**APPENDIX - SWEPT AREA ESTIMATION**

* Survey catches were standardized with respect to surface area covered by the trawl net at each sampling location.
* Swept area was calculated from a time series of trawl width observations from trawl acoustic sensors, estimates of trawl touchdown and lift-off times, and the reported trawl stop time.
* For our purposes, we assume the start time to be coincident with the trawl touchdown time, which seems reasonable given the forward speed and forward motion of the survey vessel.
* Current start time estimation is made on board the survey vessel from eSonar readouts of trawl depth and headline heights from the bottom. Afterwards, these estimates are revised using trawl depth profiles as recorded by a Minilog TD (i.e. Temperature and Depth) probe attached to the trawl headline.
* Since 2014, the survey has used a two types of Star Oddi probes, the first a temperature-pressure probe attached to the headline alongside the Minilog TD probe, and the second a tilt-angle probe fitted inside a protective bracket attached to the trawl footrope.
* These probes provide more precise measures of water temperature, pressure, and tilt angles, leading to better estimates of trawl touchdown times.
* In 2019, the last of the survey’s Minilog TD probes ceased to function and so other data had to be used to revise the on-board determinations of trawl touchdown times.
* Analytically, touchdown times are determined using two-component piecewise linear models which attempt to identify inflection points, in this case points of maximal deceleration, of trawl depth with respect to time.
* However, such estimates were often problematic when applied to Minilog depth data due to 1) ad hoc variations in winch speed in the period prior to touchdown, 2) the presence of multiple inflection points, corresponding to the touchdown of one or both doors as well as the touchdown of the footrope, 3) the relatively slow stabilization of the trawl headline even after contact of the trawl footrope, and 4) the low precision of Minilog depth readings, which are rounded to ~2 meters or even 4 meters in some cases.

**Tilt Angle Analysis:**

* Estimates based on Star Oddi tilt probe data provide a more accurate and precise measure of Trawl touchdown times.
* This is due to the fact that :
  + readings signals are easily identifiable from those gathered in water column
  + The transition between trawl descent and bottom contact is rapid, on the order of 2-4 seconds.
* However, comparison of Minilog and tilt-probe based estimates from 2018 showed an average difference x +/- (mu +- sigma) seconds.
* Similarly, comparison of Start Oddi headline and tilt-probe based estimates from 2019 showed an average difference of 3.1 +/- (mu +- sigma) seconds.
* Time differences on this scale imply change in biomass or abundance estimates of ~ X% for 2018 and Y% in 2019.

**Trawl Wing Spread Analysis:**

* Wing spread data from acoustic trawl monitoring probes has multiple issues
  + Missing measurements
  + Missing recordings (no communication with receiver)
  + Noisy signals (noise varies by bottom type, instrument malfunction)
  + Missing data distribution is not uniform, implies possible biases when interpolating.
* **Wing spread varies during trawling,** 
  + **Trawl widens initially**
  + **May close if trawl fills up with sediment**
  + **Encounters with large rocks.**
* **Limitations of past analyses:**
  + **Individual separate analyses**
  + **Sometimes difficult to identify signal from noise**
  + **Large intervals of missing data – hard to determine how to best interpolate.**
  + **Local means may no be good.**
* **Hierarchical Gaussian Process:**
  + **Models all tows simultaneously**
  + **The mean and variability of a typical tow is modelled. Serves as a reference**
  + **Robust error distribution is able to reasonably weigh noisy signals, which minimizes their impact.**
  + **Variability is modelled using temporal Gaussian processes, one for the global process and one for each individual tow.**
  + **Spatial variability in the mean is modelled via a spatial Gaussian process.**
  + **Process error and correlation, as well as observation error parameters are estimated.**