Analysis Framework for Long-term and Cumulative Effects Monitoring

Final Report

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Executive Summary

The project was initially to develop an IPM framework but moved towards working exclusively with Cape Breton Fish Harvesters Association (CBFHA) on their lobster datasets to provide information on the types, amounts, and quality of data typically gathered by lobster harvesters. We analyzed variables that are potentially useful for modeling due to the information each provides on lobster populations and how they change long term. As well, the concept of spatial or temporal differences in parameters can be applied to any model variable. We had two objectives:

1) Explore the types, quality and amount of data and present it as potential parameters for modeling projects done by others, and

2) Analyze their lobster catch data specifically characterizing the variance associated with each variable (e.g. culls, sex) on a spatial and temporal basis.

Our approach was to compile the CBFHA data and format it for exploration in the programming language R. Data consisted of data files spanning years 2011–2018. Data were brought into R and joined together, resulting in a unified, complete dataset including all records. Data were analyzed for variables important for modeling. Our focus was on lobster quality indices (e.g. size), lobster ‘culls’ (e.g. lobster with missing appendages), lobster demographics (e.g. sex), trap catches (e.g. number of lobster per trap per fishing event) and trap by-catch (other species caught in traps).

Data were analyzed with respect to seasonality within a typical lobster season. Most metrics were rather consistent in both median value and variance throughout the season. One exception was the proportion of eggs stages. Stage 1 remained relatively constant throughout the season, but the proportion of stage 3 eggs increased while stage 2 eggs decreased. Stage 4 eggs appeared late in the season.

Data were further categorized by distance from shore and location. Lobsters caught in Bras D’or had a slightly larger median carapace length, a higher proportion of eggs in stage 3 of development, and greater median fractions of males, of berried females, and of culls. The distributions of these variables were also more elongated (more variable in the extremes) than those of other locations.

Size distributions were examined with regard to the size at 50% maturity and minimum legal size. The number of lobsters caught increased drastically as they entered the size at 50% maturity range, and decreased almost as much once they reached or exceeded the minimum legal size.

Size distributions of berried females showed that very few were caught below the size at 50% maturity range, whereas many were caught right before reaching the minimum legal size, but fewer after reaching the minimum, indicating harvesting during non-reproductive years.

Effects of trap escape hatch size were also examined. Juvenile traps employed by the Fisheries Science Research Society for monitoring purposes mostly caught lobsters in the same size range as the traps with small and medium escape hatches, but also caught more lobsters on

the lower tail of the size distribution, indicating their benefit to data collection. The traps with smaller escape hatches were also able to catch more lobster than the traps with large escape hatches, as expected.

The results of this project provided value-added components to be used to build upon modeling approaches that use species and environmental data collected by proponents, FORCE, and other independent research projects. Through this project, we were also able to begin exploring the variance structures of the data, which is a key component to an IPM and also provides context for how much and what range of data would have to be regularly collected to populate such a model.

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Objectives

The proposed study was devised to connect the current state of knowledge and preliminary data types (e.g. acoustic monitoring, trapping studies) into an analysis framework for lobster and fishes using Minas Passage (tidal TISEC device deployment area) and the greater Minas Basin. We envisioned creating an analysis framework consisting of an Integrated Population Model (IPM) for lobster, but also transferable to other fish species. However, our initial round of asking various stakeholders for relevant data yielded only two replies and only one ultimately interested in collaborating. Therefore, in our Interim Report (16 May 2019) and its Addendum (3 June 2019), we outlined a project modification that was accepted.

Our project moved from working towards an entire IPM framework, to working exclusively with Cape Breton Fish Harvesters Association (CBFHA) on their lobster datasets to provide information on the types, amounts, and quality of data typically gathered by lobster harvesters. These data were from 2011–2018 and consisted of trap catches of lobster (counts), carapace length and hardness, egg stage of berried females, sex, by-catch (non-target fishes), and cull status (whether a lobster has missing appendages). Each of these variables are potentially useful for modeling because each provides important information on lobster populations and how they change long term. These data and data structure were likely typical of what any lobster association would collect including those in Minas Basin. In this case, the data were a superset of data reporting required by DFO from lobster harvesters plus some additional variables of interest to CBFHA.

These data were gathered on a regional basis with spatial coordinates spanning the fishing grounds of the CBFHA. Therefore, we anticipated various useful parameters for modeling to be available within these data. We had two objectives: 1) Explore the types, quality and amount of data and present it as potential parameters for modeling projects done by others, and 2) Analyze their lobster catch data specifically characterizing the variance associated with each variable (e.g. culls, sex) on a spatial and temporal basis. These objectives are topical for modeling in general because knowing the uncertainty associated with values obtained from large populations of lobster is a key element to consider.

Furthermore, regional or local differences in environment, fishing pressure or gear types, and so forth may create spatial and temporal differences in parameters that are important to know. For example, lobster culls are an indicator of lobster quality and is an important variable to consider because an increase in culled lobster means a decrease in time to maturity and effectively a decrease in future catches. If lobster culls are more variable in offshore regions, the parameter associated with this in a model would be more variable and lead to less precision in estimates of population size or other model outcomes. This concept of spatial or temporal differences in parameters can be applied to any model variable.

Methodology

Our approach was to compile the CBFHA data and format it for exploration in the programming language R (https://www.r-project.org/). R is a robust and detailed programming language used by scientists in many fields. Fisheries biologists and managers have adopted R as a critical component of many analyses of fisheries data. R is a base set of tools with additional ‘packages’ used to add more functionality through adding more functions (small pieces of code that perform specific tasks). We used R through a project management interface RStudio (https://rstudio.com/) and primarily packages for cleaning data, data wrangling, visualization, and statistical analyses.

Data consisted of data files spanning years 2011 to 2018. Data were brought into R and through a series of cleaning scripts, each variable was checked for entry consistency, errors (values outside of an intended range or levels of a factor that were misspelled, etc.), and so forth. Data files were joined together to accommodate datasets with variables not in common. The end result was a unified, complete dataset spanning the years indicated and including all records. 2019 data were obtained according to a new standard set by the DFO that changed how some variables were recorded or defined, making joining with previous years' data prohibitively difficult. Therefore, the reported data analysis is on 2011–2018 data years.

Data were analyzed for variables important for modeling. We did not consider all variables in the dataset. Our focus was on lobster quality indices (e.g. size), lobster ‘culls’ (e.g. lobster with missing appendages), lobster demographics (e.g. sex), trap catches (e.g. number of lobster per trap per fishing event) and trap by-catch (other species caught in traps). We anticipated that particular nodes of a model could be parameterized using values obtained from this data (i.e. estimates of what values should be used for nodes and the variance of those values). Furthermore, these parameters may be useful for modeling because each provides important information on lobster populations and how they change over time, the variances associated with each, and other characteristics revealed by the analysis.

We thought it necessary to focus on a broad review of data useful to parameterize models rather than to create an IPM framework for several reasons. First, DFO already has an IPM and probably some associated data to parameterize it, yet site-specific data may be lacking or of interest especially explored outside of the current DFO lobster assessment framework. Second, it appeared early on through our call for collaborators (see Interim Report) lobster organizations did not want to participate and provide data, thus, it seemed rather pointless to pursue an IPM at the initial, anticipated scale. Third, after considerable time considering project scope, gathering information on what is and is not available, and trying to engage stakeholders, there was ultimately a time limit for project completion.

Activities

The summary of project activities provides a relative chronological timeline of core activities. Details for many of these points are including in our Interim Report. The ultimate outcome was we focused on analyzing data provided by CBFHA.

1) A Masters student was sought for the project. Judith Bjorndahl began her masters at Acadia in September 2018.
2) Judith compiled all available catch information for lobster with the aim to produce a state-space model.
3) Lobster harvesters in Nova Scotia were contacted through a letter and email campaign. We received one immediate negative response from the Fundy United Federation, and one positive response from Cape Breton Fish Harvesters Association (CBFHA). No other organization replied to our request. Via CBFHA, Fundy North Fishers (FNF) in New Brunswick was receptive to our project, but could not commit to any activities to collect data.

FNF had formerly gathered data similar to what we require, but this was all placed with the Lobster Node project and Dr. Rémy Rochette.

4) Following the letter campaign, we considered project feasibility. Our decision was to figure out what sorts of data are available, which organizations have such data, and what is available to share with us.
5) We began collaborating with CBFHA on their data because it was available, and they were willing to share it.
6) We engaged with lobster researchers at the Ocean to Plate Workshop hosted by Springboard Atlantic on 29 Jan 2019. Here, Judith met with several groups including CBFHA, Rémy Rochette and Adam Cook (Department of Fisheries and Oceans). The synopsis was
   i. CBFHA had data and was happy to share it for our project.
   ii. Ashley Sprague from Perrennia (company involved with harvesters) and Melanie Griffin from PEI Fishermen's Association said they could ask around for potential data holders. We did not follow up with either because it appeared this would not be a successful venture.
   iii. Rémy Rochette said some lobster data is available with the Lobster Node. Upon further interactions, this data is actually not available at this time.
7) We discontinued creation of a state-space model (see point 2) because it appeared counterproductive to what is more meaningful for the long-term development of an IPM or modeling in general.
8) We produced an Interim Report (16 May 2019) and an addendum to that report (3 June 2019).
9) The agreement with OERA was amended (8 August 2019) to focus on the CBFHA data and discuss how it can help potential models and monitoring for tidal turbine impacts.
10) We produced a milestone report (4 Dec 2019) including data summaries (excluded 2019 data).
11) We responded to a review of our report and data summaries.
12) We continued to work with CBFHA on aspects of their data such as geospatial analyses. We were in the process in February 2020 of organizing face-to-face meetings with CBFHA and their spatial data specialist to explore data formatting changes required to analyze geospatial aspects of the data. We made progress on this front via virtual interactions.
13) In January 2020, we began investigating catches geospatially. We worked with Adena Peters from CBFHA who was investigating a subset of datapoints with regards to the Emera submarine cables. We thought this would be a good indicator of disturbance and could inform changes in demographics from other undersea structures such as turbines. We provided CBFHA with distances of this subset of traps from the submarine cables on 18 February 2020 using a custom R script, for further analysis using GIS (which we were not using). This question was paused in light of the Covid-19 pandemic and no further work was done.
14) The Covid-19 pandemic began and operations of CBFHA were curtailed. As well, our internal abilities to work were delayed or decreased dramatically.
15) We produced a final report (30 June 2020).

Key Findings and Outcomes

The variances to the original work package objectives are outlined in the Objectives and Methods and in the amended agreement (8 August 2019).

Most of our results were included in the Milestone 3a data summary (4 Dec 2019). A detailed description of the data, data summaries and visualizations of target variables were completed. The variables of interest (carapace length, number of lobster, proportion of males, proportion of berried females, egg stage, proportion of culls, proportion of abnormal clutch percentages, and number of bycatch), were compared across time and spatial scales to identify differences in variance structure.

The lobster season in Lobster Fishing Area (LFA) 27 is mid-May to mid-July. The data across years was pooled and divided into nine, weekly periods to provide a seasonal trends.

Key Seasonal Findings

1) Most metrics were rather consistent in both median value and variance throughout the season (Figure 1). These included:
    a. Median carapace length was consistent throughout the season; however, variability decreased with fewer larger and fewer smaller lobster caught.
    b. Proportion of males decreased throughout the season.
    c. Proportion of berried females increased throughout the season (note the small median lines within the violin plots), but the majority of catches saw very low numbers of berried females.
    d. Proportion of abnormal clutches (where coverage of eggs is <50%) increased over the season.
    e. Proportion of culls (lobster with missing appendages) remained relatively constant throughout the season.
2) One exception was the proportion of eggs stages. Stage 1 remained relatively constant throughout the season, but the proportion of stage 3 eggs increased while stage 2 eggs decreased (Figure 1). Stage 4 eggs appeared late in the season. This was the most dramatic change in summary lobster metrics.
3) Catches were variable per trap, but median catches were relatively constant except for the week of 4 July (Figure 2).
4) Bycatch per trap was mostly low with occasional increases (Figure 2).

Data were further categorized by distance from shore and location (Figure 3). Distance was near (< 1 km from shore), far (>1 km from shore), outliers (>30 km from shore), and inland (0 km) which were traps likely with imprecise or incorrect coordinates. Separated by location were traps set in Bras D'or.

Key Distance and Location Findings

1) When data were separated geographically either by location or distance from shore, some large shifts in demographics emerged (Figure 4). While there is a category for 'inland', we were awaiting confirmation to revise coordinates of these traps. Thus, here we report on trends in only four categories: near, far, outliers, and Bras D'or; inland are nonsensical and likely represent traps actually located in any of the other categories.
2) Most variables were similar across locations, except for those caught in Bras D'or.
3) Lobsters caught in Bras D'or had a slightly larger median carapace length, a higher proportion of eggs in stage 3 of development, and greater median fractions of males, of

berried females, and of culls. The distributions of these variables were also more elongated (more variable in the extremes) than those of other locations.

4) There was also a difference in distribution of the fraction of abnormal clutches between near (small and narrow) and far (higher median and wider distribution) shore traps.

Data were also characterized by trap depth, but no significant differences were visible in any variables.

Additional work done since the Milestone 3a report looked specifically at size distributions of berried females and the effect of escape hatch size. Size distribution of berried females would be important to consider with respect to turbine effects. Escape hatch size was an experiment to see the effect of adjusting escape hatches on lobster catch demographics. The outcome of this experiment may provide a solution to increasing the proportion of legal sized lobster and reducing handling of smaller lobster thus decreasing potential culls and improving health. We view this as a potential operational change to improve overall population health.

The carapace size at 50% maturity in LFA 27, where CBFHA operates, is estimated to be between 68 and 78 mm by the DFO (Government of Canada 2020). The minimum legal size is 82.5 mm. Comparing the size distribution of all lobsters across the eight years of data to these measurements shows that the number of lobster caught increased drastically as they entered the size at 50% maturity range, and decreased almost as much once they reached or exceeded the minimum legal size (Figure 5). The size distributions of berried females showed that very few were caught below the size at 50% maturity range, whereas many were caught right before reaching the minimum legal size (Figure 6). The steep decline in numbers caught above the minimum legal size likely indicates that sexually mature females were being harvested in years where they do not reproduce to a similar effect that the whole lobster population is harvested.

Some of the observations in the datasets contain information about the size of the escape hatches on the traps, broadly categorized into “large,” “medium,” and “small” escape hatches in traps used by the harvesters, as well as “juvenile” traps employed in some years by the Fisheries Science Research Society for monitoring purposes. The traps with large escape hatches caught mostly lobsters above the minimum legal limit, while the traps with medium and small escape hatches retained more lobsters below the limit (Figure 7). The juvenile traps mostly caught lobsters in the same size range as the traps with small and medium escape hatches, but also caught more lobsters on the lower tail of the size distribution, indicating their benefit to data collection. The traps with smaller escape hatches were also able to catch more lobster than the traps with large escape hatches, as expected.

Conclusions and Impact

The results of this project provided value-added components to be used to build upon modeling approaches that use lobster and spatiotemporal data collected by proponents, FORCE, and other independent research projects. Overall, and generally, modeling considers many factors that ultimately may be related to lobster populations and these factors will probably differ geographically. Working on data and collaborating with CBFHA provided a valuable analysis of real data to support modeling efforts and to provide potential values to parameterize models. Through this project, we were also able to begin exploring the variance structures of the data, which is a key component to an IPM and also provides context for how much and what range of data would have to be regularly collected to populate such a model or other models. Differences in spatial and/or temporal (within season) changes in metrics demonstrate some population demographic characteristics were more variable, showed declines or increases through season, and showed differences geographically such that these metrics probably would be ones to target in Minas Basin for tidal turbine studies.

We used various ways to connect with industry, government, and other researchers to curate data. Unfortunately, these areas of inquiry were not as transparent or mature as hoped and, in general, failed to produce as much information (e.g. data) useful for this project as we hoped. Still, we are hopeful that our journey demonstrated that streamlining pathways towards better lobster research, such as data sharing, particularly where it intersects with marine spatial planning initiatives is important to support.

This project allowed us to communicate more directly with industry than they have historically experienced over working with the DFO to address direct concerns and show them the value of their data. Knowledge gaps of particular interest to the industry partner were the size distribution of mature females relative to the minimum legal size and the value of non-harvester traps to sample smaller lobsters in the population, which even the small escape hatch harvester traps cannot sample. While these specific questions were not our priority, they provided clear insight into aspects of the lobster fishery that are important to fishers and reveal other data gaps that may be important for modeling (e.g. gaining a better understanding of size distributions through using different trap configurations).

Recommendations and Future Considerations

1) Recommendations for this area of research include the curation and assembly of spatial and temporal data more broadly in areas where tidal turbines (or other TISEC devices) may be installed, and the analyses of these data geospatially to provide broad indicators of lobster (or other fisheries) demographics important for modeling lobster population dynamics, monitoring populations, and predicting populations.
    a. We recommend the development of an IPM for lobster. Our research in this project suggest spatial and temporal differences in lobster demographics. Spatial and temporal differences in lobster demographics will parameterize an IPM differently resulting in different model predictions.
    b. We recommend investigating the sensitivity of variables within an IPM to tease out which variables are important to monitor. These analyses may be possible without the development of an IPM by using generalized linear models (GLM), resampling methods or other statistical analyses.
2) Limitations during this project were the difficulty of obtaining data, as explained in detail in the objectives and methodology sections, and the time required to prepare the data for analysis. Our recommendations rely heavily on data curation concerns and how better data will allow the effects of tidal turbines, TISEC devices in general, and more broadly marine spatial planning on fisheries to move forward more efficiently.
    a. We recommend adopting the Darwin Core (https://dwc.tdwg.org/) or some other global data sharing standard across all operations be they industry, government, or research initiatives. Standardization of existing data with regards to variable descriptions, values, and derivation is important to relay to anyone with interest in

reviewing or understanding outcomes of analyses. An initial task would be to reformat existing data to align with Darwin Core standards.

b. We recommend fisheries data in general be made broadly available and easier to acquire when it was collected or held for public consumption especially where the data relies heavily on industry participation for its collection. This recommendation could be applied to the DFO, industry research groups, or academic research projects. Having stakeholder buy-in to data availability is an important aspect of this recommendation. Awareness and outreach campaigns to address the importance of broad data availability would be a valuable initiative across the industry, government, and academia.

c. We recommend more open processes with respect to data and analyses methods because generally these lead to better and quicker development of important tools and analyses for fisheries. As climate change occurs and projects that broadly fall under marine spatial planning are initiated, quicker responses to questions provided by any group, e.g. OERA, project proponents or opponents, are important for project planning, review, and implementation. An example to underscore this recommendation is a demonstration, and/or report on the DFO IPM so its development is known to industry and is available for peer review.

Highly Qualified Personnel Summary

Judith Bjorndahl is an MSc student who worked on this data are part of her MSc thesis. Her overall project is studying variability in fisheries data and exploring visualizations and analyses that may provide insights into how to improve monitoring of fisheries in general. This OERA-funded segment of her thesis work provided the opportunity to engage in a fisheries analysis project that will help inform modeling these complex systems. Judith did the bulk of the project work including project goals, planning and implementation, attending workshops and interacting with lobster groups, researchers and others, data curation, summaries, visualizations, and reporting. Judith did not spend her entire thesis time on this project.

Dissemination

Table 1 *Pending publications, presentations, and other reports*.

Refereed publications:
We plan to collaborate with CBFHA to publish this work to answer specific questions about lobster fishing in LFA27. The questions are unrelated to this OERA project objectives, but will use the data for statistical analyses.
Abstracts:
Bjorndahl, J. and Avery, T. Using at-sea lobster data to inform modeling: Case study of Cape Breton Fish Harvesters Association. Atlantic International Chapter - American Fisheries Society, Virtual Conference, August 2020. (pending)
Invited national and international presentations
None

Awards:
None
Other:
Bjorndahl, J. and Avery, T. Report on Cape Breton Fish Harvesters Association at-sea lobster data. July 2020. (pending)

Figures

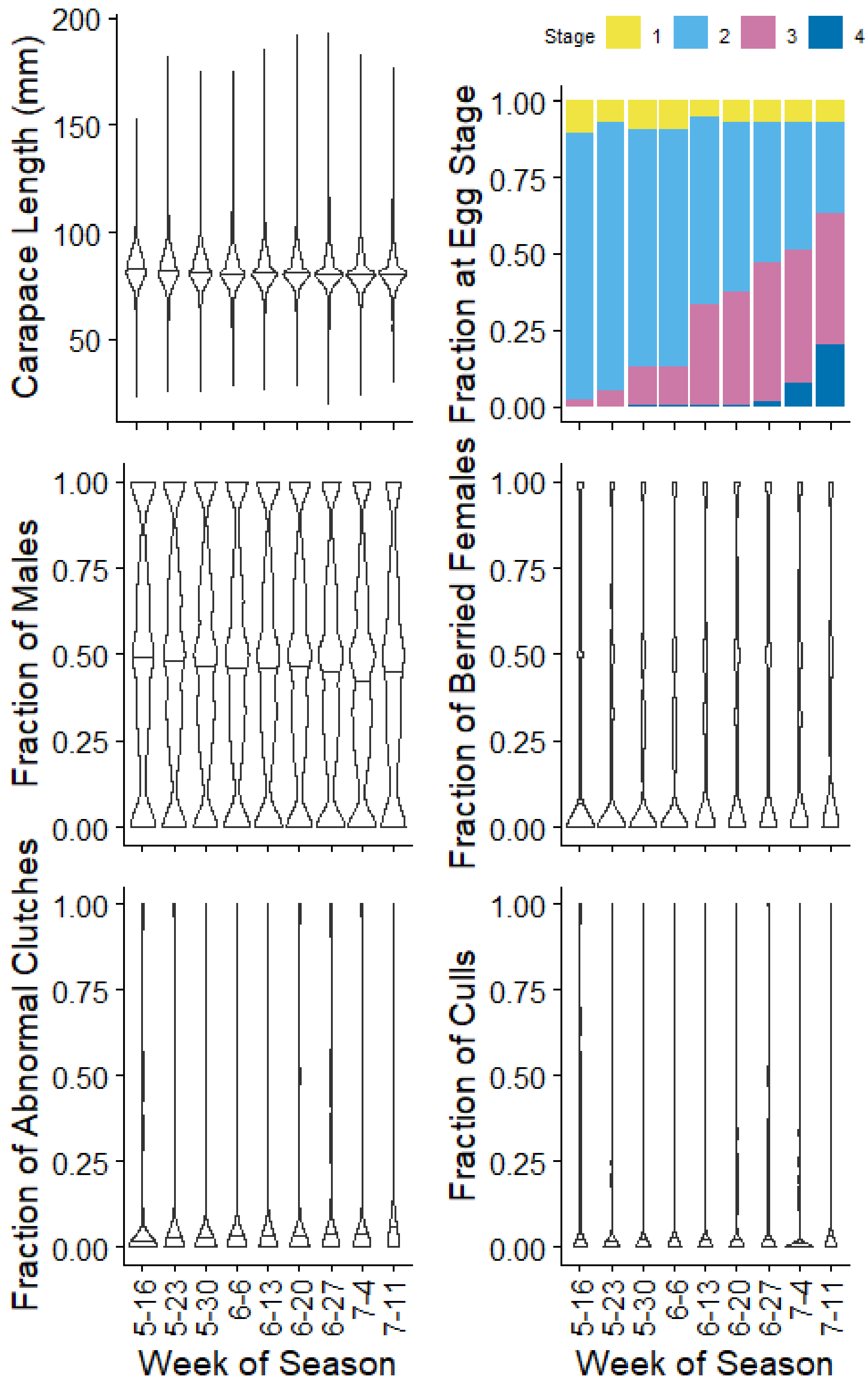

***Figure 1** Seasonal variation in six variables. Horizontal lines indicate median. In plot of egg stage, height of each colour indicates the fraction of individuals with corresponding egg*

stage.

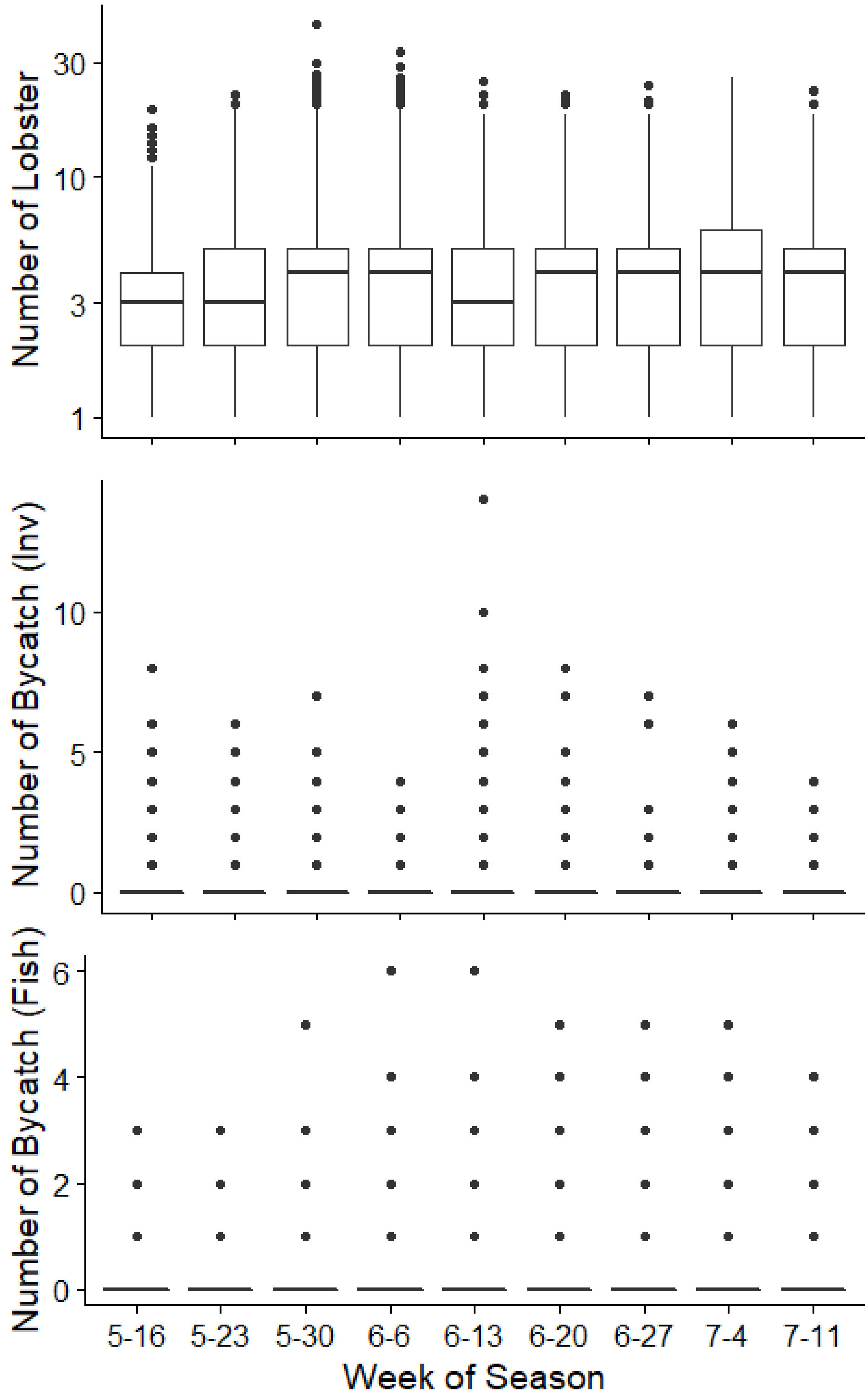

Figure 2 *Seasonal variation in three count variables. All variables represent number of individuals per trap.*

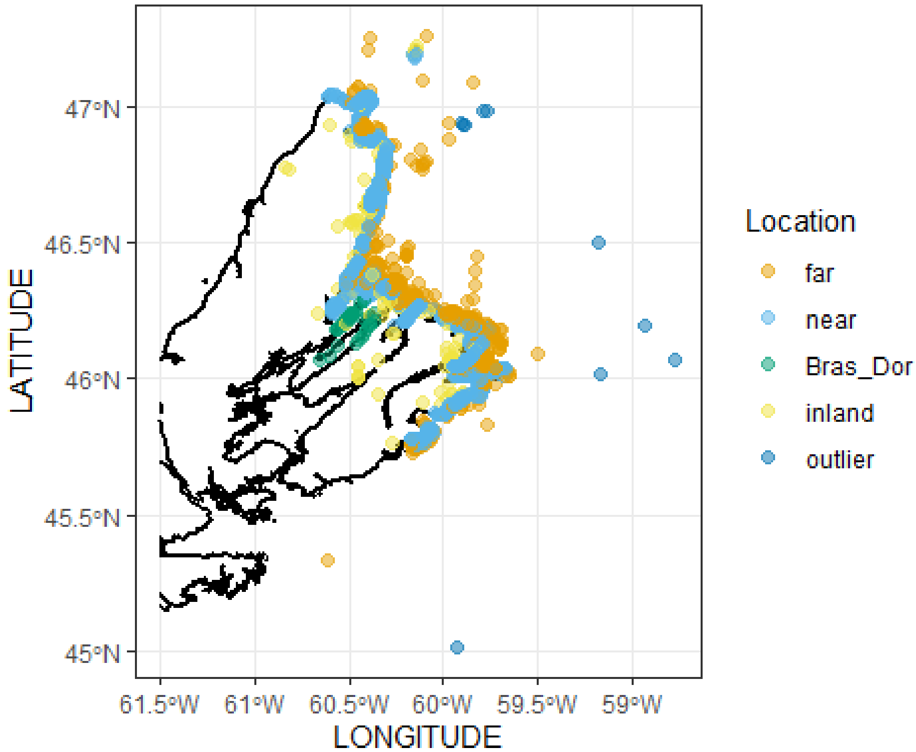

Figure 3 *Locations of all traps with location category indicated by colour.*

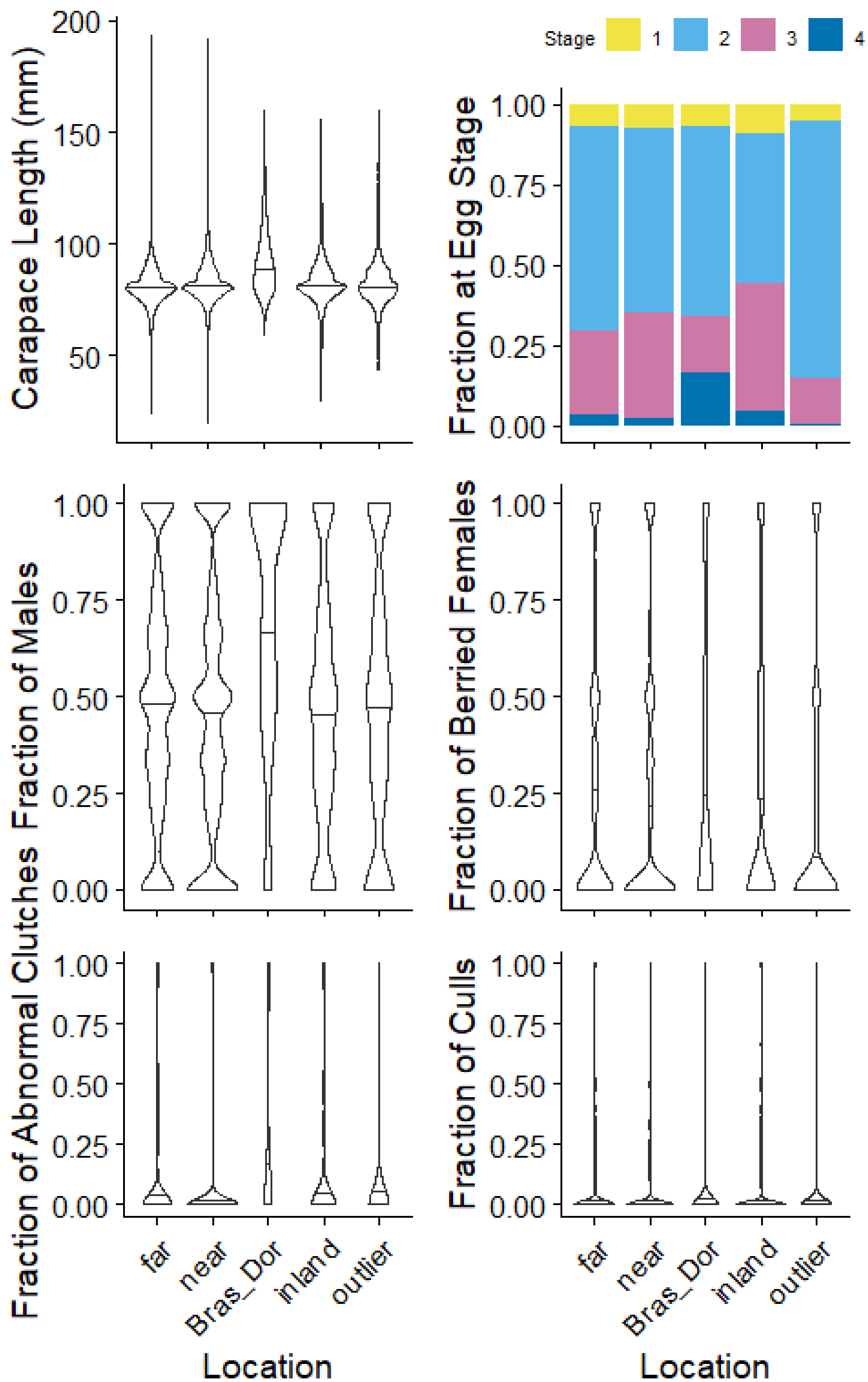

Figure 4 *Regional variation in six variables. Horizontal lines indicate median. In plot of egg stage, height of each colour indicates the fraction of individuals with corresponding egg stage.*

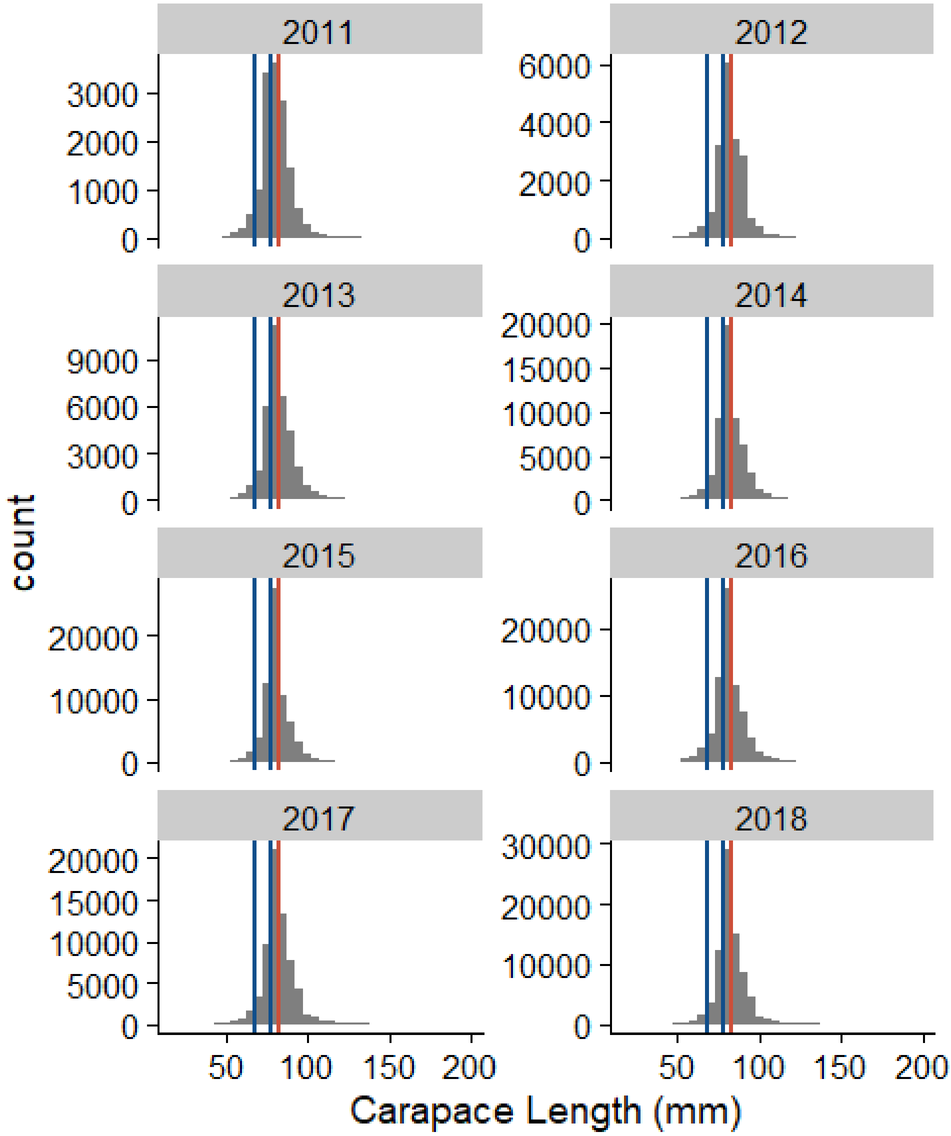

Figure 5 *Size distribution of all lobsters by year. Blue lines indicate the estimated range for 50% maturity, red lines indicate the minimum legal size (82.5 mm).*

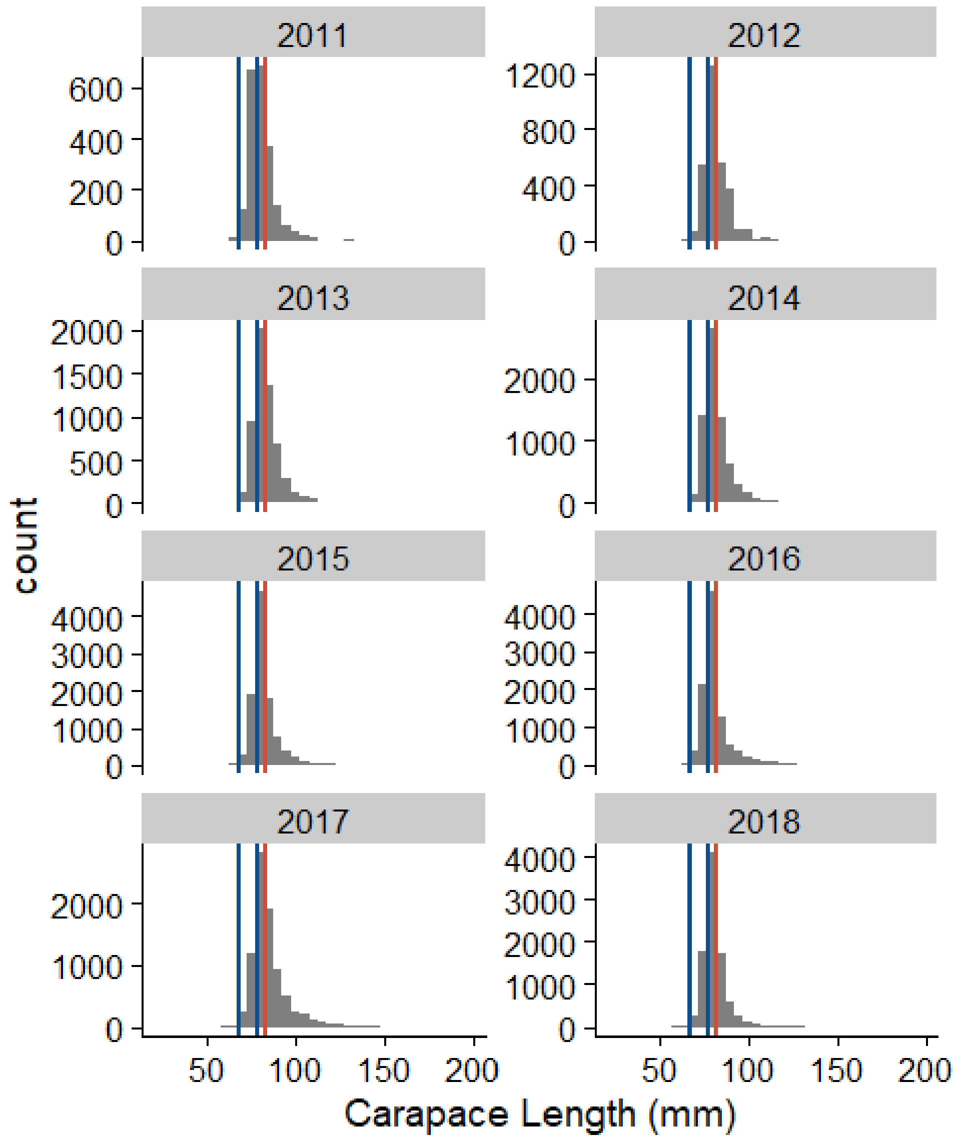

Figure 6 *Size distribution of berried females by year. Blue lines indicate the estimated range for 50% maturity, red lines indicate the minimum legal size (82.5 mm).*

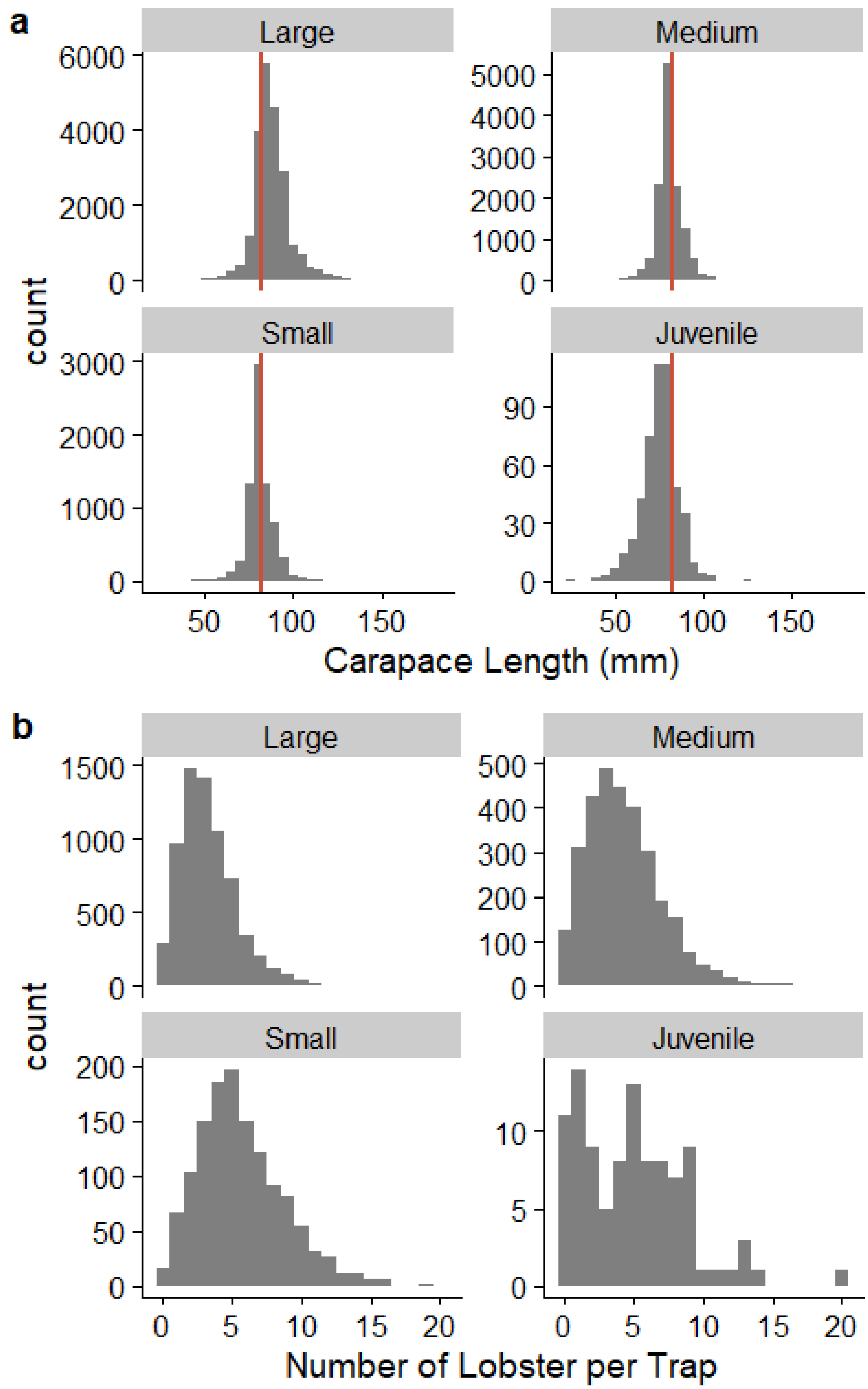

Figure 7 *The effect of escape hatch size on (a) the size of lobsters caught and (b) the number of lobsters caught in a trap. Red lines on (a) indicate the minimum legal size (82.5 mm).*

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