**Snow Crab Survey Protocol for 2021:**

**Key Questions:**

1. What is going on during the passive phase? In particular:

* How much crab is the passive trawling phase adding to trawl catches? Are these passive phase catches in proportion to its estimated swept area?
* Are the trawl doors affecting trawl footrope contact? Do the trawl doors lift off before the footrope does? Do the lateral edges of the footrope maintain contact with the sea bottom?

1. What are the best approaches to reducing and controlling the extent of the passive trawling phase?
2. What other aspects of trawling distinguish the 2019-2021 surveys from the 2017-2018 surveys?

**Pre-survey Trawl Experiment (2 days):**

Before the survey begins, we recommend the following experiment, consisting of ~20 tows at a few locations containing with high expected levels snow crab, at depths of 60-70 meters.

In addition to the usual complement of eSonar and Star Oddi survey probes, additional probes will be included:

* Star Oddi Tilt-TD probes on each of trawl doors.
* Star Oddi TD (Temperature-Depth) probes on each of trawl wings.
* Star Oddi Tilt-TD probes on the edges of the trawl footrope, using additional tilt-brackets built for the purpose.
* Winch-speed pulley on one side to monitor and record the warp cable length during winching.
* eSonar wingspread probes equipped with asymmetry measures.

**Experiment:**

The set of 20 tows are to be performed in pairs. Each tow is a regular 5-minute tow at a regular speed of 2 knots. The differences between the two tows are the end-of-tow procedures, so after the stop signal:

1. Slow and back-up the vessel so that it approaches what is presumed to be the trawl resting position.

or

1. Maintain or even increase vessel speed above 2 knots. If possible, increase winch speed while the trawl is on the bottom.

**Analysis:**

Based on crab counts and probe measurements, compare data when using either of the two end-of-tow procedures:

* Average crab counts
* Duration and distance covered by the trawl during the passive trawling phase.

Based on the results, a protocol recommendation will be made for the 2021 snow crab survey.

**Equipment:**

* eSonar wing spread probes equipped to measure asymmetry.
* Winch speed pulley $7000-$10000
* Two additional footrope tilt backets.
* 4 Star Oddi Tilt-TD probes
* 2 Star Oddi TD probes

**Context:**

The 2019 snow crab survey vessel change was accompanied by significant increases of 30-40% among male and mature female snow crab from 35mm to 95 mm CW. The scale and size range of these increases effectively rules out natural processes (i.e. recruitment, migration or low mortality) as a cause, implying rather an increase in survey catchability. Investigations suggest that an increase in the duration of latent bottom trawling phase during hauling of the net, referred to as the passive trawling phase, explains these catch increases, though only partially. Protocol changes brought in during the 2020 survey largely failed to solve these issues. The impact of these catchability increases among legal-sized crab are unknown and have not been characterized, raising concerns of over-estimation of abundance and biomass indices for 2019 and 2020. Consequently, the recent survey time series for 2019 and 2020 does not seem to be on the same scale as that of 2017-2018.

**Approach:**

Currently, survey crab catches are standardized using swept area estimates from the active trawling phase, with passive phase trawling currently being ignored in the standardization. On its face, this approach implies inflation of the resulting abundance and biomass estimates. Also problematic is that passive phase trawling has been shown to vary both regionally and annually, leading to probable differences in catchability.

A naïve approach might be to eliminate the passive trawling phase altogether. However, this approach is problematic. Firstly, passive phase trawling has likely existed throughout the history of the snow crab survey, though it may have varied in scale regionally and/or from year-to-year. Thus, there is not only a need to control the extent of passive phase trawling in future surveys, but also to retroactively estimate the scale of passive phase trawling in order to balance out its influence. Secondly, there are a number of unquantified factors which are known to reduce survey catches, but which are presently uncontrolled and unmonitored. Examples of such factors relate to the variability in the contact of the trawl footrope, due to variations in bottom type, accumulation of debris at the mouth of the trawl, asymmetry of the trawl wings under strong benthic currents, and strong sea conditions.

Given these points, a first goal is to identify factors that are known both to significantly influence survey catches, as well as vary regionally or from year-to-year. Once these have been identified, such factors are to be either controlled via suitable adjustments to the survey protocol, or characterized and quantified such that their influence can be accounted for in the standardization of survey catches. A second goal, no less important, is to situate current survey catches (2019 and 2020) relative to the entire survey time series from 1997 to 2018, as well as reconstructing the population dynamics of commercial-sized crab, so that its apparent stability over 2018 to 2020 can be placed into historical context. Attaining this goal will rely on improved knowledge of trawl behavior during the passive phase, identification of other major factors affecting trawl catchability, in combination with the development of a population dynamics model within which to incorporate this new information.

**2021 Survey season goals:**

* Characterize behavior of the trawl during the passive trawling phase under various conditions:
  + contact of the footrope along its full length,
  + contact / lifting of the trawl doors,
  + trawl speed and trawl width.
  + catchability of the trawl
* Determine the impact varying the extent of the passive trawling phase on catches.
* Stabilize and reduce the impact of passive phase trawling to a reasonable level, to levels consistent with those from the historical survey time series.
* Evaluate the bias associated with having relocated stations since 2013.

**Methods:**

**Literature review:**

Review literature on factors which affect trawl catchability, in particular snow crab catchability. In particular, the series of papers by David Somerton and Kenneth Weinberg should be probed for useful information, as they often relate to Alaska snow crab:

Somerton, David A., Weinberg, Kenneth L., and Goodman, Scott E. 2013. Catchability of snow crab (*Chionoecetes opilio*) by the eastern Bering Sea bottom trawl survey estimated using a catch comparison experiment. Canadian Journal of Fisheries and Aquatic Sciences. <https://doi.org/10.1139/cjfas-2013-0100>.

Somerton, David, Weinberg, Kenneth L., and Scott Goodman. Snow crab selectivity by the NMFS trawl survey Groundfish Assessment Program, RACE Division, Alaska Fisheries Science. Center, NOAA.

Weinberg, Kenneth L. 2003. Change in the performance of a Bering Sea survey trawl due to varied trawl speed. Alaska Fishery Research Bulletin. 10(1):42-49.

Weinberg, Kenneth L, Somerton, David A. 2006. The effect of autotrawl systems on the performance of a survey trawl. Fishery Bulletin. 104:35-45.

Weinberg, Kenneth L. & Kotwicki, S. 2015. Reducing variability in bottom contact and net width of a survey trawl by restraining door movement and applying a constant ratio of warp length to depth. Fishery Bulletin- National Oceanic and Atmospheric Administration 113(2):180-190. DOI: 10.7755/FB.113.2.6

**Table 1:** Summary of different measurement variables proposed ahead of the 2021 snow crab survey season to address current survey catchability issues, along with a description of each, their intended purpose and frequency of observation.

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| **Data variable** | **Description** | **Purpose** | **Data source** | **Frequency** |
| Footrope contact | Gather data to see how contact footrope along its length varies on different bottoms, debris loads, as well as during the passive trawling phase. | Relate differences in survey catches to variations in footrope contact. Characterize passive trawl phase catchability. | Tilt-depth probe (e.g. Star Oddi) | Small number of tows in different sediment types. |
| Door contact | Gather data to see how trawl door contact varies during trawling, especially during winching and lift-off. | Determine the relationship between the trawl lifting off of the trawl doors and trawl geometry during the passive trawling phase. | Tilt-depth probe (e.g. Star Oddi) | Infrequent random monitoring of survey |
| Trawl-vessel distance | Measure the distance between the trawl and survey vessel. | Validate indirect methods used to determine trawl position. | Trawl acoustic probe | Small number of tows |
| Winch speed and/or cable tension. | Measure how winch speed and/or cable tension varies during the passive trawling phase. | Improve methods used to determine the trawl position relative to the survey vessel in 2021 and previous survey years. |  | Small number of tows |
| Video monitoring or 3D sonar imaging probe. | Attach video and lighting equipment, or a 3D sonar imaging probe to monitor the behavior of the survey trawl. | Improve knowledge of trawl dynamics and crab catchability during trawling. | e.g. GoPro | Special experiment at the beginning of the survey. |
| Trawl symmetry | Measure whether the trawl configuration is symmetrical (i.e. equal) on either side. | Ensure that the trawl is not skewed relative to the survey vessel. |  | Regular monitoring during the survey |
| Fixed stations | Sample a representative subset of the original random sampling stations from 2013. | Check whether survey indices are biased due to relocation of survey sampling stations since 2013 |  | 50-100 survey stations |
| Double-trawl experiment | Re-analyze data from a double-trawl experiment performed in 2002, featuring a trawl-within-a-trawl design. | Directly estimate size-dependent catchability using the 2002 experiment data, used to possibly standardize catches relative to size or to validate population model size-based catchability estimates. | 2002 experiment | n/a |