Appendix XI

A Revised American Lobster Catchability Monitoring Program for the Fundy Ocean Research Centre for Energy

A REVISED AMERICAN LOBSTER CATCHABILITY MONITORING PROGRAM FOR THE FUNDY OCEAN RESEARCH CENTRE FOR ENERGY

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Introduction

TriNav Fisheries Consultants Inc. (TFC) was retained by the Fundy Ocean Research Centre for Energy (FORCE) to revise its lobster catchability monitoring program within its Crown lease site in Minas Passage, Bay of Fundy (FORCE site). Per directives from Fisheries and Oceans Canada (DFO), FORCE is seeking assistance to develop an amended lobster monitoring methodology. Specifically, the methodology must be more statistically robust and incorporates non-trap methods for evaluating lobster abundance in addition to the continued monitoring of changes in lobster presence at the site following the installation of tidal turbines.

The main mechanism through which this new monitoring program will be undertaken is the use of experimental lobster traps (*i.e.* modified commercial traps) to estimate catchability. DFO refers to lobster catchability as a measure of the effective fishing area of a trap, modelled by the following equation: $q_t = C_t/(f_t * D_t)$, where q is catchability, C is catch, f is effort, D is animal density, and t is time (Tremblay, Smith, Robichaud and Lawson, 2006). Catchability and catch rates per unit effort are common metrics used to estimate lobster abundance by DFO, via trapping studies as well as experimental trawl surveys.

While it is recognized that the use of baited traps to generate estimates of abundance and distribution of crustacean species is an imperfect method, the efficacy of trap surveys is dependent upon the purpose of the research. Should small-scale movement and distribution be the goal, then trap studies should not be considered as they are not capable of this degree of precision. Catch rates provide insight into the density of lobster located within the effective range of a lobster trap, not the specific location of a lobster. Effective lobster trap range has been found to be highly variable and related to the daily home range of the animal, not considering seasonal, larger scale movements. It is also anticipated that effective trapping area would be highly impacted by the tidal influence in Minas Passage, which will change the area of bait influence and increase the degree of trap movement. Stakeholders have indicated that trap movement can be hundreds of metres within a 24-hour soak period, so it is not possible to know the exact location of the trap at the time it entrapped the lobster.

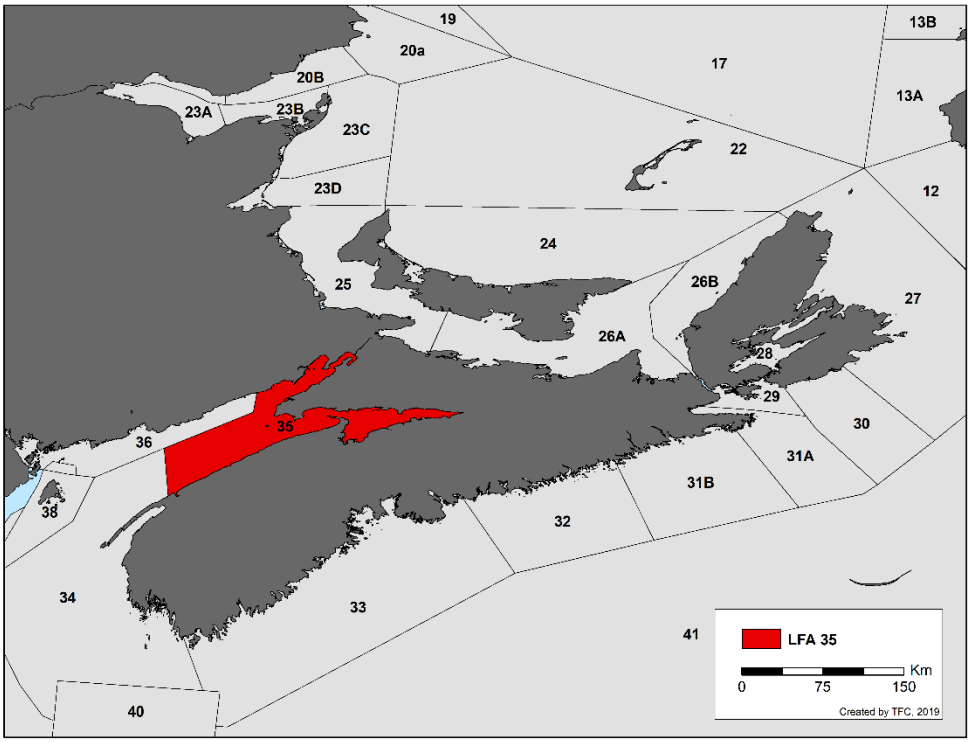
How well a trap functions is based on several key factors: trap size, bait (quantity and quality), soak time, presence of an escape vent, etc., as well as characteristics of the animal (size, sex, molt stage) and environmental factors (lunar cycle, currents, temperature). The relationship between lobster trap catch

and abundance remains poorly understood, yet it is one of the most accessible and fundamental methods currently in use as an index of abundance.

Fishery Description

The FORCE site falls within Lobster Fishing Area (LFA) 35 in the upper Bay of Fundy, covering the Minas Basin, Minas Passage, Minas Channel, and Shepody Bay (Figure 1). This LFA is one of the most productive lobster fishing areas in terms of landings per commercial license and has one of the longest fishing seasons in the Maritimes.

Figure 1. Map of Lobster Fishing Areas in the Canadian Maritimes. LFA 35 is shown in red. Produced by TFC, 2019.



DFO estimates abundance of lobster by fishing area in its *Science Response* reports through a combination of commercial landings data, commercial catch per unit effort data, and fishery-independent surveys. To manage the LFA 35 fishery in which the FORCE site falls, DFO relies on input controls rather than output; gear restrictions not a quota system is used in the Canadian lobster industry. The following table outlines recent stock monitoring metrics used to provide context during the redesign of FORCE lobster catchability monitoring program.

Table 1. LFA 35 stock monitoring metrics presented in DFO's *Science Response* 2018/049 (most recent available datum for LFA 35) & from TFC's internal fisheries database.

LFA 35 Lobster Fishery	
Number of Commercial Licenses	95*
Trap Limits	300/License
Total Traps in LFA 35	28,500
Fishing Season	Oct 14-Dec 31; Last day Feb-July 31
Min. Carapace Length (mm)	82.5
Landings (MT)	2,353 (2017-18)
Precautionary Approach Status	LFA 35-38, combined: Healthy
Commercial CPUE (Kg/Trap Haul)	LFA 35-38, combined: 2.02 (2016-17)

*As of December 31, 2017.

DFO further divides its LFA's into statistical grids. The FORCE site falls within grid number 17, which spans the entire Minas Passage. Typically, this grid accounts for an estimated 2.5% of total LFA 35 commercial landings and has seen average commercial landings of 3.22 kg per trap haul from 2016-2018.

Past Studies

While some baseline lobster catchability data exist from previous work completed at the FORCE site, study gaps and issues with consistent data collection have arisen for several reasons. In some instances, these issues resulted from study design and methods used, whereas in others the Minas Passage environment caused logistical challenges.

Due to the extreme environment in Minas Passage, successful collection of meaningful and robust lobster monitoring data has posed a challenge. Past efforts (conventional tagging, acoustic telemetry, commercial traps, experimental traps) have achieved varying degrees of success. As a result, adequate baseline data on lobster catchability does not exist at this time. The following table outlines a brief synopsis of key lobster monitoring activity within Minas Passage in recent years with a focus on lobster catchability. The 2011 study used commercial traps whereas the 2017 study used modified, commercial traps allowing for the inclusion of sublegal-sized lobster (< 82.5 mm carapace length). Limited statistical significance was presented in the 2017 study and no raw data from either study has been made available to FORCE.

Table 2. Summary of key lobster catchability studies completed at the FORCE site.

Report	Author	Data Years	Results Summary	Key Recommendations
Lobster Catch Monitoring (Feb 2011)	CEF Consultants Ltd.	2009, 2010	- Commercial catch sig. lower during fishing season - -Catch sig. lower 200-300 m away post turbine deployment	- Redesign so Before After Control Impact study can be completed - Randomize test & control stations
Lobster Catchability Study Report (Dec 2017)	Nexus Coastal Resource Management Ltd.	2017	- All but one sample categorized as high CPUE - Catch decreased over course of survey & with increased tidal range - Catch in ring 1 > ring 2	- Modify design to ensure statistical validity - Collect environmental data - Consider effects of multiple turbines

While the 2017 catchability study included some of the recommendations made in the 2011 report, others were not addressed. No control site was established and statistical analyses were limited and/or not presented. It should also be noted that the post turbine deployment survey scheduled as part of the 2017 study was not completed as no functioning turbines were present at that time.

Furthermore, some recommendations made in the 2011 lobster catchability report have become less relevant due to changes in the turbine designs being tested and the arrangement of berth sites. For example, the concentric ring design presented by Bayley during his review of the 2011 catchability study is less applicable to floating turbine designs.

DFO has echoed several of the above recommendations (2011 & 2017) with respect to lobster catchability study design, emphasizing the need for a more statistically robust study plan as well as the incorporation of non-trap methods of evaluating lobster catchability, such as underwater camera work, trawling, and divers (CSAS 2016/022).

Moving forward, FORCE is looking to employ a lobster catchability monitoring program which incorporates recommendations made by DFO, is applicable to multiple turbine designs and multiple deployments, and can monitor near and far-field effects on an ongoing basis.

Work Outline

To address the recommendations outlined above and other issues identified by TFC, a redesigned lobster catchability methodology that will help to ensure that FORCE's hypotheses can be tested with a higher degree of confidence has been developed. The modified catchability program will include fishery independent and fishery dependent data sources and allow for analysis monitoring of lobster abundance, through time, with and without turbines present. TFC has outlined the following project elements:

- Experimental trap study
    - Designed such that impacts of turbine deployment(s) at near-and far-field distances can be assessed
- Conventional tagging
- Commercial catch analysis
- Environmental variables (water temperature, tidal currents, salinity)

The overarching goal of the current study design is to facilitate long-term data collection at the FORCE site and include additional, supplemental data sources.

In addition to the components listed above, TFC has explored the potential of including other monitoring methods. TFC has relied on the expertise of its staff and internal fisheries databases to complete this project. As needed, TFC has consulted with subject matter experts, such as statisticians with experience in marine ecological studies. References are cited at the end of this report and a list of personal communications can be made available upon request.

Methodology

The following sections of this report outline TFC's prescribed methodology to undertake lobster catchability monitoring in and around the FORCE site, with consideration of the recommendations outlined in previous studies and by DFO.

Components of this proposed experimental design rely on the collection of new data and others incorporate existing datasets collected by the federal government and by other researchers conducting work in the area.

While trapping, as a method of estimating lobster abundance, is a relatively common practice using both commercial and experimental (modified commercial) traps, the extreme and challenging Minas Passage environment dictates a specialized methodology unique to research conducted in other areas.

Field Methods

It is recommended that lobster catchability monitoring take place primarily using similar experimental trap methods employed in Minas Passage in 2011 and 2017, but with key changes in study design and the addition of mark/recapture monitoring of catches. These changes are outlined in the below sections.

Experimental Traps

For lobster catchability monitoring at the FORCE site, it is recommended that standard commercial, wire lobster traps (48" x 15" x 24") be used. Typically, larger, wire traps are used in LFA 35 to help combat the tidal strength. Experimental traps should be modified so that the escape vent is blocked, allowing for legal and sublegal sized lobster to be retained.

Experimental traps should be fitted with 150 kg concrete slabs in an effort to maintain position given the strong Minas Passage tides. They should also be equipped with 100 m buoy lines to limit resurfacing time.

Traps should be baited with standard bait species and quantities aligned with that used by local LFA 35 harvesters. In the past, 1.5 kilograms and herring and redfish was used per 24-hour soak per trap. Expertise of the captain hired to complete this study can be relied upon with respect to bait used.

From previous trap surveys completed in 2017, FORCE has acquired approximately 18 modified commercial (experimental) lobster traps of a suitable size and construction for the current proposed study. As these traps have not been used or maintained since fall 2017, repairs will be needed to ensure they function properly once deployed. While the precise cost of this work is unknown, a budget of $100 per trap has been allotted (total of $1,800).

To monitor water temperature, salinity, and water depth during deployments, a conductivity, temperature, depth (CTD) instrument can be deployed. It is understood that FORCE currently owns one of these devices and thus, it would not be an additional cost to include this environmental monitoring as part of the catchability monitoring program. However, as the benthic water temperature is the target to be monitored during the study, utilizing temperature loggers adhered to the experimental traps may provide more accurate data. A device such as the HOBO Pendant MX could be deployed with traps and

would provide Bluetooth enabled data downloads to iOS and Android mobile devices. Each device costs $74, for a total cost of $888 for the 12 experimental traps.

During the 2017 study, it was determined that eight traps could be sampled during a single slack water period. However, during the 2011 study more than 20 traps were sampled during a similar time period. It would appear that the major difference between the efficiency of the two studies is related to the vessel chartered and associated captain and crew. In 2017, the vessel *Nova Endeavour* was chartered and personal communications have revealed that the skipper had experience in the fishery, but not the lobster fishery. Their experience in the Minas Passage environment was unknown. This lack of familiarity with the study area and the gear used to complete sampling is believed to have hampered efficiency. Under the guidance of an experienced lobster harvester, particularly one with experience operating and hauling traps in the Minas Passage, it is anticipated that 12 experimental traps would be safely manageable during a slack water period.

Experimental Trap Arrangement

To develop a longer-term lobster catchability monitoring program that includes BACI elements, it is recommended that a test site and control sites be established. These sites should be designated and stratified based on distance from the stressor (*i.e.* turbine(s) for testing) and from natural marine geological features. Within each of the three, equal-area strata (test, two controls), four experimental traps will be randomly deployed (Figure 2).

As discussed, it is estimated that an experienced harvester (both in terms of lobster harvesting gear and Minas Passage environment) would be capable of safely facilitating the deployment and retrieval of 12 experimental traps per slack water period. Experimental trap locations should be randomly allocated each study year, with four stations per strata. Reselecting trap deployment locations with this random and stratified method within the strata will increase coverage within the FORCE site while maintaining continuity with number of experimental traps and replicates produced.

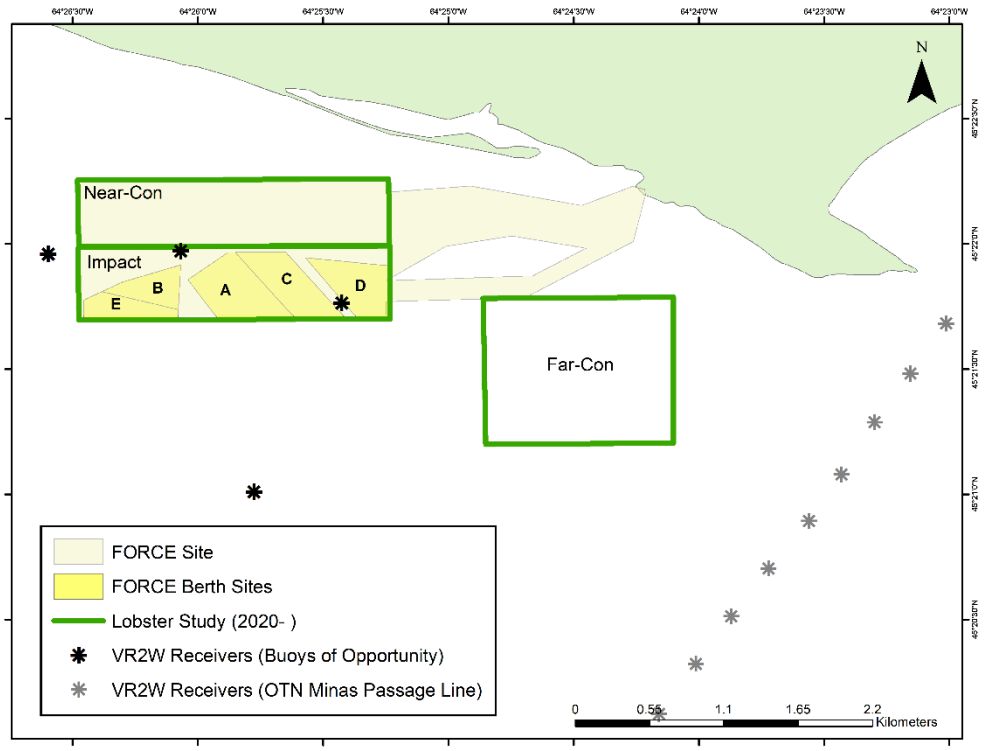
The impact site is designated at the southern half of the FORCE site itself, containing the five berth site locations, equal to half the area of the total FORCE 1.0 km-by-1.5 km lease area. This division also follows the natural marine geology of the FORCE site, with impact strata falling atop a shallower, scoured volcanic platform and the remaining northerly half of the FORCE site falling atop a deeper area with more cobble and boulder cover (*i.e.*, the near-field control site). The impact site is potentially subject to direct presence of a test turbine following deployment of a device for testing. The impact site and near-field control site will each house four randomly allocated experimental traps during each study year.

A far-field control site approximately 500 m from the FORCE site was selected to accommodate the potential for BACI-style analysis of catch data in the future that considers distance from the 'change' as a variable. The proposed location of the far-field control site is atop similar substrate to the near-field control and is expected to experience similar tidal currents.

The far-field control site will be of equal area to both the impact and near-field control sites and will also house four experimental traps each study year (latitude and longitude to be determined randomly within the confines of the area). This site also falls atop similar substrate to the near-field control site and similar water column depths. DFO scientific surveys have noted a data gap in shallow nearshore waters in the upper Bay of Fundy, an area known to have high lobster abundance.

The figure below illustrates the projected lobster catchability test and control sites. For reference, the FORCE Crown lease polygon as well as locations of current acoustic receivers (Ocean Tracking Network Buoys of Opportunity and Minas Passage Lines) have been included.

Figure 2. Map of proposed lobster catchability monitoring sites: one test site located covering the FORCE site's berth areas and two control sites located in the northerly half of the FORCE site (no berths) and approximately two kilometres east. Produced by TFC, 2019.



A protocol must be put in place during study years in which there is turbine deployment for testing in any berth. At the time experimental trap latitudes and longitudes are randomly selected in the impact stratum, exclusion zone(s) must be put in place such that the research team and their experimental traps will operate at a safe distance. Random sampling will occur until such time that four locations are selected meeting the safety buffer criteria for the specific turbine(s) that will be deployed during that study year.

Trap Deployment & Retrieval

Deployment of experimental traps should take place at and around slack water (approximately 20 minutes at its shortest) with the aim of deploying experimental traps at their prescribed locations per the random, stratified design. Personal communication with experienced principle investigators in the Minas Passage has indicated that workable time in Minas Passage is often closer to one hour. Upon deployment, the exact location (latitude and longitude via vessel GPS) should be recorded in addition to the water depth (via the vessel's sonar). Specific date and time of deployment must also be recorded so that tide height can be determined from DFO's tides, currents, and water levels data. Notes on weather conditions during the deployment and any other noteworthy observations or events should also be recorded.

Following deployment, experimental traps should be set for a 24-hour period. Soak time is known to be an important factor related to catchability of lobster. Maintaining a constant soak time amongst experimental traps will allow for the influence of other, non fishery-dependent variables to be assessed.

Any unsuccessful trap retrieval attempts should be noted by station number. For successful experimental trap retrievals, the latitude and longitude should be recorded so that trap movement within the 24-hour soak can be tracked. The time the experimental trap is retrieved should also be noted, as well as the weather and any other general observations made during the procedure.

For each experimental trap hauled, all lobster and by-catch species present must be counted and recorded. Furthermore, a detailed examination of each individual lobster must be completed. The following data should be included:

- Trap ID
- Retrieval date, time, location
- Sex
- Whether or not berried
- Clutch size
- Carapace length
- Shell hardness
- Condition notes
- Whether or not V-notched

- Whether or not tagged (if yes, record relevant information)
- By-catch present (count, species ID)
- General comments

A standard recording sheet, such as those prepared by the Fishermen and Scientists Research Society (FSRS), can be used as-is or as a template with modifications to suit FORCE's specific needs in this study. However, less detail is needed with regard to by-catch species: a simple count and species identification will suffice.

During the experimental trap retrieval process, all lobster caught should be fitted with uniquely-numbered conventional tags, such as Floy tags, as a mark-recapture tracking method to clearly identify replicates within the study areas during a single survey event. Approximate cost of Floy streamer tags for crustaceans is $100 + HST for 100 units and $100 + HST for a tagging gun (should the scientific team nor FORCE not already own one). Considering the projected number of sampling events and potential catch-per-trap based on past studies and CPUE from other LFAs, it is recommended that 1,000 streamer tags be purchased (approximately $1,000).

Use of conventional tags will help to elucidate rates of recapture in the study area within and amongst successive trap surveys. The scientific team should also make efforts to advertise this tagging effort at wharfs and through fisheries associations so that local harvesters are aware of this initiative in the hopes that, should tagged lobster be caught by commercial fishery participates, additional information on lobster movement independent of FORCE's trap surveys can be extracted. To incentivize this process, it is further recommended that a small reward be offered for supply of information in dependent of retrievals during FORCE's scientific surveys. For example, a reward of a $5 Tim Hortons gift card per retrieval successfully submitted to FORCE to a maximum of $100 per harvester. Alternatively, a larger-scale reward structure could be used in an effort to increase harvester participation, such as annual prize draws for $1,000 and $500 cash (depending on FORCE's desired reward budget). Based on past studies in LFA 35 using streamer tags, a high return rate is not anticipated.

Returning lobster to the water as soon as possible should be the aim during sampling. Should time be of the essence during sampling, it is recommended that labelled plastic totes with unique ID number corresponding to experimental trap be used to temporarily house trap contents during biometric analysis. This allows experimental traps to be redeployed more efficiently. Should any catch remain onboard for analysis after the vessel begins steaming out of the Passage, the latitude and longitude at which point the lobster are released should be recorded in field notes. While movement is not the primary focus of

conventional tagging efforts during this stage of the catchability program, these data could provide additional information regarding residency and movement, as well as recapture data for lobster obtained from the impact and control sites.

Vessel

It is recommended that a registered fishing vessel be chartered as a research platform from which to carry out the catchability study. Lobster fishing vessels in LFA 35 can be a maximum of 44' 11" plus a 5' extension and have the typical open-back design.

TFC determined through consultation that it would only be feasible to utilize the services of a commercial lobster harvester for research charter purposes during certain times of the year. During the fall fishing season, the most lucrative and busy time for LFA 35 commercial fishing, research charters would not be possible. However, during the spring season (following mid-April), research charters should not pose a problem. Preliminary discussions indicated that it was unlikely an LFA 35 harvester would be willing to take a scientific observer for FORCE along for an entire day of commercial fishing activity due to the inconvenience and anticipated harrowing workdays (> 12 hrs at sea).

A potential research platform and operator has been identified at this time. LFA 35 commercial harvester Mr. Bliss Walton has identified to TFC that, in principle, he would be capable of undertaking gear deployment and retrieval activities from his fishing vessel. Mr. Walton has indicated that his charter rate would be based on fuel use and time worked by himself and one additional crew member. Based on an estimated daily charter of six to seven hours, it is estimated that a rate of $2,500/day would clearly cover these costs and the valuable time of the skipper and his crew. Given the prescribed experimental trap arrangement and proposed sampling design (see sections below), charter fees to complete sampling during year one of study will total approximately $35,000, including a buffer to account for issues that may arise.

Should Mr. Walton be unavailable, it is anticipated that a similar charter arrangement could be reached with another experienced LFA 35 harvester.

If any commercial fishing vessel is to be utilized for the current project, it must meet all of FORCE's safety criteria. It is anticipated these stringent requirements may preclude some harvesters from being hired as a research charter. FORCE staff have indicated that there is some flexibility in its requirements, to be assessed on a project-by-project basis, but minimum requirements should include an evaluation of the following:

- Vessel safety plan
- Vessel specifications
- Vessel blue decal & registry
- List of vessel safety equipment
- Insurance information
- Any environmental policies
- Any safe work policies/procedures

Survey Schedule

Abundance of lobster in Minas Passage is variable both spatially and temporally. In an effort to collect data at the prescribed study sites to capture these fluctuations, it is recommended that a spring and a late summer/fall survey take place each study year. As discussed, when analyzing vessel charter characteristics, it would be possible to complete surveys from mid-April to mid-May and again from mid-August to early-September, so that they do not interfere with peak fishing time and/or preparations for the fishing season.

In addition to the aspect of seasonality this survey schedule affords, it also provides pre-fishing season and in-fishing season data on catch rates.

It is anticipated that six days at sea would be required to complete each of the two annual surveys (one spring, one fall), covering 12 experimental traps and four rounds of sampling during each. This would require a total of 12 chartered days at sea per study year and generate 96 samples (48 per survey). An extra day at sea has been budgeted in per survey to account for any issues that may arise during work in relation to retrieving traps, weather, etc. It is anticipated that the six days needed per survey would be spread over approximately 1.5 weeks, depending on weather events and avoiding spring tides. Experimental trap deployment would be scheduled in two groups of three days, with rounds one and two to take place over two consecutive tides as would rounds three and four.

The aim of this revised lobster catchability methodology is to develop a survey schedule that can be carried out year-on-year, irrespective of turbine presence or absence, such that intra-annual and inter-annual comparisons can be made with statistical confidence. Given the number of samples possible to safely collect within FORCE's budget, it is anticipated that meaningful data be collected, particularly if the prescribed ongoing nature of the surveys is maintained.

Licenses & Protocols

To complete the field methodology outlined above, obtaining the necessary scientific licenses from DFO will be necessary. Preliminary liaising with DFO's licensing department together with past experience of

researchers at the FORCE site have not indicated that this will be an issue. The 2017 scientific license was obtained in FORCE's name and, thus, reissuance of the same license should be a fairly simple process with only a nominal fee. It should be noted that a second scientific license will be needed to undertake surveys outside of the commercial fishing season.

While American lobster are invertebrates and thus are not subject to animal care protocol, it is recommended that samples be treated with respect and handled with due care throughout the biometric measuring and tagging process and subsequent release back into the environment.

In addition, safety while on board the chartered research vessel will be paramount in light of the extreme conditions of the work environment. Individuals on the appointed scientific team are advised to wear personal floatation devices at all times and have current training in marine emergency duties.

Design Adaptability

It is recognized that the Minas Passage environment presents challenges when designing ecological monitoring studies. The proposed lobster catchability monitoring program should be adaptable such that lessons learnt during the initial surveys can be used to improve the methodology. For example, preliminary experiences carrying out the study may inform the trap deployment methods or the number of traps able to be deployed per slack water period.

Data Analysis

The field methodology presented in the previous section will allow the contracted researcher to produce a robust and informative analysis, considering several natural and anthropogenically introduced variables and how they impact lobster catch rates.

It is anticipated that a multivariate analysis of variance on catch rates in relation to the following could be assessed for significance:

- Carapace length
- Sex
- Whether or not berried
- Recaptures
- Test site (impact, near-field control, far-field control)
    - Associated with water depth, substrate, tidal currents
- Turbine(s): present or absent
- Water temperature
- Tidal stage

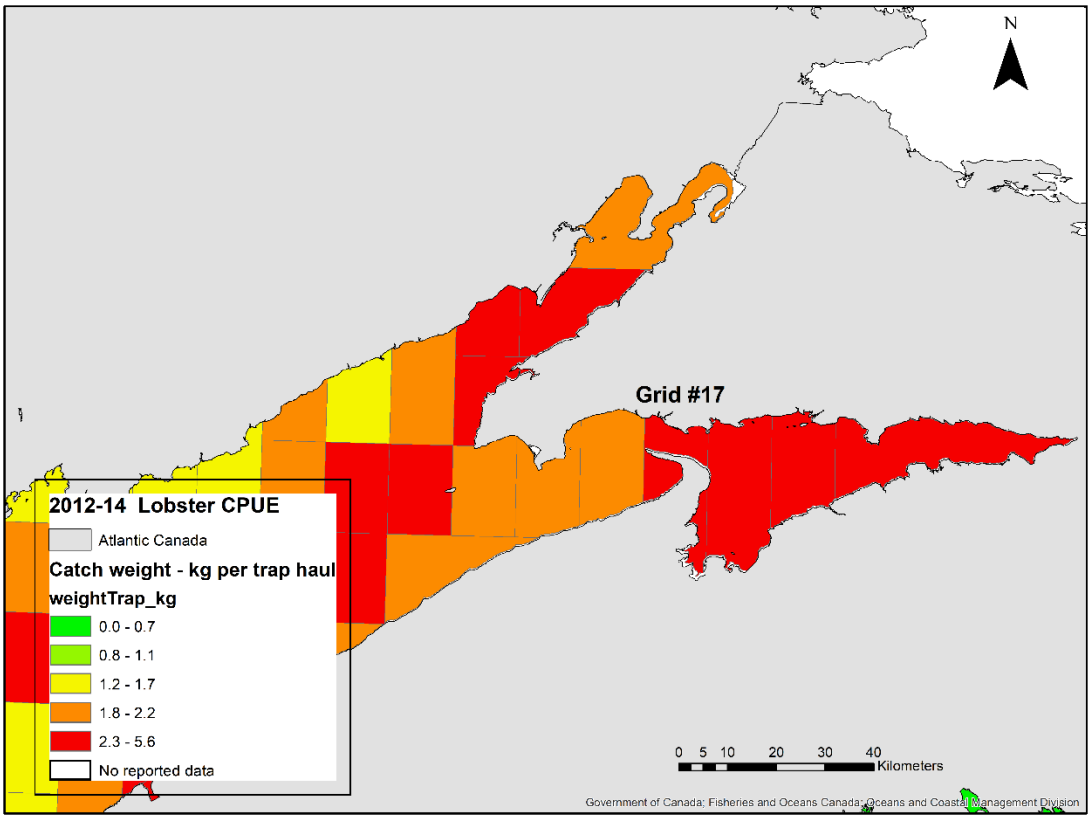
In essence, this will be a factorial experiment which integrates experimental trap data collected and attempts to quantify relationships between these data, as well as environmental data and commercial fishing data sourced from DFO. Catch data can then be fitted to a linear model (recommended negative binomial generalized linear model or Poisson regression based on data type). The following table outlines the anticipated sources of data to be used.

Table 3. Potential data sources to be used to analyze FORCE lobster catch data and construct models for analysis.

Proposed Data Sources	
Experimental catch rates	FORCE catchability study
Streamer tags	FORCE catchability study
Water temperature	FORCE CTD
Tidal currents	ADCP on site at FORCE and/or existing current data model
Substrate	Bathymetry (Seaforth Geosurveys)
Tidal cycle stage	Government of Canada
Commercial catch rates & fishing effort	DFO Statistics Division
Commercial CPUE (kg/trap haul)	DFO Statistics Division

Commercial harvesters are required to submit to DFO logbook data containing valuable information about their activity, including fishing effort and catches. This long-term data can be sourced through DFO's Statistics Division and used to validate findings during FORCE's catchability monitoring programs. As mentioned, FORCE falls within statistical grid number 17, encompassing the entire Minas Passage (Figure 3). It is recommended that a comprehensive data request to DFO Statistics be made such that catch rates, fishing effort, and possibly variance of the two through time can be better understood within Minas Passage.

Figure 3. Map of commercial lobster fishing effort from 2012-2014 in the upper Bay of Fundy in kilograms of lobster per trap haul. Data source: DFO, produced by TFC (2019).



Through the 12-trap study design with four replicates comprising a single survey, each spring and fall lobster catchability survey conducted in a year will generate 48 samples (96 for the year) equally representing the impact, near-field and far-field control sites. Given safety and budgetary constraints, this is the maximum number of samples producible in a balanced design that will provide the structure needed for a longer-term monitoring program. To ascertain whether this sample size is sufficient to achieve significance is not possible for an ANCOVA or MANOVA, as baseline levels of variance in lobster catch rates are not known. While averaged CPUE data can be obtained through DFO logbooks, the level of variance between trap hauls is not known. This poses a major issue when attempting to determine the number of experimental traps sampled and repetitions required in order to avoid type II statistical errors and effectively detect 'changes' in catchability. As data is collected, through time, variance data will be collected and can be used to inform future study design – within the safety constraints of the Minas Passage and FORCE's budget. It should be noted that the principal investigator of the study will choose how to undertake the data analysis in terms of statistical testing and modelling.

Given the large amount of uncertainty as it relates to lobster abundance and population dynamics in the upper Bay of Fundy and, specifically, the FORCE site, the aim would be to construct an integrated population model (IPM). IPM's are a Bayesian approach widely accepted as a good solution to ecological modelling. IPM's account for stochastic events that are not considered in traditional models and do not rely on a solely deterministic approach. An IPM for the purposes of this study could include catchability data collected with experimental traps at the FORCE site through time, historical data sourced from DFO to model long-term productivity of the system, and mark/recapture data collected in the field and/or modelled through simulations.

Simulating or resampling requires significant data processing capacity but can help to determine adequate sample size using the limited existing data or data from a similar population. There are several forms of resampling, for example the bootstrap method. This method examines the degree of overlap between confidence intervals and allows for suitable test statistics to be calculated. Bootstrapping maintains separation of treatment groups during the sampling process and, thus, is less reliant on distribution amongst the groups being similar. A bootstrap resampling technique will help to shape a field design for experimental trap placement to ensure that sufficient power is achieved.

To complete this task, raw data sourced from 2011 and 2017 catchability studies at FORCE can be resampled so that the they approximate the true parameters of the lobster population in and around the FORCE site. In this instance, mean CPUE (by weight or number of lobster) as well as standard deviation and standard error should be considered. Should it not be possible to obtain raw data from past FORCE lobster catchability work, it is suggested that similar datasets from long-running research projects, such as those from the Fishermen and Scientists Research Society (FSRS) or graduate level theses be sourced for a suitable estimate of variance.

Budget

Based on the methods for lobster catchability monitoring at the FORCE site proposed in this document, the following annual budget has been prepared in light of FORCE's goals, recommendations received, and desired spending.

Proposed 2020 Lobster Catchability Budget	
Experimental Trap Repair	$1,800
Bait	$300
Streamer Tags & Tag Gun	$1,100
Temperature Loggers	$900
Study Implementation, Data Analyses, Reporting	$32,500
Ship Time	$35,000
Miscellaneous	$5,000
TOTAL	**$76,600**

The miscellaneous category is built into the budget to include unanticipated expenses, but is also scheduled to include the following items alluded to in this document:

- Scientific license fees
- Mark/recapture rewards
- Wharf advertisement of mark/recapture program & protocol
- Plastic totes for onboard lobster storage
- Buoys & line for traps should they also require repair/replacement
- Identification tags for experimental traps

This budget has been developed in a conservative manner, building in buffers and miscellaneous categories capable of covering any unforeseen incidents. It is possible that should operations run smoothly actual costs incurred will be less than the total presented in this report.

Discussion & Alternative Methods

Several issues arose during the process of developing a revised lobster catchability program suitable for the FORCE site. The primary issue relates to the logistics of completing field research activities in the Minas Passage. Extremely short (minimum 20 minute) periods of slack water between flooding and ebbing tides affords a narrow window during which time work can safely be completed. This is a major consideration for study design, as it influences how many experimental traps can be sampled during each sampling event.

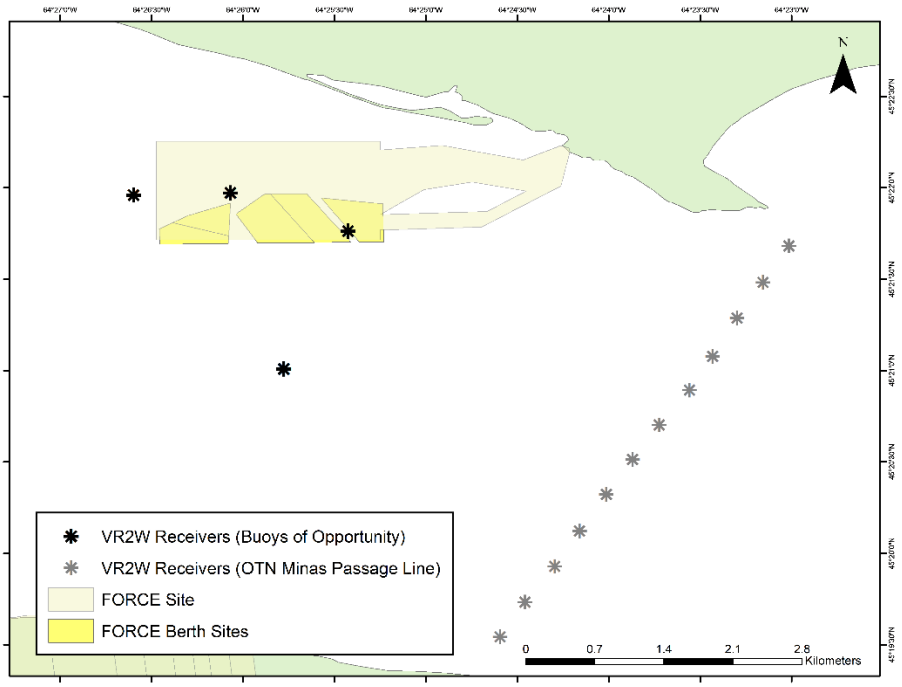
Another factor impacting how future lobster catchability work can be completed at the FORCE site is related to the lack of access to baseline data. The 2011 and 2017 lobster catchability work completed could serve as a small baseline dataset for the site; however, raw data from these trap surveys were not provided to FORCE for its records or further analysis. In an effort to overcome this issue, the revised survey design will set up an ongoing lobster monitoring program that will, in the long-term, provide more robust data that can be strategically analyzed.

Another consideration that must be discussed in relation to field experimental design for lobster catchability is the effectiveness with which BACI design functions. BACI's have been critiqued for their inability to determine if differences noted in treatments result from the introduction of a stressor or from differences inherently embedded within the impact and control sites. Including multiple methods of analysis and data forms to model findings in a Bayesian approach as previously described may help to overcome this variability, which is strongly related to the extreme natural variability existing within Minas Passage from tide to tide.

Another factor constraining future lobster catchability work at the FORCE site is the budget. FORCE has a desired annual budget for its lobster catchability program of $70,000, including experimental design, gear, data collection, and data analysis. Given this proposed budget, not all recommendations provided by DFO can be incorporated in a meaningful and effective way. The proposed methodology presented in this report, whenever possible, utilizes data collected by other entities in an effort to limit costs and foster collaboration amongst the scientific community and industry stakeholders.

One particular objective that is a challenge to meet is the inclusion of acoustic telemetry as a monitoring tool for lobster at the FORCE site. The reasoning behind this recommendation is two-fold: this type of technology is expensive and past experience with acoustic telemetry in the Minas Passage with lobster has not provided extensive results. TFC had discussions with InnovaSea on their recommendations in terms of acoustic telemetry monitoring technology for the proposed project. At this time, four acoustic receivers (Vemco VR2W) are located near the FORCE site housed in sub-sea buoys (two within the FORCE site and outside near but outside the FORCE site) as part of the Ocean Tracking Network (OTN) Buoys of Opportunity program. In addition, the OTN maintains a line of receivers spanning in the easterly end of Minas Passage (Figure 4).

Figure 4. Map of current acoustic receiver locations in Minas Passage. Data sources: Government of Nova Scotia, OTN, Seaforth Geosurveys, FORCE.



These receivers provide some degree of coverage and accessible data, but additional receivers would be required for the purposes of lobster catchability monitoring within the FORCE site. The table below outlines acoustic telemetry options and approximate number of units required to achieve statistically sound results (not inclusive of shipping and handling). The AquaMeasure environmental data logger also presented below would provide real-time temperature, tilt, salinity and turbidity data, as recommended in the Nexus lobster catchability study (2017) and should be considered independent of using other acoustic telemetry as part of the proposed study.

Table 4. Quotation provided by InnovaSea for Vemco acoustic transmitters, receivers, and environmental monitoring devices for lobster in Minas Passage, Bay of Fundy.

Technology	Unit Cost	Projected Units Required	Total Cost
V13 – 1X Transmitter	$410.00*	75	$30,750.00 + HST
VR2W – 69kHz Receiver	$2,255.00	4**	$9,020.00 + HST
AquaMeasure Data Logger	$2,500.00	1	$2,500.00 + HST
Other associated costs***	$74.00	-	$74.00 + HST
		TOTAL	**$42,344.00 + HST**

*Includes 2.5% discount for orders over 50 units.
** In addition to the 16 units currently deployed in Minas Passage.
*** Nominal costs for lithium battery and magnetic activation probe.

Acoustic data storage (ADST) transmitters are another option which log both temperature and pressure data. ADST tags are over two times the price of V13 tags ($880.00 per unit) and, given that temperature

monitoring can be obtained in more cost-effective manners and lobster remain relatively at or near the seabed, these transmitters are not recommended for this study.

Past experience with acoustic telemetry in Minas Passage garnered limited results. The level of marine noise and turbulence associated with currents, as well as the limited range of movement of lobster on short-term time scales, does not justify the use of such expensive technology. Past telemetry studies and local ecological knowledge indicate that there is some movement of lobster into and out of the Minas Passage on a seasonal basis. Lobster tracking studies completed for FORCE in 2011 and 2012 recorded low rates of detection of tagged lobster (40% and 15%, respectively), and those detected showed wide variation in the number of detections logged. While a small number of transmitters showed a series of detections, most did not and in some cases transmitters were determined to have been lost, (*i.e.* dislodged from lobster carapace). TFC communicated with scientists who have previously used this technology in Minas Passage and their expert opinion did not support its use for FORCE's objectives moving forward.

The purpose of acoustic technology must also be considered when attempting to determine its viability as a monitoring tool at the FORCE site. Past acoustic telemetry studies for lobster in the area have focused on movement patterns of a larger spatial and temporal scale. With respect to a catchability study, fine-scale movements, residency and dispersal through following a VPS-style (Vemco positioning system) design would be the desired outcome. This has been studied in the past by DFO using a small number of ovigerous tagged lobster in low tidal range environments (Tremblay, Andrade, O'Dor, 2003) as well as on other *Homarus* species. Similar VRAP (predecessor to VPS) studies have occurred in the Bay of Fundy with juvenile lobster in low tidal range environments with a relatively small sample size. However, it is not expected that similar results could be achieved in Minas Passage due to the high degree of movement and diminished positioning accuracy.

Another technique used to monitor lobster behaviour as they approach, enter, and are within commercial and experimental traps is the use of video surveillance. It is known that a portion of lobster that enter traps escape prior to the trap being hauled. Video systems attached to traps can provide insight into how effectively the trap retains lobster and can help to correct abundance estimates. Video surveillance techniques could also be applied (theoretically) to monitoring lobster use of turbines as a form of increased habitat heterogeneity and refugia. However, in the case of the Minas Passage, video surveillance could potentially help to characterize the degree of turbulence and resultant trap movement. However, given past video and photographic surveys completed, it is not anticipated that footage would provide substantially meaningful data given the extreme nature of the turbulence in the Minas Passage.

In lieu of a scientific observer aboard a commercial fishing vessel, the concept of electronic video monitoring (EVM) can be considered. EVM as a method of surveillance for CPUE aboard commercial vessels is a topic currently under exploration in other commercial fisheries in Canada. While EVM can provide detailed data on catch rates, it is a very sensitive topic and typically receives little cooperation from industry; this method is expensive and invasive.

Should FORCE be able to receive permission and cooperation from a harvester known to the organization, the opportunity to pay for and install a camera system on board a commercial vessel operating in the Minas Passage (and elsewhere in LFA 35) could be used to provide further CPUE data. While detailed data such as carapace length, sex, berried vs. non-berried females and condition likely would not be collected from video footage, information of number of hauls and number of lobster per haul could be obtained and used in IPM models.

To achieve the desired data, multiple camera angles would be required. This multi-angle footage coupled with GPS or the vessel's automatic identification system could be used to supplement scientific trap data and compared with DFO logbook data. It is anticipated that, EVM for the purposes of this study, could be collected with a simple waterproof two-camera system mounted aboard a single vessel during the commercial fishing season for a nominal cost (< $1,000) as additional sensors and location capabilities will not be required.

Due to time constraints during the course of TFC's lobster methodological evaluation for FORCE, discussion of this potential study element with an LFA 35 harvester was not possible (*i.e.* it is currently peak fishing season in LFA 35 and harvesters were unavailable).

Finally, DFO's suggestion of divers is not possible to incorporate into a lobster monitoring program at the FORCE site for safety concerns. It is impossible to perform this type of research in Minas Passage for safety reasons and this should not be considered a viable option.

Recommendations

As described in this document, the following are the synthesized recommendations as to how FORCE should proceed with its lobster catchability monitoring program such that it takes into account previous recommendations and lesson learned. While determining the sample size required to produce statistical significance is not possible (due to a lack of variance data), the study design presented in this report represents a sound methodology given the Minas Passage environment and FORCE's budget.

- Establish a test area and both near-and-far-field control areas such that BACI-style design can be achieved.
- Conduct one survey in the spring (in-commercial fishing season) and one in the fall (pre-commercial fishing season), annually, in an ongoing basis.
- Deploy experimental traps at randomly selected locations within the three strata identified so that monitoring is not focused around single turbine deployments.
- Maintain trap locations during both surveys in a given year and reselect in subsequent years.
- Increase the number of experimental traps sampled to 12 per tide and increase the number of rounds of sampling to four.
- Mark lobsters caught with streamer tags so that recapture data during FORCE scientific surveys and the commercial fishery can be collected.
- Use an experienced captain for research charter purposes, both in the lobster fishery and Minas Passage.
- Integrate catch data collected with DFO logbook data. CTD environmental data, and mark/recapture data collected to produce an IPM.

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