**Proposal for sGSL Snow crab Framework Assessment**

**Context:**

A change in snow crab survey vessel in 2019 was accompanied by an apparent 30-40% increase in catchability among sub-legal male and mature female snow crab. Investigations indicated that part of the issue was an increase in unaccounted dragging of the trawl, called the passive trawling phase, caused by slow winch operation and forward vessel movement after active trawling was assumed to have ended. These issues raised doubts as to the comparability of the 2019 abundance indices with the historical time series, resulting in uncertainty assessing stock status. In spite of a protocol adjustment, these issues persisted during the 2020 survey and assessment. In addition to these recent issues, other factors related have been highlighted as causes of bias of stock indices, among them the current practice relocating sampling stations to alternates in response to trawl damage, progressive expansion of survey area through time, changes in spatial sampling design, multiple changes in survey vessel, and inter-annual variability in survey fishing practices.

This Framework Assessment for the sGSL snow crab stock has the following goals:

1. **Review** and **formalize** the current **survey fishing protocol**, in order to control, among other things, the extent and variability of passive trawling phase.
2. Consider new methods to **retroactively standardize the historical survey time series** of stock indices, in order to improve its reliability when used to assess stock trends and status.
3. **Situate 2019-2021 stock indices** within the historical survey time series.

**Deliverables:**

1. Research Document summarizing key results, discussions and conclusions regarding survey standardization.
2. Technical Report or Research Document of population modelling results and discussion.
3. Preliminary abundance and biomass indices from the 2021 snow crab survey.

**Date:** December, 2021 (TBD)

**Methods:**

1. Present results from the new **2021 survey trawl monitoring data**:

* Present data gathered by various probes, some of them new, attached to different parts of the trawl as part of the 2021 survey.
* Summarize how the survey trawl changes shape changes during the various phases of trawling (e.g. descent, touchdown, active trawling, winching, lift-off), as well as under different fishing operations (e.g. vessel speed or manoeuvres), different sediment loads and sampling locations.
* Test if passive swept area characteristics are stable and how they compare with past survey years.

1. Retroactively analyse trawl **swept area** from both the **active** and **passive** trawling phases using new and updated methods (1989-present).
   1. Active trawling phase:

* Trawl touchdown and lift-off times will be re-estimated using tilt and trawl depth profiles for the survey time series.
* Past issues with the quality and quantity of survey wing spread data will be accounted for in the new analyses.
* Historic annual summary statistics will be presented and compared.
  1. Passive trawling phase:
* Swept area of the trawl during the passive trawling phase will be estimated over most of the survey time series, based on inferred winch speed, observed vessel GPS, and physical and geometric considerations.
* The extent of the passive trawling phase between years, vessels, and regions will be discussed, as well as other characteristics.

1. Review of candidate **variables** for **standardizing** set of historic survey catches.

* Variables will be explored for possible use in standardizing survey catches. Candidates include depth and temperature, revised active and passive swept areas, survey timing and seasonality, time of day and sediment type.

1. Present more modern **spatial statistical methods** as possible **replacements** to **kriging**:

* A wide variety of powerful spatial statistical methods are currently available which offer a much wider range of modelling options than the implemented kriging method which is used for snow crab.
* These newer methods allow for easier inclusion of predictive variables (i.e. depth, temperature, etc…) as well as more tools for evaluating and comparing the quality of different models.
* We can reasonably expect prediction of local densities will be improved, with concurrent improvements in precision for zonal and global abundance and biomass estimates.

1. Review whether **survey station relocations** from 2013 onward led to bias in abundance and biomass indices.

* The current set of survey sampling stations were set in 2013, following an internal review and expansion of the survey area. While a fixed station design was followed, current practice allowed for relocation of survey sampling stations to a new alternate random station in response to significant trawl damage. Almost half of surveys sampling stations have been moved since 2013.
* A representative subset of sampling stations was chosen to target stations from the original 2013 random design in order to determine whether the station relocations have led to biases in stock indices.

1. Review snow crab **population dynamics** model results, in particular:
   1. Estimates of relative *annual catchability*:

* Estimates of annual catchability could be used for standardizing snow crab abundance and biomass time series, which is the core of the stock assessment.
* Abundance indices from the sGSL groundfish survey could be compared with these results, which may contribute to current efforts at combining data from different scientific surveys.
  1. Estimates of annual *natural and fishery mortality* rates:
* Trends and patterns in mortality are central to understanding the dynamics of the snow crab stock.
* Also of interest is the impact of fishery removals and by-catch mortality on the commercial component of the stock. This may be important for understanding why catchability increases among sub-legal crab were seemingly different in the commercial stock in 2019 and 2020.
  1. *Predictions* of population and fishery *recruitment*.
* The current prediction model is rather poor at predicting fishery recruitment, as it does not account for a number of factors which are suspected of having significant and varied impacts from year to year, such as skip-moulting, variable mortality, and survey catchability. The population model will provide some information on each of these processes, thus improving recruitment predictions.

1. Determine whether to **rescale current abundance** and **biomass indices** (i.e. 2019 and 2020) with respect to the historical time series using presented results, and discuss impacts of updating the historical time series on management of the sGSL snow crab fishery.

* Discuss how recent estimates of exploitation rates compare to those of the historical time series after revision.
* Discuss if reference points for the sGSL snow crab stock require revision, see as these were based on historic maximum or minimum biomass estimates.
* This is an important topic that should be discussed among industry and fisheries management representatives, maybe at a future meeting.

**Participants:**

**2 or 3 people among:**

* Statistical analysis (e.g. Joanna Mills Flemming (Dalhousie University), Noel Cadigan (Marine Institute), Brad Hubley (NS)).
* Population modelling (e.g. Noel Cadigan, Brian Healy, Shareef Siddeek (Alaska), …)
* Trawling and catchability expert (e.g. Kenneth Weinberg (NOAA)).

**Up to 5 among:**

* DFO biologists (e.g. Darryl Mullowney (NF),Julia Pantin (NF), Krista Baker (NF), Cedric Juillet (QC), Bernard Sainte-Marie (QC), Jae Choi (NS), Hugues Benoît (QC), Adam Cook (NS), Brad Hubley (NS)).

**Plus:**

* Industry representatives (e.g. Robert Haché, Basil McLean, Martin Noel, Kris Vascotto).
* Gulf Crustacean Section staff.

**Intro text:**

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 spatio-temporal differences in catchability.

One approach might be to eliminate the passive trawling phase altogether, but 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 as a means of counteracting its influence. Secondly, there are a certainly other factors which are known to reduce survey catches, but which are neither controlled nor monitored. Examples of such factors can be related to the effective or variable contact of the trawl footrope with the sea bottom, which can, for example, vary by bottom type, accumulation of debris at the mouth of the trawl, asymmetry of the trawl wings, or strong sea conditions.

Given these points, a goal is to identify factors that are known both to significantly influence survey catches, and that also 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.

**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