**Snow crab – Framework Assessment – December 2021**

**Context:**

* The last two snow crab Framework Assessments date back to 2006 (ref) and 2010 (ref), which resulted in major changes in survey design and areal expansion, plus minor methodological changes.
* In the past few years,
* … update of the statistical methods used to generate abundance and biomass indices.
* … present new population model
* … refine survey catch standardization, incorporate new information, data and analyses.

**Objectives:**

1. Present results from the new **2021 survey trawl monitoring data**.
2. Present new trawl **swept area** estimation methods and retroactive analysis of historical data (1989-present).
   1. Active trawling phase.
   2. Passive trawling phase.
3. Review set of **variables** used to **standardize** survey catches.
4. **Update** abundance and biomass **estimation methods** and compare with past estimates.
5. Review snow crab **population dynamics** models, in particular:
   1. Annual estimates of relative *catchability*.
   2. Annual estimates of natural and fishery *mortality* rates.
   3. Short-term *prediction* of population and fishery *recruitment*.
6. Determine whether to **rescale annual abundance and biomass indices** using presented results, with special attention to recent years and the vessel change of 2019.

**Deliverables:**

1. Technical Report or Research Document summarizing results, discussions and conclusions.
2. Update and formalized survey statistical sampling protocol and design.
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**:

* Describe how the survey trawl configuration changes during the various phases of trawling (e.g. descent, touchdown, active trawling, winching, liftoff).
* Data will be provided by various probes attached to different parts of the trawl as part of the 2021 survey.
* The variation of trawl configurations in different locations and fishing operations will also be discussed.

1. Present new trawl **swept area** estimation methods and retroactive analysis of historical data (1989-present).
   1. Active trawling phase:

* Trawl touchdown and lift-off times will be estimated using tilt and trawl depth profiles for the survey time series.
* Issues with the quality of survey wing spread data will de discussed and accounted for in the analyses.
* 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 the survey time series, based on inferred winch speed, observed vessel GPS, and physical and geometric considerations.
* Variability in the characteristics and extent of the passive trawling phase between years, vessels, and regions will be discussed.

1. Review set of **variables** used to **standardize** survey catches.

* Additional variables will be explored for use in standardizing survey catches.
* These may include depth and temperature, revised active and passive swept areas, survey timing and seasonality, time of day and possibly sediment types.

1. **Update** abundance and biomass **estimation methods** and compare with past estimates.

* Since the implementation of the current estimation method, i.e. kriging, in the mid-1980s, statistical models allowing for a much richer specification of random effects, including spatio-temporal effects, have become widely available in statistical software packages.
* These methods provide for a more natural and expandable modelling framework, along with more varied diagnostics and reproducibility.
* These are more fully integrated into modern statistical culture than kriging, which has not followed suit since its implementation in the sGSL.
* Also analyses have not benefited from the many-fold advances in computing power since the 1980s many aspects of its implementation were chosen based on available computing speed at the time, rather than precision.
* The survey is considered to be relatively high resolution, so changing the analytical method is not expected, by itself, to change global mean values, but rather improve on local and region estimates, with corresponding benefits in the precision (as opposed to the accuracy) of global estimates.

1. Review snow crab **population dynamics** models, in particular:
   1. Annual estimates of relative *catchability*:

* If deemed reliable, these estimates could form the basis of a method for standardizing snow crab survey abundances through time.
* These estimates could be validated against snow crab abundance indices from the sGSL groundfish survey.
  1. Annual estimates of 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 is vital for understanding why catchability increases among sub-legal crab were seemingly different in the commercial stock in 2019 and 2020.
  1. Short-term *prediction* of population and fishery *recruitment*.
* The current prediction model has a generally poor performance record 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.
* A population model cannot only serve to estimate and parse out these processes, but should also improve abundance predictions if these processes prove to have estimable structure.

1. Determine whether to **rescale annual abundance and biomass indices** using presented results, with special attention to recent years and the vessel change of 2019.

* Re-estimation of survey biomass for past survey years entail revision of reference points for the sGSL snow crab stock., as these were based on maximum or minimum estimates.
* On top of the, it may be desirable to rescale the entire series so that …
* This is an important topic that should be discussed among industry and fisheries management representatives.

### Sources of Uncertainty

Meaningful interpretation of long-term trends and variations of snow crab stocks relies on a robust sampling protocol, sampling design and standardization of survey catches. In addition to current survey catchability issues, the survey has undergone a number of changes to its sampling design, including multiple areal expansions, survey station redistributions and five survey vessel changes. In particular, the practice of relocating survey stations when trawl damage is encountered has led to only half of stations having remained in their original fixed locations since the last survey redesign in 2013. This practice has been highlighted as a potential source of bias as stations tend to be relocated to more trawlable bottoms. These issues can weaken our ability to track population trends as well as situating the stock with respect to the harvest control rule limits and reference points.

Environmental conditions in the sGSL are known to affect a number of life history processes including molting and growth, reproduction, larval development and migratory behavior. Varying conditions are only expected to affect abundance and biomass estimates through seasonal migratory changes, making the timing of survey sampling a potential issue along more marginal survey areas. Varying life history processes lessen our ability to predict fishery recruitment, which currently assumes homogeneity through time.

Of major concern for the long-term future of the stock is the consistent warming of the waters of Laurentian Channel, which would significantly lower the quality of snow crab habitat if they penetrate further within the sGSL. Incursions of these warmer waters are currently limited to peripheral areas in areas 12E, 12F and the northeastern part of Area 19.

Another method which was explored, a Leslie analysis, which yielded an estimate the biomass at the start of the fishery. This depletion method, which is based on extrapolating weekly declines in fishery CPUE, suggested an overestimation bias. However, the application of this method, generally used in data-poor contexts, raised concerns in that its underlying assumptions were untenable and its results unreliable.

**CONCLUSIONS AND ADVICE**

Despite the potential overestimation of the 2019 and 2020 commercial biomass estimates, the stock is still considered to be in the healthy zone of the PA showing strong signs of recruitment and productivity. Past changes in survey vessels, fishing practices, statistical design, and survey station relocations can lead to variations in survey catchability. Such changes must be either controlled or otherwise accounted for if abundance and biomass estimates are to remain comparable from year to year, i.e. perceived changes in abundance and biomass indices may no longer reflect true changes in stock size.

In 2019 and 2020, survey catchability increased among sub-legal crab in 2019 and 2020.

This increase was partially explained by an increase in the extent of a passive trawling phase, brought on by changes in winch speed and end-of-tow vessel manoeuvres, though other unknown mechanisms associated with the 2019 vessel change are thought to have played a role. However, the relation of these mechanisms to the commercial stock is not clear.

Shown below is a risk table summarizing the probability of exceeding the limit and upper stock reference points for different levels of assumed bias for the commercial stock biomass, along with the corresponding exploitation rates. These catchability increases and the corresponding increases in passive phase trawling were highlighted following the 2019 survey, but no corrective actions were taken. The fishery caught 89% of its TAC in 2020. This is consistent with overestimation of the commercial stock, though this is not conclusive evidence and was partly due to a late fishery opening and NARW area closures.

Overestimation of the commercial stock increases the projected exploitation rate. Potential short-term consequences of higher-than-normal exploitation rates would be lower fishery performances in 2021, i.e. low CPUEs, which would increase the amount of fishing effort required to catch the TAC. In the long-term, stronger size-selective pressures on the stock could lead to decreases in size-at-maturity and dwarfism, along with a reduction of reproductive potential of large males, as documented in other snow crab stocks.

Describe what is proposed to be done to avoid being stuck in the same situation next year… Bullets from the recap document, could be put in a nice paragraph.

• Explore technological tools to assess trawl catchability and behavior after the active trawling phase (camera system, sensors, positional/movement detector, etc.);

• Refine end-of-tow operation to reduce the passive phase impact on the data series;

• Adopt a subset of fix stations (number to be determined) for the survey to avoid the drift towards better grounds;

• Deepen spatial analysis of catch data to detect potential trends in bias related to depth and/or bottom temperature;

• Continue work on population model as a means of estimating annual changes in catchability and retroactively standardizing the survey time series;

• When available, utilize other sources of comparative data to develop indicators and to groundtruth the survey biomass indices.