**Population modelling:**

**Introduction:**

Goals:

1. Gain insight on temporal changes in survey catchability, with a view towards standardizing the survey time series.
2. Improve short-term prediction model.
3. Estimate natural / fishing mortality.

**Methods:**

* A length-based population model was developed and fitted to snow crab survey data.

**Data :**

* Snow crab were divided into immature and mature groups based on morphometric maturity.
* Because of issues with the consistency of shell condition between survey years, identification of skip-moulters and fishery recruits were not identified in the input data, but rather estimated in the model.
* Data from 1997-2022 was used.
* Scaling issues with the survey:
  1. Expansion survey area
  2. Spatial distribution is not uniform
  3. Survey grid design changes
  4. Kriging scale changes (so differences induced by the interpolation).

**Model :**

* A population dynamics model was used to analyze snow crab size-frequency data from the trawl survey from 1997 to 2022.
* Density data were averaged by 10x10 grid for data prior to 2012 to partially account for spatial heterogeneity in the distribution of survey sampling stations in this earlier portions of the survey.
* Average size-frequency data by year was then calculated from snow crab density data, separated by sex, maturity and survey year.

Population processes were defined as follows:

1. **Growth**:
   1. A size-based growth-at-moult model was used to map pre-moult size to post-moult size. Because immature and adolescent/mature crab have different growth-at-moult relationships, a type of piecewise linear model was used to predict growth from year to year.
   2. Let be a function of size , defined as where is an intercept parameter, and are slope parameters, is the size at the onset of adolescence and is a transition window width parameter. This function is a type of piecewise linear model, smoothed over the transition point .
   3. Let the standard error of the growth linearly scale with , defined as , where is a scaling parameter.
   4. In order to restrict growth to being positive, a gamma distribution was used as an error model for predicting post-moult size. The moments and were thus used to define shape parameter and scale parameter .
   5. Because size was rounded to 1 mm size intervals, the resulting gamma density was integrated by 1 mm size intervals in order to obtain probabilities of moulting to a given size, i.e. a growth transition matrix.
2. **Population recruitment**:
   1. Population recruitment was expressed as abundances of instars V allowed to vary from year to year. The size distribution of these instars was assumed to be Gaussian with means and corresponding standard errors . Abundance levels were for year .
3. **Maturation and moulting**:
   1. Moult to maturity:
      1. Snow crab maturation was expressed as a function of size, allowing for an early, accelerated phase and a late phase of maturation.
      2. Let the early and late phases be modelled by logistic functions and , parameterized by inflection points and , and slope parameters and . . Let be the mixing proportion between the two phases, the maturation probability function is .

* 1. Skip-moulting
     1. Skip moulting probability was modelled as a scaled logistic function

1. **Scaling effects**:
   1. Selectivity :
      1. Trawl size selectivity was modelled using a gamma cumulative density function as
   2. Catchability : Catchability was modelled as a annual random effect, necessarily confounded with time varying mortality.
2. **Mortality**: