**APPENDIX - SWEPT AREA ESTIMATION**

* Survey catches are standardized with respect to surface area swept by the trawl.
* Swept area for each tow is calculated using trawl width measurements from trawl acoustic sensors, position or speed information from the survey vessel, plus time bounds which specify when trawling starts and ends.
* For our purposes, we assume the start time to be coincident with the time that the trawl touches down, which is estimated from tilt-angle probe data from the attached footrope mechanism.
* The trawl end time for the active trawling phase is defined by the time when winching of the trawl net is initiated and deceleration of the survey vessel begins.
* The bounds of the passive trawling phase are defined by the stop time and the time at which the trawl lifts off the sea bottom, as estimated from tilt-probe data.
* The width of the trawl varies by bottom type and water depth.
* As the trawl accumulates sediment and debris, the Nephrops trawl often closes under the increased tension generated by the added weight.
* Trawl wing spread is used as a proxy of the width of the trawl.
* Two eSonar probes were attached on the wings on either side of the trawl.
* These probes relayed their measurements to an attached acoustic receiver one the underside of the survey vessel.
* However, wing spread data had two major issues.
* Firstly, observations were often missing, either due to faulty measurement or failure in relaying the measurement to the receiver. Moreover, the number of data observations often tapered off or vanished as the trawl accumulated debris. It is not uncommon to have no usable wing spread data for a given tow.
* Secondly, wing spread data are often very noisy, and the level of noise varies significantly from tow to tow, depending on the type of sea bottom, water depth and the performance of the probes and receivers.

To account for these issues, the following statistical model was used:

**Trawl Wing Spread Analysis:**

* **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.**