**Survey Notes:**

* Jean Mathieu : first four tows, the fish measurement precision was 1 cm.
* Measured herring lengths were pinched lengths on both survey vessels.
* September 19th: Shortened trip due to electronic issue with the Avalon Voyager II.
* The bracket holding the flowmeter, and especially the attached GoPro and lights, were often entangled in the trawl net. Early in the comparative survey, the dummy plug in the secondary vessel’s flowmeter was lost during hauling and thus its use was abandoned.
* **GC304F** : One of the two quick release clamps of the flowmeter (with camera and lights removed) was detached during trawling.
* **GC339F** : Rough sea conditions (25-30 knots).
* September 21st : Only one paired tow was performed (305F) due to rising winds (18-20 knots during fishing). Heavy vessel rocking.
* The Jean Mathieu had difficulty obtaining wing spread data. Here are some covariates which may be used to predict the missing values:
  + Water depth
  + Warp-to-depth ratio
  + Wing-spread correlation analysis (i.e. use other vessel’s data).
  + Sediment type / trawl loading.
* The weight balance on the Jean Mathieu had some difficulty with respect to stability, in part due to weather conditions, and so its accuracy was generally limited to 0.1 kg. Species or taxa with small weights should be viewed as suspect.
* Under strong weather conditions, the vessel heading occurs in the wave direction to minimize vessel bobbing.
* There is at least one pair of tows which seem to straddle the thermocline : one has a lot of lobsters and the other doesn’t.

**Survey recommendations:**

* Recommend extracting Olex data on survey vessel next year.

**Estimation of Swept Area during the Passive Trawling Phase:**

Our ability to make meaningful comparisons between abundance or biomass indices between regions or years requires any nuisance factors be accounted for, i.e. that catches be standardized. Currently, survey catches are standardized with respect to estimates of the area swept by the trawl. However, any additional swept area incurred by the trawl during the passive trawling phase is presently not considered. Moreover, calculation of this component of the swept area is more complex than that of the active trawling phase, as the forward movement of the trawl is due not only to the forward movement of the vessel, but also to winch action pulling the trawl towards the vessel.

If we assume the vessel has more or less the same bearing during the passive phase, we can calculate the vessel’s contribution to the trawl movement using , where is the vessel’s average speed and is the duration of the passive phase. When the winch speed is known, the distance that the winch drags the trawl across the sea floor is given by:

where is the water depth, is the warp cable length during regular trawling (i.e. ). The total swept area of the passive phase for each tow is given by , where is the average trawl wing spread. The lift off angle between the trawl cables and the sea bottom are given by . For a 3:1 warp ratio, during regular trawling up to the beginning of the passive phase. As the trawl approaches the vessel, will increase up to some value until the trawl finally lifts off the bottom.

Vessel

Door at stop

position

Door at liftoff

position

Depth

Warp length at stop position

Door movement

Warp length at liftoff

**Figure X** : Trigonometric model of the distance travelled by the trawl due to winch action alone (movement due to vessel movement is ignored).

**Table X**: Description of input parameters used to calculate statistics of the passive trawling phase for each survey tow.

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Description** | **Source** |
|  | Passive phase duration | Analysis of Star Oddi tilt probe data. |
|  | Vessel speed | Vessel GPS. |
|  | Warp length | Counting off 25 fathom cable markers by captain. |
|  | Winch speed | Haul time divided by warp length. |
|  | Water depth | Water depth according to ship sonar. |
|  | Trawl width | eSonar wing spread observations. |

Vessel and trawl characteristics during the passive trawling phase during the 2019 survey were compared to those of 2017 and 2018. The data and methods used were identical between years. Table X shows a summary of the input parameters used to characterize and derive other passive phase statistics, as well as their respective data sources.

**Results**

Summary statistics for the passive phase swept area calculation are shown in Table X.

Most of the measured values scale with water depth and so deep-water tows along the Laurentian Channel consequently have much higher values than most other tows in the Gulf, but these represent only about X % of trawl stations and generally have low densities of snow crab.

This aspect of the data implies some of the data are left-skewed, leading to a contrast between median and mean values, through both are presented.

Statistics show that overall vessel speeds during the passive phase were comparable between years, at around 0.8 meters per second. The median passive phase duration went from 50 and 43 seconds in 2017 and 2018, to 89 seconds in 2019. The increase in durations led to corresponding increases in the distance covered by the vessel during the passive phase, to a median of 68.1 meters in 2019, from median values of 35.2 meters in 2017 and 32.6 meters in 2018.

The calculated winch speeds were comparable during the 2017 and 2018 with median values of 1.26 meters per second, whereas the 2019 median dropped to 0.90 meters per second. Liftoff angles increased slightly to a median of 34.0o in 2019, from 27.9 o in 2017 and 28o in 2018. Higher liftoff angles in 2019 imply that the trawl was brought closer to the vessel before lifting off the bottom. Thus, we see a corresponding increase in the distance travelled by the trawl due to winch action to a median value of 87.6 meters in 2019, up from 65.9 meters in 2017 and 56.9 meters in 2018. Trawl wing spread values decreased slightly to a median of 6.5 meters in 2019, from 6.9 meters in 2017 and 7.0 meters in 2018.

The resulting swept area estimates for the passive trawling phase increased to 992 m2 in 2019, from 688 m2 (44% increase) in 2017 and 605 in 2018 (64% increase).

**Table** : Tow summary statistics of the passive trawling phase from the 2017, 2018 and 2019 surveys.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **Percentiles** | | | | |  |
| **year** | **variable** | **units** | **2.5%** | **25%** | **50%** | **75%** | **97.5%** | **average** |
| 2017 | vessel speed | m/s | 0.24 | 0.61 | 0.82 | 0.99 | 1.44 | 0.81 |
| 2018 | vessel speed | m/s | 0.32 | 0.66 | 0.81 | 1.00 | 1.32 | 0.82 |
| 2019 | vessel speed | m/s | 0.46 | 0.65 | 0.81 | 1.03 | 1.45 | 0.86 |
| 2017 | duration | s | 9 | 25 | 50 | 82 | 439 | 82.1 |
| 2018 | duration | s | 8 | 24 | 43 | 75 | 441 | 74.6 |
| 2019 | duration | s | 15 | 58.75 | 89 | 117 | 544 | 116.2 |
| 2017 | vessel distance | m | 11.1 | 23.7 | 35.2 | 50.2 | 217.4 | 48.8 |
| 2018 | vessel distance | m | 10.4 | 23.1 | 32.6 | 45.6 | 192.5 | 45.7 |
| 2019 | vessel distance | m | 19.1 | 47.3 | 68.1 | 87.7 | 440.3 | 91.0 |
| 2017 | winch speed | m/s | 1.01 | 1.21 | 1.26 | 1.30 | 1.39 | 1.25 |
| 2018 | winch speed | m/s | 1.03 | 1.22 | 1.26 | 1.30 | 1.36 | 1.25 |
| 2019 | winch speed | m/s | 0.71 | 0.84 | 0.90 | 0.97 | 1.31 | 0.92 |
| 2017 | liftoff angle | degrees | 19.1 | 24.9 | 27.9 | 32.2 | 56.1 | 29.3 |
| 2018 | liftoff angle | degrees | 19.7 | 24.7 | 28.0 | 31.5 | 47.6 | 29.2 |
| 2019 | liftoff angle | degrees | 20.5 | 26.7 | 34.0 | 42.6 | 64.2 | 35.5 |
| 2017 | winch distance | m | 13.0 | 35.8 | 65.9 | 105.4 | 511.1 | 100.3 |
| 2018 | winch distance | m | 11.9 | 33.5 | 56.9 | 89.3 | 515.3 | 89.9 |
| 2019 | winch distance | m | 20.9 | 58.4 | 87.6 | 113.8 | 482.6 | 112.1 |
| 2017 | wing spread | m | 4.5 | 6.3 | 6.9 | 7.5 | 9.4 | 6.9 |
| 2018 | wing spread | m | 4.2 | 6.4 | 7.0 | 7.5 | 9.5 | 6.9 |
| 2019 | wing spread | m | 3.3 | 5.5 | 6.5 | 7.2 | 8.9 | 6.3 |
| 2017 | swept area | m2 | 160 | 425 | 688 | 1118 | 4932 | 1014 |
| 2018 | swept area | m2 | 135 | 394 | 605 | 945 | 4781 | 938 |
| 2019 | swept area | m2 | 227 | 613 | 992 | 1392 | 6067 | 1270 |

**Discussion**

The new survey vessel, the Avalon Voyager II is a heftier, more powerful vessel than the previous survey vessel, the Jean Mathieu. In particular, the winch aboard the Avalon was somewhat over-powered with respect to the survey trawl, leading to gear entanglements early on in the survey. This in turn forced the captain to use a slower speed setting for the remainder of the survey.

Unfortunately, this lower speed setting was markedly slower than those of the Jean Mathieu in previous years. This led to large increases in the bottom time during the passive trawling phase, a phase which is currently unaccounted for in survey catch standardizations. Based on auxiliary survey data, it was possible to approximate the swept area for individual tows during the passive phase which, as expected, showed large increases in 2019 relative to 2017 and 2018. This was in large part due to the survey vessel travelling further during the prolonged time periods. A secondary factor was the winch having to drag the trawl closer to the survey vessel due to its slower haul speed.

Median passive swept area estimates represent 24.8%, 22.3% and 32.2% of regular swept areas estimated for the active trawling phases, out of 2278 m2, 2709 m2 and 2739 m2, for 2017, 2018 and 2019, respectively. As this component of the swept area is currently unaccounted for in catch standardizations, its inclusion would lead to correspondingly large decreases in abundance and biomass estimates, relative to the current method.

For example, the commercial snow crab biomasses were calculated at 52271 tonnes in 2017, down 20.5%, 65136 tonnes in 2018, down 19.3% and 57681 tonnes, down 27% in 2019. Thus, when we account for the passive swept area, there is a relative decrease of 11.4% between the corrected commercial biomasses from 2018 to 2019, in contrast to a 2.1% decrease for the uncorrected estimates.

**Historical perspective:**

Past survey protocols intended to limit the scale of trawling after the stop time by recommending that the survey vessel slow down to a negligible speed, then back up slowly during hauling. The execution of this step must be undertaken with special care to avoiding gear entanglement with itself and the survey vessel’s propeller. GPS vessel tracks from the 2012 survey, performed by the CFV Marco Michel, showed that this practice was commonly in use.

With the introduction of the Jean Mathieu in 2013, it appears that this practice was somewhat, though not completely, relaxed. There is also some indirect evidence that the winch was slightly lower on board the Jean Mathieu versus the Marco Michel, as its passive phase duration was generally slightly longer. GPS vessel tracks in 2017, 2018 and 2019, showed that the survey vessel almost consistently held its bearing, i.e. continuing along the tow path, during the passive phase. This shows that the behaviour of the behaviour of the survey captain changed sometime between 2013 and 2017.

Since the intended purpose of manoeuvering backwards was to minimize the swept area of the passive phase, the failure to adhere to this aspect of the protocol probably led to introduction of a negative bias in swept area estimates. These lead in turn would imply corresponding overestimations in abundance and biomass indices for the affected years.

**Uncertainties:**

The passive swept area estimates rely on a number of simplifying assumptions, the violation of which would lead to biases in its estimation.

The trigonometric model outlined above relies on the warp cables being a straight line to the survey vessel when in reality they will sag under their own weight. This implies that the trawl is generally closer to the survey vessel than we consider here, making the distance travelled due to winching, and thus its contribution to the swept area, smaller by comparison. Also, estimates of lift off times, though calculated using the same method for all years considered, may be somewhat overestimated. The lifting off of the footrope is a more protracted process, unlike the touch down. In particular, the contact of the footrope in locations other than its center, which is monitored by the tilt probe, is unknown during the lifting of the trawl doors, which may be lifting the trawl wings.

Other factors might be affecting the catchability of crab encountering the trawl. For example, it is known that the trawling speed is generally faster during the passive trawling phase than in the active trawling phase. In addition, the configuration of the trawl may be less than optimal during this phase, leading to possibly lower catchability. In particular, asymmetry between the warp cables during winching would lead to a possibly lower effective wing spread, and thus to lower effective swept areas.

**Recommendations:**

Because of the shortness of snow crab survey tows, they are especially susceptible to end-of-tow processes and thus require more formal instructions with respect to end of tow procedures, notably those relating to vessel speed and manoeuvres, as well as trawl winching.

With regards to retroactive standardization of the time series, it is recommended that Minilog TD data be analyzed to determine liftoff times. This will yield passive phase durations which, in combination with vessel GPS tracks, will yield insight as to the swept area corrections which need to be applied for previous years catches to render them comparable.

**References:**

Wallace, J.R., West, C.W. 2006. Measurements of distance fished during the trawl retrieval period. *Fisheries Research*. 77(3), pp. 285-292.