and other) stock assessments utilizing data from the 83-112 survey trawl.

APPROACH: The primary objective is to acquire new acoustic data and develop a habitat-specific catchability-at-size function for the Bristol Bay red king crab (BBRKC; *Paralithodes camtschaticus*) stock. The model will be used to adjust station-specific size compositions and the overall-abundance time series that are used for the annual assessment of this stock. This project will also generate a consistent set of quantitative habitat data to characterize the seafloor and water quality on the eastern half of the EBS continental shelf. These foundational habitat data will be broadly applicable to other (shell)fish-assessment, scientific, and management needs in the region.

Acoustic data will be collected with three different sonars during a 20 day cruise on NOAA Ship *Fairweather* (8-27 August 2016). *Fairweather* is a multi-mission survey vessel equipped with a hydrographic-quality multibeam echosounder (Kongsberg EM710, 73-97 kHz), as well as specialized equipment to support the project's high-speed broad-coverage side-scan sonar system (Klein 7180 LRSSS, 180 kHz) and the independent vertical-incidence single-beam echosounder (38 kHz) mounted on the LRSSS towfish. Quantitative backscatter and bathymetric data will be simultaneously and continuously acquired with the three sonars along tracklines defined by the standard NMFS bottom-trawl survey stations (Fig. 2). Physical measurements and samples of the seafloor will be collected periodically to aid the interpretation of backscatter data during post-processing. For this proposal, we will focus on the eastern half of the EBS survey grid, fully covering the Bristol Bay region where red king crabs are found.

Paired fishing experiments have been conducted to estimate the relative catchability of the NMFS 83-112 survey trawl. The Bering Sea Fishery Research Foundation[1] (BSFRF) is an industry group supporting cooperative research to improve the sustainability and management of fishery resources of the Bering Sea, with emphasis on the commercially valuable crab stocks. On three occasions (2013-2015), the BSFRF sponsored trawling with a specially designed *Nephrops* trawl at the 60 NMFS bottom-trawl-survey stations where BBRKC typically occur. Catch and effort data for the 83-112 and the *Nephrops* trawls were simultaneously collected along parallel courses ~400 m apart. These side-by-side studies were intended to inform the survey selectivity used in the length-based, stock-assessment model currently used by the State of Alaska and NMFS to co-manage the BBRKC stock.

[1] http://www.bsfrf.org/index.htm

Analyses will account for spatial and temporal variability in catchability-at-size of BBRKC that is related to benthic habitat characteristics and will support predictions at locations where BBRKC occur, but where direct estimates of survey-trawl catchability are not available. Specialized geo-processing and analytical software will be used to correct the backscatter data from the three sonar systems and generate multiple descriptive statistics from spatial data [2,3] (Fig. 2). The relative catchability of the NMFS 83-112 trawl will be calculated using the side-by-side catch and effort data (2013-2015). If possible, the pivotal assumption that catchability of the *Nephrops* trawl is 1.0 (Somerton *et al.* 2013) will be evaluated using video from a camera mounted on the *Nephrops* footrope. A generalized additive model will then be developed to explain the observed spatial variability in 83-112 catchability for males and females at incremental carapace lengths (as supported by the data and specified by the stock assessment team), using descriptive backscatter statistics from one or more of the sonars in combination with temperature and depth covariates. The EBSSED database of bottom sediments (Smith and McConnaughey 1999) that was used by Somerton *et al.* (2013) for the snow crab catchability study has been updated, and is available for use as an alternative (or failsafe) input to the GAMs. The best-fitting model will be used to generate adjusted station-specific size compositions and a corrected time series of BBRKC abundance estimates based on the standard NMFS bottom-trawl-survey data. The results will be provided to the North Pacific Fishery Management Council Crab Plan Team and the BBRKC stock-assessment scientist for consideration, if the abundance estimates are statistically different.

The project will be conducted over a (preferably) consecutive two-year period. In year 1 (FY16), the habitat data will be acquired and the side-by-side trawl data will be compiled. In year 2 (FY17), the catchability model and corrected estimates will be produced and disseminated.

BENEFITS: This research will develop a habitat-based catchability-at-size function to produce corrected abundance inputs for the 2017 BBRKC stock assessment. As described above for snow crab, a significantly different time series would likely change the OFL for the stock. Our methodology is directly applicable to other FMP groundfish and crab stock assessments in Alaska and other LMEs that incorporate abundance or biomass estimates from bottom-trawl surveys (*e.g.*, New England groundfish).

An improved species-distribution model for BBRKC will provide additional benefits. The new habitat data will expand the geographic and environmental scope of the previous model by Yeung and McConnaughey (2008). In addition to new backscatter data, sensors mounted on the LRSSS towfish will continuously measure CDOM, chl-a, turbidity, and temperature to characterize water quality near the seafloor. Such an improved model and the associated environmental mapping would not only elevate the EFH description for BBRKC from Level 1 to Level 2[4], the resulting descriptive and predictive capabilities would also provide appropriately scaled prerequisites for next generation ecosystem assessments (IEAs), enable forecasts of

[2] ***Fledermaus* software** available from Quality Positioning Services, Inc., Zeist, The Netherlands.
[3] ***IMPULSE15* (formerly *IMPACT*) software** available from Maritime Way Scientific Ltd., Ottawa, Canada.
[4] See **https://www.st.nmfs.noaa.gov/st4/documents/habitatAssessmentImprovementPlan_052110.PDF**.

species-redistribution and vulnerabilities due to environmental change, and improve models that assess the impacts of bottom-contact fishing (*e.g.*, Fujioka 2006).

Completion of an acoustic survey over the remaining (western) half of the EBS survey grid at a later date, combined with additional industry-sponsored side-by-side trawling as necessary, would extend these benefits to all the commercially and ecologically important species assessed by the NMFS bottom-trawl survey (Fig. 2).

DELIVERABLES:

1. Metadata and data in accordance with the NMFS Data and Information Management Policy resulting in easy public access to gridded habitat data.
2. A generalized additive model to explain the observed spatial variability in catchability-at-size for male and female BBRKC.
3. A corrected time series of BBRKC abundance estimates based on the standard NMFS bottom-trawl-survey data.
4. A NOAA Technical Memorandum detailing methodology, data, and results.
5. A presentation at the May or September 2017 meeting of the Bering Sea – Aleutian Islands Crab Plan Team.
6. A peer-reviewed manuscript describing the general methodology, results, and the fishery-management impact.
7. Processed bathymetric data to the NOAA Pacific Hydrographic Branch for updating nautical charts in areas with outdated or non-existent information.
8. A cooperative research plan to complete coverage of the EBS continental shelf and slope.

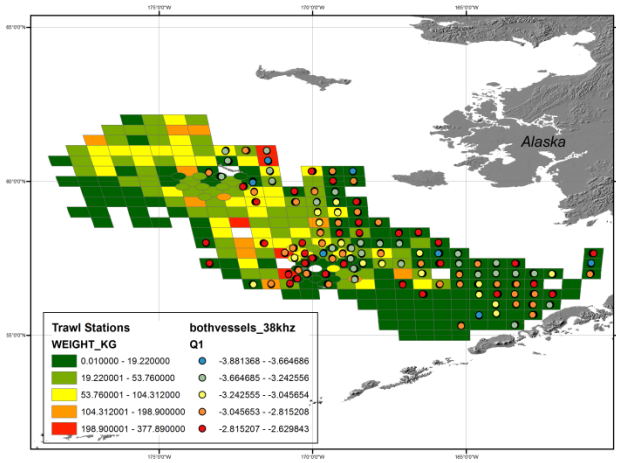

Figure 1. Snow crab biomass (kg) estimates from the 2009 RACE bottom-trawl survey and the corresponding 1st principal component (Q1) for processed ES60 single-beam vertical-incidence backscatter at the stations where side-by-side trawl data were collected by the crab industry. The acoustic data are being used to improve the snow crab catchability model used in the stock assessment.

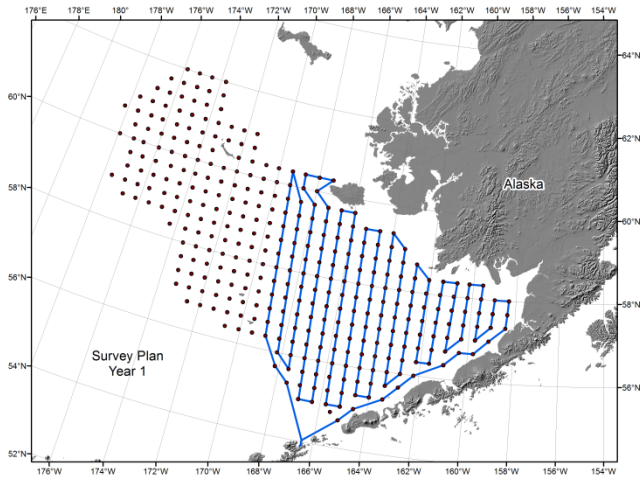

Figure 2. Tracklines for the acoustic surveys to characterize the seabed at NMFS bottom-trawl-survey stations. The eastern half of the continental shelf will be sampled in Year 1, which is the area occupied by the Bristol Bay red king crab stock. The remaining stations (points only) will be sampled at a later date

ITEMIZED BUDGET:

Category	**FY16**
Personnel	$15,000
Fringe Benefits	$0
Travel	$0
Equipment	$0
Supplies	$0
Contracts	$100,000
Other	$0
Total Direct Charges	$115,000
Indirect Charges	$0
Total	$115,000

BUDGET JUSTIFICATION:

General: This budget supplements **a linked two-year proposal to the FY16 Habitat Information for Stock Assessments program**, which does not include the following costs. Details for the complete project budget are available for review.

Personnel. Overtime salary and benefits for at-sea work by federal employees.

Contracts. Two Navy technicians and their equipment will support mobilization, at-sea, and demobilization tasks, including round-trip travel to Dutch Harbor and labor at $85/hr, via an existing interagency agreement.

Note: NOAA ship time allocated to the project is valued at $368,400.

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