EVALUATING ALTERNATIVE BAIT OPTIONS FOR THE PRINCE EDWARD ISLAND LOBSTER FISHERY IN LOBSTER FISHING AREA (LFA) 25, ATLANTIC CANADA

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ABSTRACT

The American lobster (*Homarus americanus*) fishery in Prince Edward Island (PEI) relies on bait to capture lobster. There is unease in the industry that rising prices and pressure on specific baits, in particular, Atlantic mackerel (*Scomber scombrus*), will lead to bait shortages and further amplified prices. A scan of the current information on some alternative baits that are being used in the industry was conducted to ascertain their potential to alleviate some of the pressure that is currently placed on the bait sources being utilized by the industry. In addition, an economic sensitivity analysis of the species cunner (*Tautogolabrus adspersus*) was carried out, as it was found from the scan of potential options, to be one of the most promising species to be developed as auxiliary bait to the lobster fishery in PEI. Primary research was conducted with seven fishermen from the PEI side of Lobster Fishing Area (LFA) 25 to determine the potential catch rate of cunner. Additionally, 12 fishermen from the same LFA were surveyed to determine the potential costs of fishing and the value of cunner as auxiliary bait to that lobster fishery. In all scenarios evaluated during this study, except if cunner is valued at CAD .70 and less than five traps are fishing, cunner are economically viable and beneficial for fishers in LFA 25 to use as auxiliary bait. Further research is needed to determine if cunner is a source of sustainable bait or if auxiliary fishing activities could deplete stocks.

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CHAPTER 1: GENERAL INTRODUCTION

1.1 Signature project introduction

Prince Edward Island (PEI) is well known for its seafood, especially the American lobster *Homarus americanus* (from here on referred to as *lobster*), but there is concern over the future availability of bait for this industry (PEI Fishermen's Association, 2017). The lobster fishing industry in PEI supports the local economy, and the bait that entices lobster into traps is crucial to overall productivity of this industry. In 2017, the PEI lobster fishery landed 36,401,489 lbs worth an estimated CAD 225,877,410.50 (C. Campbell, PEI Provincial statistics officer, personal communication, January 17, 2018). There is no complete record of bait regarding the species and amounts of bait used in the fishery, but the Department of Fisheries and Oceans (DFO) conducted telephone surveys in 2005 and 2011 to gain estimates, approximating that in 2012, all PEI Lobster Fishing Areas (LFA) would use 3,594 tonnes of Atlantic mackerel (*Scomber scombrus*) and Atlantic herring (*Clupea harengus*) combined (Criquet, Brêthes, & Allain, 2013). PEI has three LFAs: LFA 24 and 26A are active in the spring season, which runs from May until the end June, while LFA 25 is fished in the fall season and is active from early August until early October (DFO Gulf Fishing Area Maps, 2014). We focused our efforts on the PEI side of LFA 25 due to the timing of this signature project, and more specifically because of a request to DFO from the LFA 25 Prince County representative to consider tagged modified lobster traps to be fished strictly for bait for the lobster fishery (PEI Fishermen's Association, 2017).

Out of the three LFAs, LFA 25 supplies the smallest portion of the lobster landed on PEI, as it has the least amount of active lobster licenses (Criquet et al., 2013). In 2017, PEI fishers in this area landed a total of 7,536,372 lb, which was up from 2016’s total landings of 6,896,341 lb.

Due to a drop in wharf prices and despite higher landings in 2017, the value of lobster in LFA 25 fell from CAD 43,486,922. 95 in 2016, to CAD 32,122,569.00 in 2017 (C. Campbell, PEI Provincial statistics officer, personal communication, January 17, 2018). The need for and price of bait is ever increasing (Harnish & Willison, 2009; Overton, 2017). Paired with the short-term loss of CAD 11,364,353.95 in lobster market value (C. Campbell, PEI Provincial statistics officer, personal communication, January 17, 2018), and the increase in daily operation cost for fishing such as bait prices, the recent situation has become a matter of concern.

Even though bait offers a small source of organic carbon when compared with primary production, it represents a direct subsidy of secondary production (Saila, Nixon, & Oviatt, 2002) and some even debate that wild lobster populations are "cultivated" through bait as food sublimation (Tlusty, Myers, & Metzler, 2007). For instance, it has been established in Maine that herring bait used in lobster fishing provides enough nutrition to increase lobster growth by 15%. They also found that around 80% of lobster gut contents are composed of bait, and isotope analysis indicates that approximately 70% of lobster tissue in the New England area is a result of bait input or secondary production (Grabowski, Gaudette, Clesceri, & Yund, 2010). It is unlikely that these numbers adequately reflect output in LFA 25 as bait is a smaller source of secondary production because the fishing season is short in comparison to New England's and fewer fishers are putting bait into the system. Bait associated with the lobster industry affects the structure of benthic communities (Tlusty et al., 2007) and therefore should be considered in resource management to ensure sustainability and adequate resources for the lobster industry (Saila et al., 2002).

Bait should not only be of interest to those who manage the fishery, but also to lobster fishers because it constitutes a large part of the cost that goes along with fishing for lobsters.

Lobster traps are set in the ocean, along coastal shorelines and baited to entice the lobster to enter the trap. The traps are often baited each day, but baiting practices are specific to the individual fisher (Harnish & Willison, 2009). Most baits are consumed ineffectively and not always by legally harvestable lobster (Harnish & Willison, 2009). For instance, sub-legal lobsters and non-targeted marine animals consume a significant portion of all bait in lobster traps (Tlusty et al., 2007).

The southern Gulf of St. Lawrence (sGSL) lobster fishery is supported by its coastal water species of fish (Hanson, Comeau, & Rondeau, 2014). In particular, the lobster fishery is heavily dependent upon Atlantic mackerel (*Scomber scombrus*) and Atlantic herring (*Clupea harengus*), although many other baits such as rock crab (*Cancer irroratus*) and silversides (*Menidia menidia*) (Criquet et al., 2013), are used in lower quantity at any given time depending on price and availability (Harnish & Willison, 2009). Herring supplies are not consistent, and prices vary with the supply (Overton, 2017; Schreiber, 2012). Local mackerel stock sustainability has been questioned and the species, quantity, and price of bait are not always reported in fisheries statistics (Criquet et al., 2013). However, both mackerel and herring (fall spawner component) are most often bought by lobster fishers to use in PEI's lobster fishery; therefore, the quantity used is recorded by those species fishery management systems (Criquet et al., 2013). There is debate whether using this source of protein as bait is appropriate. Mackerel and herring are both human-quality foods and can be consumed directly by humans in a more eco-efficient manner (Harnish & Willison, 2009). From an economic standpoint however, we wonder if PEI herring should be frozen and stored for months in which bait is scarce instead of being shipped out of PEI to be processed as food for humans. It appears to be time to explore other potential baits to supply the PEI lobster fishery with, sustainable bait.

1.2 Project objectives

Unfortunately, bait prices are not stable, and new local bait sources are hard to find. Additionally, alternative baits often come from foreign sources that can introduce invasive species and new pathogens to local bodies of water and marine animals. Moreover, lobster fisheries are heavily dependent on two bait sources, mackerel and herring, but it is unlikely that the current exploitation of these baits are ecologically and economically sustainable (Criquet, Brêthes, & Allain, 2013; MSC, 2014). It is vital to assess the potential for alternative baits to alleviate pressure on traditional bait sources and monitor the impacts of bait choice on the economics of lobster fishing. The goals of this signature project were two-fold:

i. Firstly to document the feasibility for potential alternative baits for the lobster industry and to determine if one such bait would be both accessible and profitable to fish as auxiliary bait to the lobster fishery in LFA 25.

ii. Secondly to determine the conditions under which the most feasible alternative bait (cunner) would be most economically viable to fish as auxiliary bait.

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CHAPTER 2: A SCAN OF THE CURRENTLY AVAILABLE INFORMATION: ASSESSMENT OF EXISTING AND POTENTIAL ALTERNATIVE BAIT OPTIONS IN THE AMERICAN LOBSTER (*Homarus americanus*) FISHERIES

2.1 Introduction

Lobsters are opportunistic feeders that will eat both vegetation and flesh. The response of lobster to different bait types seems to be based on their environmental energy needs and the ease of access to the bait. Lobsters are drawn to the plume of odour and oils that are released by the bait (Winiger, Lokkeborg, & Pol, 2016) and are enticed to enter the trap to feed. Some lobster will remain in the trap to consume bait and others take the pilfered food back to their burrows to bury and consume at a later time (Cobb & Phillips, 1980).

2.2 Alternative & exotic bait debate

For reasons mentioned above, bait is a crucial factor to the lobster fishing industry and therefore bait sustainability and affordability is important. Since bait prices are increasing and bait can be hard to find, commercial lobster fishers have experimented with land-based and marine-based alternatives from around the world (Whittle, 2016). It is imperative for fishers not only to consider the most efficient bait for catching lobster, but also what ecological effects that bait input has on local marine ecosystems. For instance, foreign bait can transfer unknown and new diseases to marine species and the environment (Schreiber, 2012).

Only some imported bait from specific areas are included in the Fish Inspection Act and Regulations (CFIA, 2014b) by the Canadian Food Inspection Agency (CFIA). The declared species and origin of the bait determines if the importer must obtain an import permit from CFIA under the Aquatic Animal Health Program to clear the Canadian Border Services Agency (CBSA) for entry into Canada. The Automated Import Reference System (AIRS) is used by

importers to determine if a product they want to import is permitted and if there are any specific requirements for that import. Once imported into Canada, there are no domestic movement controls for bait (CFIA, 2018).

2.3 Asian carp

Over the last few hundred years, a growing number of aquatic invasive species have become established in Canadian waters (Poirier, Ramsay, St-Hilaire, & Quijon, 2017). Asian carp is a general name used to describe several invasive species of carp that include the bighead carp (*Hupophthalmaichthys nobilis*), and the grass carp (*Ctenopharyngodon idella*) which have invaded the Canadian waters of the Great Lakes and the parts of the U.S. Invasive Asian carp are causing much concern due to their ability to adapt to most environments and their voracious appetites (Varble & Secchi, 2013). Moreover, research suggests that the abundance of invasive Asian carp is hurting the body condition of native planktivores that have a diet overlap (Irons et al., 2007). The use of Asian carp as lobster bait has potential to reduce and make use of some of the Asian carp population and could offer a cost-effective way to slightly decrease the invasive species population while providing a cheap source of bait. Asian carp have been used as lobster bait for years in the U.S. (Waterman, 2011) and in 2013 was selling for around USD 0.05/lb (Varble & Secchi, 2013). Regardless of potential inflation and difference in currency, Asian carp seem to be a cheap option for bait.

Using Asian carp as bait may supply lobster fishers with cheap bait, but it might also increase the risk of introducing diseases to marine organisms (Schreiber, 2012). For instance, the viral pathogen Viral Hemorrhagic Septicemia Virus (VHSV) found in carp and other Canadian fish species is a bio-security threat to both freshwater and marine animals. Although some

research has been performed around eradicating the VHSV from carp used as bait, VHSV remains remarkably resistant to freezing. The virus might be best inactivated by salting Asian carp used for bait, but this takes several days (Schreiber, 2012). Asian carp has excellent potential to be a sustainable lobster bait source, but there is a remote chance that VHSV could be introduced to other fish populations and therefore frozen and fresh Asian carp is not permitted to be exported to Canada from the United States for bait use (CFIA, 2018).

2.4 Green crab

The European green crab (*Carcinus maenas*) is also an invasive species to Canada (Poirier et al., 2017). The rapid dispersion of green crab in Atlantic Canada causes concern to fishers and shellfish harvesters alike (O'Neill-Yates, 2017; Poirier et al., 2017). There have been recent developments to commercialize green crab harvesting on PEI to provide a new resource for inshore fishers and to aid in controlling this species (Poirier et al., 2017). This adds to the already existing market for green crabs being used for lobster bait elsewhere in Canada (St-Hilaire et al., 2016). In 2014, the market value for green crab bait in Canada was between CAD 0.30 and CAD 0.90/lb (St-Hilaire et al., 2016). The crab was sold directly between fishers, reducing the additional cost of transportation, handling, and storage (St-Hilaire et al., 2016).

Unfortunately, green crab is not preferred bait for PEI lobster fishers. This might be due to unfavourable press when the push to develop green crab bait was at its highest in 2015 (Trotter, 2015; Withers, 2015). Concerns were raised when scientists found parasites in green crab populations (Bojko et al., 2017) that have the potential to be transferable to lobster (Trotter, 2015; Withers, 2015). Green crabs are considered the intermediate host of *Profilicollis botulus*, which is an acanthocephalan (worm) parasite (Thompson, 1985). Scientists examining this

parasite spoke to the media about anecdotal evidence that lobster could theoretically be weakened and potentially die during holding as a result of high parasite loads transferred from green crab bait (Trotter, 2015; Withers, 2015). To our knowledge, there has been no published research to prove that lobster vigor is lost and that mortalities occur as a result of the parasite transfer from green crab to lobster. Additionally, since the parasite does not have any effect on humans and does not affect the taste of the lobster meat (Ayers, 2015), we think that it still has potential as lobster bait. We believe that there are a lot of questions around this parasite's interaction with lobster that need further exploration before this species is being discounted as viable bait for lobster fisheries.

2.5 Salmon by-products

Figure 1. Canadian farmed Atlantic salmon heads (Callaghan, 2018)

Canada is one of the major producers of farmed Atlantic salmon (*Salmo salar)* in the world and the largest producer in North America. While British Colombia generates a significant part of the Atlantic salmon production in Canada, there is a considerable salmon aquaculture industry on Canada's east coast (Burridge, et al., 2010). The waste from processing farmed salmon provides the potential for an economically viable bait source for the PEI lobster fishery. Bait used in the lobster fishery that comes from salmon processing can be composed of the leftover head and backbones once fillets have been taken as a food source for humans (Figure 1).

Concerns around the risk associated with disease transfer from farmed salmon by-products were examined in a study by Vike, Duesund, Andersen, and Nylund (2014). They investigated how long the infectious salmon anemia (ISA), which is a transferable virus, could last in dead salmon and proved that particles of ISA lasted for up to five days post mortem in heart tissue. First detected in 1996, ISA is established in Atlantic Canada (Woodbury, 2018). Although wild salmon populations of have been found to carry a strain of the ISA virus, disease outbreaks of the virus have only been found in farmed Atlantic salmon (MacLachlan, 2017). It appears unlikely that the use of farmed salmon by-products will result in any health issues in lobster and it can be assumed that it is unlikely for salmon by-product bait to contain heart tissue or to transfer ISA to other farmed salmon populations. There are multiple steps that must happen for transmission of pathogens from by-products to occur. In addition, another study on the risk associated with farmed salmon by-products as bait for the lobster and crab creel fishery in Scotland found there to be a low probability of transmission but the consequences would be serious if it would occur (Murray, 2015). Therefore salmon processing by-product utilized as lobster bait should be studied more but shows great potential as it eliminates the waste from the harvest of salmon fillets and could serve as a potentially cheap, local source of bait.

2.6 Gaspereau

Gaspereau is a common name for both the Blueback herring (*Alosa aestivalis*) and Alewife (*Alosa pseudoharengus*) species, locally used as bait in the lobster fishery (DFO, 2001). Some even say that at certain times of year, gaspereau are an excellent bait to attract hard-shell lobster (Overton, 2017). Exploitation rates were recommended to be decreased in 2001 to rebuild stocks (DFO, 2001). Recently in Nova Scotia, to help re-establish gaspereau, a fish ladder was built as part of a memorandum of understanding between the Nova Scotia Power and DFO,

which is suspected to have boosted the population (Williams, 2016). A recent abundance study conducted in Nova Scotia using weirs found that gaspereau were the most observed fish, and catch abundance and size structure were comparable to the 1980s (Porter, Porter, Spares, & Dadswell, 2017). The gaspereau resurgence has resulted in lobster fishers taking advantage of the situation to alleviate their bait issues (Overton, 2017; Williams, 2016). There is excitement in the fishing industry that gaspereau have had a dramatic comeback, but we urge caution towards hasty increases in exploitation rates. In many places, catches are not recorded in a purchase slip database or logbook programs and are sold directly from fisher to fisher (DFO, 2001).

2.7 Cunner

Cunner (*Tautogolabrus adspersus)* shows great potential for being an auxiliary bait for the lobster fishery, it is one of the most common species of fish found in coastal Atlantic Canada (Savaria & O'Connor, 2013). Lobsters are scavengers and feed opportunistically (Harnish & Willison, 2009), their overlapping geographic range (Barshaw & Lavalli, 1988) makes cunner a part of lobster's natural diet (Hanson et al., 2014). Additionally the staff of the PEI Provincial Department, formerly known as Fisheries Aquaculture and Rural Development (DFARD), verified that fishers were using cunner legally caught as by-catch in the PEI lobster fishery as bait. In fact cunner is such desirable bait for the lobster fishery, cunner are also being illegally fished with lobster traps that were modified to capture cunner to be used as bait (PEI Fishermen's Association, 2017).

The Marine Stewardship Council (MSC) is a non-profit, market-based, third-party certification organization that sets standards for sustainable fisheries. The MSC requested that the PEI lobster fishery and its stakeholders provide evidence of a partial strategy for, and to

define methods in, reducing mackerel bait use to grain re-certification for the PEI lobster trap fishery (Global, 2014). As a condition for MSC re-certification, the PEI lobster fishery had to provide qualitative and quantitative information on the main by-catch species (Global, 2014). In 2015, as part of the Integrated Fisheries Management Plan (IFMP) and the DFO's Sustainable Fisheries Framework, a by-catch study was carried out in the southern Gulf of Saint Lawrence (sGSL) lobster fishery. This study supplied the MSC with information on by-catch composition, quantity, and specimens' survival and identified cunner as the third most commonly caught species in the lobster fishery (Rondeau, Comeau, & Hanley, 2017). Under the lobster license conditions cunner is allowed to be retained and used as bait (Criquet et al., 2013). Therefore, because cunner could take some pressure off of mackerel use in the fishery, is a common by-catch of the existing fishery and is already being utilized as bait, cunner is likely the best alternative bait source for the PEI lobster fishery.

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CHAPTER 3. EXPLORING THE ECONOMIC FEASIBILITY OF CUNNER AS AN AUXILIARY BAIT FOR LFA 25 AMERICAN LOBSTER (*Homarus americanus*) FISHERY ON PRINCE EDWARD ISLAND

3.1 Introduction

The development of a cunner bait-fishing license was brought up by LFA 25 fishers at the January 2017 southern Gulf Lobster Advisory Committee meeting. The meeting focused on concerns with the fisheries' dependency on mackerel as bait, the scarcity of bait, and the high price of bait. The MSC wants the PEI lobster fishery to lessen its dependency on mackerel use as bait, to ensure that it does not obstruct the recovery of the Canadian mackerel stock (Criquet et al., 2013). Also lobster caught using fresh mackerel are seven times more likely to be graded as weak at the processing stage than lobster landed using other bait types. This could be due to the amino acid histidine which is found in fresh mackerel and other scombroid fish species and can lead to bacterial histamine contamination, which is associated with adverse lobster health (Lavellée, Spangler, Hammell, Dohoo, & Cawthorn, 2000).

The commercial fisheries licensing policy for Eastern Canada states that "a bait-fishing-license can only be issued to the head of an enterprise which holds a license to fish commercially by a method which traditionally includes the use of bait in such a fishery (lobster, crab, groundfish hook and line, tuna, swordfish longline, shark)" (DFO, 2010). Additionally, lobster fishing license conditions state that rock crab, sculpin, and cunner are allowed by-catch in lobster traps to be retained as bait for lobster fishing (DFO, 2010). Since cunner is allowed to be caught and used as bait in the lobster fishery and there are no known risks of bacterial histamine contamination, parasite or aquatic pathogen transfer from cunner to lobster, cunner is likely the best alternative bait to develop to be used as bait in the LFA 25 lobster fishery. At the southern

Gulf Lobster Advisory Committee meeting, a representative of the Prince County Fishermen's Association also requested that DFO consider allowing modified lobster traps to fish cunner strictly for bait (PEI Fishermen's Association, 2017). To determine if this could be a probable scenario, fishers used modified lobster traps to gain data on the potential catch rate of cunner in LFA 25, from this data an economic scan was conducted on cunner as an auxiliary bait source to the LFA 25 lobster fishery.

3.2 Methods

3.2.1 Primary Research Study Area

The western portion of the Northumberland Strait between PEI and New Brunswick and a small part of Nova Scotia is considered to be Lobster Fishing Area 25 (LFA 25). The primary research in the study presented here focused on cunner catch rates with PEI fishers from LFA 25. Cunner traps were set and hauled during the lobster season, which takes place from early August to early October each year. In the western half of the strait in LFA 25, the sampling primarily took place along the coast of PEI (Figure 2). The substrate in this area is made up of sand and sandy gravel, with protrusions of bedrock, cobble, and rock (Hanson et al., 2014).

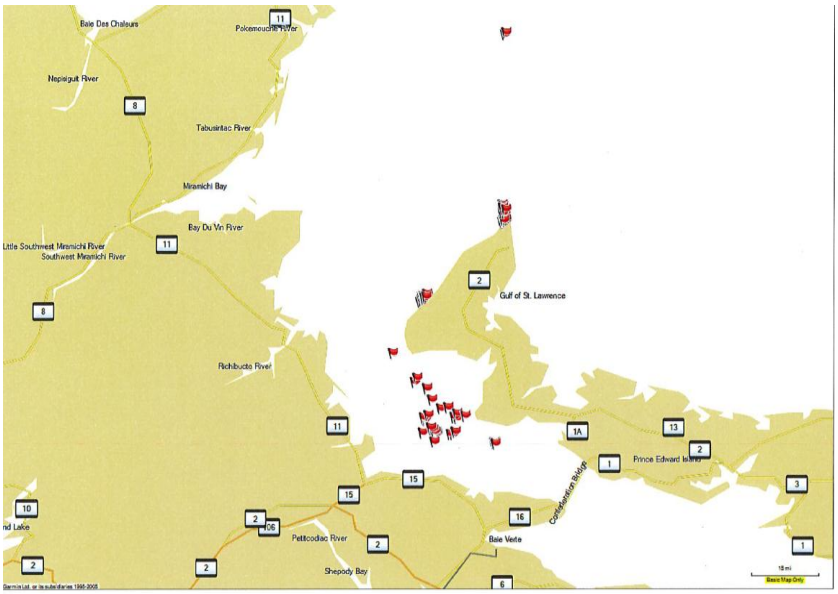

Figure 2: Cunner catch rate study, trap locations in LFA 25 Prince Edward Island, Canada

3.2.2 Data source

The selection process for participants began with a notice posted on the PEI FA's website and the LFA 25 Facebook page. The notice informed core lobster license holders in LFA 25 that they would have an opportunity to volunteer to participate in a UPEI graduate level economic study on feasible alternative bait sources for the PEI lobster fishing industry. The notice explained that the assessment was being conducted in two phases to examine the possible economic befits of fishing cunner as an auxiliary bait. In phase one fishers would be asked to fish for cunner to determine the possible catch rates of cunner in that area and in phase two participant would be asked to complete a short survey (Appendix). Additionally, contact information for the researcher and all risks and benefits were explained in the notice. No volunteer participants came forward within the time allotted. Therefore, potential participants were directly contacted to see if they would be interested in participating. Due to confidentiality protocol around sharing private information, such as contact information with non-members of the PEI FA, a staff member drew the potential participant's names/contact information using an online random number generator (https://www.random.org/lists/). The online random number generator parameters were set at one set of 40 unique numbers, ranging between one and 226, as there are 226 active licences on the PEI side of LFA 25 (Criquet et al., 2013).

Ten names were initially randomly drawn to cover the 10 ports of interest in LFA 25. When 10 fishers from 10 different ports were confirmed, an additional six names were drawn by using the random number generator. If a fisher from a particular harbour did not want to participate in the study, another name was generated until the port came up again. This was done to assure the study covered most of the shoreline fished in LFA 25. In total, 16 participants were confirmed to participate with one to two participants from each of the 10 ports.

3.2.3 Data collection

Once fishers confirmed they wanted to participate in phase one of the study, a package was delivered with a consent form, the licence to conduct scientific research, four tags, and the necessary equipment (hand-held scale and a bucket) needed to determine their catch daily catches of cunner. The study was explained in detail, and any questions surrounding the study were answered. Phase one of the study was carried out from August to October 2017 and focused on determining the catch rate. The 16 participants met individually with the primary researcher to go over the details of the project and collect the necessary field equipment and logbook.

3.2.4 Phase One Field sampling

The participants were required to supply four traps directed towards fishing cunner. These traps were not standardized, and most of the fishers who participated in the study either built their traps or bought their traps from one particular trap maker in the western part of PEI. Fishers were asked to record how many days they fished cunner, the number of traps they fished, how often they hauled the traps in per day, and the length of time the trap was set with bait before it was hauled. Participants were also asked to weigh and record the catch, the location the traps were set, depth in which they set the traps, and bait and state of bait (e.g., frozen or fresh) used in each trap.

3.2.5 Survey

Phase two of the study was conducted from October 16 to 17, 2017. This phase of the study consisted of a short phone survey with the participants lasting 15 minutes. The purpose of the survey was to capture the basic economic costs associated with fishing cunner. Anonymity was assured for all participants who agreed to participate in the study and all provided informed

consent. Additionally, it was explained to all participants that they had the right to withdraw or not answer any question without penalty or fear of retribution. The questions in the survey were designed to allow for open communication with the fishers. Each question was asked neutrally to ensure that each fisher felt at ease and not pressured to answer one way or another. If a fisher did not want to answer a question or it did not pertain to their fishing efforts, the question was skipped. In general, the fishers understood the questions, but clarification was provided when needed. The hard copies of the survey and data were stored in a locked cabinet, and the data was entered into a secure password database and analyzed in December 2017.

A submission to amend the permit to conduct scientific research was unknowingly not approved and as a result study participants had to change their trap design to lift the trap off of the bottom so that the traps would avoid any lobster by-catch. Four metal braces were handed out to the participants in the study to assist in immediately suspending the cunner traps off the bottom. These metal braces were given to fishers as a short-term fix to avoid any potential fines for noncompliance with the license. Fishers were asked to amend their traps at sea in the short period of time that was allotted by DFO and additional costs were to be incurred at their own expense. As a result, many of the participants took their traps out of the water and decided not to continue with phase one of the study. Seven remaining participants were willing to complete phase one and fish for cunner to determine the catch rate. Six of participants were given a picture of a trap design created by one of the remaining participants (Figure 3). Traps were amended, and the seven

Figure 3: Reconfigured cunner traps to avoid lobster as by-catch, LFA 25, 2017

participants captured data from that point on. Data collected prior to the amendment of traps were not discernibly different and therefore used in the study results. Although more than half of the participants pulled out of phase one of the study, most of the original participants agreed to continue with the second phase of the study and completed the phone survey. A total of 12 surveys with lobster fishers from LFA 25 were completed on their bait requirements and the cost of fishing cunner.

3.2.6 Data Analysis

By using various value scenarios, the minimum pounds of cunner a fisher would have to catch per trap per day to break even for the season were estimated. Phase two of the study captured the values used as a proxy for the value of cunner and were based on the top three average wharf-side bait prices. The numbers of traps were based on the participants' average desired number of traps to fish cunner as bait for their lobster enterprise. The break-even market price of cunner was also estimated using the median pounds caught by fishers during phase one of the study. Additionally, the potential net return in savings on bait expense with the associated cost of fishing was calculated using different numbers of traps and cost situations.

The employed models consisted of fixed and variable costs. Fixed costs were comprised of depreciation using a straight-line method on the price of gear purchased for the sole purpose of fishing cunner. The opportunity cost, was set at 0% of the fixed-capital cost because fishers are harvesting lobsters during the time they would be fishing cunner. Therefore they are not missing out on any other money making opportunities. The cost of the license fee was also included in the fixed cost and this was based on the regulations set by DFO that state "any species, in any case not otherwise provided for in this item (licenses), per species $30.00"

(SOR/86-21, 2017). For this study, cunner fishing was assumed to be used solely to obtain supplemental bait by fishers in their lobster fishing enterprise. Therefore, fishers would not need to buy a boat or other major equipment to fish. It was also assumed that fishers would purchase or build traps, and in some instances there would be an additional price of fuel or sailing gear if the cunner traps were not set near the fishers lobster traps. Additionally, the price of rope and buoys needed to fish the cunner traps, as given by fishers who participated in the survey during phase two of the study, was included.

During phase two of the study, fishers were surveyed and asked to give their estimated cost of fishing cunner (e.g., labor, bait needed, and cost of bait) and other pertinent information. Variable costs included the cost to bait the cunner traps (i.e., cost of bait x amount of bait used per trap x number of traps set x number of days in the season). We took the average number of traps which fishers participating in the survey indicated would be their ideal amount to fish cunner for bait. We also wanted to see if a lower number of traps could be used to supplement bait needs and therefore we also used the lowest two numbers suggested by fishers in our projections. Labor costs were set at $0/hr because of the nature of lobster fishing and the labor associated with this fishing sector. For instance, hired help on lobster boats are not paid on an hourly basis, and additional work related to lobster fishing is often assumed and included in their salary for that season. The total fixed and total variable costs were added together to determine the total cost to fish cunner.

The potential gross returns were determined by taking the fishers average catch information from both phases of the study (i.e., average number of traps fishers deemed necessary x median pound of cunner caught in the field experiment x average number of days in the season). This number was then individually multiplied it by the average low, medium, and

high wharf-side values of baits used in the LFA 25 fishery. The average low, medium, and high wharf-side bait prices were set at CAD 0.70/lb, CAD 0.80/lb, and CAD 1.00/lb and were used as a baseline for the potential savings. With this information, it was possible to determine the range of potential returns scenarios and thus the potential value of cunner as bait. The array of wharf-side prices used to calculate the potential returns in savings on bait provided estimates of the most likely current values that cunner could be worth to fishers as auxiliary bait.

The total cost and gross returns using the average low, medium, and high wharf-side bait prices were used to calculate the potential net returns, and in this case, savings, if fishers used cunner as bait instead of traditional bait. These values were used to calculate the minimum pounds of cunner that are needed to be caught per trap, per day, to break even using the following equation:

$$Lbs\ of\ cunner\ per\ trap\ per\ day\ = \frac{Total\ cost}{Days\ in\ the\ season\ \times\ no.of\ traps\ per\ day\ \times\ price\ of\ cunner\ per\ lb}$$

The estimated break-even price for cunner was determined by dividing the median poundage caught per day, multiplied by the number of traps and the by the total costs in a 50-day season (to allow for four non-fishing days due to inclement weather), using the following equation:

$$Price\ per\ lb\ = \frac{Total\ costs}{Median\ poundage\ \times\ no.traps\ \times\ 50\ days\ in\ the\ season}$$

3.3 Results and Discussion

It is expected that currently utilized bait sources may become too scarce or too expensive in the years to come (Schreiber, 2012). Fishers are trying a cornucopia of bait from around the world to be used in the lobster fishing industry, but some of the risks involved with using these baits are yet unknown or undetermined (Murray, 2015; Schreiber, 2012; Waterman, 2011). Therefore, it is surprising that few studies have been performed on alternative bait supplies, considering the high economic value of lobster and the influence bait can have on our marine ecosystem. Cunner is allowed to be landed as by-catch in the LFA 25 lobster fishery. While other marine animals that are allowed to be retained as by-catch are documented, cunner is undocumented, thus the consequences of removing them from existing populations are unknown (Rondeau et al., 2015). Further research on cunner is needed to discern if they are a sustainable bait option for the LFA 25 lobster fishery. Although it is not known if cunner is sustainable auxiliary bait for LFA 25 lobster fishery, the focus of this economic viability assessment is on cunner, as it is a local species which is currently retained in the lobster fishery as by-catch, and used for bait.

The economic scan of cunner as auxiliary bait to the LFA 25 lobster fishery considers various possible scenarios. A total of 222 data points were recorded by seven fishers. Of those data points, 220 traps were baited, and the median pounds was 9.6 lbs of cunner caught per trap, per day fished. It is important to note that although primary research was conducted to establish the catch rate of cunner in LFA 25, this experimental approach was not designed to provide data on the absolute catch rate. Additionally, it is imperative to note that this catch rate was not sustainable for all fishers who participated in the study, as cunner was not evenly distributed, and the probability of capturing a high number of cunner seemed better in the northern part of LFA

25. Therefore, it is likely that not all fishers in LFA 25 would utilize cunner as bait because the species is not always abundant in their regular lobster fishing grounds.

We developed a tool to establish the approximate pounds of cunner fishers would have to catch to break even. The break-even value per pound cunner would have to make it be worth to fish for it as auxiliary bait given the assumed pounds of cunner per trap and associated costs for their efforts. Three different price scenarios were used, based on the average low, medium, and high wharf-side bait prices, which were provided by fishers who participated in the survey. A 50-day season appears to be the most likely scenario, and five traps would be the optimal number allowed to fish for cunner as auxiliary bait. Three bait values were used as a proxy for cunner value in our analysis, CAD 0.70/lb, CAD 0.80/lb, and CAD 1.00/lb. At these values, the net return on savings for bait would be CAD 162.20, CAD 402.20, and CAD 882.20 respectively for the season (Table 1).

The break-even poundage needed to be caught at these values would be .08 lb, .05 lb, and .03 lb respectively per trap per day (Table1). This is well below the lowest pounds caught by all except one fisher who caught zero cunner in one trap. In this scenario, the break-even value would be CAD 0.56/lb, also well below the lowest wharf-side bait price (Table 1). The catch-to-bait ratio is a model that expresses the economic efficiency of capturing the desired species (cunner) with bait. The catch-to- bait ratio was 1:3.5 in scenario one, 1:4.0 in scenario two and 1:5.1 in scenario three. Therefore for every dollar of bait used in cunner traps the minimum value of cunner caught was $3.50 and the maximum was $5.10. It should be noted that all catch-to-bait ratios are approximates and should not be used to make decisions about this resource.

Table 1. Break-even pounds of cunner per trap with different market prices as proxy for cunner value (scenarios 1: CAD 0.70/lb, 2: CAD 0.80/lb, and 3: CAD 1.00/lb) based on current wharf-side bait prices and a 50-day season.

Assumptions	Scenario 1	Scenario 2	Scenario 3
i) Days in Season	50	50	50
ii) Bait cost per lb of bait ($)	$1.00	$1.00	$1.00
iii) Median bait per trap (lb)	1.9	1.9	1.9
iv) Cost per trap ($)	$150.00	$150.00	$150.00
v) Number of traps	5	5	5
vi) Median cunner caught per trap (lb)	9.6	9.6	9.6
vii) Labor per day (man hrs)	-	-	-
viii) Cost of labor per man hr ($)	$0	$0	$0
ix) Proxy value of cunner per lb ($/lb)	$0.70	$0.80	$1.00
x) Other charges per trip (i.e. gas, other…)	$17.00	$17.00	$17.00
xi) Cost of other gear for fishing season ($)	$37.80	$37.80	$37.80
xii) License fee	$30.00	$30.00	$30.00
Net returns in savings on bait [gross return- total costs]	$162.20	$402.20	$882.20
Break-even lbs of cunner per trap per day for given costs (lb)	0.08	0.05	0.03
Break-even value per lb given assumed lbs of cunner/trap and costs ($)	$0.56	$0.56	$0.56

Table 1.1. Projected annual value statement with different market prices for bait (scenarios 1: CAD 0.70/lb, 2: CAD 0.80/lb, and 3: CAD 1.00/lb) based on current wharf-side bait with five traps fishing in a 50-day season.

Estimated value of bait/lb	Scenario 1 $0.70	Scenario 2 $0.80	Scenario 3 $1.00
Gross returns on bait savings	$1,680.00	$1,920.00	$2,400.00
Total costs for initial set up	$1,517.80	$1,517.80	$1,517.80
Initial net savings on bait expense	$193.70	$433.70	$913.70
Total lbs for season (lb)	2,400	2,400	2,400
Fixed assets	$787.80	$787.80	$787.80
Fixed cost	$30.00	$30.00	$30.00
Variable costs	$1,325.00	$1,325.00	$1,325.00
Variable cost per $/lb	$0.55	$0.55	$0.55
Catch-to-bait ratio	3.5	4.0	5.1

In a 50-day season, if cunner is valued by fishers beyond the CAD 0.56 break-even price (Table 1) an auxiliary fishery would be very beneficial to LFA 25. The total cost to initially set-up and operate under all three of the value scenarios with five traps in a 50-day season is CAD 1,517.80, which suggests that after the first season, the investment would be paid back to the fishermen as gross returns in savings on bait (Table 1.1). This was based on straight line depreciation of six years for the gear, as suggested by fishers participating in phase two of the study (survey). In all of these value scenarios, fishing enterprises benefit by fishing cunner as auxiliary bait. The gross return of savings on their bait is CAD 1,680.00 if the bait is worth CAD 0.70/lb, CAD 1,920.00 if it is worth CAD 0.80/lb, and CAD 2,400.00 if it is worth CAD 1.00/lb (Table 1.1). Over the six years life of the gear, fishers who can fish for cunner as auxiliary bait could benefit from a gross total of CAD 14,400 in savings on bait.

Using the average days (50) fished by fishers who participated in phase one of the study, we calculated the net returns using a CAD 0.70/lb value and various numbers of traps that could be fished (three, four, or five traps fished). In the first year, net return in savings on bait were only evident with five traps over the 50-day season and resulted in CAD 162.20 in savings on bait (Table 2). Using these scenarios, the break-even poundage of cunner per trap per day using three traps is 0.07 lb and the break-even price is CAD 0.52. Using four traps the break-even poundage is 0.03 lb and the break-even price is CAD 0.42. Moreover, using five traps the break-even poundage is 0.08 lb and the break-even price is CAD 0.36. The poundage needed to break even in all scenarios is well below the median 9.6 lbs caught by fisher per trap on a daily basis, even for the highest break-even value, which was found to be CAD 0.52. In fact, the catch-to-bait ratio in this scenario is, CAD 1.00 of bait used produces CAD 3.50 worth of cunner caught

Table 2. Break-even pounds of cunner per trap with a market price of CAD 0.70 /lb as proxy for cunner value and value cunner must be worth to break even in a 50-day season, using three, four, or five traps fished.

Assumptions	Scenario 1	Scenario 2	Scenario 3
i) Days in season	50	50	50
ii) Bait cost per lb of bait ($)	$1.00	$1.00	$1.00
iii) Average bait per cunner trap (lb)	1.9	1.9	1.9
iv) Cost per cunner trap ($)	$150.00	$150.00	$150.00
v) Number of cunner traps	3	4	5
vi) Median cunner caught per trap (lb)	9.6	9.6	9.6
vii) Labor per day (man hrs)	-	-	-
viii) Cost of labor per man hr ($)	$0	$0	$0
ix) Purposed value of cunner per lb ($/lb)	$0.70	$0.70	$0.70
x) Other charges per trip (i.e. gas, other…)	$17.00	$17.00	$17.00
xi) Cost of other gear used in fishing season ($)	$37.80	$37.80	$37.80
xii) License fee	$30.00	$30.00	$30.00
Net returns in bait savings[gross return- total costs]	$(269.80)	$(53.80)	$162.20
Break-even lbs of cunner/trap/day for given costs (lb)	(0.24)	(0.26)	0.08
Break-even value per lb given assumed lbs of cunner/trap and costs ($)	$0.81	$0.66	$0.56

(Table 2.1), making this an economically productive species to fish as auxiliary bait under these scenarios.

Table 2.1. Projected annual (value) income statement with cunner value at CAD 0.70 at three, four, and five traps fished.

Assumed number of traps fished	3	4	5
Gross return in bait savings	$1,008.00	$1,344.00	$1,680.00
Total costs	$1,277.80	$1,397.80	$1,517.80
Total lbs for season (lb)	1440	1920	2400
Fixed assets	$487.80	$637.80	$787.80
Fixed cost	$30.00	$30.00	$30.00
Variable costs	$1,135.00	$1,230.00	$1,325.00
Variable cost per $/lb	$0.79	$0.64	$0.55
Catch-to-bait ratio	3.5	3.5	3.5

Using a similar setting of 50 days with a bait value set at CAD 0.80, we find net returns of CAD 138.20 using four traps and CAD 402.20 using five traps respectively but no net savings using three traps (Table 3). The catch-to-bait ratio in this scenario is 1:4, which means that for every CAD 1.00 of bait put in traps to catch cunner, CAD 4.00 worth of cunner is caught (Table 3.1).

Table 3. Break-even pounds cunner per trap with market price of CAD 0.80 as proxy for cunner value and value cunner must be worth to break even under a 50-day season, using scenarios of three, four, and five traps fished.

Assumptions	Scenario 1	Scenario 2	Scenario 3
i) Days in Season	50	50	50
ii) Bait cost per lb of bait ($)	$1.00	$1.00	$1.00
iii) Median bait per trap (lb)	1.9	1.9	1.9
iv) Cost per trap ($)	$150.00	$150.00	$150.00
v) Number of traps	3	4	5
vi) Median cunner caught per trap (lb)	9.6	9.6	9.6
vii) Labor per day (man hrs)	-	-	-
viii) Cost of labor per man hr ($)	$0	$0	$0
ix) Price of cunner per lb ($/lb)	$0.80	$0.80	$0.80
xi) Cost of other gear used in fishing season ($)	$37.80	$37.80	$37.80
xii) License fee	$30.00	$30.00	$30.00
Net returns in bait savings [gross return-total costs]	$(125.80)	$138.20	$402.20
Break-even value per lb given assumed lbs of perch/trap and costs	$0.81	$0.66	$0.56
Break-even lbs of cunner per trap per day for given costs (lb)	1.76	0.10	0.05

Table 3.1 Projected Annual (Value) Income statement with cunner value at CAD 0.80/lb at three, four, and five traps fished.

Assumed number of traps fished	3	4	5
Gross return in bait savings	$1,152.00	$1536.00	$1920.00
Total costs	$1,277.80	$1,397.80	$1,517.80
Total Lbs for season (lb)	1440	1920	2400
Fixed Assets	$487.80	$637.80	$787.80
Fixed cost	$30.00	$30.00	$30.00
Variable Costs	$1,135.00	$1,230.00	$1,325.00
Variable cost per $/lb	$0.79	$ 0.64	$0.55
Catch-to-bait ratio	4	4	4

The break-even number of traps with cunner value set at CAD 1.00, and traps fished set at three, four, and five in a 50 day season resulted in net returns in savings on bait of CAD 162.20, CAD 522.20, and CAD 882.20 respectively (Table 4). The catch-to-bait ratio is highest in this situation, with every CAD 1.00 of bait invested in fishing for cunner producing CAD 5.10 worth of cunner bait, if cunner is worth $1.00/lb (Table 4.1). The high catch-to-bait ratio is not surprising, but it must be stated that it would not apply for every fisher who attempts to fish cunner as auxiliary bait. The catch-rate of cunner in the various locations sampled was considerably different. Also, not all fishers think that cunner makes good bait but as bait prices have been rising and are likely to be higher in the 2018 lobster season, cunner should be worth as much or more than CAD 1.00/lb.

Table 4. Break-even pounds of cunner per trap with market price of CAD 1.00/lb as proxy for cunner value and value cunner must be worth to break even in a 50-day season, using scenarios of three, four, or five traps fished.

Assumptions	Scenario 1	Scenario 2	Scenario 3
i) Days in season	50	50	50
ii) Bait cost per lb of bait ($)	$1.00	$1.00	$1.00
iii) Median bait per trap (lb)	1.9	1.9	1.9
iv) Cost per trap ($)	$150.00	$150.00	$150.00
v) Number of traps	3	4	5
vi) Median cunner caught per trap (lb)	9.6	9.6	9.6
vii) Labor per day (man hrs)	-	-	-
viii) Cost of labor per man hr ($)	$0	$0	$0
ix) Price of cunner per lb ($/lb)	$1.00	$1.00	$1.00
x) Other charges per trip (i.e. gas, other…)	$17.00	$17.00	$17.00
xi) Cost of other gear used in fishing season ($)	$37.80	$37.80	$37.80
xii) License fee	$30.00	$30.00	$30.00
Net returns in savings on bait [gross return-total costs]	$162.20	$522.20	$882.20
Break-even lbs of cunner per trap per day for given costs (lb)	0.10	0.04	0.03
Break-even value per lb given assumed lbs of cunner/trap and costs	$0.81	$0.66	$0.56

Table 4.1 Projected annual (value) income statement with cunner value at CAD1.00 at three, four, and five traps fished

Assumed number of traps to fish	3	4	5
Gross return in bait savings	$1,440.00	$1,920.00	$2,400.00
Total costs	$1,277.80	$1,397.80	$1,517.80
Net savings on bait expense	$193.70	$553.70	$913.70
Total lbs for season (lb)	1440	1920	2400
Fixed assets	$487.80	$637.80	$787.80
Fixed cost	$30.00	$30.00	$30.00
Variable costs	$1,135.00	$1,230.00	$1,325.00
Variable cost per $/lb	$0.79	$0.64	$0.55
Catch-to-bait ratio	5.1	5.1	5.1

The more likely scenario is that of a 52-day season, with bait valued at CAD 1.00, and five traps fished. This is due to the likelihood of a fisher taking advantage of every possible day to fish cunner, while allowing for the possibility of inclement weather affecting a few days of fishing. The cunner value is probably closer to CAD 1.00, as most of the fishermen indicated in the survey portion of this study, that bait is most often CAD 1.00 or more. In this scenario, net returns on bait in the first season are CAD 925.20 (Table 5), and gross returns are CAD 2,496.00. Total cost to fish is CAD 1,570.80 (Table 5.1). Three different possible situations were assessed to determine if the worst-case, most probable-case, and the best-case scenarios would all be profitable for fishers to fish cunner as auxiliary bait in LFA 25. The worst-case scenario of a 28-day season, three traps fished every day, and cunner valued at CAD 0.70, is not profitable. The total cost to fish in this scenario is CAD 778.40 but the gross return on savings in bait is CAD 564.48 in a 28-day season, therefore fishers are spending CAD 213.92 on bait expenses in the first season (Table 5.1). Although it should be mentioned that CAD 213.92 would be a very small cost to bait lobster traps for a season when compared to traditional bait cost for a season.

Table 5. Break-even pounds of cunner needed to be caught per trap and the value cunner must be worth to break even during a worst case (28-day season with three traps and cunner valued at CAD 0.70), probable case (50-day season with four traps and cunner valued at CAD 0.80), and best case (52-day season with five traps and cunner valued at CAD 1.00).

Assumptions	Scenario 1 Worst-case	Scenario 2 Probable-case	Scenario 3 Best-case
i) Days in season	28	50	52
ii) Bait cost per lb of bait ($)	$1.00	$1.00	$1.00
iii) Median bait per trap (lb)	1.9	1.9	1.9
iv) Cost per trap ($)	$150.00	$150.00	$150.00
v) Number of traps	3	4	5
vi)Median cunner caught per trap (lb)	9.6	9.6	9.6
vii) Labor per day (man hrs)	-	-	-
viii) Cost of labor per man hr ($)	$0	$0	$0
ix) Price of cunner per lb ($/lb)	$0.70	$0.80	$1.00
x) Other charges per trip (i.e. gas, other…)	$17.00	$17.00	$17.00
xi) Cost of other gear used in fishing season ($)	$37.80	$37.80	$37.80
xii) License fee	$30.00	$30.00	$30.00
Net returns savings on bait [gross return-total costs]	$(213.92)	$138.20	$925.20
Break-even lbs of cunner per trap per day for given costs (lb)	(0.42)	0.10	0.03
Break-even value per lb given assumed lbs of cunner/trap and costs	$0.83	$0.66	$0.56

Table 5.1 Projected annual (value) income statement with worst case (28-day season with three traps and cunner valued at CAD 0.70), probable case (50-day season with four traps and cunner valued CAD 0.80), and best case (52-day season with five traps and cunner valued set at CAD 1.00) scenarios.

Cunner bait proxy value set at	Scenario 1 $0.70/lb	Scenario 2 $0.80/lb	Scenario 3 $1.00/lb
Assumed number of days able to fish	28	50	52
Gross return in bait savings	$564.48	$1,536.00	$2,496.00
Total costs	$778.40	$1,397.80	$1,570.80
Total lbs for season (lb)	806.40	1920	2496
Fixed Assets	$487.80	$637.80	$787.80
Fixed cost	$30.00	$30.00	$30.00
Variable Costs	$635.60	$1,230.00	$1,378.00
Variable cost per $/lb	$0.79	$0.69	$0.55
Catch-to-bait ratio	3.5	4.0	5.1

A closer look was taken at the scenario considered to be the likely maximum number of cunner traps allowed to be fished as auxiliary bait for the lobster fishery, also considering the second most likely maximum days that fishers would be able to fish cunner out of a total of 54 lobster fishing days against three wharf-side bait prices to determine the general cost of fishing cunner. In this scenario, four traps are fished for 50 days in a season. The total cost per season to fish cunner as auxiliary bait is CAD 1,397.80 and is comprised of fixed and variable (operational) costs. The total fixed-capital cost is CAD 637.8, which is composed of traps and other gear need to fisher cunner (Table 6). The total fixed cost was set at CAD 167.80, which was comprised of license fees, interest on fixed capital, and depreciation. The depreciation of this gear is set at CAD 100.00 over six years. The interest on fixed capital was set at zero because it was an insignificant amount of money. The license fee was determined to be CAD 30.00 as it states in schedule II (Section 17) of the Atlantic Fisheries Regulations 1985 in Commercial Licence to fish section," any species, in any case not otherwise provided for in this item, per species $30.00" (SOR/86-21, 2017) (Table 6). Operational costs per season are CAD 1,230.00 and include bait, labor, and other charges per trip (e.g., gas). Labor was set at zero as hired help in the lobster fishery are not paid an hourly wage and are generally expected to do what the captain requires of them for the lobster fishing season. To bait four cunner traps for a 50-day season, cost is CAD 380, but the gross return in bait savings are at least CAD 1,344.00 and up to a maximum of CAD 1,920.00 for a season (Table 6).

Table 6. Projected annual (value) income statement for four traps fished and the number of days fished set at 50, with the low, medium, and high median bait prices set as proxy for cunner value (scenarios 1: $0.70/lb, 2: $0.80/lb, 3: $1/lb CAD)

		Bait Prices at 4 traps fished for 50 days		
Gross Returns				
	Total catch (lbs)	1920	1920	1920
	Median Bait Price ($/lb)	0.7	0.8	1
	Gross return in bait savings	$1,344.00	$1,536.00	$1,920.00
Costs				
	Fixed capital			
	Traps ($)	$600	$600	$600
	Other gear ($)	$37.80	$37.80	$37.80
	Total fixed capital cost	$637.8	$637.8	$637.8
	i) Depreciation on fixed capital ($)	$100.00	$100.00	$100.00
	ii) Annual other gear ($)	$37.80	$37.80	$37.80
	ii) License fee ($)	$30.00	$30.00	$30.00
	Total fixed cost per season (i+ii+iii)	$167.80	$167.80	$167.80
	Interest rate	0.0%	0.0%	0.0%
	Opportunity cost ($)	0	0	0
Variable (or operational) costs	i) Bait cost ($)	$380	$380	$380
	ii) Labor cost ($)	0	0	0
	ii) Other charges per trip ($)	$850.00	$850.00	$850.00
	Total variable cost per season (i+ii+iii)	$1,230.00	$1,230.00	$1,230.00
Total Cost per season		$1,397.80	$1,397.80	$1,397.80

Net returns in savings on bait [gross returns - total costs]		$(53.80)	$138.20	$522.20
	i) Gross returns per trap/day	$140.00	$160.00	$200.00
	ii) Median cost to bait per trap/day	$(0.10)	$1.40	$1.40
	iii) Net return per trap/day	$140.10	$158.60	$198.60

DFO follows a precautionary approach towards decision making around marine species. Information on the abundance, distribution, and productivity, as well as the potential impact of cunner removal from the ecosystem and the impact of gear used to fish cunner must be examined before this species can be considered for an auxiliary bait fishery for the lobster fishery (DFO, 2010). Although there are no size restrictions to retain cunner caught as by-catch, we assume that DFO will apply one for auxiliary bait fishery. This is to ensure that the cunner population will not be threatened by fishing activities. The size at the onset of sexual maturity, or size of maturity (SOM), is often used to determine the acceptable size of fish to retain. Nova Scotia cunner were examined for age in relation to length by using otoliths and their SMO was established at two years old, when cunner were found to be 8–12 cm in length. Cunner appear to exhibit highly localized growth patterns (Nitschke, Burnett, & Kelly, 2001), and therefore additional research is need to evaluate the PEI cunner populations' size structure. Additionally, the impact cunner traps could have on the bottom if they are dragged was not yet assessed, but because lobster traps have a medium-low impact on the seafloor (Criquet et al., 2013), it is fair to assume the same or less impact for cunner traps as the ones used in our study were of similar

design. They might harm the substrate less then lobster traps because they are suspended off of the bottom on two wooden rails, and there will only be a fraction cunner traps fishing compared to the number of lobster traps.

3.4 Recommendations and Implications

Some important information that is needed to consider cunner as sustainable auxiliary bait to the LFA 25 lobster fishery is still lacking. Without this additional information on cunner populations, the DFO is unable to make management decisions on establishing an auxiliary fishery to the lobster fishery. It is recommended that quantitative data on cunner abundance, predator-prey dependency, and distribution be collected. Also, the amount of cunner harvested as a by-catch should be determined. As part of the Lobster Recourse Monitoring Program delivered by the PEI Department of Agriculture and Fisheries, participants in the voluntary index portion could be asked to record their estimated amount of cunner by-catch that is retained as supplementary bait for lobster fishing. As well, an exploratory harvest plan would be necessary to outline the roles and responsibilities with regards to management (DFO, 2010).

This research should not be used to make management decisions on cunner as bait. Although, if DFO determines that cunner is a sustainable bait supply, they would require it to be managed with an integrated approach that blends business principles and science. Therefore, this research may aid in understanding the economic stability of cunner as auxiliary bait for the lobster fishery in LFA 25.

3.5 References

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3.6 Appendix

Phase 2: Phone Survey - Lobster Fishing Area 25 Participants

Key# **Survey #**

Script: Hi Madam/Sir,

This is Michelle Hewitt. We met back in August to go over the field aspects of the perch study. As you might remember, when you agreed to participate in the perch study, you also consented to participate in a fifteen-minute follow-up survey on the economic viability for a potential perch/cunner auxiliary fishery for the LFA 25 lobster fishery. This survey will require you to estimate the likely cost to fish perch/cunner during your lobster fishing season. All information collected in this questionnaire will be kept anonymous in the final report but will be used to estimate the cost of fishing perch/cunner and determine if it would economically beneficial for LFA 25 fishers to fish perch as bait. You have the right to withdraw at any time and/or not answer any question, without repercussions. The complete assessment will be made available to the general public and sent to all fishers who are interested in a copy. I appreciate your participation in this study.

Is now a convenient time for you to do the survey? Are you aware of the possible costs associated with the project? Do you consent to participate?

Consent: Yes No **Date**: Day/Month/Year / /

Field	Value	Notes
How many days in the lobster fishing season do you think you could fish perch? (#)		
How many traps do you think you would need to fish perch as an auxiliary bait fishery to the lobster fishery? (#)		
Bait cost/ lb to bait lobster traps ($)		
What are the top three avg high, med, low bait prices you paid in 2017? ($)		
Median bait/ lobster trap (lbs)		
Median bait/ perch trap (lbs)		
Bait cost/ lb to bait perch traps ($)		
Extra cost associated with labor in the initial setup ($)		
Extra cost associated with labor /day to fish perch ($)		
Additional cost of fuel to fish perch traps ($)		
Cost to modify lobster traps into perch traps or purchasing perch traps ($)		
Other cost (i.e. freezing costs or storage) ($)		
Cost associated with additional gear (bait bags, rope, buoys, etc.) ($)		
What are your primary baits for lobster fishing?	o Mackerel o Herring o Crab Other _____	o Mostly fresh o Mostly frozen o Both
Do you believe that an auxiliary perch fishery will lessen your use of mackerel?	o Yes o No	o Maybe o Not sure

CHAPTER 4. LIMITATIONS, CONCLUSIONS, AND OVERALL RECOMMENDATIONS

4.1 Limitations

The major limitation of this study was the need to use non-academic or non-peer-reviewed newspaper articles as sources. Information on alternative baits for the lobster fishery are poorly represented in published academic papers. Additionally, the scope of the literature review on alternative baits was narrow, as the approach did not extend into the economics of using additional alternative bait sources. A fully detailed literature review and economic scan on the subject could have been a signature project on its own. Another limitation is that only estimated values for baits being sold to fishers could be used. Brokers that were contacted would not release the prices at which they sold bait to fishers. A major limitation of the primary research conducted was the change in the study due to the miscommunication between the primary researcher and DFO. As a result, a smaller number of fishers were able to complete phase one of the study and which resulted in a lack of full coverage of lobster fishing grounds in LFA 25.

4.2 Conclusions

Alternative baits are being utilized in lobster fisheries and show great promise, although there are unknown risks that should be assessed and controls put in place to avoid or lessen potential negative impacts. For instance, Asian carp, an invasive species that is potentially a great bait for LFA 25, is of little concern in terms of sustainability, and the price per pound is very low. But a minor risk remains, which lies in transmitting diseases to other marine animals.

Although, if controls around carp such as using only salted bait instead of frozen were implemented, there would be even less chance of diseases spreading (Schreiber, 2012).

Salmon processing by-products as bait options for PEI fishers were also considered. By-products from salmon processing has some of the best potential to provide a cheap available bait because it can be sourced locally in the Maritimes and since it is a by-product, it should be relatively cost-effective. The associated risk lies in the transfer of pathogens to other farmed populations, although this risk is considered minor. It is unlikely that a bait by-product meant for the lobster industry would make it to regional salmon farms and therefore we believe that it would make excellent bait for the lobster fishery.

Green crab has had a lot of bad press, but still has the potential be an excellent source of bait for the lobster fishery. Like Asian carp, it is an invasive species, and therefore sustainability is not an issue. There is currently a market for green crab as bait, and it is successfully used as bait in different lobster industries (St-Hilaire et al., 2016). Green crabs contain parasites that potentially may be transmittable to lobster, but it is unknown what effects these parasites have on lobster health and their ability to be shipped long distances. Therefore, more research should be conducted into this subject to alleviate any concerns regarding parasite transfer.

The resurgence of gaspereau has also brought old bait to the forefront of the alternative bait discussion. Gaspereau stocks have recently rebounded in some areas, and since gaspereau are considered excellent bait, this is a good news story for local fishers. Fishers tend to sell this bait from fisher to fisher, and therefore there is little data retained on landings. Consequently, it is crucial that any increased harvesting is done with scrutiny and stock sustainability in mind.

Cunner is currently being used as bait in the PEI fishery (PEI Fishermen's Association, 2017). In addition, a 2017 study conducted in the sGSL revealed that it is the third most caught species of by-catch in the PEI lobster fishery (Rondeau, Comeau, & Hanley, 2017). Our study concluded that fishers in LFA 25 could catch a median 9.6 lb of cunner a day per trap set (Table 1), with net return on savings in bait up to CAD $925.20 a season based on cunner value being CAD 1.00/lb in a 52-day season with five traps fished (Table 5). All break-even values were below any bait prices provided by fishers in phase two of the study (survey). In all scenarios the pounds needed to be caught by fishers in each trap are well below the median pounds caught per trap per day. In a 28-day season, with three traps fished and cunner value set at CAD 0.70, the break-even value was set at CAD 0.53, which is the highest of the values needed to break even fishing cunner (Table 5).

4.3 Overall Recommendations

It is recommended that further research is carried out on the ecological and economic impacts and benefits of cunner as an auxiliary bait source for PEI lobster fishers. A similar study should be conducted in LFA 24 and 26A in order to assess if cunner would be an economical bait to fish as auxiliary bait in the spring fishery. It is also recommended that an in-depth study be conducted on what baits, both common and alternative, are being used in the PEI lobster fishery, the amount of each bait type being utilized, and any concerns these baits might raise. Furthermore, more studies should be carried out on the potential for pathogens or substances to be transferred to lobster populations or other marine animals from bait sources.

The head of a commercial lobster enterprise can hold a bait-fishing licence (Department of Fisheries and Oceans, 1996) but not all fishers take advantage of these bait licenses, and those

that do often catch fresh mackerel with nets (Observation, August 2017). As mentioned above, there is concern that the lobster fishery is putting too much pressure on mackerel stocks. Therefore, if assessments prove cunner is sustainable to harvest as auxiliary bait, it is suggested that the DFO considers allowing an exchange of bait-fishing nets for the equal number of cunner traps to fish solely for the purpose of personal bait needs for lobster fishing. This could take some pressure off of mackerel stocks being utilized for bait and potentially improve lobster transportability.

Finally, the recommendation is to conduct a cost-benefit analysis to assess if it is economically beneficial for fishers to retain herring and freeze and store it for future bait needs instead of shipping it off PEI to be processed. This would include gathering information on how much herring is used in the lobster fishery as bait, how much is shipped off PEI to be processed, and how much cold storage would need to be available. The associated costs would also have to be considered in this analysis. This could make be an excellent signature project for a future student with interest in marine fisheries.

4.4 References

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