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Assessing Economic Performance of Maine's Lobster Fleet Under Changing Ecosystem Conditions In the Gulf of Maine

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ASSESSING ECONOMIC PERFORMANCE OF MAINE'S LOBSTER FLEET

UNDER CHANGING ECOSYSTEM CONDITIONS

IN THE GULF OF MAINE

By

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A DISSERTATION

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An Abstract of the Dissertation Presented
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This thesis explores the inter-disciplinary space that lies between fisheries management and stock conservation, resource extraction and economic return at the individual producer level, balanced with societal welfare. It considers policy implications in support of changing marine ecosystems and considers the values of the Maine lobster communities, which depend on it. We conducted a comprehensive lobster industry survey to assess costs and effort expended at the producer level for a representative fishing year, and establish a series of production function performance baselines for future comparison. The demographic data, attitudes and valuations collected allow us to characterize the fishing effort and regional dependency on the resource. We look at the Maine Lobster limited entry licensing system, to understand how the future participation in the fishery might change, and how Maine's communities might be affected. We examine the influences of ex-vessel price in the Maine lobster fleet, as a primary driver of profitability and economic value of the fishery. We apply multiple disciplines, and present four separate essays, with appendices containing the tabulated results of our three surveys. First, we evaluate and model a stochastic frontier production analysis to assess lobster producer efficiency and create a vessel-level profitability model. We then evaluate willingness to pay for a Maine Lobster license model with a censored regression Tobit model, and general linear regressions to

evaluate desired number of traps, as stated by existing and potential new entrants. We explore the variety of influences of ex-vessel price through a multiple linear regression, building on previous studies that demonstrated an inverse demand price response in the Maine fleet; we consider how changes in monthly landings have created excessive inventory holdings and examine this has on ex-vessel price. We then conclude by applying a retrospective analysis to evaluate future profitability and economic performance in the fishery, under potential changing conditions facing the coupled natural and human system. In aggregate these analyses identify risks of overcapitalization in the Maine Lobster fishery which are likely to confound efforts to effectively manage the resource in times of changing harvest patterns, and in light of variability in supply and market demand.

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1. INTRODUCTION

The rate of change to our earth's climate has accelerated over the past century (Parry et al. 2007; Perry et al. 2011; Perry et al. 2005; Pinsky et al. 2013) shedding new and urgent light on risks facing the long-term sustainability of our ecosystems (Pecl et al. 2017). It has become clear that we must adapt our policies to look not only at species survival, diversity, resilience and the key role of ecosystem services, but also human behavior and resource extraction rates in light of the scientific evidence presented (Johnson et al. 2011; Perry et al. 2005; Wernberg et al. 2011; Hobday et al. 2016; Philippart et al. 2011). Evolutionary forces have allowed a continual adaptation of natural systems to occur over long periods of time, and new equilibriums have been reached and maintained repeatedly across various land, air and sea based ecosystems (Visser 2008; Travis 2003; Parry et al. 2007). The relatively new introduction of the human species, however, has led to a coupled natural and human system with a different pattern of stress and the inclusion of bottom-up effects (Greene and Pershing 2007), resulting in different patterns of adaptations, as well as an acceleration in the effects of certain stressors previously felt over longer time scales (Pecl et al. 2017; Popova et al. 2016). Thresholds are just as important as averages, and these can be exceeded yielding surprise responses that present in non-linear fashion (Ottersen et al. 2013). Episodic events such as recruitment failure can have long-term consequences for a fishery (Vert-pre et al. 2013; Liermann and Hilborn 2001). Research to capture changes to global specific ocean hot spots (Wernberg et al. 2011; Philippart et al. 2011; Hobday et al. 2016) and the study of coupled natural and human systems (Liu et al. 2007; Lehuta et al. 2014; Perry et al. 2011) provide new insights, and can lead to improved understanding and forecasts of potential effects that may be observed in the future in other sites (Liu et al. 2007).

Similarly, research into assessing the economics of fisheries as a classic natural resource extraction firm with production characteristics evolved from the field of agriculture, and has provided analytical tools to assess and describe the effects of such changes in underlying resource basis of production (Gordon 1954; Copes 1972) as seen in wild capture and even aquaculture fisheries. Seminal works by Gordon 1954 demonstrated the concepts of fisheries economics on the basis of maximized rent returns for the utilization of a fishery, and how intensity of fleet effort has a maximum net economic yield, where the fishery both prevents over-fishing, and captures the optimum yield from the fishery. The idea of community objectives for the fishery as well guide the notion of optimum, where fleet efficiency may be balanced with jobs and wage opportunities (Hilborn 2007; Anderson 1980; Anderson 1973). This field of study now extends into complex evaluations of management strategies to inform the decision-making process of fisheries managers (Ana and Petermala 1990; Munro 2010).

The research presented in this thesis focuses on the impact of changing conditions in the Gulf of Maine and it's lobster fishery, at the ecological, economic and policy levels to understand present state, and characterize potential future scenarios, as an example of how a large ecosystem may adapt to changes associated with altering climate and habitat.

One of the primary drivers of change in our oceans is global temperature, including sea surface temperature (SST), bottom of the ocean temperature, long-range temperature averages and also maximum and minimum temperature thresholds (Alexander et al. 2018). Temperature effects can result from changes in key global oceanographic drivers (Popova et al. 2016), which may be felt differently in localized regions, and at different time scales (Pershing et al. 2014). Responses of the natural system components then are seen to through direct contact with the changed water temperature, but also through broader altered chemical and physical characteristics of the natural system (Chen et al. 2014), and components of the food web including pelagic species and other forage (Lehuta et al. 2014). Temperature effects felt mostly from the bottom up are coupled with responses of fishing behavior, which tend to be top down effects on the ecosystem (Greene and Pershing 2007). Fluctuations in the North Atlantic oscillation (NAO), the dominant mode of atmospheric variability, can lead to short term and long changes in sea surface temperature (SST) and also affect stratification and depth of mixing layers, as well as dissolved oxygen in the ocean, and primary production as the base of the food web (Drinkwater et al. 2003). Teasing apart the effect of temperature alone can be difficult, and should be considered an element of the natural systems changes that can occur (Liu et al. 2007; Incze et al. 2010; Tanaka and Chen 2016; Bell et al. 2015). Its important to note that changes in temperature include both increases and decreases in SST, and these tend to have differing impacts.

The effects of temperature take place against a backdrop of seasonal and inter-annual variability, felt differently at differing latitudes and within different localized systems (Nye et al. 2009). Localized short-term temperature changes can result from an atmospheric drivers such as the NAO (Drinkwater et al. 2003) and underlying shift or intensification of boundary currents, such as the California current or Eastern Australian current, and are often felt near the global upwelling sites which boast nutrient rich waters and higher primary productivity (Popova et al. 2016). Multiple hotspots, where temperature has increased more rapidly, have been observed globally and have contributed to our understanding of the effects of temperature on ecosystems (Perry et al. 2011; Hobday et al. 2016; Mills et al. 2013). Short-term changes have been observed to alter migration and distribution patterns (Nye et al. 2009), changing species composition, changing diets, and altered growth rates (Drinkwater et al. 1996). Initially a system will develop coping mechanism, and we look at top down and bottom up forcing as separate elements of the system, to determine the major forces at work in a given system and assess rates of change (Pinsky et al. 2013; Kleisner et al. 2016).

The effect of SST changes can be felt directly, but also through the effect on circulation patterns (Drinkwater et al. 2003), affecting the phytoplankton community first (Drinkwater et al. 2003), then up through the zooplankton (Pershing et al. 2005), then the small pelagic species and finally the higher trophic levels (Popova et al. 2016). In the case of phytoplankton, increased temperature affects their turnover rate, and changes in stratification have altered the critical depth for primary production to occur and leads to changes in the timing of the spring phytoplankton blooms (Pecl et al. 2017). Increased temperature has been observed to affect metabolic rates of zooplankton, where changes in development rates have been observed. Zooplankton are further affected by changes in temperature (Pershing et al. 2005), through their contact rates with food supplies i.e. phytoplankton (Drinkwater et al. 2003). Zooplankton such as *Calanus finmarchicus* represents a fundamental building block upon which higher trophic levels rely, and changes in abundance of zooplankton have been associated with increase in SST. Long term effects of SST on zooplankton include changes in the lipids and therefore protein quality of the zooplankton (Runge et al. 2012).

As these lower trophic levels experience changes, so too do the fish assemblages, which depend on them such as the herring, sardine, and the commercial valuable species such as cod and lobster (Frank 2005; Pershing et al. 2014; Pinsky et al. 2011). Highly mobile small pelagic species respond to changes in temperature by increasing their metabolic rate, and by shifting their distributions in response to changes in food availability (Nye et al. 2009; Lucey and Nye 2010; Thomas et al. 2017; Henderson et al. 2017). In large fish species, changes in distribution then also result as they follow the food source, and changes in life history traits and recruitment have also been observed, leading to reduced yields and reduced stock productivity (Link et al. 2011).

Human responses to these ecosystem shifts can be temporary and may include short term fishing behavior changes include riding out the storm behavior, through tactics such as intensification of effort and diversification of fishing effort into other species involving gear modifications, licensing diversification (Stoll 2017), and migrations or longer trips farther sites to follow the fish (Perry et al. 2011). It's not uncommon to see a temporary dispatch of the fishing fleet to far away fishing grounds and then a return home with the catch during periods of decreased abundance of certain key species. Market response is also a factor, where supply and demand can lead to ex-vessel pricing changes, and alter the economics of the fishing activity (Hobday et al. 2016; Norman-López et al. 2014). Fishing pressure plus the emergence of new species in local waters, such a squid or jellyfish, can also lead to an opportunistic shift targeted species (Gucu 2002).

In the Gulf of Maine we saw an unprecedented increase in SST in 2012 (Thomas et al. 2017; Hobday et al. 2016; Anderson et al. 2013; Morse et al. 2017), revealing a complex set of interactions between the natural, human and market systems not felt with previous fisheries in the region (Pershing et al. 2015). The Maine lobster fishery experienced an unseasonably warm spring, which led to an early spring season for the Maine lobster industry across all Maine Lobster management Zones (Mills, et al. 2013). We saw an earlier spring molt, likely a metabolic response to the increased temperature, and suspect changes in mortality, and susceptibility to lobster shell disease, based on experiences in other regions such as Long Island Sound (Tanaka et al. 2017; Palmer 2014). This change in the ecological systems was rapidly followed by a shift in the seasonal timing of the lobster harvest, as well as a shift in the centroid representing the spatial distribution of the harvest (Maine Dept. of Marine Resources).

This period of increased biological production has led to a sharp increase Maine lobster supply, which has been unfettered by policy constraints and has led to significant variability in the ex-vessel price per pound, directly correlating with volume (Dicolo and Friedman 2012). Compressed time periods and seasonal spikes in landings were seen to spark political unrest and competition between U.S. and Canadian lobstermen for limited Canadian processing capacity for the soft shell lobster product in 2012 (Woodward 2012), potentially creating a combined supply and demand challenge. Vessel level profitability was reported to decrease in the wake of 2012 price deflation, (personal communication, Dayton and Sun) and led to an intensification of winter fishing, as well as an increase in the distance traveled to harvest lobsters from inshore to offshore during periods of higher price yields (Maine Dept. of Marine Resources). Feedback between the human and natural coupled system has been observed and pressure on the resource increased, likely at a declining rate of return to the economy (Fogarty and Gendron 2004). Longer-term implications of this feedback response have yet to unfold, but early signals suggest a decline in the lobster population abundance is likely to occur in the next five years with further destabilization of the coupled ecosystem.

Long-term changes can result from these types of short-term episodic events, especially when a threshold has been exceeded. In the case of the Maine lobster, research has shown that SST of 20 degree Celsius represents a significant threshold, and as we near this benchmark, changes are likely (Wahle et al. 1991). Other experiences have shown that long term changes might include habitat changes, life history response such as changes in fishery age structure leading to a evolutionary response decrease in average age of maturity, permanent ecosystem restructuring and regime shifts with changes in abundance of species, and the emergence of new species in a system, as well as new speciation events (Steneck et al. 2002; Xue et al. 2008; Daskalov et al. 2007). The ecosystem will likely lose some resilience and tend to resist returning to the previous state, even as the stressors are removed, such as over-fishing (Greene and Pershing 2007). Long-term changes in the human component response in other regions have included geographic migrations that may include permanent resettlement closer to the fishing resource, socioecological change, economic contraction or diversification, re-training and reduction in professional pluralism, out-migration, and even community closures (Perry et al. 2011).

The Gulf of Maine has already experienced radical changes in the past decade due to the impacts of SST on Gulf of Maine Cod, which provides important context and lessons for other fisheries faced with the same challenges (Pershing et al. 2015). Changes in the Gulf stream positioning, and atmospheric blocking through the jet stream which that brought warm air into the region (Chen et al. 2014), may have also added to fresh water melt in Greenland, causing changes in the distribution of *C. finmarchicus* which shifted steadily north and eastward over the period of the past decade (Castonguay et al. 2008; Runge et al. 2012). Other impacts include a physiological change and decline in copepod quality as forage, which has led to a decrease in food availability for Gulf of Maine Cod, and has contributed to the decline in abundance, and stock structure. As well, the removal of older Cod fish through fishing effort has progressively led to changes in the age structure of the population (Frank 2005; Palmer 2014; Pershing et al. 2015), thereby reducing the resilience of the stock and increasing risks to the reproductive capacity. Response on the part of policy makers to progressively limit the days of fishing available to members of the fleet in an effort to control catch, has lagged the decline of the population and likely does not adequately protect the resource from over-fishing. In turn, vessel permit database (NOAA Fisheries Office Greater Atlantic Region) reveals that the fishing fleet shifted its center of operations closer to fishing grounds based on stated homeport, suggesting an increased effective fishing effort, rather than a decrease.

New management measures in the form of catch shares were ultimately implemented in the Northeast multi-species complex to protect the multi-species ground fish fishery (NEFMC 2010), but these reactive actions came very late for Gulf of Maine Cod and the fishing economy that depended has depended upon it. The fleet has substantially consolidated and contracted, and the community has been left with socio-economic consequences and federal disaster relief has been provided. A similar pattern was experienced in the N.W. Atlantic Cod stocks off the coast of Canada in the late 1990's, and still today, despite a complete fishing moratorium in effect, the stock did not rebound as expected (Fu et al. 2001). An increase in the number of seals was observed, as well as increases in shrimp and crabs, coupled with a decrease in zooplankton

(Cook and Trijoulet 2016; Pershing et al. 2005). This provides an example of a permanent shift in the ecosystem structure, a foundational change in the food web, to where it can no longer support the original assemblage. The human system response has been a shift to other target species, including lobsters, urchin, shrimp and scallops. In the Gulf of Maine most recent experience, we have observed a pattern of fishing down the food web (Steneck and Wahle 2013) leading to marked decrease in the diversity of the fishery assemblage and community; we also begin to see the emergence of new species such as squid and warmer water species such as black sea bass, with consequences yet to be realized (McMahon 2017). Some have proposed that the inter-relationship between the fisheries can destabilize other fisheries unintentionally (Frank 2005) through trophic cascades. For example removal of top predators such as cod, or the initial mid water pelagic capture and subsequent re-deployment of herring as bait in the lobster fishery for example, may have unintended consequences (Grabowski et al. 2010; Thunberg 2007; Grabowski et al. 2009).

Humans have the ability to adapt and respond to long term as well as short term changes within the same generation, for example through education, re-deployment of capital to alternate uses, and by partnering. But risk assessment guides our probability of changing behavior (Kahneman and Tversky 2013) and so a decision-making takes place at the individual level and can alter expected outcomes. Ecological systems do not possess this measure of adaptation with the same generation and must rely on evolutionary processes to alter their interaction with the natural system in its new state. Longer lived species, such as lobster, may take longer to adapt to changing conditions, are suffer a population extinction well before it can genetically adapt or migrate to new habitat (Pinsky et al. 2013; Greene and Pershing 2007; Visser 2008). Therefore, governance models, education and community values are often the cornerstone elements determining the fate of the coupled natural and human systems and warrant further attention in our collective efforts to understand and adapt to shifting ecosystems and continue to derive economic utility and food supply from them (Hobday et al. 2016; Holland 2011; International Sustainability Unit 1998; Link et al. 2011). Our ability to learn from prior lessons in fisheries often depends on the ability to understand the potential impacts of changes. This research is motivated by a desire to understand the economic implications of climate change, and examines the Maine lobster fishery as a case study for how a large marine ecosystem may adapt to changes associated with climate and habitat shifts.

This first chapter of my research provides a quantitative assessment of the lobster fishery economics in the form of a stochastic frontier production model. I estimate profitability and technical efficiency of Maine's lobster industry for the fishing year 2010, using confidential firm-level data and survey responses for 1,007 fishermen. The Cobb-Douglas and Translog stochastic frontier production models were estimated using the maximum likelihood method. I develop an economic stochastic frontier production-modeling framework to assess the three different vessel class production functions, and identify the combination of characteristics, which maximizes the production. Empirical results highlight the differences in technical inefficiency, and signal that societal benefits associated with employment levels have characterized the lobster production environment, over firm-level efficiency.

Because of the variety of technical expertise and capitalization rates available for production maximization in Maine, we aim understand the vessel-level production functions, as a way to inform motivation and likelihood of firm participation in the fishery under changing input conditions. Producer efficiency is vulnerable to operational characteristics and subject to climate based regime shifts and shifts in resource distribution. Harvester effort, which is only marginally constrained by lobster management zones and trap quantity, will be driven by producer maximization characteristics. Current policies in effect will be tested by these market-drivers and increased fishing effort could result in over-fishing. This model is compared to experiences of other lobster fisheries.

The second chapter of my research focuses on Maine's Lobster Limited Entry Licensing Program, and explores the issue of additional entry into the Maine lobster fishery, as a social consideration in light of limited employment opportunities, but balanced with the concerns that the fishery is already over-capitalized and fishing at maximum yield. I conducted two contingent valuation surveys, one to elicit a value for a Maine lobster license and to describe the currently waiting additional incoming human and operating capital into the Maine lobster fishery through potential new boats and also increase in trap quantity for existing license holders. I offer comparison to other crustacean trap fisheries that have engaged in effort limitations and resource conservation through policy reforms, for consideration as precautionary approach in advance of any downward or upward landings adjustments or other landings anomalies in the Maine lobster fishery. I consider two dimensions, first the social equity question of licensing, and second the economic impact of the potential incoming capital.

In the third chapter of my research, I analyze the influences affecting Maine ex-vessel lobster price, as a primary driver in the economic performance of the fleet. Landings patterns have changed due to climate related underlying changes in the ecosystem, and the market demand struggles to align with current supply, especially with the increase in late season landings in October and November. I evaluate the impact of this late season supply on the next year in-season ex-vessel price, with a regression analysis on the landings data, including Canadian imports of frozen lobster to the U.S. I also consider the effect of forecasted landings projections on this relationship.

In the fourth chapter of my research, I have applied a retrospective analysis and model the potential vessel-level profitability impacts associated with changes in resource abundance and spatial distribution in Maine's American Lobster fishery associated with climate variability and under current licensing policies. I describe the climate variability issues observed in other fisheries globally, and explore some of the early indicators of climate change observed in the Gulf of Maine specifically. I then analyze the profitability impact of changing spatial harvest patterns and landings volume on firm level short-run vessel profitability where there is sunk capital. I have modeled the potential return of the fishery to more historic landings volumes of 70 million pounds but with current fleet participation and capitalization rates. Scenarios presented look forward 5 years and assume modest market price response associated with changes in supply and demand, as well as modest changes in other production inputs such as bait, and fuel. I evaluate long-run vessel participation rates in the fishery, with implications for Maine lobster fishery management and policy reform.

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2. TECHNICAL EFFICIENCY IN THE MAINE LOBSTER INDUSTRY: AN ESTIMATE OF THE STOCHASTIC FRONTIER PRODUCTION MODEL

2.1 Abstract

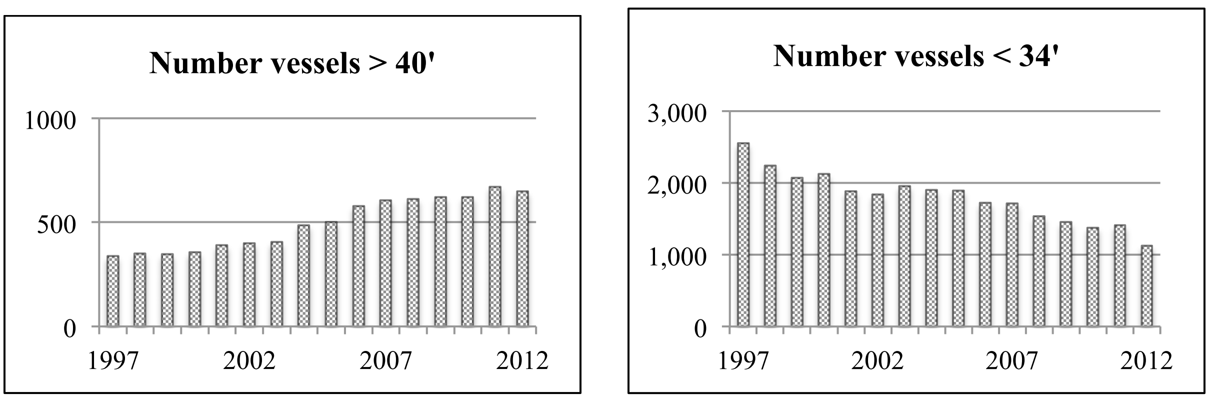
After several decades of steadily increased landings, the American Lobster fishery now dominates Maine's marine economy. But, there is uncertainty about the future robustness of the stock due to underlying ecological and climate factors, and despite the volume increases the economic value and profitability of the fishery is vulnerable at both an individual and State level in recent years. The results of this research provide a quantitative assessment of the fishery economics in the form of a stochastic frontier production model. This paper quantifies the profitability and technical efficiency of Maine's lobster industry for the fishing year 2010, where confidential firm-level data and survey responses for 1,007 fishermen are used. The Cobb-Douglas and Translog stochastic frontier production models were estimated using the maximum likelihood method. Empirical results show that the industry is not characterized by constant returns to scale, and reported societal benefits associated with employment levels have characterized the lobster production environment, over firm-level efficiency. Further investigations into vessel class specific production functions reveal inshore fishing inefficiencies associated with larger vessels, which have become the dominant class along the Maine Coast, and suggest the fleet to be overcapitalized should spatial and temporal harvest patterns associated with increased water temperatures prevail. This paper establishes a baseline for comparison, to enable the evaluation of future policy reforms in the U.S. lobster fishery and provides a discussion of some of the drivers of the inefficiencies identified.

2.2 Introduction

The Maine Lobster fishery dominates the Maine Coast, has seen steadily increasing landings over two decades or more, peaking in 2016 at 136 million pound, with an ex-vessel value of $536 million (Maine Dept. of Marine Resources). The lobster resource has done well in the Gulf of Maine for 50 years, both inshore and offshore where cold rich waters have helped to bolster landings, which have steadily increased over the past two decades (Maine Dept. of Marine Resources). The stock is not currently over-fished, and over-fishing is not occurring (ASMFC 2015). But recent landings reports reveal changes in spatial and temporal patterns over time, which may be early indicators of underlying changes in the resource health. These changes may be associated with a variety of factors including top-down or bottom-up forces such as depredation (McMahon et al. 2013), food availability (Tlusty et al. 2008; Grabowski et al. 2009), changes in habitat suitability (Tanaka and Chen 2016; Tanaka and Chen 2015; Chang et al. 2010), climate and temperature (Chang et al. 2010; Tlusty et al. 2008). This variability in stock abundance, and shifts in timing and spatial distribution of the harvest can have predictable and unpredictable effects and affect economic return, with great impact on working communities (Cheng and Townsend 1993).

Maine has a large number of communities that rely on the lobster fishery, deriving an average of 83% of their household income from fishing (Dayton and Sun 2012). Prior anthropological research has found that lobstermen derive not only income, but also their identity from their occupation, and the culture of the working waterfront communities depends on the fishery too (Acheson and Gardner 2012). Maine fishermen operate as traditional firms seeking maximum profits, but there is also a social element where Maine seeks to maximize the number of jobs, regardless of the profitability of those jobs. According to neoclassical economic theory, all firms are assumed to be fully efficient in their use of technology, but there are examples where this is not the case (Hilborn 2007) and the idea of a worker satisfaction benefit as an additional form of utility derived from the occupation has also been proposed (Anderson 1980) to explain this phenomenon. A maxima is achieved where the number of jobs in the fishery lies at the point where the last unit of effort has a marginal cost of effort equal to the marginal return on effort. Maine's lobster fleet provides an interesting contradiction, where the fishery dissipates rents through over-capitalization of inputs such as labor and vessels. This provides an example of this inefficiency, where this highly lucrative fishery operates in a fashion that is not economically optimal, especially when compared to other crustacean trap fisheries such as New Zealand or Australia, which have undergone significant policy changes (Reid et al. 2013; Norman-López and Pascoe 2011; Gardner et al. 2014).

Maine's fleet has observed a change in the fishing practices over the past twenty years (Lobster Advisory Council 1999), driven by changes in policy and governance (Steinback et al. 2008), where a decrease in licensing flexibility for multiple species has led to a specialization of effort in each fishery (Stoll et al. 2017), and discourages multi-species fishing and seasonal gear changeovers. This has led to an increase in capitalization rates of lobster specific vessels, traps and technologies, which seems to have helped improve the efficiency in some portions of the fleet. Some operators are choosing to invest upwards of $300k+ in a boat, and many fishermen now hold inshore and offshore fishing permits allowing year round access to the fishery. Over the past two decades, there has been an increase in vessel capitalization, reflected in the and 52% decline in the number of vessels under 20 feet since 1996, and a 180% increase in vessels over 40 feet during that same period as shown in figure 2.1. The number of vessels greater than 40 feet rose from 4% of the total in 1997 to 11% of the total in 2011. Meanwhile, the number of vessels under 20 feet dropped from 40% of the total in 1996 to 20% of the total in 2012. The number of mid-size vessels has remained relatively constant over time but overall, there has been fleet-wide trend towards larger vessels, and with a greater technological advances on board the vessel, such as GPS receivers, satellite, and even acoustics.



Source: Maine Dept. of Marine Resources

Figure 2.1 Maine Lobster Vessel Size Distribution 1990 - 2012

The observable physical attributes of the vessels in the fleet, however, are only one dimension of the performance of a fisherman (Squires 1987), and may not account for all of the variation among vessel catch. Other attributes have been suggested to explain variation in producer outputs (Thunberg 2007), such as the skills of the operator, age, education, competition from other fishermen, spatial and temporal fishing constraints and choices, and luck are also factors. Other utility derived on the part of the fisherman include non-pecuniary benefits (Fullenbaum et al. 2017), such as quality of life and freedom of choice in professional activities. Prior studies in the English channel as well as New Zealand (Pascoe and Coglan 2002; Sharp et al. 2004) have attributed the variation in vessel performance on the skills of the operator, with certain individuals characterized as 'highliners' who seem to be able to earn substantially more than others with similar vessel. And still other studies have concluded that 'luck' is at the source of the variation.

The degree of income these operators require to offset their capital investments is the subject of much question and leads directly to implications for the resource underlying these business models. Other lobster fisheries worldwide have observed similar long-term trends in vessel capitalization and effort escalation, and responded with governance reform (Australia 2009b; Australia 2009a; Yandle 2006; Philippart et al. 2011). The range of reforms is wide, and often a progression from effort controls, such as trap limits or seasonal restrictions, to output controls, such as ITQs and TACs. In many cases, crisis and resource collapse have been the driver for radical change, for example New Zealand, where communities tend to resist adaptation until alternate options have been fully exhausted (Popova et al. 2016; Yandle 2008). In these reactive situations it can be hard to assess whether policy reform has been successful after the fact, due to a lack of baseline data on the fishery performance stable performance periods (Sharp et al. 2004).

This research is motivated by future changes to understand the impacts of changes to production inputs in the Maine lobster fishery, and to provide a contribution to the economics literature through the designation of the vessel of a unit of effort for evaluating technical efficiency and the idea that a fleet can comprise of several homogenous sub-groups within an otherwise non-homogenous fleet. We hypothesize that the differences in producer efficiency lie in the characteristics of each individual operation, and choices made by the producer to maximize their profit. We have developed and implemented an industry survey to obtain original data with which to develop profit and producer production functions, and test our hypothesized differences in efficiency associated with the different firms, or in this case vessel characteristics.

2.3 Empirical Approach

2.3.1 Estimation of the Stochastic Frontier Production Function

Theoretical Model specification

According to neoclassical economic theory, all firms are assumed to be fully efficient in their use of technology so that input and output prices are the only factors that decide output level. Farrell (1957) proposed a provocative idea to define the output of the most efficient firm as the production frontier for all firms. Given that efficient firms with full information should operate at "maximum" potential output levels (i.e. full technical efficiency), any deviation from the production frontier measures technical inefficiency. This allows for the fact that firms may encounter various uncontrollable exogenous factors (random effects), such as performance of various machines, weather conditions, uncertainty of input supplies, etc.

Battese and Coelli (1995) propose a model that imposes allocative efficiency, removes the first-order profit maximizing conditions, and permits panel data. The Battese and Coelli (1995) model specification can be expressed as:

$$Y_i = \exp(X_i\beta + \varepsilon_i) = \exp(X_i\beta + y_i - u_i) \quad \varepsilon_i = v_i - u_i, \;\; i = 1, \;\ldots, N \qquad (1)$$

where Y_i measures lobster catch of the ith firm; X_i is a $k \times 1$ vector of output value and input costs; $\beta(1 \times k)$ is a vector of unknown parameters; the v_i's are assumed to be identical independently distributed (*i.i.d.*) random errors with $N(0, \sigma_v^2)$ and are independently distributed of the technical inefficiencies u_i; the u_i's are assumed to be non-negative random variables associated with technical inefficiency. A common approach is to assume that u_i is either non-negative normal and truncated at zero $N(0, \sigma_u^2)$, or for u_i to have an exponential distribution with mean, m_i , and variance, σ_u^2.

The catch inefficiency in this Stochastic Production Frontier (SFPF) (1) can be specified as:

$$u_i = z_i\delta + w_i \qquad (2)$$

where z_i is a $p \times 1$ vector of variables which may influence the efficiency of the ith firm; and δ is an $1 \times p$ vector of parameters to be estimated. Note that the distribution range of the random errors v_i is $[-\infty, +\infty]$, the distribution range of the random inefficiency factor u_i is $[0, +\infty]$, and w_i is a truncated random error $(\geq -z_i\delta)$.

Following the exposition of Battese and Corra (1977), the probability density functions for v_i and u_i are assumed mutually independent so they can form a joint p.d.f. We then apply a γ-parameterization to search for suitable starting values with an iterative maximization algorithm.

The log-likelihood function, in terms of γ-parameterization, is:

$$\ln L = -\frac{N}{2}\ln\frac{\pi}{2} - \frac{\pi}{2}\log(\sigma^2) + \sum_{i=1}^{N}\ln[1-\Phi(S_i)] - \frac{1}{2\sigma^2}\sum_{i=1}^{N}(\ln Y_i - X_i\beta)^2 \qquad (3)$$

where,

$$s_i = \frac{(\ln Y_i - X_i\beta)}{\sigma}\sqrt{\frac{\gamma}{1-\gamma}} = \frac{\varepsilon_i\lambda}{\sigma} * \Phi(.)$$

is the cumulative density function of the standard normal random variable. The maximum likelihood (ML) estimates of β, σ_s^2 and γ are obtained by finding the maximum value of the log-likelihood function, defined in equation (3). The ML estimators are consistent and asymptotically efficient (Aigner et al., 1977). The computer program, FRONTIER Version 4.1, is used to obtain the ML estimates for the parameters of this model.

Hypothesis tests

Generalized likelihood tests are used to test the hypotheses outlined below to ensure that inefficiency effects are absent from the model.

(i) $H_0: \mu = 0$,

(ii) $H_0: \gamma = \delta_0 = \delta_1 = \ldots = \delta_p = 0$, or the null hypothesis which specifies that inefficiencies are absent from the model.

(iii) $H_0: \gamma = 0$, or the null hypothesis which specifies that inefficiencies are not stochastic.

(iv) $H_0: \delta_1 = \delta_2 = \ldots = \delta_p = 0$, or the null hypothesis which specifies that inefficiencies effects are not a linear function of each of the base effects.

Under the null hypothesis, $H_0: \gamma = 0$, the model is equivalent to the traditional average response function, without the technical efficiency effect μ_i. The test statistic is,

$$LR = -2\left\{\ln\left\{\frac{L(H_o)}{L(H_1)}\right\}\right\} = -2\left\{\ln[L(H_0)] - \ln[L(H_1)]\right\} \sim \chi_1^2 \quad (5)$$

where $L(H_o)$ and $L(H_1)$ are the values of the log-likelihood function under the null and alternative hypotheses, and the test statistic has a χ^2 distribution with twenty-three degrees freedom. Because $\gamma = 0$ lies on the boundary in the parametric space, the generalized loglikelihood- ratio statistic, LR, has an asymptotic distribution which is a mixture of the two chi distributions, namely $\left(\frac{1}{2}\right)\chi_0^2 + \left(\frac{1}{2}\right)\chi_1^2$ (Battese and Coelli, 1995).

2.3.2 Empirical Model Specification

Data Source and variable definitions

A 2011 economic and fishing effort survey of Maine's lobster industry is used in this study. The input costs and output catch and revenue for the various classes of lobster vessels across the seven Maine lobster zones were obtained through a telephone survey, administered by market research firm. For the purpose of this study, only those fishermen who landed more than 1,000 lbs. during the calendar year 2010 were considered. These data were then merged with Federal dealer reported catch and revenue daily transaction source link party_id field, allowing firm-level individual catch and revenue to be appended, and observation level analysis for a sample population of *n* = 1,007, representing an average 23% sample frame of all full-time active lobstermen in Maine. Average input costs for the industry fell roughly into these categories: 24% bait, 22% fuel, 21% labor, 21% gear and vessel maintenance and 12% administrative & miscellaneous.

Firm level observations were created for each calendar quarter in which the firm reported fishing effort, and in which revenue and catch were reported in the dealer data. Catch was used as the output (Y); labor including owner operator labor, measured as costs; intermediate inputs such as bait, fuel, repairs were measured as costs; capital including vessel replacement values plus costs of traps and rigging were used as the value of assets.

Table 2.1 Descriptive statistics cost survey variables

Variable	Definition	Mean (Std Dev)
Lbs	Production annual of the *i*th firm	29,414 (24,879)
Labor	Labor cost annual	98,699 (88,460)
Bait	Bait cost annual	14,922 (10,350)
Fuel	Fuel cost annual	9,014 (9,776)
Yrs_exp	Years of experience	29 (16)
Age	Age of fisherman	50 (15)
Vessel_length	Length of fishing vessel	33.77 (7.01)
Engine Size	Engine horsepower	309.15 (166.38)
Max traps	Maximum number of traps fished	655 (241)
Money Owed	Loan Amount	50,221 (51,855)
Vessel Value	Current vessel value	84,493.63 (75,757.07)
% Income lobster	Proportion from lobstering	70.70 (29.30)
Gear cost	Cost of traps and rigging	8,695.13 (3,328.89)
Years planned	Years intending to keep fishing	52.39 (39.49)

Table 2.2 Variable definitions

Variable	Definition	Unit
Lbs_Q	Lobster production quantity of the *i*th firm at interval Q	lbs.
Labor_Q	Labor per quarter	US $
Bait_Q	Bait cost per quarter	US $
Fuel_Q	Fuel cost per quarter	US $
Maint_Q	Maintenance costs annual	US $
Admin_Q	Administrative costs annual	US $
Yrs_exp	Years of experience	Yrs.
Age	Age of fisherman	Yrs.
Vessel_Cat	Length of fishing vessel category $i = 1$ to 3	ft.
Engine Size	Engine horsepower	Hp
Max traps	Maximum number of traps fished	Integer
Traps hauled_Q	Number of traps hauled per calendar quarter	Integer
Number_trips_Q	Number of fishing trips taken per calendar quarter	Integer
Number qtrs	Number of calendar quarters fished per year	Integer
Distance_traveled	Steam time * average speed	Miles
Quarter_dummy_Q	$QDi = 1$ if the *i*th firm was actively fishing during calendar quarter *i*; otherwise $QDi = 0$	Integer
Zone	Maine fishing Zone (A to G).	1 – 7

We acknowledge three shortcomings in our data: amortization schedule for annual asset depreciation used a standard 20-year schedule across all firms; annual reported bait costs were allocated by calendar quarters in proportion according to reported trap hauls per quarter;

observations with no crew costs cited were adjusted to zero crew costs, which may understate labor costs in some cases.

The Translog stochastic frontier production model functional form selected used to measure the technical efficiency of Maine's lobster industry is defined as:

$$\ln Y_i = \beta_0 + \sum_{i=1}^{n} \beta \ln X_{ji} + \frac{1}{2} \sum_{j=1}^{n} \sum_{k=1}^{n} \beta_{jk}\, ln\, X_{ji}\, ln\, X_{ki} + v_i - u_i \quad (6)$$

where Y_i is the observed output, and *i* represents the *i*th lobsterman for i = 1, 2, … 1,007 and X_{ji} represents the amount of input of *j* used by each lobsterman, and there is symmetry in the input cross-effects by assuming $\beta_{jk} = \beta_{kj}$. The estimated parameters $\beta_1, \beta_2, \ldots, \beta_n$ represent output elasticity of corresponding inputs, and the sum of these parameters equals the total estimated output elasticity. We define output elasticity as the percentage change in output, resulting from a 1% change of all input factors. Output elasticity greater than one indicates increasing returns to scale for the industry.

For our study, we define technical efficiency μ_i for each lobsterman as a combination of the inputs representing technical ability and production conditions in the Gulf of Maine inshore fishery, and that technical efficiency for each individual lobsterman is specified as follows:

$$\mu_i = \delta_0 + \delta_1 \mathrm{License_{yrs}} + \delta_2 \mathrm{Age} + \delta_3 \mathrm{Soak} + \delta_4 \mathrm{Vessel_{hp}} + \delta_5 \mathrm{Traps_{owned}} + \delta_6 \mathrm{Bait_{per_{lb}}} + \delta_7 \mathrm{Price_{per_{pound}}} + \delta_8 \mathrm{Dist_{travel}} + \delta_9 \mathrm{Income_{lob}} + \delta_{10} \mathrm{Traps_{fished}} + \delta_{11} \mathrm{Q_1} + \delta_{12} \mathrm{Q_2} + \delta_{13} \mathrm{Q_3} + \delta_{14} \mathrm{Zone_A} + \delta_{15} \mathrm{Zone_B} + \delta_{16} \mathrm{Zone_C} + \delta_{17} \mathrm{Zone_D} + \delta_{18} \mathrm{Zone_{DMI}} + \delta_{19} \mathrm{Zone_E} + \delta_{20} \mathrm{Zone_F} + \delta_{21} \mathrm{Zone_G} + \delta_{22} \mathrm{Zone_A} + \varepsilon \quad (7)$$

In equation 7, the fisherman's $\mathrm{license_{yrs}}$ is used to represent technical ability. Two sets of dummy variables are included, one for Zones, and for calendar quarters, to account for differences in seasonal and spatial patterns.

Output Elasticity

For each input factor Xj, (j = 1, 2, …., 4) there is a corresponding output elasticity evaluated at a sample mean, which is defined as the percentage change in the ith lobsterman's output for a 1% change in the jth input factor.

The production elasticity of the *i*th input is defined as:

$$EX_{ij} = \frac{\partial \ln Y_i}{\partial \ln X_{ij}} = \frac{\partial Y_i}{\partial X_{ij}} \cdot \frac{X_{ij}}{Y_i} = \beta_j + \sum_{k=j}^{4} \beta_{jk} \ln X_{jk} \quad (8)$$

The output elasticity for each input depends on the relative input of the other factors used. If $\beta_{jk} = 0$ for all j and k then the production model specification reduces to where the output elasticity for the *j*th input is defined as Bj, and the sum of the parameters equals the estimated returns to scale. Since EX_{ij} is different for each lobsterman from the definition in Eq. (5) we use the sample mean of each input factor *j* across all lobstermen, EX_j to represent EX_{ij}.

2.4 Results and Discussion

Input factors to estimate output quantity

Table 2.3 shows the estimation results of the SFPF, separately evaluated for three classes of vessels in Maine's Lobster industry, using production functions based on lobster 'catch' as the dependent variable. All variables except *trips per quarter* are on a 'per trip' level. Coefficients should be interpreted as output elasticities[1].

Under the stochastic frontier model specification provided by Battese and Coelli, we are interested in the error structure of the parameterized model application, so we can tease apart the error due to random noise, from the technical inefficiency effects of interest. The null hypothesis, that there are no technical inefficiency effects in the model, can be conducted by testing the null and the alternative hypotheses, and most commonly the Wald statistic was used in most historical applications. However, this is often insignificant, and has a large probability of Type I error due to size properties, and so alternate methods have been identified involving gamma, and with generalized-ratio tests to test if inefficiency effects are absent from the model.

Table 2.3 Production function output elasticity estimation results by vessel class.

Vessel Category		34' and below		35' to 39'		40' and above	
Variable	Parameter	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err
Constant	β_0						
Labor[2]	β_1	-4.97**	2.20	0.92	3.31	4.31**	2.19
Trap hauls[3]	β_2	-5.38**	0.91	1.48	3.42	5.07**	1.01
Gallons of fuel	β_3	0.31	2.08	0.42	2.31	2.21**	1.65
Trips per quarter	β_4	2.89**	1.95	0.41	4.08	-0.72**	2.80
n =		139		276		105	
Log likelihood		-180.65		-369.75		-122.04	

[1]The percentage change of the *i*th fisherman's output for a 1% change in the *j*th input.
[2] Includes owner hours spent on fishing activities, as well as paperwork, and gear maintenance;
[3] Number of traps fished functions as the land equivalency of *i*th firm.
**Denotes variable significant at the 95% confidence level.

We are evaluating three separate vessel classes, and perform hypothesis tests for each empirical model evaluation presented in tables 2.4, 2.5 and 2.6, and summarized as follows:

(i) This null hypothesis tests specifies that under a generalized truncated-normal specification of the stochastic frontier model, we can simplify to a half-normal distribution and adequately represent the data. We estimate the model for both the null and alternate hypotheses and if H_0 is true then our test statistic is assumed to be asymptotically distributed as a chi-square random variable. We compare our result to the critical chi-square value. We test whether the error term u_i has a truncated normal distribution, obtained by truncating (at zero) the normal distribution with mean mu, and variance sigma-squared. Given our model specification, the test statistic for the semi-normal distribution is H_o: μ = 8.43, 39.28, and 21.28 respectively, this leads to a rejection of the null hypothesis in all cases.

(ii) Our second hypothesis tests for the existence of the inefficiency factor. We test the null hypothesis that there is no inefficiency in the industry. However, a significant likelihood test value of 202.19, 375.06, and 161.64 with 23 degrees of freedom allows us to reject H_o and implies the presence of inefficiency among the Maine Lobster industry.

(iii) This null hypothesis test specifies that the inefficiency effects are not a linear function of each of the inefficiency factors. As well, the difference between the null hypothesis $H_0: \gamma = 0$ and alternate hypothesis $H_0: \gamma > 0$ provides for a potential asymptotic distribution, or a mixture of chi-square distributions. In our case, $H_0: \gamma = 0$ represents the boundary space for parametization of our model. We evaluate the log likelihood-ratio value of the full model to determine if it exceeds the one-sided adjusted χ_2, we reject H_0 in favor of H_1, suggesting that the traditional average response function is not an adequate representation of the data.

(iv) This final hypothesis test specifies to what degree the existence of inefficiency affects the technical efficiency. The null hypothesis $H_0: \delta_1 = \delta_2 = \dots = \delta_p = 0$ is rejected in our analysis with a LR Ratio test value for each vessel class of 28.661, 40.893, and 27.061 against a test statistic of 23.68, which indicates the inefficiency effects are not part of a normal error distribution.

For the model reflecting smallest vessel class (<34 ft.), three of our parameters were found to be significant. The large negative parameters for labor and trap hauls, indicate that a 1% increase in labor or trap hauls would have a negative effect and decrease output by 4.97% and 5.38% respectively. Conversely, a 1% increase in the number of trips per quarter would increase output by 2.89%. None of the parameters for the mid-size vessel model were found to be significant, although the model itself was found significant. For the largest vessel class, we note that all of the parameters were found to be significant, which we interpret to indicate that a 1% increase in labor or trap hauls increase output by 4.31% and 5.07% respectively. The trips per quarter parameter in this vessel class was also found to be significant, indicating that a 1% increase in number of fishing trips would cause a 0.72% decrease in output.

Technical efficiency related to production frontier; managerial experience, ownership characteristics

Table 2.7 shows the technical inefficiencies of the three separate models specified by vessel size. Positive parameter estimates indicate relative technical inefficiency, while negative parameters

Table 2.4 Technical efficiency specification tests for model effects (vessels < 34')

Null hypothesis	Log Likelihood Reduced Model	Log Likelihood Full Model	Likelihood Ratio Test (LR)	Degree freedom	Critical Value	Decision
$H_0: \mu = 0$	-180.65	-176.43	8.43	1	2.7	Reject H_0
$H_0: \gamma = \delta_0 = \delta_1 = \ldots = \delta_p = 0$	-180.65	-79.55	202.19	23	35.172	Reject H_0
$H_0: \gamma = 0$	-180.65	-110.51	23.06	13	22.36	Reject H_0
$H_0: \delta_1 = \delta_2 = \ldots = \delta_p = 0$	-180.65	-176.32	28.661	14	23.68	Reject H_0

Table 2.5 Technical efficiency specification tests for model effects (vessels 35' – 39')

Null hypothesis	Log Likelihood Reduced Model	Log Likelihood Full Model	Likelihood Ratio Test (LR)	Degree freedom	Critical Value*	Decision
$H_0: \mu = 0$	-369.75	-350.11	39.28	1	2.7	Reject H_0
$H_0: \gamma = \delta_0 = \delta_1 = \ldots = \delta_p = 0$	-369.75	-182.22	375.06	23	35.172	Reject H_0
$H_0: \gamma = 0$	-369.75	-350.11	39.28	13	22.36	Reject H_0
$H_0: \delta_1 = \delta_2 = \ldots = \delta_p = 0$	-369.75	-349.30	40.893	14	23.68	Reject H_0

Table 2.6 Technical efficiency specification tests for model effects (vessels > 40')

Null hypothesis	Log Likelihood Reduced Model	Log Likelihood Full Model	Likelihood Ratio Test (LR)	Degree freedom	Critical Value*	Decision
$H_0: \mu = 0$	-122.04	-111.40	21.28	1	2.7	Reject H_0
$H_0: \gamma = \delta_0 = \delta_1 = \ldots = \delta_p = 0$	-122.04	-41.22	161.64	23	35.172	Reject H_0
$H_0: \gamma = 0$	-122.04	-109.35	25.37	13	22.36	Reject H_0
$H_0: \delta_1 = \delta_2 = \ldots = \delta_p = 0$	-122.04	-110.51	27.061	14	23.68	Reject H_0

* Has a mixed Chi-square distribution.

indicate relative technical efficiency, within each model and relative to the vessels in the size class. All variables are on a ‘per trip’ level. Parameters should be interpreted as factors contributing towards production inefficiency. Negative values indicate less inefficient and positive values indicate more inefficient.

For our first, small vessel model (< 34 ft.), inefficiency appears as statistically significant for the variables indicating calendar quarter fished, and for the southernmost Lobster management Zone G. The parameters provide interesting insights into the temporal and geospatial aspects of the fishery, where those vessels who also fish in Q2, Q4, and Q1 are 3.32%, 1.88% and 1.01% respectively more inefficient in their operations in those calendar quarters. Similarly, the Zone G fishing vessels are 0.67% more inefficient. Other parameters in this model were significant, notably: License_yrs, Age, soak time, Number of traps fished, and amount of bait used. Younger operators with more experience, who deploy more traps, and input more bait, which soak longer, are found to be 0.65%, 0.37%, 0.54%, 0.39%, and 0.67% respectively less inefficient for each of these managerial decisions.

For our medium size vessel model (35 – 39 ft.), we observe a similar trend where inefficiency appears as statistically significant for the variables indicating calendar quarter fished, and for the Mid-Coast Lobster Management Zone D, Monhegan Island specifically. Mid-size vessels who also fish in Q2, Q4, and Q1 are 3.10%, 2.17% and 0.88% respectively more inefficient in their operations in those calendar quarters. The only other parameters in this model that emerged as significant, was the amount of bait used, where vessels which deploy more bait, are found to be 0.43% less inefficient for this managerial decisions.

For our large size vessel model (> 40 ft.), we observe a similar trend where inefficiency appears as statistically significant for the variables indicating calendar quarter fished, and for Lobster Management Zones D and G. Large vessels who also fish in Q2, Q4, and Q1 are 2.94%, 2.16% and 0.96% respectively more inefficient in their operations in those calendar quarters. Zones D and G large fishing vessels are 1.44% and 1.86% respectively more inefficient. Other parameters

Table 2.7 Technical inefficiency model estimates for each specified vessel class model

Vessel Category		34' and below		35' to 39'		40' and above	
Variable	Parameter	Coeff	t-value	Coeff	t-value	Coeff	t-value
Constant	δ_0	11.51	2.71	11.79	6.27	11.51	2.71
License_yrs	δ_1	-0.37*	-2.17	0.14	1.23	0.06	0.28
Age	δ_2	0.65*	2.39	-0.01	-0.06	0.36	0.89
Soak	δ_3	-0.67*	-2.93	0.17	1.08	-0.55	-1.86
Vessel_hp	δ_4	0.17	1.01	-0.20	-2.09	-0.43	-1.47
Traps_owned	δ_5	0.46	1.55	-0.38	-2.76	1.96	2.00
Bait_total_cost	δ_6	-0.39*	-3.56	-0.43*	-3.93	-1.05*	-3.46
Price_lb	δ_7	0.09	0.14	-0.51	-1.18	-0.54	-0.87
Dist_travel	δ_8	-0.04	-0.55	-0.06	-0.97	-0.22*	-2.21
Income_lob	δ_9	-0.33	-1.83	-0.37	-1.67	-0.92	-2.66
Traps_fished	δ_{10}	-0.54*	-2.46	-0.27	-1.79	-1.18*	-3.35
Q1	δ_{11}	3.32*	10.22	3.10*	12.87	2.94*	8.65
Q2	δ_{12}	1.88*	12.44	2.17*	12.30	2.16*	8.48
Q4	δ_{13}	1.01*	8.16	0.88*	5.67	0.96*	4.43
Zone_A	δ_{14}	0.16	0.60	-0.02	-0.13	0.46	1.66
Zone_B_SI	δ_{15}	0.00	0.00	-0.26	-0.96	0.00	0.00
Zone_C	δ_{16}	0.12	0.47	-0.27	-1.53	0.78	1.94
Zone_D	δ_{17}	0.25	1.02	0.04	0.24	1.44*	4.00
Zone_D_MI	δ_{18}	0.00	0.00	-1.61*	-3.52	0.00	0.00
Zone_E	δ_{19}	0.30	1.20	0.26	1.27	0.25	0.58
Zone_F	δ_{20}	0.32	1.33	0.33	1.63	0.42	1.21
Zone_G	δ_{21}	0.67*	2.42	-0.09	-0.36	1.86*	3.93
Sigma	σ^2	0.20	7.01	0.27	9.28	0.24	6.00
Log-likelihood		-79.22		-182.22		-41.22	

***, **, * Indicate estimates are significant at the 1%, 2% or 5% level respectively.

in this model were significant, notably: number of traps fished, amount of bait used, and distance traveled. Vessels that deploy more traps, input more bait, and travel farther offshore are found to be 1.18%, 1.05%, and 0.22% respectively less inefficient for each of these managerial decisions. Most interestingly, the distance-traveled parameter was found to be significant in the large vessel model, but not the other models, suggesting that larger vessels operate more efficiently offshore than they do inshore.

The technical expertise parameters such as age and years experience were found to be significant in only the smaller vessel class model; however, we note the directional trends of the parameters provide some insights. For the small vessel model, increased years of experience contributed to a less inefficient operation, which is offset by the age parameter, where older captains are more inefficient. For the large vessel model, these parameters were both positive, and so increased years experience contributed to a more inefficient operation, where the age of the captain had a negligible impact on the inefficiency and so there was no differentiation among the vessels based on age. This is surprising, as we would expect technical experience to promote efficiency; however, the more seasoned captains may be more consistently engaging in additional measures aimed at resource conservation, such as v-notching, which requires operational time and may account for the observations in this parameter. Alternately, because many fishermen begin their fishing careers as crew, they develop significant experience early.

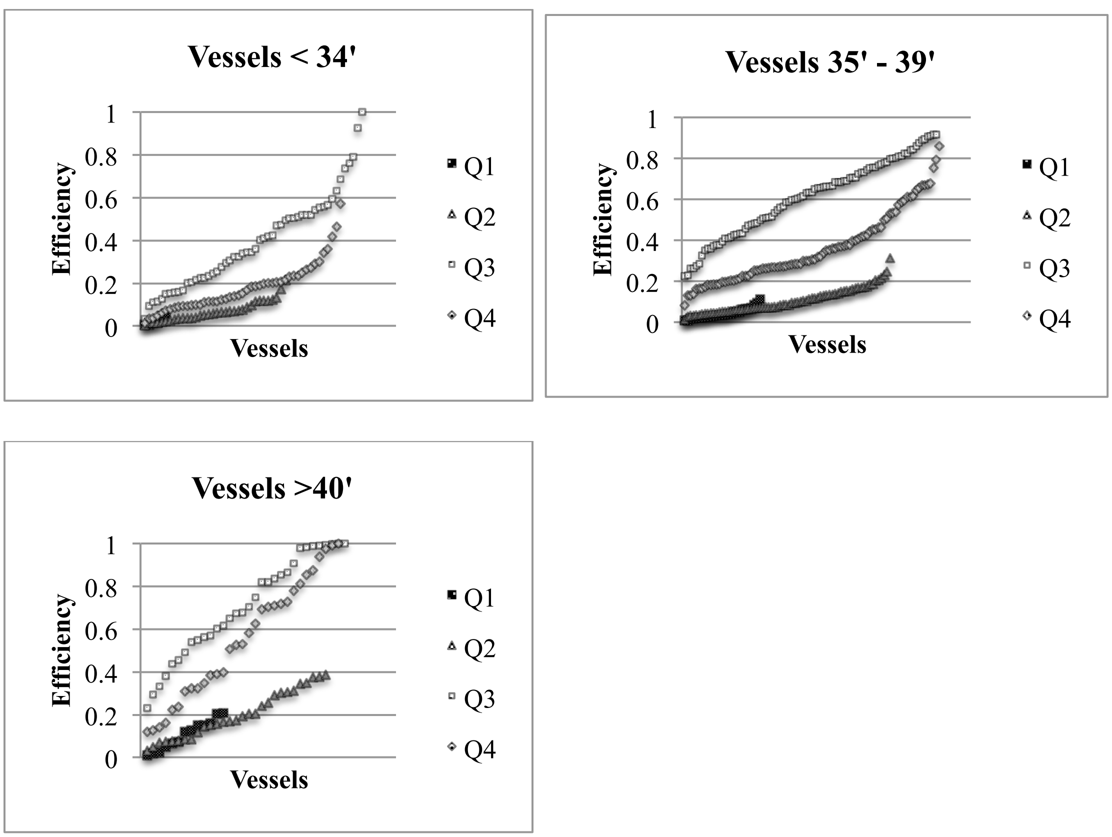


Figure 2.2 Technical inefficiencies scores for vessels in our study, relative to the frontier

In figure 2.2, we see the distribution of vessel efficiency within each vessel class model. We note that interpretation of technical efficiency of each vessel class is relative to the most productive quarter, Q3, which serves as our base for comparison for the class, and relative to the maximum producer or stochastic frontier within the vessel class. The mid size vessel class appears to be only modestly less efficient in Q4, relative to Q3. The same patter holds true for the large vessel class, which does not appear to have much of an advantage in Q4 efficiency, despite the large capital investments.

2.5 Conclusions

Through our study of the production functions for the Maine lobster fishery, we are able to observe a range of fleet producer efficiency, which differs for in-shore and off-shore vessels and varies by vessel class. Human capital and vessel capital do not appear to be operating at optimum yield in Maine, where social fabric and job have been valued over efficiency, consistent with prior research. This leaves room for effective effort increases, despite the restrictions on new entrants into the fishery.

In our study, we have established an effective baseline measure, with repeatable methods to assess producer efficiency for in-shore and off-shore harvest vessel classes. For the study year with base data for year 2010, we have observed different producer classes exhibit different production economics and vary in their inefficiencies. For the smaller vessels under 34 ft, we see that as that human capital and vessel capital are not exhibiting optimum production. This has been historically acceptable, where the Maine social fabric and job creation have been valued over efficiency of fishing operations. This allows maximum participation in the fishery with lower costs of entry.

The traditional vessel size for the coast of Maine (between 34 ad 39 ft.) appears to have the least inefficiency of inshore fishing operations of all the three vessel classes we examined, especially during the peak harvest months in Q3 in which the fishery sees the largest proportion of the landings. This bodes well for these traditional vessels under changing conditions, as they are traditionally more nimble in their operational scaling and represent less capital investment to the producer.

The large vessel class (40 ft.+) benefits from additional investments in labor, trap hauls and fuel, which improves efficiency in the Q3 time period relative to the other vessel classes. These vessels can withstand the winter ocean conditions as well, and show less inefficiency in Q4 and Q2 but under declining harvest volumes may have too much invested in capital to remain profitable.

And as we look to the future, it's important to note that producer efficiency is vulnerable to subject to climate-based regime shifts and shifts in resource distribution where harvest is constrained by lobster management zones, and the Hague Line. The lobster resource has seen changes in recruitment patterns, and landings are expected to also shift even further (Mills et al. 2013; Wahle et al. 2009; Fogarty and Gendron 2004; Holland 2011; Steneck and Wahle 2013). Stratification of waters in the Gulf of Maine have been changing, and additional research looking into suitable habitat for lobsters would help to inform the future of vessel profitability to build on prior knowledge (Wahle et al. 1991). Where mid-size vessels appear optimally positioned, larger vessels appear over-capitalized for shifting distributions favoring eastern most fishing grounds, and more inshore areas of Maine. Overall, lobster industry human and fixed capital, appear non-malleable (Munro 2010), due to the limited alternate employment opportunities associated with resource economies such as forestry and fishing for example, but efforts to diversify marine economies and licensing could offset this.

Input controls have been a long-standing choice for trap fisheries worldwide (Anderson 1976; Anderson 1985), where the gear lends itself to simple restrictions such as trap limits (Gordon 1985). But input controls are only as effective at restricting effort for fishing operations that could never exploit further inputs effectively (Deacon 1994; Deacon et al. 2011, Campbell and Lindner 1990). Fisheries with allocation by first come-first served, observe competition to acquire the stock before the competitor raises cost, and this cost increase can then simultaneously ration the access to the stock. The net result is a rent dissipation from an optimum level the stock could generate if managed efficiently and the extent of rent dissipation can depend on production input prices and on the elasticity of substitution of those inputs, (Deacon 1994).

We have demonstrated that the Maine lobster fishery possesses additional effort increase through improved technical capacity of existing producers. And since the Maine lobster fishery management relies exclusively on a limited-entry system, with no other restrictions such as effort controls or volume controls, a decrease in harvest volume coupled with increases in consumer market preferences for lobster, will affect supply and demand relationships and inversely impact ex-vessel prices (Barten and Bettendorf 1989). This positive ex-vessel price trend may lead to increased participation in the fishery through activation of latent effort, and increased production inputs to sustain volume, which poses a risk for the resource as well as the fishermen who depend on it. Further research is suggested around target fleet capacity and optimum yield for the fishery, and implementing harvest controls for both biological conservation and also market controls.

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3. WILLINGNESS TO PAY FOR A MAINE LOBSTER LICENSE AND POTENTIAL FURTHER CAPITALIZATION OF THE FISHERY

3.1 Abstract

This research focuses on Maine's inshore lobster fishing fleet consists of approximately 6,500 commercial fishermen, organized into diversity of firms of differing sizes and with differing technical experience, as characterized by size of fishing vessel ranging from 10' to 50' in length and organized by management Zone. By further performing a quantitative assessment of the incoming capital, managers can evaluate the risks associated with changes to the entry allowed. This research applies contingent valuation methods to provide an estimate of the Willingness to Pay (WTP) for a license, as well as quantify the intended capital investment levels on the part of new entrants and existing participants in the fishery. The desired number of traps on the part of existing license holders provides a gauge for potential increase in effort through improved technical skills and suggests a market for latent permits from within the fishery. We have conducted two contingent valuation surveys, one administered to existing license holders, and a separately designed survey was administered to non-license holders who are on the waiting list, currently estimated at a 10-year average wait time. We have further captured community attitudes towards the goals of the licensing program, and uncovered core values of the community, which lie at the root of the economic argument. We have evaluated the willingness to change and consider new licensing policies.

3.2 Introduction

Many lobster fisheries worldwide have faced increasing fishing effort with decreasing resource abundance, leading to policy reform and other measures to ensure long-term sustainability of the resource (Townsend 1990; Australia 2009b; Australia 2009a), with acknowledgement that at times the number of individuals deriving a livelihood from the species might need to contract (Jensen 2002; Yandle 2008; Yandle 2006; J. Sun 1999). A wide range of management frameworks for lobster fishery management have been implemented globally, as shown in figure 3.1, and we see that Maine's lobster fishery has retained effort controls, in contrast with other jurisdictions that have adopted a form of output control. Given the current technical inefficiency in the Maine lobster fishery (Dayton and Sun 2017), an increase in effective effort is possible, suggesting the fleet may have excessive capacity. In New England ground fish and elsewhere, the connection between excessive effort that could lead to over-fishing, has caused jurisdictions to realize that the vessel capacity must be reduced, and have engaged in buy-back programs to ensure their permanent retirement (Kitts et al. 2000) and compensate the fisherman for the lost utility (Holland et al. 1999). This process of sharp downsizing of a fleet in response to resource crisis comes with an economic and also social toll, leaving many fishermen seeking alternate employment often in geographic regions where limited alternatives exist (Holland et al. 1999), effectively stranding the non-malleable capital including boats and labor (Munro 2010). As well, total contraction of the fleet can leave the working waterfront infrastructure vulnerable to development for alternate uses, such as tourism and real estate, which are non-reversible. Any economic benefits of future recovery of an underlying fishing stock could be difficult to reap once a human fishing infrastructure shift has occurred, and the tenuous balance of the ecosystem has exceeded a threshold (Popova et al. 2016).

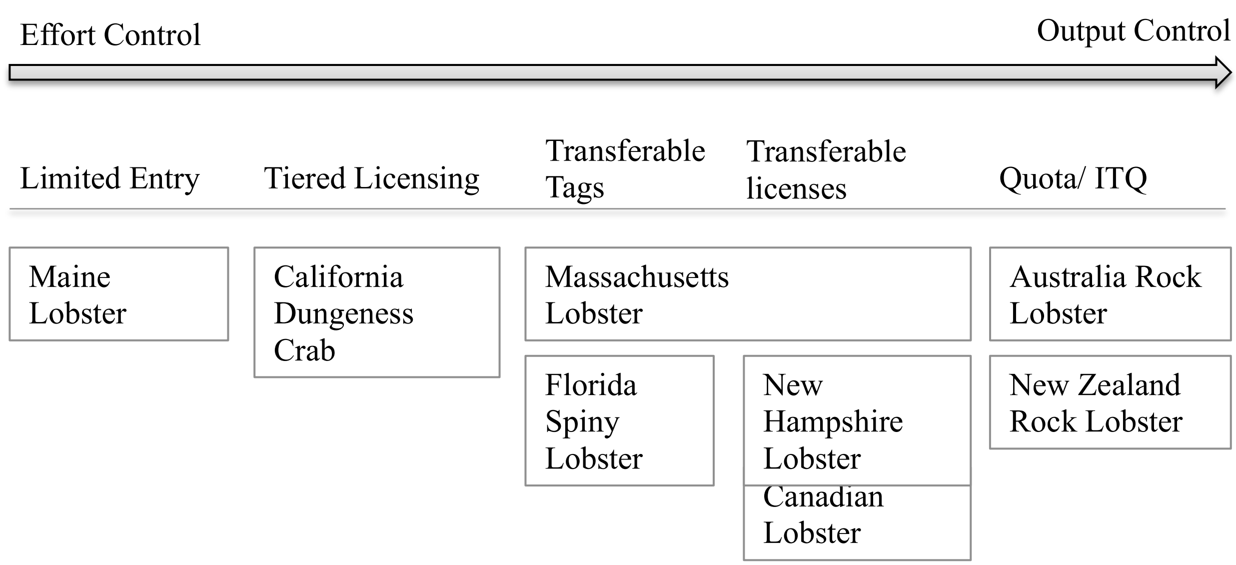


Figure 3.1 Continuum of management options used for lobster fisheries

To enable effective decision-making around policy options, economic theory provides for non-market valuation techniques that have been used in various industries to assess the value of different natural assets, and also arrive at values for goods, which have no transactions directly to measure, or which present hypothetical transactions in the future (Sagoff 2000; Carson 2012). The classic example, valuation of clean air (McGartland 2013) or the willingness to pay (WTP) for restoration for example, is difficult to measure directly and requires inferred approaches to assess the value a population places on this (Bateman et al. 2002). Within the forestry context, a resource not too dissimilar from fisheries, WTP analysis has been successfully applied to estimate the value of changes on forest management practices (Teisl and Boyle 2006).

In a fisheries context, we see a growing body of research aimed at understanding attitudes of fishery participants and general public in valuing this natural resource for the extraction benefit, but also the recreational value, and ecosystem values. Previous research has applies contingent valuation to assess community WTP for Coho salmon restoration on the Columbia River in Oregon (Bell et al. 1995). Sport fishermen in Maine were surveyed for their perceptions on the added value of Penobscot River restoration efforts related to Atlantic Salmon, providing a critical perspective to the conservation effort (Teisl et al. 1996). Research has been done to quantify the WTP for a salt water angling licenses, and studies have shown that the use of funds from a license can strongly influence the WTP estimates (Whitehead et al. 2001), and that anglers from across different types of groups consistently support fees which improve quality of fishing experiences. In 2001, researchers also demonstrated the WTP for increased license fees in Fort Hood, Texas and further derived number of potential displaced anglers so as to estimate impacts on fishery participation rates (Sutton et al. 2001).

Currently, there are no estimates of WTP for a Maine Lobster License or Maine lobster trap tag, which we believe to be an important consideration prior to policy changes, which may create an open market for these assets. In today's policy framework the transaction of licenses and tags is strictly limited to the initial issuance, and retirement of license with the Department of Marine Resources only. Open market transactions are strictly prohibited. In the nearby Canada lobster fishery however, private transactions of license sales have been allowed, and the cost of a license reported ranges from $10,000 - $1,000,000 (Dayton and Sun 2012). In Massachusetts, transactions of licenses are allowed on a restricted basis, and prices have ranged closer to $5,000 - $10,000 where the additional provision for a 10% trap tap reduction 'tax' on transfers helps to prevent effort escalation over time. There has been speculation about the impact of these additional license costs on the fishing firm's profitability and hence fishing behavior, and questions have been raised as to the level of fishing return needed to pay back this investment.

But to date, no one has quantified the WTP for a coveted Maine lobster license, and our research fills this important gap in our knowledge-base.

The question of biological sustainability has been raised when fishing effort increases to the extent needed to cover these additional license acquisition costs, and raises real questions for fishery managers in Maine, should licenses become a transferrable commodity in Maine. And so, our research will help inform lobster policy and licensing reform efforts to ensure that consideration is given to the open market forces that may ensue from licensing changes aimed at addressing social equity concerns.

Maine lobster governance reform will likely reflect the community's priorities between managing the lobster harvest at optimum economic yield, with retention of the jobs and community structure that has long defined Maine. This research provides a quantitative assessment of the new entrants' and existing fisherman's attitudes towards various policy options, and a measure of the amount of production capital that could enter the fishery if unconstrained. We also look at an age analysis of the Maine fishing community, as a by-product of the current entry licensing system for insight into how the long-term resilience of the fleet may be impacted.

3.3 Background

In response to concerns about escalating effort on the Lobster fishery in the mid 90's, territorial conflicts, and potential risk of resource collapse, The Maine Department of Marine Resources in partnership with the lobster industry and the Maine State Legislature, developed a formal management regime to institutionalize and preserve the traditional harbor-based nature of the fishery in 1995 (Acheson and Gardner 2012; Acheson 1974). Maine established a zone management system that divides the coast up into seven geographically defined management zones and moved some of the decision-making from the State to local Lobster Policy Management Councils. A trap tag system with an individual trap limit of 1,200 (with a build-down for those who were fishing more) was also enacted in 1995 and lobstermen were required to declare the zone in which they fish the majority of their traps, and to purchase trap tags to identify their lobster traps. No restrictions are placed on the number of hauls per trap. Further constraints on entry beyond a Lobster Apprentice Program were implemented through the 1999 Limited Entry Law. In addition, an owner-operator provision was put in place, requiring the owner of a fishing vessel to hold a lobster license and be on board the vessel when it is fishing for lobsters. A tight social fabric, and low degree of vertical integration characterize the inshore sector; where harvesters engage in conservation measures such as V-notching of females and self-enforcement as a society (Acheson and Gardner 2012). Lobstermen actively co-manage the resource with regular Zone Council meetings, and listen and adopt measures specific to their Zone (Acheson and Acheson 2010).

A lack of seasonal restrictions however, allows harvesters to choose when they wish to fish within their Zone, and lobster product landed is not subject to any further quality, quantity, or other restrictions apart from legal minimum size limit of 3 ¼" and maximum 5" carapace length. Harvesters can choose to fish only in summer months, with or without crew, as a second profession for example, or year-round as a primary occupation. There is no limit placed on trap hauls, only a limit placed on number of total number of traps, and limits that 49% of the traps must be placed within the primary Zone fished (Maine Dept of Marine Resources).

Entry into the fishery only can occur as exit from the fishery takes place, an effort to ensure a constant level of effort in the fishery, or even a reduction over time. And since 1997, the number of licenses declined statewide by 12%, suggesting reduced effort - but it's the number of tags which are a more accurate measure of effort, as they reflect the annual registered traps that can be deployed. The number of trap tags has increased by 13% since 1997 (Dayton and Sun 2012), and overall fishing capacity has also increased in the past decade in the form of larger vessels, more crew, hauling more often. Scientific and industry consensus suggests that the number of traps actively being fished is near the maximum for the resource and gear density. Fishermen have reported high fishing effort densities in certain regions, and cite increases in competition as a factor in decreased catches per trap (Wilson 2007).

As well, many of the existing licenses and tags are currently under-utilized, or not fished at all (Maine Dept. of Marine Resources). At the same time, a long waiting list of new entrants has created a sense of social inequity, raising the question of fairness of the current system. With high exit-to-entry ratios, latent tags keep new entrants out by remaining on the books and latent licenses and tags pose a high risk to the resource. ASMFC analysts have raised concerns about the uncertainty of potential effort. Likewise, latent tags pose a risk to current fishermen. If inactive tags became active traps, they would have an impact on individual earnings, especially in high-density fishing areas. This also poses a risk of future overfishing and hinders fishery management efforts, should those licenses be re-activated in an already congested fishery.

Our survey of waiting list members suggests that many are either already fishing likely as crew, plan to take over a family business, or want to fish part-time. We see individuals who have sought higher education and returned to Maine, only to be subsequently excluded from the fishery. This gives rise to social consequences as a result of excluding these groups of individuals from the fishery. The current student license program allows ample opportunity for those who satisfy the age criteria of the program to enter the fishery, and fishermen attitudes indicate they believe the student program should be kept and that it continues to be an important element for communities. However, social equity concerns have been raised as a result of the policy that allows students to by-pass the long line of apprentices and others on the waiting list (Steinback et al. 2008). We now see that over half of the people on the waiting list are 36 or younger, which suggests regional economic cost associated with excluding these individuals from the fishery, and favoring the younger under-educated adults who have remained homebound. An increase in social issues such as opioid drug addiction among deck hands and crew in particular, has also more recently been observed, and raises additional major concerns.

In Figure 3.2, we also see the age structure of the current Maine license holders population. It reveals a significant number of older fishermen, who represent the bulk of the fishing fleet effort as of 2014. We also observe a large cohort of under 18 fishermen with student licenses, but note a low conversion rate of only 5% who continue into full commercial activity with the fleet, as shown through the decrease in numbers of active fishermen between the ages of 19 – 39 over the past two decades. This has contributed to a lack of fishermen in the labor pool during their most

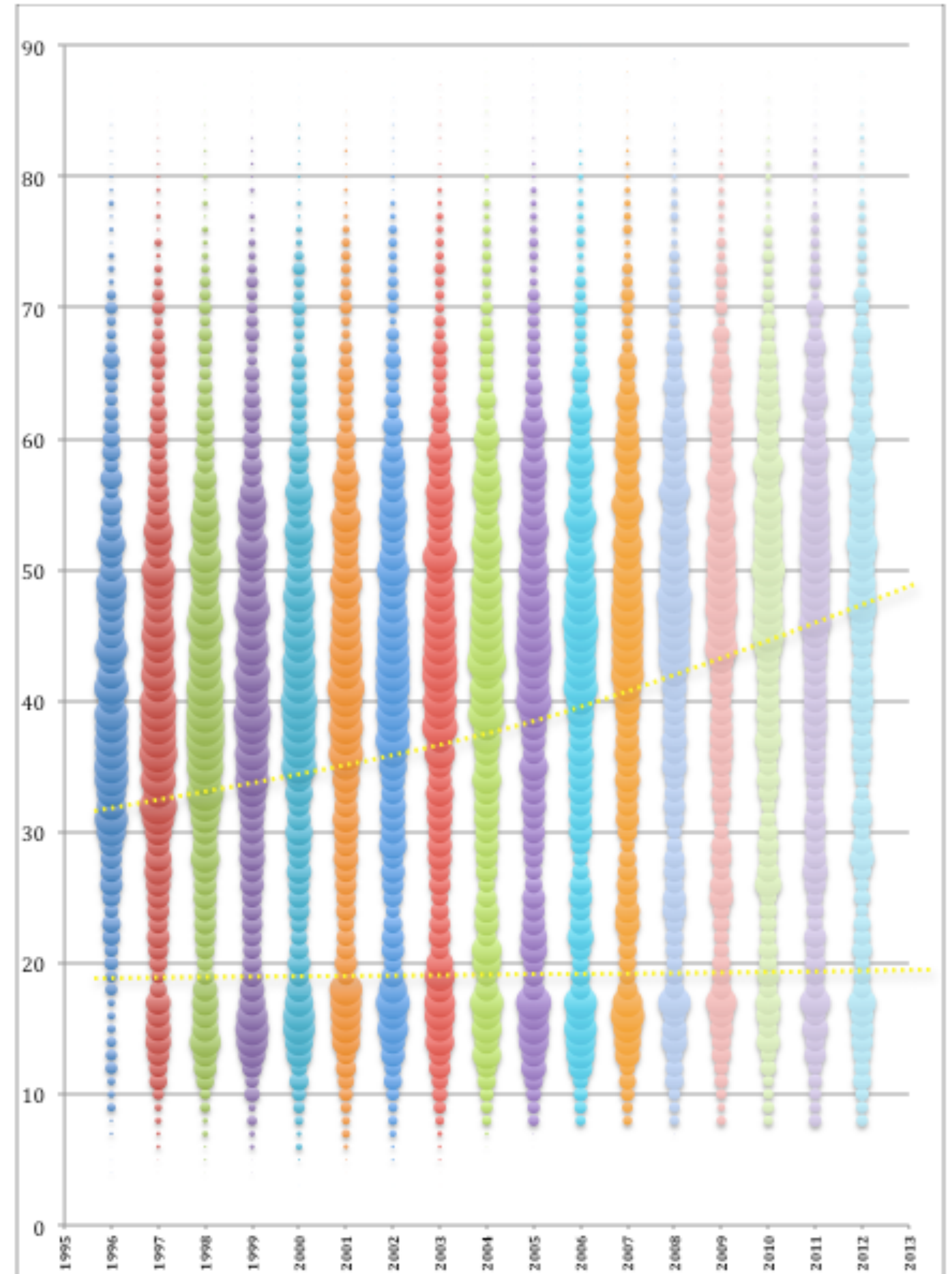


Figure 3.2 Age cohort analysis of Maine lobster fishermen (2013)

physically able and highest income earning years, and draws concerns over the long-term outlook for this industry.

At the same time, the currently restrictive entry into the fishery is likely to ease significantly as the dominant older cohort of fishermen reaches terminal age. This will create both opportunity, and also creates concern over increased fishing effort. The incoming new entrants represent significantly more fishing effort through age, technical skill and long pent up demand for entry. Any review of the licensing policy needs will do well to consider this additional pressure. As we see in figure 3.3, there also remains the potential for 56% immediate increase in fishing effort if all latent trap tags become active. It is hard to judge the full implications of latent licenses and tags because much depends on the intentions of the holder – some keep licenses and tags as a sense of identity, some to keep their options open, and some in the hopes of monetizing their value.

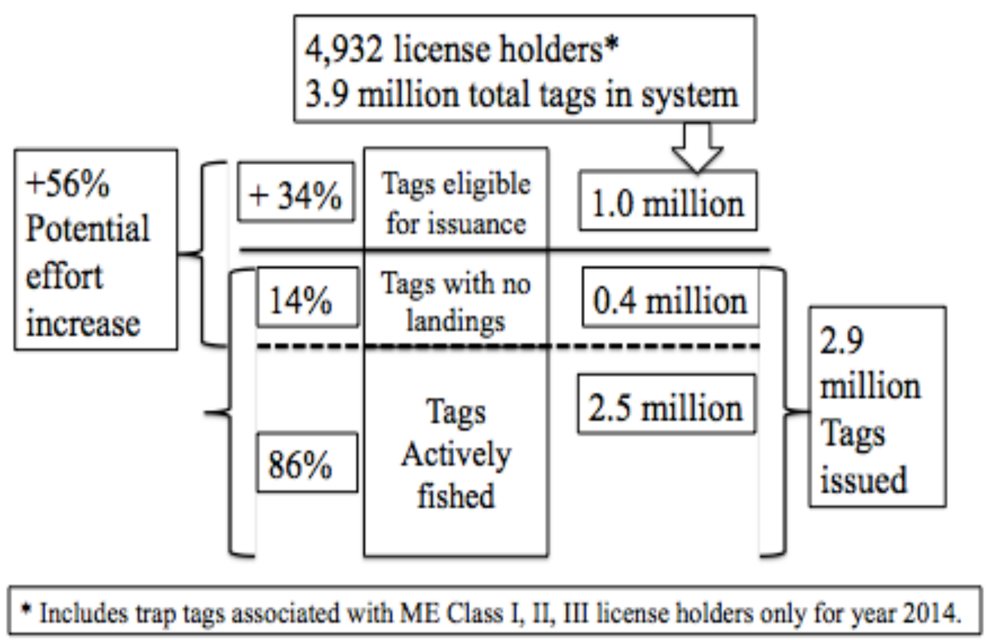


Figure 3.3 Estimated latent license and effort in the Maine lobster fishery (2014)

Should economic uncertainty persist, or should sudden increases in price and profits occur, micro economic theory would suggest that new firms would enter the fishery, or in this case the latent effort might activate into active effort over a short period of time, and the health and sustainability of the underlying resource becomes an important consideration as the sheer number of participants tests the current framework. The governing principles then must guide decision-makers to choose between economic viability of individual businesses in a free-market environment, or maximize jobs, and prioritize equal access rights to all who have a public interest in the Maine Lobster fishery. As well, a sharp decline in the harvest could occur, which in a congested fishery could leave many fishermen without the needed income to continue to operate, resulting in stranded capital assets such a labor and boats (Munro 2010).

In this research we integrate a variety of disciplines to arrive at new insights and evidence into what seem to be perennial arguments with and amongst fishermen. The questions of equity of access, property-rights, funding for government and fisheries management (Agrawal and Ostrom 2001), as well as individual fisherman's profitability require a broad perspective on the issue (Schlager and Ostrom 2016). Valuation of the increased utility associated with fishery access, or additional fishing effort provides a measure of the importance the community places on these goods, and we apply contingent valuation techniques in this research.

We examine three separate models; first we estimate a general linear regression on the stated number of traps desired by current lobstermen, if and when licenses and traps became transferrable and effort per person was thereby unconstrained. We then estimate the WTP for a license and separately WTP for a trap tag of fishermen interested in gaining access to the Maine Lobster fishery as full commercial license holder, and quantify the stated rates of capitalization desired for potential new entrants. We have applied contingent valuation techniques in the form of two separate surveys to elicit the value for these products and services for which we do not have observable transactions.

In the following sections, we describe the survey methodology and the study population of both existing lobstermen and those seeking entry to the fishery. Then we describe the theoretical model of our general linear model, and the WTP and its estimation with the censored regression

(Tobit) model for both a Maine lobster license, and separately and Maine lobster trap tag. A discussion of the factors influencing the number of traps desired, and the WTP estimates are then presented. Conclusions, policy implications, and suggestions for future research follow.

3.4 Survey Questionnaire Design and Response

Data for this analysis were drawn from responses to two different surveys administered; one survey for fishermen currently licensed, and a second separate survey for those who are apprenticing, or waiting to be admitted to the fishery. Both surveys were designed as multi-purpose research instruments, seeking the opinions of fishermen on variety of matters including efficacy of the current limited entry licensing system, goals for the licensing system, attitudes towards alternate management structures in particular output controls, and open-ended response formats for our WTP and capitalization rate questions. Both surveys were designed in consultation with fishermen, and written with the input of local lobster scientists, anthropologists and resource managers. The survey was pre-tested with a small sample group to identify problematic questions and other design issues.

The sample files consisted of commercial lobster license holders as well as those not holding a commercial license but are on waiting lists to acquire a license or who are completing training. Sample lists contained 5,195 commercial lobster license holders and 1,572 non-license holders (1,276 in training programs and 296 on a waiting list). Sample files contained addresses for mailing. A separate survey was developed for the license holder and non-license holder groups.

Data collection took place between August 10, 2012 and September 10, 2012. Potential respondents from the sample list were mailed a survey along with a cover letter stating the purpose of the research, and a business reply mail envelope for easy return. In addition to the survey, we collected comments through public meetings and provided on the back of the cover letter was a list of those meetings which were scheduled to be held in various locations across the state regarding the limited entry lobster license system. Furthermore, additional comments were gathered through a dedicated phone line. The number and instructions on how to access the phone line were included in the cover letter as well. Survey data were collected on 1,416 license holders and 313 non-license holders. A breakdown of response rates is provided in the table below:

Table 3.1 Survey response rates and quantities

Type of Survey	Total Surveys Mailed	Returned as Bad Address	Total Completed Surveys Returned	Response Rate
License Holder	5,195	27	1,416	27.4%
Non-License Holder	1,572	20	313	20.2%
Total	*6,767*	*47*	*1,730*	*25.7%*

The non-license holders survey

The survey included questions designed to elicit baseline demographics, and future intentions for fishing effort level, quantity existing capital investment in gear and boats, as well as intended future investment. The survey also included a section eliciting the amount a fisherman would be willing to pay for a commercial lobster license, and separately how much a fisherman would be willing to pay for a single trap tag. We considered best practices for elicitation of this value in accordance with guidance from the NOAA Blue Ribbon Panel (Arrow 2013) on contingent valuation, as well as guidelines set out by Mitchell and Carson (1989) (Bateman et al. 2002), as we aimed to assign a value for these non-market goods.

The survey also asked respondents to rate their concerns for the health of the lobster resource and then prioritize the different potential goals of a licensing system. The responses to these additional questions provide a measure of sensitivity associated with the valuation component of the survey, and offer insight into the social dynamics of the potential new entrants and what they perceive as threats or opportunities. The valuation questions were presented as open-ended responses, due to the limitation of space in the questionnaire and because of the multi-purpose goal of the survey instrument. This open-ended method is not the preferred method for contingent valuation as it allows for protest and idealistic responses and fails to offer a probability associated with the valuation. We acknowledge this shortcoming and consider this limitation in our results interpretation. The specific wording of the questions, are as follows:

How much do you currently have invested:

a. lobster gear? $ ____________________ b. Lobster boat? $ ____________________

How much do you plan to invest?

b. lobster gear? $ ____________________ b. Lobster boat? $ ____________________

If licenses were transferrable, how much would you be willing to pay for one? $ ____________________

If tags were transferrable how much would you be willing to pay for one? $ ____________________

Data were visually inspected for obvious errors, and observations, which did not provide a response to the WTP question, were considered protest responses and these were omitted from the data set. Observations, which contained a zero response, were deemed a response and were included in the final data set. The distribution of the open-ended survey questions is often presented with a large number of zero responses. The selection of statistical tools in this study reflects this normal distribution with a probability spike for the 'zero' response.

The license holder survey

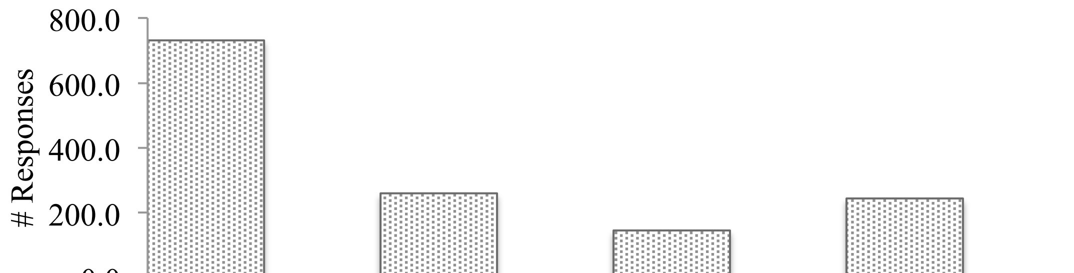
This separate survey also included questions designed to elicit baseline demographics, license type, and future intentions for fishing effort level, quantity existing capital investment in gear and boats, as well as intended future investment through number of traps desired. The survey included an open-response format eliciting of the total number amount of traps a fisherman would want to fish with their commercial lobster license, and what restrictions should apply, given alternative licensing transferability options. Once again, we considered best practices for elicitation of this value in accordance with guidance from the NOAA Blue Ribbon Panel (1993) (Arrow 2013) on contingent valuation, as well as guidelines set out by Mitchell and Carson (1989), as we aimed to assign a value for these non-market goods.

This survey also asked respondents to rate their concerns for the health of the lobster resource and then prioritize the different potential goals of a licensing system; a question regarding their support for transferability of licenses and trap tags was also included. The responses to these additional questions provide a measure of community values, and offer insight into the perceived or real threats and/or opportunities. The number of traps desired question was presented as open-ended response format, and the specific wording of the questions as follows:

13. If tags were transferable, how many traps would you ideally fish (max # in the water at once)?
____

Data were visually inspected for obvious errors, and observations, which did not provide a response to the desired number of traps question, were considered to be satisfied with status quo and included in the data set with their current totals. Observations, which contained a zero response, were deemed a response and were included in the final data set as a zero.

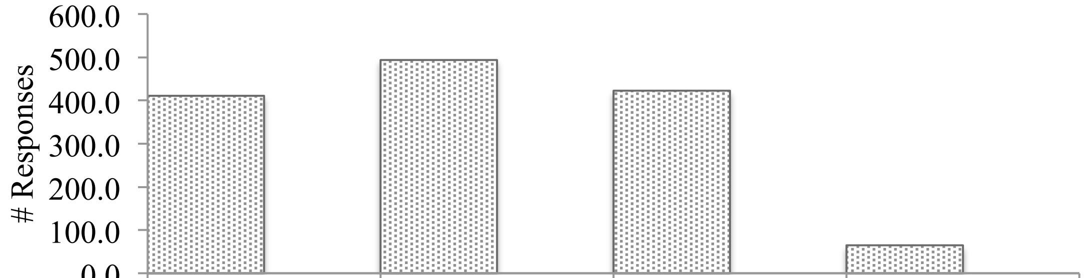
According to the 2012 License Holders Survey results, approximately 52% of existing license holders indicate they derive between 80 – 100% of their livelihood from fishing activity, 18% indicate they derive between 50 – 80% income from fishing, for a total of 70% if the industry derives more than 50% of their income from lobster fishing.



	80% - 100%	50% - 80%	25%- 50%	Less than 25%
Series1	732.0	260.0	146.0	244.0
Series2	51.7%	18.4%	10.3%	17.2%

Figure 3.4 License holders self-reported percent income derived from fishing activity.

Over 65% of the fishermen surveyed report either somewhat or very concerned about the level of fishing in their area. This suggests that additional effort in the form of traps and licenses would likely incur a congestion effect.



	Very	Somewhat	No Worries	No Opinion
Series1	411.0	494.0	422.0	64.0
Series2	29.0%	34.9%	29.8%	4.5%

How worried are you about number of traps fished in your area?

Figure 3.5 Perceptions of fishing congestion and concern for total fishing effort

Of those individuals seeking entry to the fishery, 26% of the people already fish (likely as a sternman) on a full-time basis, 14% fish on a part-time basis, and 33% are students. The average reported earnings for this group already in the fishery is $25,000/year. Forty percent earn less than $10,000/year. Approximately 60% of the surveyed new entrants indicate they wish to fish full-time, 29% indicate they wish to fish part-time seasonally, 9% indicate they wish to fish part-time year round, and less than 2% are seeking to fish recreationally.

Theoretical Models

Should economic uncertainty persist in the Maine lobster fishery, or should sudden increases in ex-vessel price occur, micro economic theory would suggest that new firms would enter the fishery (Deacon et al. 2011; Anderson 1985; Anderson 1980), and existing firms would increase production inputs to maximize profits (Homans and Wilen 1997). Given the policy constraints on new firm participation through the limited entry and restricted supply of available licenses, rents would not be dissipated and therefore each unit of access would retain a monetary value, which can be captured through a willingness-to-pay contingent valuation analysis. Economic theory would expect this valuation to be in keeping with possible rent returns from the fishery, which may or may not be the case for this fishery, and provides us with an interesting research question. A second source of increased production could also occur through an increase in firm production inputs, in this case additional traps may be deployed on the part of existing producers or hauled more often, which we mode separately. We employ two modeling approaches in this research described as follows:

(i) *General Linear Model*

To estimate the firm's increase in production associated with additional traps, we evaluate the factors, which influence firm level decisions. The general linear model is a statistical linear model can be written as follows:

$$\mathbf{Y} = \mathbf{X}\mathrm{B} + \mathbf{U} \tag{1}$$

where,

Y is a matrix with series of multivariate measurements, **X** is a matrix of attributes, **B** is a matrix containing parameters to be estimated and **U** is a matrix of error terms. The errors are assumed to be uncorrelated across measurements, and follow a multivariate normal distribution. In this case, where **Y**, **B**, and **U** are column vectors, the matrix equation above represents a multiple linear regression. Hypothesis tests with the general linear model are evaluated through the log likelihood function and model fit was evaluated with AIC score.

(ii) *Censored Regression (Tobit) Model*

Fishermen possess a utility function, which is increasing in z, the composite of all market goods and services; increasing in x in fishing access, and increasing in q, fishing quantity. The expenditure function, $e(p, c, F, q, u)$ results from expenditure minimizing, where $\{\min[pz + cx + F] s.t. u = u(z, x, q)\}$, where the variable p is equal to the price of all goods, c is the cost of fishing, and F is the incremental cost of the Maine lobster license. The expenditure function is increasing in in p, c, F, and u but then decreasing in q through trap tag limits.

It is required to hold a license, which in this analysis would come at a cost but also representing a measure of Hicksian surplus (Willig 1976). Holding quality constant, the WTP for access to the Maine lobster fishery is defined as the difference of two expenditure functions. One expenditure function represents the amount of expenditure needed to reach a reference utility level given the status quo scenario. The other expenditure function represents the expenditure needed to reach the new reference level of utility (i.e. possess a license), where the license purchase cost reaches the choke price, or F^c, the maximum price that a fisherman is willing to pay to achieve this higher level of utility.

$$WTP_{F^c,F} = e(p, c, F^c, q, u) - e(p, c, F = 0, q, u) \quad (2)$$

This equation specifies that fishermen will compare the expenditures necessary to reach the reference level of having a Maine lobster license, and the WTP will be greater than or equal to zero, since $F^c > F$ and $q < q^*$.

For our open-ended survey format, we calculate the arithmetic mean WTP as follows:

$$\bar{x} = \sum_i^n \frac{x_j}{n} \quad (3)$$

We further specify X_i as a vector of variables z, that provide explanatory power for the WTP responses, and estimate a vector of corresponding coefficients β_i, for i = 1, …, n respondents and to assign relative strength of the parameters of interest on the WTP value. The error term $e_i = u_i + v_i$, is the sum of the individual error and the model effects error term.

Where our WTP data do not allow for negative values, and we have a probability spike at zero, we can not estimate our vectors of coefficients by ordinary least squares regression, for it is likely to be inconsistent and likely to yield a downwards-biased estimate of the slope coefficient and an upward-biased estimate of the intercept. We therefore look to the Tobit model, originally proposed by James Tobin in (1958), which describes the relationship between a non-negative dependent variable and an independent variable or vector of variables, and for which Takeshi Amemiya (Amemiya 1979) has proven that the maximum likelihood estimator suggested by James Tobin is consistent. The model supposes that there is a latent (i.e. unobservable) variable y_i^*, which linearly depends on y_i via a parameter (vector), which determines the relationship between the independent variable (or vector) and the latent variable y_i^* as follows:

$$y_i = \begin{cases} y_i^*, & y_i^* > 0 \\ 0 & y_i^* \leq 0 \end{cases} \quad (4)$$

where y_i^* is a latent variable:

$$y_i^* = \beta\, x_i + \varepsilon_i;\ \varepsilon_i \sim N(o, \sigma^2) \tag{5}$$

The observable variable y_i is defined to be equal to the latent variable y_i^* whenever the latent variable is above zero and, zero otherwise. There is also a normally distributed error term to capture random influences on this relationship.

Next, let Φ be the standard normal cumulative distribution function, and $\emptyset$ to be the standard normal probability density function. For our data set with n observations, the likelihood function for this Tobit model is defined as:

$$\mathcal{L}\,(\beta_0, \beta_1, \sigma) = \prod_{i=1}^{n} (\tfrac{1}{\sigma}\ \emptyset\ \left(\frac{y_i - \beta_0 - \beta_1 x_i}{\sigma}\right))^{y_i}\ (1 -\ \Phi\ \left(\frac{\beta_0 + \beta_1\, x_i}{\sigma}\right))^{1 - y_i} \tag{6}$$

Where the values of β_0, β_1 and σ are resolved to maximize the likelihood function and then taken as the Tobit estimators of the model parameters. The log likelihood function for this model is given by:

$$\text{Log}\,\mathcal{L}\,(\beta_0, \beta_1, \sigma) = \sum_{i=1}^{n} y_i \log(\tfrac{1}{\sigma}\ \emptyset\ \left(\frac{y_i - \beta_0 - \beta_1 x_i}{\sigma}\right)) + (1 - y_i) \log\,(1 -\ \Phi\ \left(\frac{\beta_0 + \beta_1\, x_i}{\sigma}\right)) \tag{7}$$

Where the marginal effect of each parameter is interpreted by evaluating either (1) the change in y_i for values above the limit, weighted by the probability of being above the limit, and (2) the change in probability of being above the limit, weighted by the expected value of y_i if above as follows:

$$\frac{\partial\, E\,(\,y\,|\,x\,)}{\partial\, x_k} = \beta_k\ \Phi\ (\frac{x'\,\beta}{\sigma}) \tag{8}$$

We considered incentive compatibility, and tested to ensure effects were heterogeneous across respondents.

3.5 Empirical Approach

Our regression analysis of the survey response data revealed insights into the demographic factors influencing the desired number of traps, should transferability be introduced to the licensing system and eliminate the cap on total number of traps per license. It also reveals factors influencing WTP estimates for a Maine lobster license, and trap tags on the part of non-license holders. We also observe specific attitudes towards the licensing system, which influence the different dependent variables, and interestingly these are different between the two primary survey groups. We first look at the responses to key demographics questions, as these inform the results of the modeled regressions.

Table 3.2 Variable definitions for license holders model

Name	Definition
AGE	Age
HOW_WORRIED	Level of concern for fishery health. Category = 1 (low) to 4 (high)
PCT_INC_FISH	Percent income from fishing
STABIL_LIC	Stabilize the number of license holders in the fishery
REDUC_LIC	Reduce the number of license holders in the fishery
STABIL_TRAPS	Stabilize the number of traps fished in the fishery
REDUC_TRAPS	Reduce the number of traps fished in the fishery
PROTECT_LOB	Protect the lobster resource from depletion
VIABLE_BIZ	Ensure the financial viability of existing license holders by limiting participation
ENTER_YOUNG	Ensure that there is a mechanism for young people to obtain a lobster license
ENTER_ADULT	Ensure that there is a mechanism for adults to obtain a lobster license
ZONE	Zone A to G; binary no = 0 or yes = 1
LIC_TYPE	Category = 1 to 4 for ME License Type Class = l, II, III, LCO
FED_EEZ_FLAG	Federal EEZ (offshore) lobster license? No = 0 or yes = 1
ELIM_LIC	Eliminate latent licenses not fished
ELIM_TAG1	Eliminate latent tags issued but not fished
ELIM_TAG2	Eliminate latent tags not issued and not fished
TRANSFER_Y	Support transferability of license? No = 0 or yes = 1
RESTRICT1	Restrict transferability? No = 0 or yes = 1
QUOTA_Y	Support for quota on overall pounds landed in ME

Table 3.3 Variable definitions for non-license holders model

Name	Definition
L_TYPE	Category = 1 to 4 for ME License Type Class = l, II, III, LCO
EMPLOY	Current level of employment; category = 1 to 4
EDU	Highest level of education; category = 1 to 5
AGE	Age
INCOME	Household income
FTPT	=1 if intending to lobster full time, 0 for part time
WHY	Category = 1 to 5; motivation
WAIT_TIME	Expected wait time to obtain license (yrs.)
LN_INV_TRAPS	Amount currently invested in lobster traps
LN_INV_BOAT	Amount currently invested in a lobster boat
ZONE	Maine lobster zone
STABIL_LIC	Stabilize the number of license holders in the fishery
REDUC_LIC	Reduce the number of license holders in the fishery
STABIL_TRAPS	Stabilize the number of traps fished in the fishery
REDUC_TRAPS	Reduce the number of traps fished in the fishery
PROTECT_LOB	Protect the lobster resource from depletion
VIABLE_BIZ	Ensure the financial viability of existing license holders by limiting participation
ENTER_YOUNG	Ensure that there is a mechanism for young people to obtain a lobster license
ENTER_ADULT	Ensure that there is a mechanism for adults to obtain a lobster license
QUOTA_Y	Support for quota on overall pounds landed in ME; binary no = 1 yes = 1
TRANSFER_Y	Support transferability of license? No = 0 or yes = 1

The variables used in the analyses are defined in tables 3.2 and 3.3, and we have called out several of the survey responses in the following section, as they help to directly inform the interpretation of the empirical models. Figure 3.6 shows the distribution of the number of trap tags this group has indicated they wish to fish if admitted to the fishery. We see that the number of traps ranges from 0 to 2,000 with a spike at 800 traps desired, and again at 600 traps desired. A trap count of 1,200 was also seen, and in keeping with former trap limits allowed prior to the start of trap rationalization. Also notable are the number of fishermen who would fish between 400 and 500 traps, a significant reduction from today's 800 trap limit and perhaps an early indicator that efficiency of fishing effort over volume of fishing effort may be sought in the longer term.

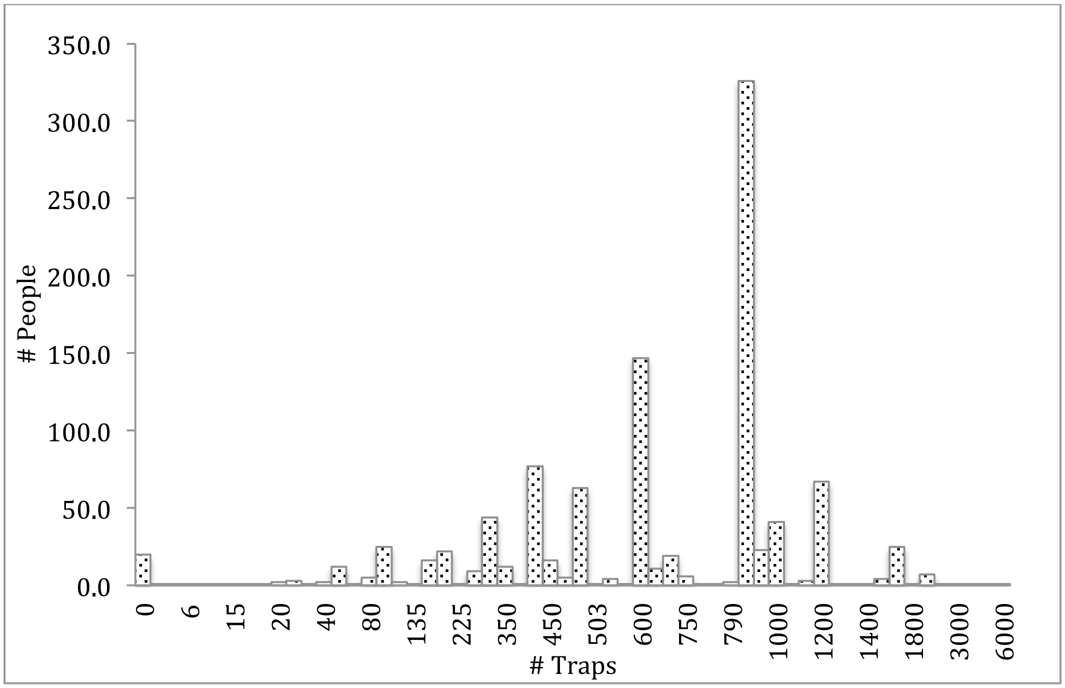


Figure 3.6 Distribution of desired number of traps desired by existing license holders

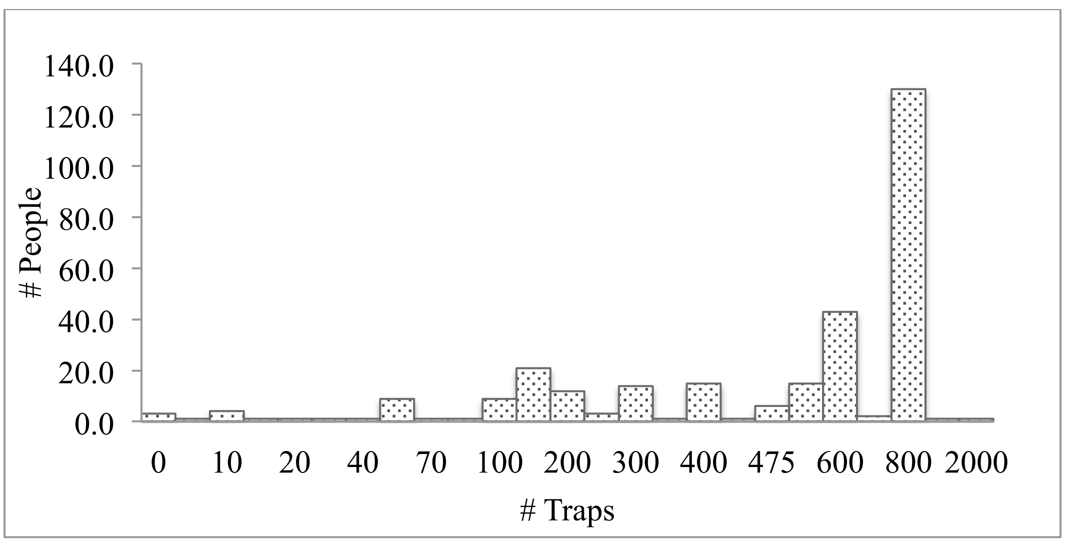


Figure 3.7 Number of trap tags desired by new entrants

The distribution of the WTP_LIC responses shown in Figure 3.8 follow the distribution expected from an open-ended survey question, and the application of the Tobit model appears warranted. The distribution of the WTP_TAG estimates shown in Figure 3.9 also follows a truncated one-tailed distribution, with a spike at one dollar.

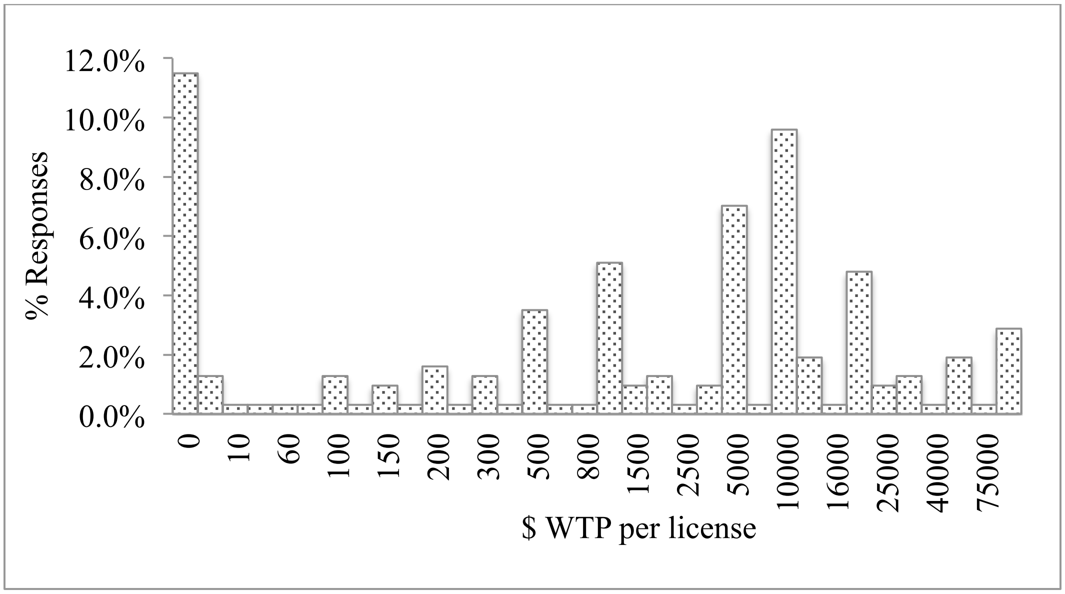


Figure 3.8 Distribution of WTP responses for a Maine lobster license

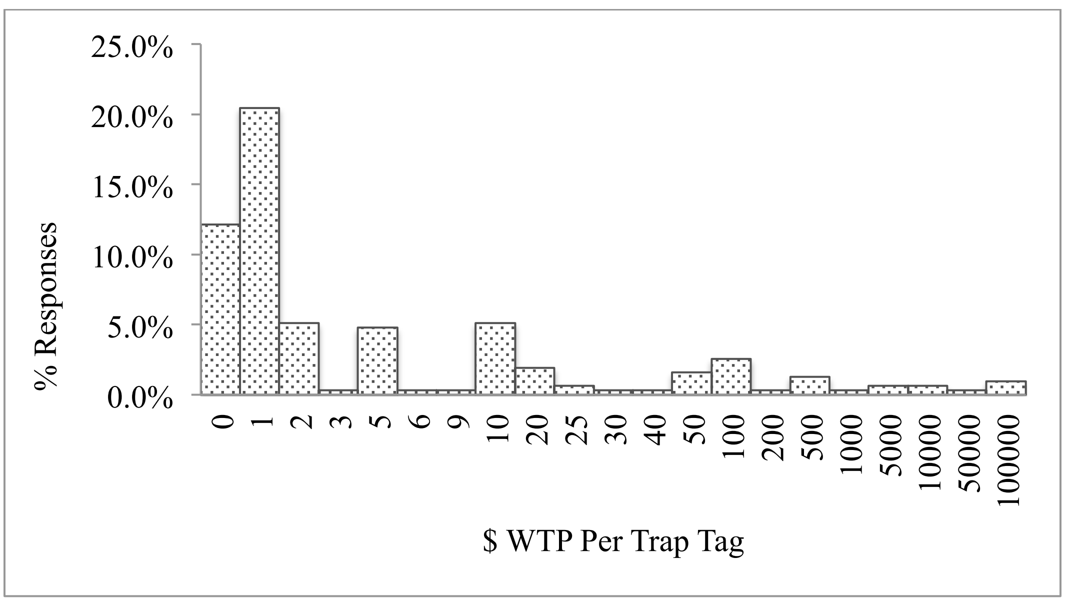


Figure 3.9 Distribution of WTP responses for a Maine lobster trap tag

We have further calculated the mean WTP_LIC estimate, which on average for the entire population sampled is $16,665 (+/- $72,869). Differences in sub-groups provide some interesting insight into the length of amortization expected on this additional cost needed to achieve the higher utility level of having a license, for each of the sub-groups and correlates with average age of the sub-groups sampled, and expected length of time to realize benefits associated with their higher utility.

Table 3.4 Mean willingness-to-pay calculation for a license and trap tag by user group

	All	Wait List	Apprentice	Student
AVG AGE	27	38	36	14
WTP_LIC	$16,665	$6,037	$9,434	$28,160
Std Dev.	$72,869	$6,776	$16,092	$107,869
Max.	$1,000,000	$25,000	$100,000	$1,000,000
WTP_TAG	$1,896	$169	$213	$4,040
Std Dev.	$12,591	$1,250	$998	$18,703
Max.	$100,000	$10,000	$5,000	$100,000
n =	*203.0*	*64.0*	*49.0*	*90.0*

Table 3.5 Mean willingness-to-pay calculation for a license and trap tag by Zone

	WTP_LIC	Std Dev	Max	WTP_TAG	Std Dev	Max	*n* =
Zone A	$10,554	$21,165	$100,000	$137	$800	$5,000	39
Zone B	$50,124	$170,923	$1,000,000	$10,347	$29,573	$100,000	34
Zone C	$8,113	$20,942	$100,000	$15	$34	$100	23
Zone D	$14,402	$27,142	$100,000	$441	$1,838	$10,000	36
Zone E	$10,649	$16,106	$50,000	$31	$118	$500	18
Zone F	$7,172	$11,233	$50,000	$414	$1,958	$10,000	26
Zone G	$6,817	$7,561	$25,000	$6	$8	$25	27

In addition to the WTP estimates, we can evaluate the reported fishing effort intentions stated in the survey, and apply an economic impact multiplier to calculate a hypothetical economic value of the potential fisheries activity of members of waiting list. However, the vast uncertainties associated with the current exploitation rate of the resource by zone, potential conflict on the water, effectiveness of new entrants, and the market price response introduce too much variability to the model to allow for such generalizations to be used as absolute values and should be viewed to provide relative trend.

Table 3.6 Potential incoming capital investment to lobster fishery

	Sample Responses (*n=203*)	Expanded to full population
Total Sum Desired Tags	163,492	653,968
Total Current Assets – Gear	$946,495	$3,785,980
Total Current Assets – Boat	$2,623,500	$10,494,000
Potential Capital Investment in Traps	$5,369,100	$21,476,400
Potential Capital Investment in Boats	$12,376,900	$49,507,600
Total Potential Jobs	203	1,248
Total Potential Earnings ($25K ea.)	$7,800,000	$31,200,000
Total Additional License Revenue Possible to State of Maine		$3,383,093

We applied a simple expansion factor using the proportion of the population surveyed relative to the total population, which allows for a straight forward projection of this hypothetical potential incoming capital into the fishery as seen in table 3.6. Our survey penetration was 20.8% of the total population, for a total possible population 1,572 individuals seeking entry to the Maine lobster fishery.

In Table 3.7 we see the differences in beliefs held by the two surveyed populations. For the license holders, the primary objective of the licensing system is to allow for students to enter the fishery, where the non-license holders place greater priority on ensuring entry for adults as well as students. Notable differences between the groups surface around the attitudes concerning financial protections provided to existing fishermen through the current limited entry system, with 50.1% of existing license holders reporting that ensuring for viable business is important, as opposed to the minority 23.2% of non-license holders who felt this was a top priority. Existing license holders also place much greater priority on reducing number of licenses and reducing number of traps than the non-license holders group. Both groups had over 50% strong agreement that the limited entry system goals should involve protection for the lobster resource.

Table 3.7 Comparison of surveyed groups' priority ranking of limited entry system goals

Name	Statement	% Strongly Agree License holders	% Strongly Agree non-License holders
STABIL_LIC	Stabilize the number of license holders in the fishery	52.5	39.9
REDUC_LIC	Reduce the number of license holders in the fishery	36.1	15.7
STABIL_TRAPS	Stabilize the number of traps fished in the fishery	45.8	41.5
REDUC_TRAPS	Reduce the number of traps fished in the fishery	44.5	19.5
PROTECT_LOB	Protect the lobster resource from depletion	50.2	51.4
VIABLE_BIZ	Ensure the financial viability of existing license holders by limiting participation	50.1	23.2
ENTER_YOUNG	Ensure that there is a mechanism for young people to obtain a lobster license	62.7	63.3
ENTER_ADULT	Ensure that there is a mechanism for adults to obtain a lobster license	39.8	51.1

4.5.1 Estimation of General Linear and Censored Regression Models

The coefficients of the WTP model are estimated with a censored regression procedure as described in Greene (2000), using software package 'R' by CRAN, and the coefficients of the Q_Trap_Desired model are estimated with the general linear model procedure.

Empirical Model Specifications

(i) *General Linear Model*

The general linear model functional form selected used to evaluate the desired number of traps for license holders in the Maine's lobster industry is defined as:

$$Y_i = \beta_o + \beta_1 X_1 + \cdots \beta_j X_j + \varepsilon_i \quad (8)$$

We consider n observations of one dependent variable and p independent variables. Thus, Y_i is the i^{th} observation of the dependent variable, and i represents the ith lobsterman for i = 1, 2, … 1,413, X_{ij} is i^{th} observation of the j^{th} independent variable, j = 1, 2, ..., p. The values β_j represent parameters to be estimated, and ε_i is the i^{th} independent identically distributed normal error.

For our study, we perform a multiple linear regression of the stated number of desired lobster traps for each lobsterman as our dependent variable, analyzing a combination of the demographics, and attitudes towards the licensing system goals for fishermen sampled in the Gulf of Maine inshore fishery to explain the variation observed, as follows:

$$Q_{TRAP_{WANT}} = \beta_o\, AGE + \beta_1\, LIC_{TYPE} + \beta_2\, FED_{EEZ_{FLAG}} + \beta_3 HOW_{WORRIED} + \beta_4\, PCT_{INC_{FISH}} + \beta_5\, STABIL_{LIC} + \beta_6\, REDUC_{LIC} + \beta_7\, STABIL_{TRAPS} + \beta_8\, REDUC_{TRAPS} + \beta_9\, PROTECT_{LOB} + \beta_{10}\, VIABLE_{BIZ} + \beta_{11}\, ENTER_{YOUNG} + \beta_{12}\, ENTER_{ADULT} + \beta_{13}\, ELIM_{LIC} + \beta_{14}\, ELIM_{TAG1} + \beta_{15}\, ELIM_{TAG2} + \beta_{16}\, TRANSFER_Y + \beta_{17}\, RESTRICT1 + \varepsilon \qquad (9)$$

The estimated parameters $\beta_1, \beta_2, \ldots, \beta_n$ are interpreted to represent the relative effect of each parameter on the dependent variable, as a one unit contribution to the value of the dependent variable.

(ii) *Censored Regression (Tobit) Model*

The censored regression functional form selected used to measure the willingness to pay for a lobster license of Maine's lobster industry is defined as follows:

$$\ln Y_i = \beta_0 + \beta_k\, \mathbf{X}_{ij} + \varepsilon \qquad (10)$$

where Y_i is the WTP response, and i represents the ith lobsterman for i = 1, 2, … 313 and X_{ji} is a vector of variables, β_k is a vector of corresponding coefficients to be estimated represents the demographic characteristics j used by each lobsterman. The estimated parameters $\beta_1, \beta_2, \ldots, \beta_n$ should not be interpreted as the effect of x on y, as one would with a linear regression model; instead they should be interpreted as the combination of (1) the change in y of those above the limit, weighted by the probability of being above the limit; and (2) the change in the probability of being above the limit, weighted by the expected value of y if above.

3.6 Estimation Results and Discussion

3.6.1 Desired Number of Traps Model

We sought to determine the factors influencing the desired number of traps for existing lobstermen. As we see in table 3.8, we first evaluated a reduced model with demographic and the system goals attitude variables, labeled Model 1.

Table 3.8 General linear model estimation results for desired number of traps

	Model 1			Model 2			Model 3		
Variable	Coeff	t-ratio		Coeff	t-ratio		Coeff	t-ratio	
(Intercept)	973.52	0.000	***	851.83	0.000	***	965.50	0.000	***
AGE	-5.59	0.000	***	-6.00	0.000	***	-6.05	0.000	***
HOW_WORRIED	4.50	0.656		3.62	0.719		8.26	0.403	
PCT_INC_FISH	-67.44	0.000	***	-48.66	0.000	***	-48.20	0.000	***
STABIL_LIC	-6.51	0.098	.	-5.84	0.130		-6.17	0.103	
REDUC_LIC	-7.10	0.090	.	-5.52	0.188		-7.44	0.069	.
STABIL_TRAPS	-1.17	0.765		-1.16	0.764		-0.91	0.811	
REDUC_TRAPS	11.85	0.003	**	9.88	0.013	*	9.68	0.013	*
PROTECT_LOB	2.17	0.560		1.07	0.771		0.72	0.842	
VIABLE_BIZ	-4.66	0.220		-3.64	0.330		-0.16	0.965	
ENTER_YOUNG	-4.13	0.239		-2.22	0.554		-2.37	0.519	
ENTER_ADULT	0.98	0.545		1.07	0.765		1.62	0.646	
LIC_TYPELC2				66.12	0.040	*	76.29	0.016	*
LIC_TYPELC3				188.96	0.000	***	210.69	0.000	***
LIC_TYPELCO				87.51	0.230		107.24	0.134	
LIC_TYPELCU				-85.96	0.550		-122.2	0.385	
FED_EEZ_FLAG							118.86	0.000	***
ELIM_LIC							-14.82	0.249	
ELIM_TAG1							-10.44	0.183	
ELIM_TAG2							18.69	0.100	.
TRANSFER_Y							-24.34	0.022	*
RESTRICT1							-3.33	0.000	***
n = 1413									
AIC	21310			21261			21209		

Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

This model performed well, and we see the AGE, PCT_INC_FISH, and trap and license reduction goals emerge as significant parameters. From these results, we see that fishermen who fish full time, are younger in age, and share in license and trap rationalization goals for the licensing system, are more likely to desire a higher trap count, should higher trap quantities become available through transferability, for example.

In our second model, we then included the factors associated with the geographic location of their fishing effort, and the commercial license type they currently hold. This model was a slightly better fit for the data, driven by the strength of the license type parameter, specifically for those fishermen who bring 2 or 3 crew on board. The Zone variables were not found to contribute to the model and we did not present them in our results. For our final model 3, we dropped the non-significant variables from prior model runs, and added in the final set of attributed related specifically to their offshore fishing activity (i.e. do they hold a Federal offshore license as well) and their attitudes towards license and trap transferability, support for output controls in the form of a quota system, and efforts to eliminate latent effort and restrictions on transfers if allowed. Model 3 was the best fit to the data, and the variables FED_EEZ_FLAG, TRANSFER_Y and RESTRICT1 were found to be significant, suggesting that individuals who also fish offshore, believe in transferability with tight restrictions are more likely to desire a higher number of traps.

3.6.2 Willingness-To-Pay Model for Maine Lobster License

We sought to determine the foundation factors influencing the WTP estimates for a Maine Lobster license, on the part of non-license holders. As we see in table 3.9, we first evaluated a reduced model with demographic attributes only, labeled Model 1. This model performed well, and we see the AGE, INCOME, plus EMPLOY parameters emerge as significant parameters. As fishermen on the waiting list get older, for each year older our model predicts a .5% decrease the willingness-to-pay, and for a one-bracket shift in income our model predicts a 4% increase in willingness-to-pay. The education parameter did not emerge as a statistically significant variable, reflecting an underlying social factor in this fishery.

We next estimated an enhanced model, Model 2 in Table 3.9, which builds on Model 1 and includes parameters associated with future intentions and desired level of participation in the fishery, to determine additional factors influencing the WTP estimates for a Maine Lobster license.

Table 3.9 Tobit model parameter estimates for willingness-to-pay for a license

	Model 1			Model 2			Model 3		
Variable	Coeff	p-value		Coeff	p-value		Coeff	p-value	
Intercept	8.112	0.000	***	7.429	0.002	**	12.991	0.000	***
L_TYPE	0.094	0.863		-1.638	0.123		-1.720	0.094	.
EMPLOY	-0.255	0.081	.	-0.107	0.469		0.006	0.968	
EDU	-0.095	0.581		-0.023	0.896		-0.140	0.408	
AGE	-0.058	0.039	*	-0.069	0.018	*	-0.079	0.004	**
INCOME	0.405	0.052	*	0.354	0.098	.	0.359	0.100	.
FTPT				-0.395	0.106		-0.532	0.023	*
WHY				0.394	0.030	*	0.363	0.034	*
WAIT_TIME				0.007	0.634		-0.001	0.961	
LN_INV_TRAPS				0.011	0.916		-0.063	0.517	
LN_INV_BOAT				0.168	0.153		0.199	0.078	.
ZONE_A				2.926	0.079	.	2.875	0.076	.
ZONE_B				4.553	0.012	*	5.058	0.004	**
ZONE_C				1.102	0.501		1.437	0.361	
ZONE_D				3.144	0.064	.	3.484	0.034	*
ZONE_E				1.143	0.553		1.216	0.514	
ZONE_F				3.796	0.041	*	4.154	0.021	*
ZONE_G				2.687	0.156		3.000	0.097	.
STABIL_LIC							0.061	0.511	
REDUC_LIC							0.237	0.052	.
STABIL_TRAPS							0.063	0.510	
REDUC_TRAPS							0.037	0.732	
PROTECT_LOB							-0.110	0.220	
VIABLE_BIZ							-0.192	0.061	.
ENTER_YOUNG							0.197	0.034	*
ENTER_ADULT							-0.144	0.096	.
QUOTA_Y							-2.482	0.000	***
TRANSFER_Y							-0.230	0.346	
n = 313									
Log Likelihood		-521.52			-508.58			-494.75	

Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

This model also performed well, with LR likelihood ratio statistic exceeding critical chi-square, and indicating that Model represents the data better than Model 1 ($p < .001$). We see the AGE, and INCOME parameters emerge as again significant parameters, but EMPLOY is now not significant. The newly added variable WHY, which measures the intentions and reasons for entering the fishery, is significant in this model, and suggests that it is not so much current employment status but aspirations and desired goals of the fisherman that motivate the individual and influence WTP estimates. We also see strong regional parameters emerge as significant, suggesting certain fishing grounds may be more productive and therefore command a higher WTP. We see a 4.5% increase in WTP on the part of fishermen waiting to enter ZONE_B and a 3.8% increase for ZONE_F, which correspond to fishing sites in relatively populated areas of the coast near Ellsworth and Casco Bay Portland, Maine. We note that WAIT_TIME has no impact on WTP, and LN_INV_BOAT also does not emerge as significant parameter in this model, which was a surprise where we might expect current capital investment to influence their motivation.

In Model 3 of our analysis, we incorporated a series of attitude variables, which aim to quantify the goals for the limited entry licensing system. Model 3 outperformed both Model 1 and Model 2, and was deemed a better fit to the data through likelihood ratio test ($p < .001$). Several new statistically significant parameters emerged in Model 3. The ENTER_YOUNG and VIABLE_BIZ parameters indicate that individuals who believe the licensing system should ensure for viable businesses, provide for the entry of adults, and who are open to a quota system are predicted to be willing to pay less for a lobster license than others who seem to favor the entry of young people to the fishery and believe the system should reduce the number of active license holders. We also see the LN_INV_BOAT parameter emerge as significant in this model, indicating that fishermen with higher current capital investment in a boat have a 2% higher WTP for a license.

3.6.3 Willingness-To-Pay Model for Maine Lobster Trap Tag

We further sought to determine the foundation factors influencing the WTP estimates for a Maine Lobster trap tag. As we see in table 3.10, we first evaluated a reduced model with demographic variables only, labeled Model 1. This model performed well, and we see the AGE, and INCOME parameters emerge as significant parameters. Fishermen who are younger in age, and with higher income are more likely to desire a higher trap count, and the entry of young people parameter emerges as significant when we include it in Model 3, again reinforcing the community values around new entry to the fishery.

Table 3.10 Tobit model parameter estimates for willingness-to-pay for a trap tag

	Model 1			Model 2			Model 3		
Variable	Coeff	p-value		Coeff	p-value		Coeff	p-value	
Intercept	1.365	0.000	***	1.291	0.000	***	1.228	0.000	***
L_TYPE	0.048	0.933		-0.525	0.626		-0.771	0.462	
EMPLOY	-0.086	0.568		-0.026	0.864		-0.022	0.889	
EDU	0.275	0.115		0.292	0.105		0.296	0.095	.
AGE	-0.099	0.002	**	-0.087	0.008	**	-0.086	0.006	**
INCOME	0.916	0.000	***	0.802	0.000	***	0.686	0.002	**
FTPT				-0.434	0.095	.	-0.529	0.036	*
WHY				0.082	0.663		0.065	0.719	
WAIT_TIME				-0.004	0.784		-0.006	0.668	
LN_INV_TRAPS				0.009	0.934		-0.011	0.910	
LN_INV_BOAT				0.076	0.535		0.098	0.399	
ZONE_A				0.636	0.707		1.311	0.427	
ZONE_B				3.462	0.054	.	3.976	0.022	*
ZONE_C				-0.408	0.809		-0.232	0.888	
ZONE_D				0.552	0.751		0.729	0.669	
ZONE_E				-0.851	0.675		-0.949	0.633	
ZONE_F				2.499	0.176		3.226	0.074	.
ZONE_G				0.029	0.988		0.466	0.806	
STABIL_LIC							0.056	0.566	
REDUC_LIC							-0.102	0.406	
STABIL_TRAPS							-0.143	0.151	
REDUC_TRAPS							-0.010	0.928	
PROTECT_LOB							0.008	0.930	
VIABLE_BIZ							-0.129	0.227	
ENTER_YOUNG							0.178	0.065	.
ENTER_ADULT							-0.012	0.890	
QUOTA_Y							-0.478	0.507	
TRANSFER_Y							0.381	0.114	
n = 313									
Log Likelihood		-312.15			-301.42			-219.2	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

In Model 2, where we add the geographic and future intention parameters, we note fishermen seeking entry to Zones B have a 3.5% higher predicted WTP and in our final Mode 3 those entering Zone F also show a 3.2% higher WTP for a trap tag. The FTPT parameter also emerged as significant in both models, again reinforcing that future intentions of employment drive their behavior rather than their current status of employment. Again, we see the ENTER_YOUNG.

3.7 Conclusions

We have summarized the results of two contingent valuation surveys: a survey of existing Maine lobstermen, and another survey of those waiting to enter the fishery. Through these surveys we described the willingness to pay for a Maine Lobster License, a Maine Trap tag, and quantified the potential additional incoming effort in the form of traps and vessel capital, should entry policies to the fishery be relaxed.

We experienced several empirical problems commonly associated with survey research that necessitate further study of individual vessel level panel data. We recognize the limitations imposed by our survey design where the open-ended question format may have biased our estimates, given the potential for unrealistic responses of high value. Despite these problems, the statistical results presented confirm that waiting entrants and future Maine lobstermen are generally willing to pay for the privilege to fish. In addition, the modeling results provide-insights about the community concerning the Maine limited entry-licensing program

Willingness to pay for a Maine lobster license was calculated overall at $16,665 and is closely related to the age and intended fishing effort of the new entrant, with younger individuals willing to pay more. We also see a strong regional component to the WTP estimates, where certain fishing Zones command a higher WTP, such as Zone B, which was reported to be an average of $50,124. Other zone averages clustered more tightly around $10,000 WTP for a license. Our empirical modeling found that certain parameters for our WTP for a lobster license model are significant, and positively correlated with WTP, notably age and whether the individuals are seeking full time entry to the fishery.

Willingness to pay for a Maine lobster trap tag was estimated overall at $1,896 and is closely related to the age and intended fishing effort of the new entrant as well, with younger individuals willing to pay more. We also see a strong regional component to the WTP estimates, where again certain fishing Zones command a higher WTP, such as Zone B, which was reported to be an average of $10,347. Other zone WTP averages clustered more tightly between $5 and $400 for a trap tag. Our empirical modeling found that certain parameters for our WTP for a lobster license model are significant, and positively correlated with WTP, notably age and whether the individuals are seeking full time entry to the fishery.

We see that the survey reported prioritization of limited entry system goals influences WTP estimates in different directions. The linkage between the endorsement for the goals and objectives of the licensing program and the WTP estimates is an extremely interesting result, for it underscores the importance of community outreach and education when devising licensing policies, and resource protection strategies. We see the goal of ensuring entry for young people emerge in all of our surveys, again reinforcing the strong community values around new entry to the fishery for young people, and maintaining generational access to the fishery.

But this comes in juxtaposition with the education parameter in our analyses, where higher education is negatively correlated with WTP. The opportunity cost is higher for those individuals with higher education levels, and so this result is in keeping with expectations. It is important to note that the current licensing system has historically and unintentionally created a barrier to entry for the individuals who may have chosen to further their education after high school and prior to settling down for a full time lobstering career. These individuals may be more conservative or realistic in the amount of money they are willing to pay for a license and tags, given the possible future returns. The lower estimated amount of capital investment desired also supports the theory that they hold a more prudent perspective on the financial outlook of the profession with potentially greater insight into the unintended consequences of increased capital investment, and what it means for the long-term health of the resource.

This fairness of access to the fishery, and the viability of the labor pool issue is a significant social issue for Maine to grapple with. From our surveys we see clear signals that Maine lobstermen wish to protect the fabric of the existing fishing community and also preserve access to a traditional way of life. However, the age cohort structure of the fishing population reveals big gaps in participation by fishermen in their 30s and 40s and we see a strong pent up effort pool ready for entry and with it additional capital. The age structure of the current licensed fishing population reveals that a large proportion of the current population is aged between 50 and 60 years old, and this group is nearing retirement age within the next 5 to 8 years. This suggests that exit from the fishery will accelerate, allowing an accelerated rate of entry into the fishery at that time. Therefore, the social concerns over excluding individuals from the fishery in the prime earnings years will likely be addressed through this natural attrition, and negate a need to change the policies for the sole purpose of fairness.

The potential jobs associated with new entrants to the fishery however, both on the water and through ancillary professions, is a significant source of potential income for Maine and offers a cost recovery mechanism for fishery managers. Our survey revealed that a potential 1,200 individuals are willing to fish an additional 654,000 trap tags, which would contribute an additional $3.3 million in trap tag and license fees per year. The incoming entrants are estimated to be willing to capitalize new lobster businesses for a total of $49 million in boats and $21 million in gear, and generate an additional $31 million in annual wages, based on a per job average of $25,000/year. The incremental ratio of this added and investment and fishing effort in the Maine lobster fleet could be either to offset exiting license holders capital holdings and create a source for capital malleability, or it could further split the fishery into proportionally smaller allocations of resource access, and declining profitability for all.

Our analyses reveal that in addition to entry for young people, both existing fishermen and those seeking entry, fifty percent of the study population responded that a licensing system should function primarily for the purpose of managing fishing effort, stabilizing and reducing the number of licenses, and ensuring the viability of lobster businesses. A clear opposition attitude towards the idea of output controls emerged though and surprisingly, we found that only 50.2% of existing license holders and 51.4% of non-license holders indicated that ensuring the health of the resource was a goal of the licensing system. Maine lobster governance and resource protection of the future will require amendment as the fishery faces changes associated with climate shifts, and the results of our surveys provide insights into the goals of the community, which will be critical considerations.

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4. ASSESSING THE IMPACT OF INVENTORY HOLDINGS ON EX-VESSEL IN-SEASON PRICE IN THE MAINE LOBSTER FISHERY

4.1 Abstract

In 2012, abnormally warm water temperatures in the Gulf of Maine pushed the start date of the lobster harvest season an average of 25 days earlier than normal, and created a high landings scenario during a compressed time period. The Maine fishery saw an average of 109% increase in landings over prior year, which then also coincided with the peak of the Canadian lobster season. The market responded with an average 40% decrease in price and fisherman's profitability decreased significantly. This study analyzes Maine's ex-vessel lobster prices, as a primary driver of vessel profitability, and with rent return implications for the fishery. Classic fisheries economics has assumed a stable price of output as a component of the social optimization for a fishery; advances in modeling techniques have sought to relax this assumption. This research builds on these advances and provides a case study for how price impacts rent returns in a volume-driven fishery, and further highlights the need for a robust policy platform to ensure continued resource health of the resource and to optimize fleet capacity. We considered the timing of Maine lobster landings and the seasonality of the Canadian lobster supply to show to what extent these factors impact the lobster ex-vessel price and how prices respond to landings anomalies such as those created by climate related impacts on the fishery. The monthly ex-vessel prices, trade of processed lobster between U.S. and Canada are compiled to specify a price function for U.S. wholesale lobster market, based on soft shell high volume product. This study provides an example of how the timing of the U.S. and Canadian lobster landings can have unintended consequences for markets and supplies, thereby calling for specific management objectives to reduce oversupply and maximize product quality and meat yield, as well as reduce capacity in the fishery. The intertwined objectives of business viability and resource sustainability lie at the intersection of this ex-vessel price. New policies may be needed as the environment alters traditional harvest patterns and expectations of the fishery, leading to changes in the economic return of the fishery with consequences for the community.

4.2 Introduction

The Maine lobster fishery provides over 6,000 jobs to the Maine economy and is an important economic driver for the state of Maine (Maine Dept. of Marine Resources). Nearby Canada also supports a large lobster fishing industry, with similar revenues and trends as the U.S. fishery, although under different production economics and governance. The combined global valuation of these two dominant markets places the American lobster *(Homarus americanus*) as the most valuable fishery in North America. Profit maximizing firm behavior within this fishery exhibits sensitivity to ex-vessel price (Thunberg 2007), which can be observed through the U.S. vessel level production functions (Holland 2011). Recently observed climate change (Mills et al. 2013) has altered the supply and demand market relationships, with a price response, a trend likely to continue. We propose that ex-vessel price response is a key variable in fishing vessel profits and optimization of resource rent return from the fishery (Gordon 1954).

In the Gulf of Maine we saw an unprecedented increase in sea surface temperature (SST) in 2012, revealing a complex set of interactions between the natural, human and market systems felt with previous fisheries in the region (Pershing et al. 2015). The Maine lobster fishery experienced an unseasonably warm spring, which led to an early spring season for the Maine lobster industry across all Maine Lobster management Zones (Mills, et al. 2013). We saw an earlier spring molt, likely a metabolic response to the increased temperature (Drinkwater et al. 1996), and suspect changes in mortality, and susceptibility to lobster shell disease, based on experiences in other regions such as Long Island Sound (Tanaka et al. 2017; Palmer 2014; Pearce and Balcom 2005). This change in the ecological systems was rapidly followed by a shift in the timing of the lobster harvest, as well as a shift in the centroid representing the spatial distribution of the harvest (Maine Dept. of Marine Resources).

This led to a period of dramatic Maine lobster harvest abundance increase in Maine, which has been unfettered by policy constraints, and has led to significant variability in the ex-vessel price per pound, directly correlating with volume (Dicolo and Friedman 2012; Barten and Bettendorf 1989). Compressed time periods and seasonal spikes in landings have sparked political unrest and competition between U.S. and Canadian lobstermen for limited Canadian processing capacity for the soft shell lobster product in 2012 (Woodward 2012), potentially creating a combined supply and demand challenge. Vessel level profitability was reported to decrease in the wake of 2012 price deflation, (personal communication, Dayton and Sun) and led to an intensification of winter fishing, as well as an increase in the distance traveled to harvest lobsters from inshore to offshore during periods of higher price yields (Maine Dept. of Marine Resources). Feedback between the human and natural coupled system has been observed (Liu et al. 2007; Lehuta et al. 2014; Xue et al. 2008; Incze et al. 2010) increasing pressure on the lobster and bait resources, likely at a declining rate of return to the economy (Fogarty and Gendron 2004). Prior research has shown that entry restriction controls only one of the inputs used to produce fishing effort, leading to expansions of effort, participation in the fishery, or other production inputs which lie on the uncontrolled margins of the production environment (Deacon et al. 2011). The net result of this lack of controls is a derby effect, which can have counterintuitive effects on behavior and in turn pushes the industry toward too much effort as ex-vessel price increases (Deacon et al. 2011). The study of ex-vessel price becomes therefore critical to the understanding of this economic system of a fishery.

The classical study of fisheries economics, pioneered in the 1950's (Gordon 1953, 1954), and applied to countless fisheries in the U.S. has generally allowed for fishery rent maximization analysis which assumes a fixed price of output in a perfectly competitive market. Gordon (1953) suggested that social maxima in a fishery can be achieved where the marginal revenue of output (MR_Q), is equal to the marginal cost of output (MC_Q). The concept of a received doctrine model provides tools for managing the fishery at a socially optimal level, where total revenue of effort (TR_E) is equal to total cost of effort (TC_E) (Anderson 1973; Andersen 1982). But this model framework assumes that the output of the fishery does not change and a that price is fixed. This limitation potentially leads to bias in determining the social optimum for a commodity fishery, especially where commodity products are known to have a high degree of price volatilility (Pindyck 2004).

Price variability can have significant impacts on the profitability of the fishing industry, as well as the rents derived from the fishery, and the participation rates. Further seminal work by economists (Copes 1972) relaxed the assumptions of price in the Gordon model, and allows for a study with variable price of output yielding new techniques for fishery economists (Norman-López et al. 2014; Barten and Bettendorf 1989). In our research we contribute an understanding of the relationship between price and the shifts in the underlying resource harvest and supply changes driven by climate variability. We seek to understand the price determinants in the Maine lobster fishery, which will allow us to assess the vessel level proftability and characterize the vessel level economics of the fishery, with implications for policy to optimize rent returns from the fishery. We conclude with a discussion of maximum economic yield (MEY) as potential management reference point for the Maine lobseter fishery, and a potential policy reform framework that builds on the experience of other jurisdictions (Anderson 1973; Copes 1972; Gardner et al. 2014; Reid et al. 2013).

4.3 Background

Maine lobster landings have increased each year for the past decade as shown in figure 4.1. However, the trend of increased landings has occurred at a time of year when community demand for luxury goods such as lobster, during back-to-school fall time period are low, as seen in figure 4.2. In the months following recent peak Maine harvest in October, there is a lag until Christmas and New Year's, which present the first major demand opportunity. This is followed by the traditional Chinese New Year in late January, but again this demand period is four months offset with peak harvest. Recently, we've observed expansion of the Chinese market in particular (Lindkvist et al. 2008), with early October festivals in Asia such as the popular Chinese weddings period, which has offered a new source of demand but its unclear if this can absorb all of the recent supply excess.

This timing mismatch between supply and demand has been a perennial problem for the lobster industry in both the U.S. and Canada, and has led to efforts such as holding lobsters in salt ponds over a period of time until markets or quality were optimal, a practice called 'pounding'. In the past decade though, Maine has moved away from pounding practices, favoring direct disposition of live product into the wholesale and retail markets (MIELDA). However, under recent shifts in harvest patterns (Maine Dept. of Marine Resources), Maine's late November harvest may not be fully absorbed by the market and therefore has potentially contributed to stored frozen inventory holdings over the winter months. Efforts to bolster consumer demand for lobster product in a variable luxury goods market may have offset this effect to some degree (Maine Marketing Collaborative).

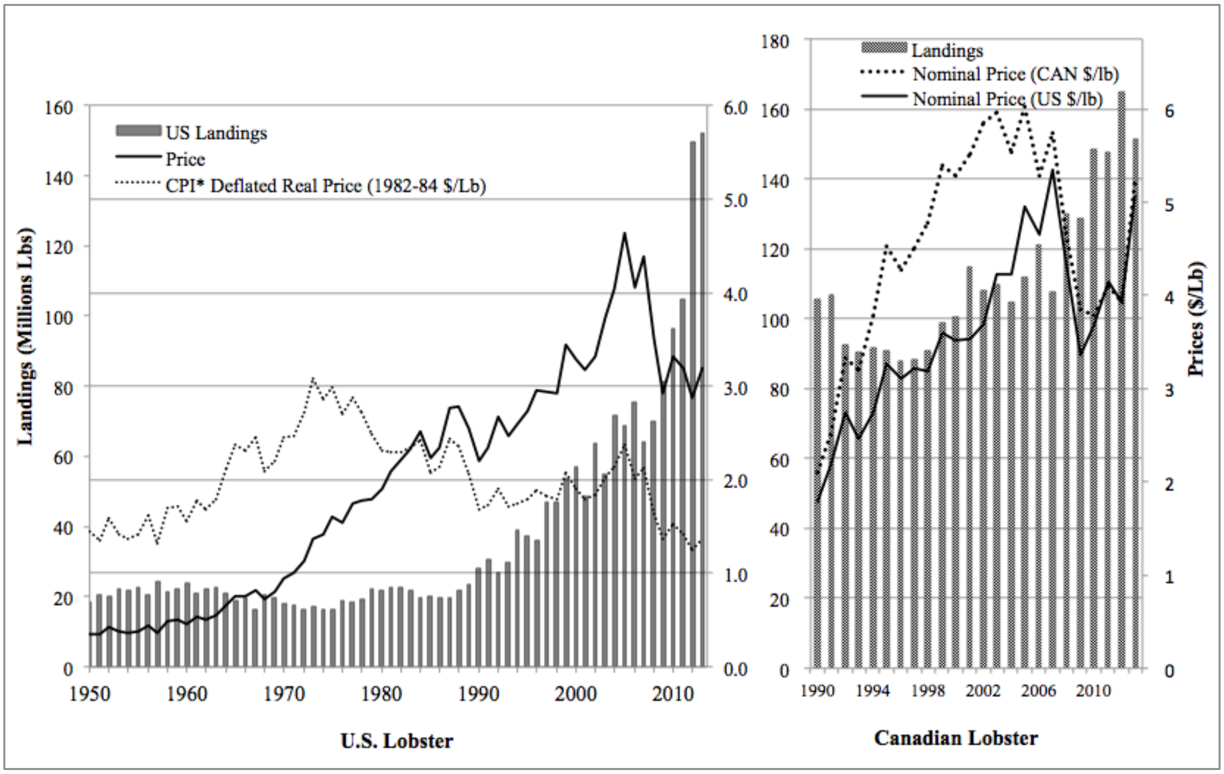

Figure 4.1 U.S and Canadian lobster landings and ex-vessel price for period 1950 - 2014

As an additional source of lobster supply, we consider the similar pattern of increased harvest volume, which has been occurring in the Canadian lobster fishery as suggested by figure 4.1. Ongoing trade flow of product in a variety of forms has been observed between the two countries, and product substitution effect has likely been observed in the U.S. through alternate product forms imported from Canada (Fig 4.2). Previous studies have examined the impact that Canadian firm lobster pounding has on U.S. ex-vessel price (Cheng and Townsend 1993) and showed that this product did contribute to overall product volume spikes due to product substitution for fresh harvest lobster, with clear impacts on U.S. lobster in-season ex-vessel price.

Equally important to consider in a homogenous product fishery, are the supply chain dynamics, (Plagányi et al. 2014). The quality of the landed lobster product varies by season, affecting the meat yield and therefore ex-vessel price paid by the wholesaler. The Maine live lobster market is divided between low price new shell product, which makes up about 75% of landings, and the more valuable hard shell lobster market, which makes up 8% of landings. Approximately 17% is ungraded (Maine Lobstermen's Association). The new shell is typically caught between July and the end of November and is predominantly for the summer and fall restaurant market and the processing sector. The new shell season has been extending earlier in the summer in recent years, associated with the observed changes in climate, and of consequence and importance from a value and market loss perspective, as well as price response.

The soft shell product, which does not have the needed resilience to withstand the added transport for the live market and as much as 20% shrink, will be sold and transported to a primary processor, historically in Canada during their closed season, where it is typically processed into lobster meat product. The meat yield tends to be as low as 37% of the harvest weight, and provides meat that is the sold to a second value-added processor as filling for pasta, for example, or canned meat product, at a lower price near $7.00/lb (Maine Lobsterman's Association 2015). The various players in the supply chain deduct the expected 20% loss from the price, from the dock to the wholesaler, adding to the buyer power of the dealers. The hard shell product is typically harvested in winter months November through early June, and tends to be more resilient to transport with a meat yield as high as 85% of the harvested weight, and supplies a market that commands higher prices, near $20.00/lb. There has also been increased market segmentation in recent years, with an increase in added value products[1]and improved transport methods, all demonstrating the value and possibility of increased market access through product segmentation and the existence of new market opportunities for further product specialisms.

The observed volatility in early season June ex-vessel price in years 2011 – 2016 calls for stabilization in supply rather than peaks in production, and research into other crustacean trap fisheries has shown this can lead to higher rent returns (Gardner et al. 2014). In Maine however, harvesters are by law not allowed to collude on price or volume (Sullivan 2000) and limited

[1] Retail ventures such as Shucks Maine Lobster, Calendar Island Lobster, Catch a Piece of Maine and Linda Bean's Maine Lobster.

entry does not limit the extraction rates, only the number of participants, and so the fishery effectively operates as a regulated open access fishery with sole ownership (Copes 1972).

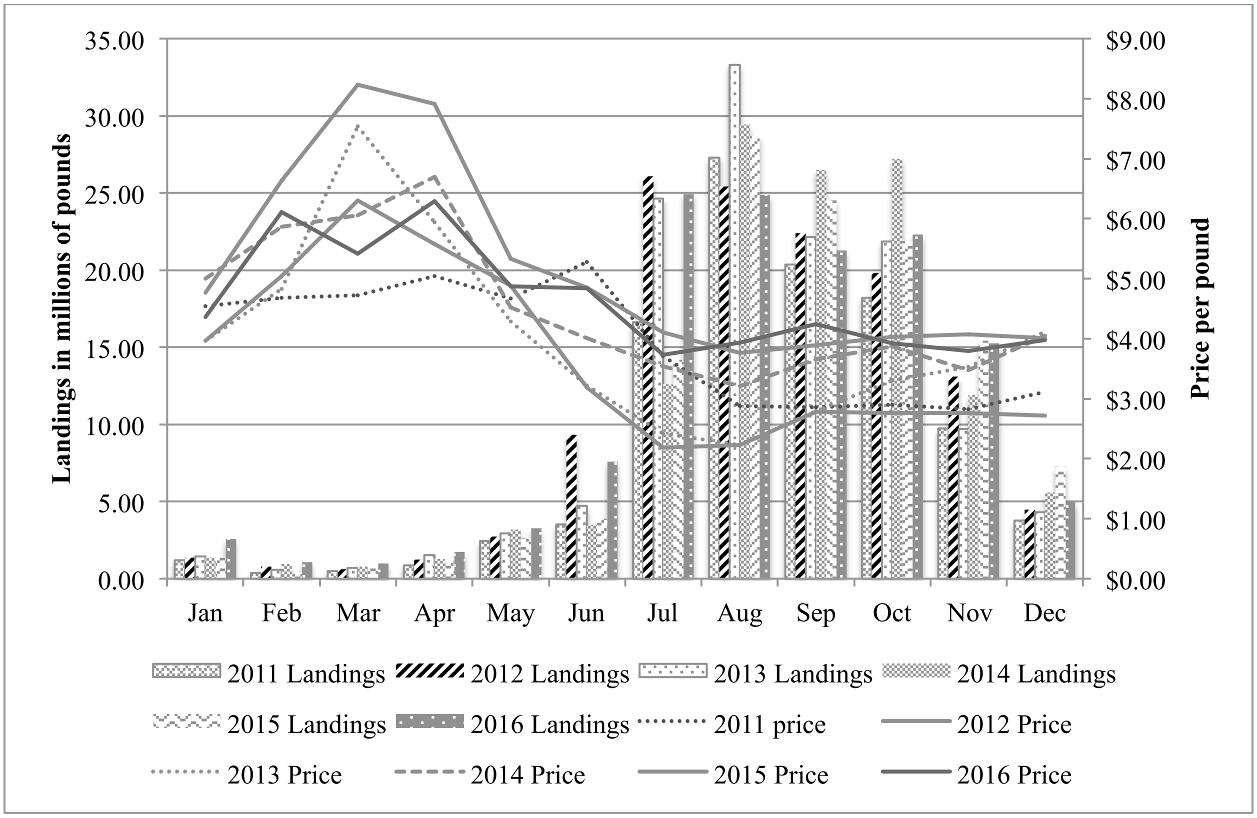

Figure 4.2 Monthly Maine lobster landings and ex-vessel Prices 2011- 2016

Given a future increasing volume trajectory for the fishery, the question remains as to how much of the product can be dealt with through existing supply chains, and how much of the product needs increased demand and access for the conventional and less specialist market. On a declining volume trajectory, the question remains how much is there available for the current level of fleet capitalization to derive a living.

Under these circumstances, we hypothesize that the in-season ex-vessel price the wholesaler is willing to pay a harvester will depend on the existing inventory held, the mix of hard and soft shell product coming in, balanced with the market demand and price received in the retail market. The price received by the wholesaler is a function of the consumer income, seasonal patterns affecting consumption rates, and any product substitution opportunities.

4.4 Ex-Vessel Pricing Model Empirical Estimation

Theoretical Model

According to economic theory, firms will behave as profit maximizers, and their supply decision is guided by the relationship where marginal cost of supply is equal to or less than marginal return of supply. Should a price-taking firm be faced with a market price below "shut-down price", the profit maximizing decision would be to produce nothing. A price that allows for production at a level above the marginal cost of output is likely to lead to continued supply operations by the firm, even though profits may be negative when fixed costs are considered.

In our study, we propose that the price the wholesaler is willing to pay a harvester will depend on the existing inventory held, the mix of hard and soft shell product coming in, balanced with the market demand and price received in the retail market. Based on prior research examining price changes in response to changes in lobster supply due to minimum size decrease (Wang and Kellogg 1988), we hypothesize that the price received by the wholesaler is a function of the consumer income, seasonal patterns affecting consumption rates, and any product substitution opportunities. The ordinary least squares regression functional form using log-log transformed data is selected used to measure this price response of Maine's lobster industry is defined as:

$$ln\, P_x = \beta_0 + \sum_{i=1}^{n12} \beta\, ln\, X_i + \varepsilon_i \qquad (6)$$

where,

P_x is the observed average monthly ex-vessel price, and *i* represents the *i*th month of the year for i = 1, 2, … 12 and X_i represents the amount of input of *total* lobster catch in each month plus other explanatory variables. We further assume a normally distributed error term $N\ (0, \sigma^2)$.

The estimated parameters $\beta_1, \beta_2, \ldots, \beta_n$ represent relative contribution of each factor to the wholesale price, with each observation reflecting the total by month of each of the factors examined, for the actively fishing population across Maine. We interpret the percentage change in price, resulting from a 1% change of the model parameters.

Empirical Estimation

The main purpose for modeling the lobster markets is to evaluate the impact of dealer inventories held over in frozen form from prior year, on in-season ex-vessel price paid to harvesters. We use a multiple linear regression model, to look at a variety of factors that may influence harvester ex-vessel price. We consider factors such as seasonality of product demand, including summer tourism season in Maine, Chinese weddings in October, and summer restaurant peaks in consumption. We compare the inventory holdings parameters in models run for two separate time periods, to assess the recent impact of climate driven volume changes since 2011.

We specify U.S. ex-vessel price (P_t), as a function of the Gross Domestic Product (GDP) as a proxy for consumer income, three seasonal variables to capture effect of seasonality in demand (SD1, SD2, SD3), lagged inventories (Q_{t-1}), landings in U.S. (Q_t), and frozen meat (QCAN_Z) and live (QCAN_NZ) imports from Canada as follows:

$$lnP_t^{US} = f(lnGDP, \mathrm{SD1}, \mathrm{SD2}, \mathrm{SD3}, ln\,Q_{t-1}^{US}, lnQ_t^{US}, lnQCAN\_Z, lnQCAN\_NZ) \qquad (1)$$

We use the demand shifters to capture seasonal peaks in the market, where SD1 is a binary variable to represent the months July through September; SD2 represents the months with holidays including October, December, and January. All other months are considered SD3. We have also included live imports from Canada as a factor in our regression, on the basis that while live product forms of lobster sold in to the U.S. tend to immediately flow into the retail market directly, this could still affect market demand, and therefore U.S. ex-vessel price. We have used a log-linear functional form for our model evaluation, and ordinary least squares regression.

Data Sources

NOAA Office of Science and Technology was the source for U.S. lobster landings and values. Within the Office of Science and Technology website, the foreign trade section provided U.S. lobster imports from Canada in terms of landings and total value. U.S. ex-vessel prices and lobster trade prices from Canada were calculated by dividing total value of landings volume. The Department of Oceans and Fisheries Canada, Statistics group and web site were the source of exports to the U.S. and other countries, with notable implications in the timing of these exports to the United States and for impact on trade. The other variables included in the regressions were economic indicators. The Federal Reserve Bank of St. Louis, Research and Data section was the source for the U.S. personal consumption index, U.S. and GDP.

The model is estimated with monthly data during two separate time periods, to enable comparison and contrast. We have a pre-2011 model for time period 1990 – 2010 and a second model post-2011, for time period from January 2011 – December 2016. Data on prices and income are in real terms.

4.5 Results

We first analyzed the broad trends in the data. In figures 4.2 and 4.3 we see the annual trade patterns of the U.S. and Canada, and observe an increase in exports for both countries. In figure 4.4, we see the annual spring large influx of Canadian live lobsters to the U.S., and in figure 4.5 we observe a pattern that supports the findings of Maine caught, Canadian processed, and shipped back to the U.S., lobster meat which coincides at times with Maine's opening of the annual live harvest market.

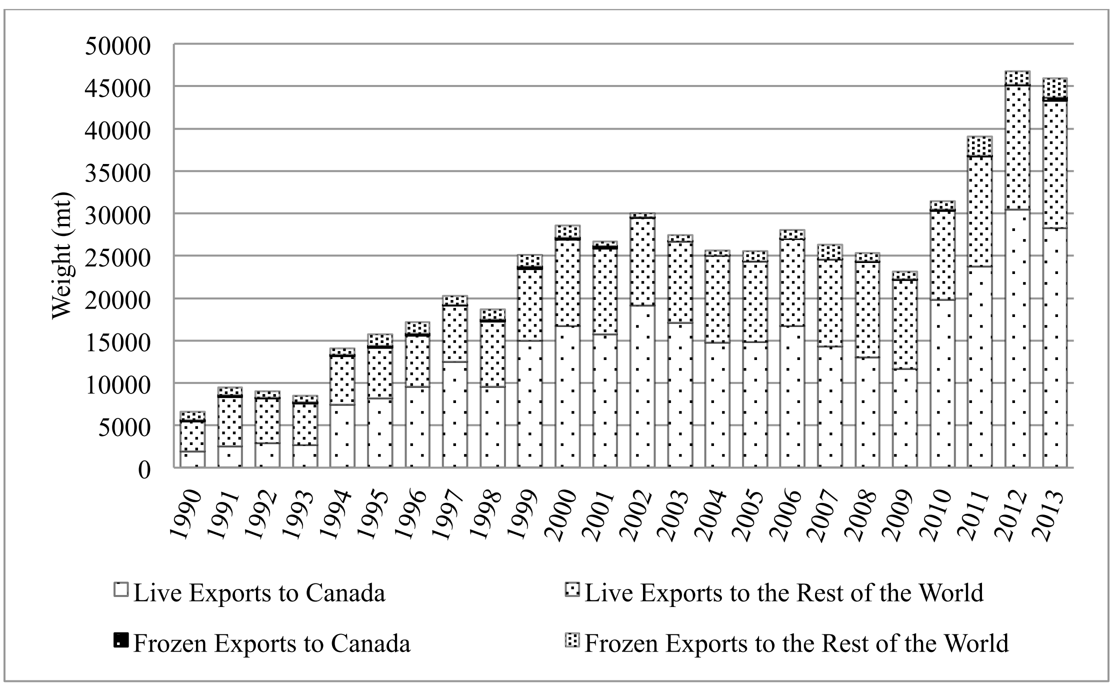

Figure 4.3 U.S. Lobster exports 1990 - 2013 by lobster product type

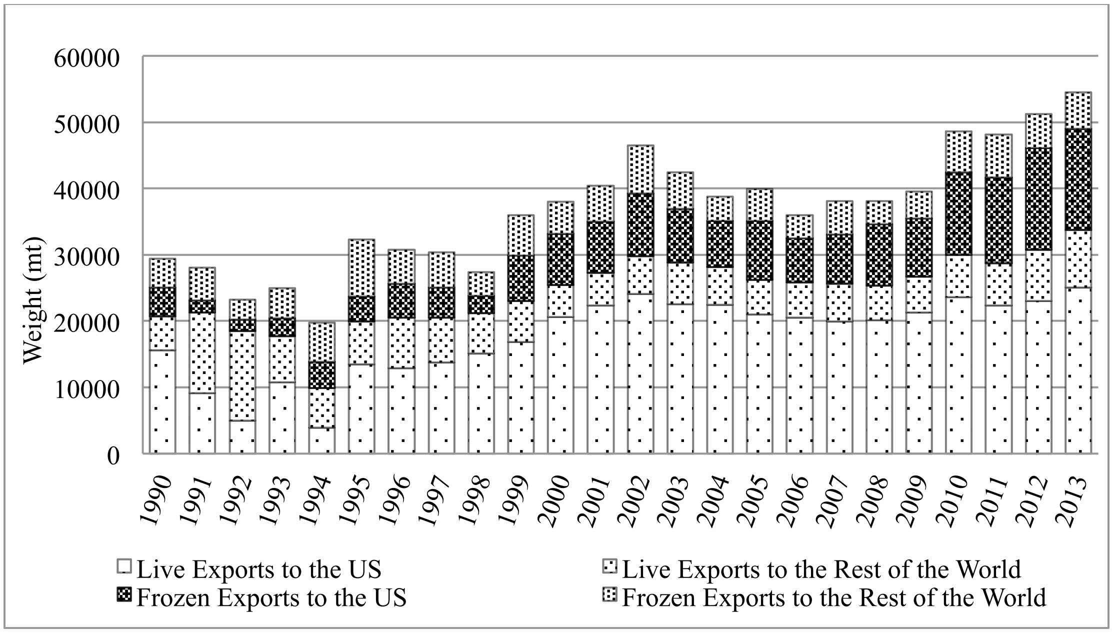

Figure 4.4 Canadian lobster exports 1990 – 2013 by lobster product type

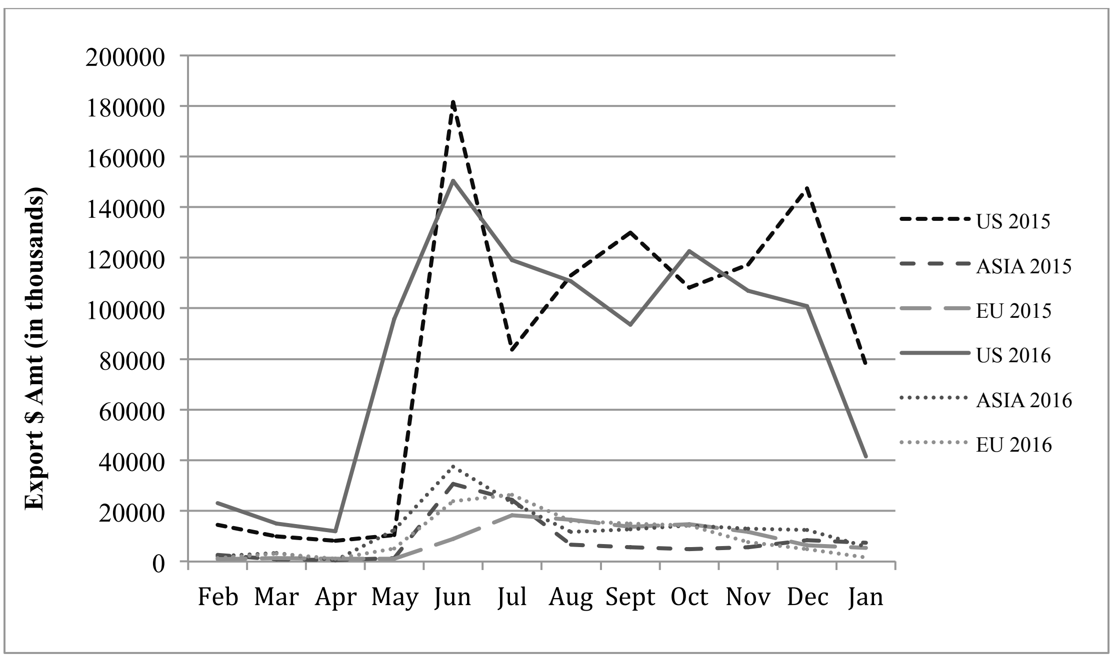

Figure 4.5 Value of monthly Canadian exports to U.S., Asia, and EU for years 2015 - 2016

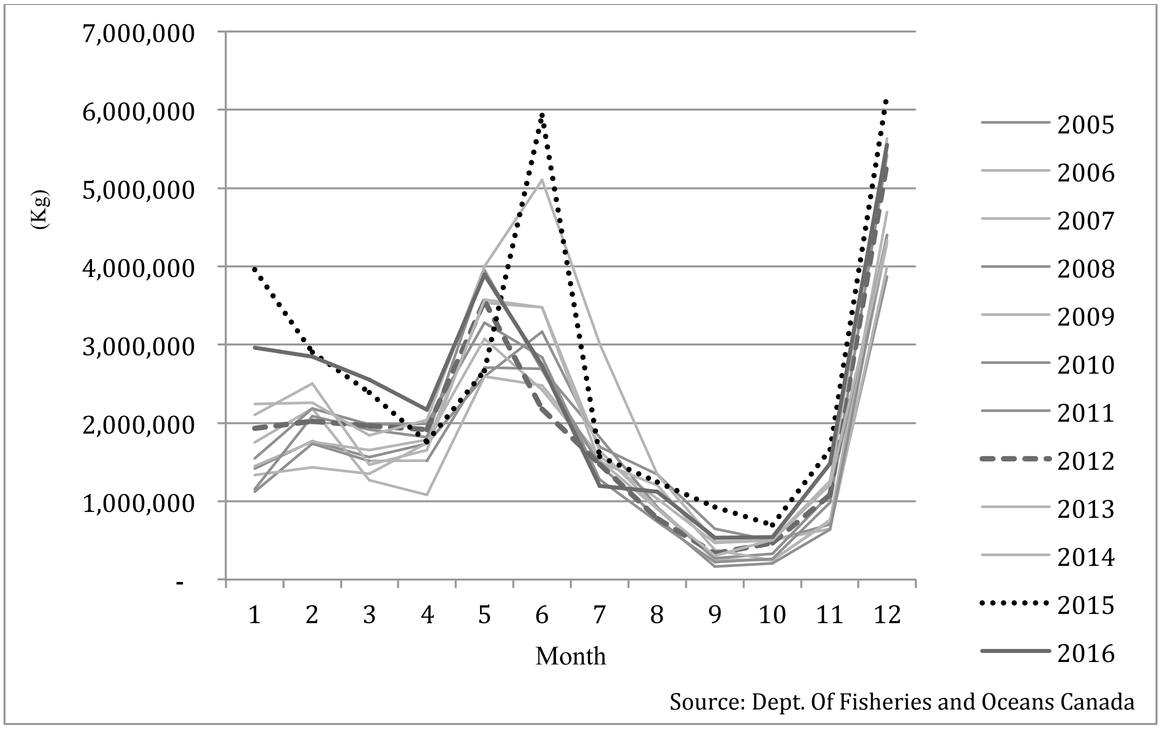

Figure 4.6 Monthly Canadian live lobster exports to U.S. 2005 - 2016

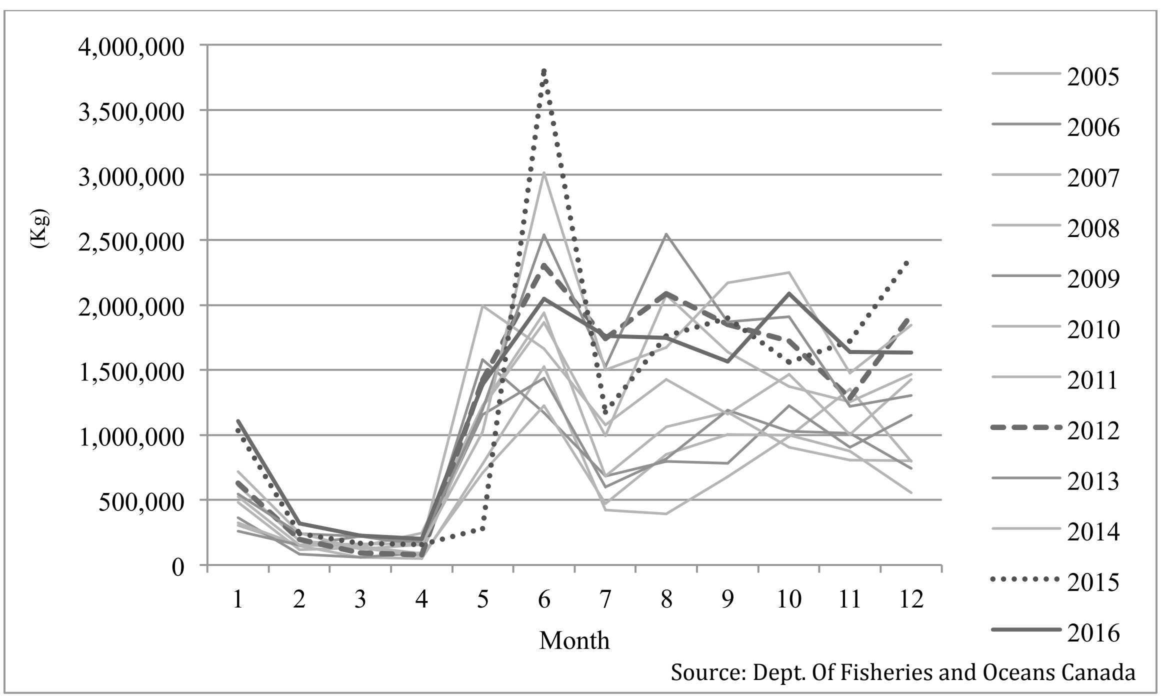

Figure 4.7 Monthly Canadian processed lobster exports to U.S. 2005 - 2016

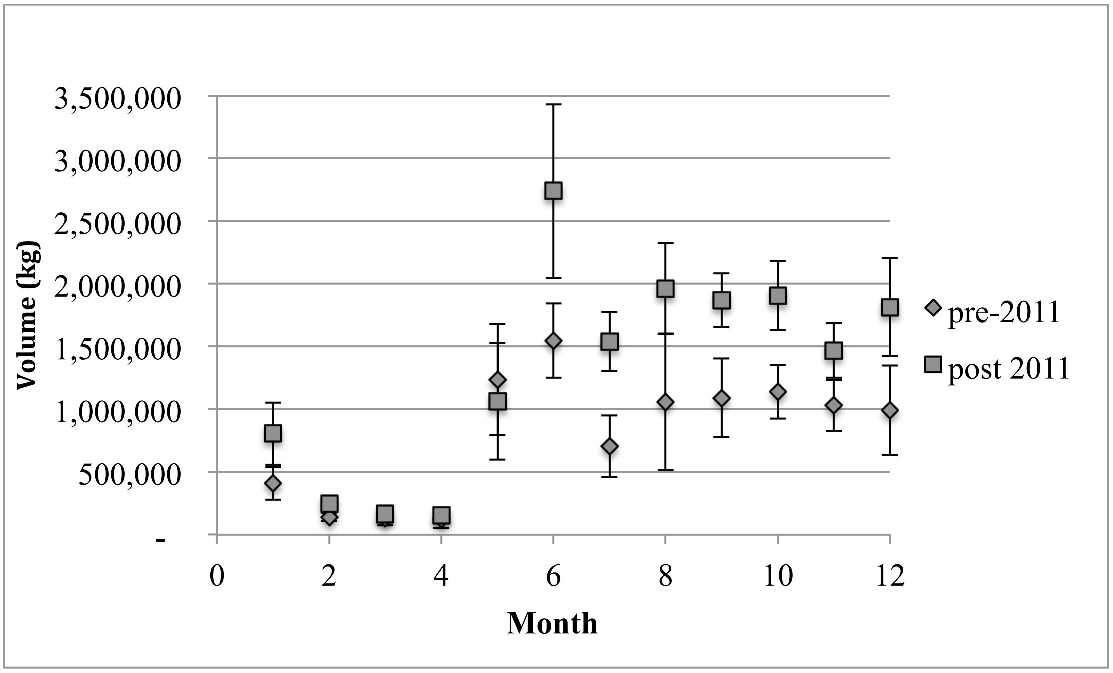

Figure 4.8 Average monthly volume of processed Canadian lobster exports to U.S.

In figure 4.5 we see a significant change in the post -2011 import pattern of Canadian frozen and processed products, especially in the second half of the year and with a peak in June; this was a statistically significant difference from pre-2011 import patterns (ANOVA $p < .05$, $F = 4.386$), and we hypothesize that this contributes to the influences on U.S. ex-vessel price in new ways.

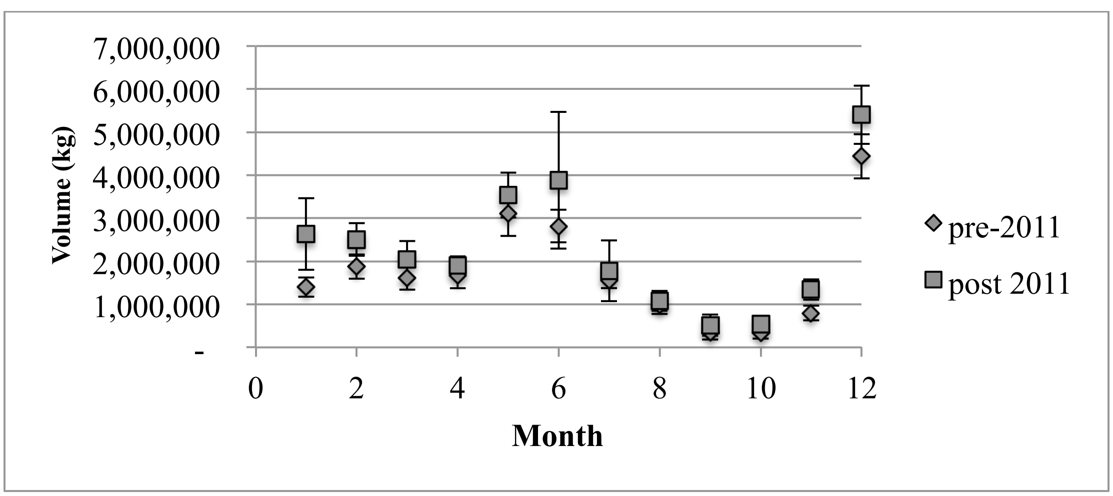

Figure 4.9 Average monthly volume of live Canadian lobster exports to U.S.

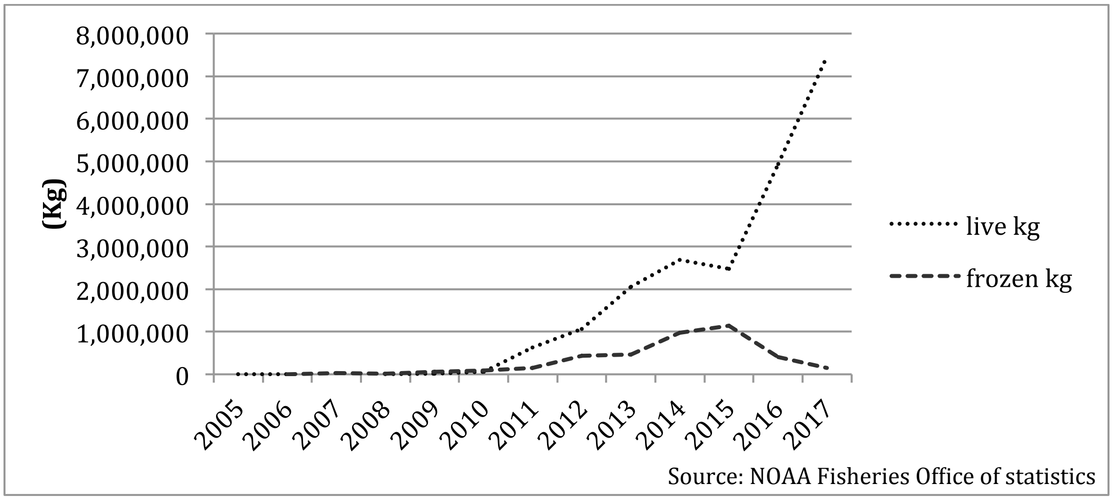

Figure 4.10 U.S. annual lobster exports to China 2005 - 2017

U.S. exporters have increased their export volume for both the processed product form and the live product form since 2011 with 7,000,000 kg exported to China in 2017 (Fig 4.10) and 2,000,000 kg exported to Hong Kong in 2017 (Fig 4.11). This is the result of improved handling and shipping practices since 2016, which have decreased shipping mortality significantly. A decrease in processed product lobster exports was observed as a result of this change in shipping practices.

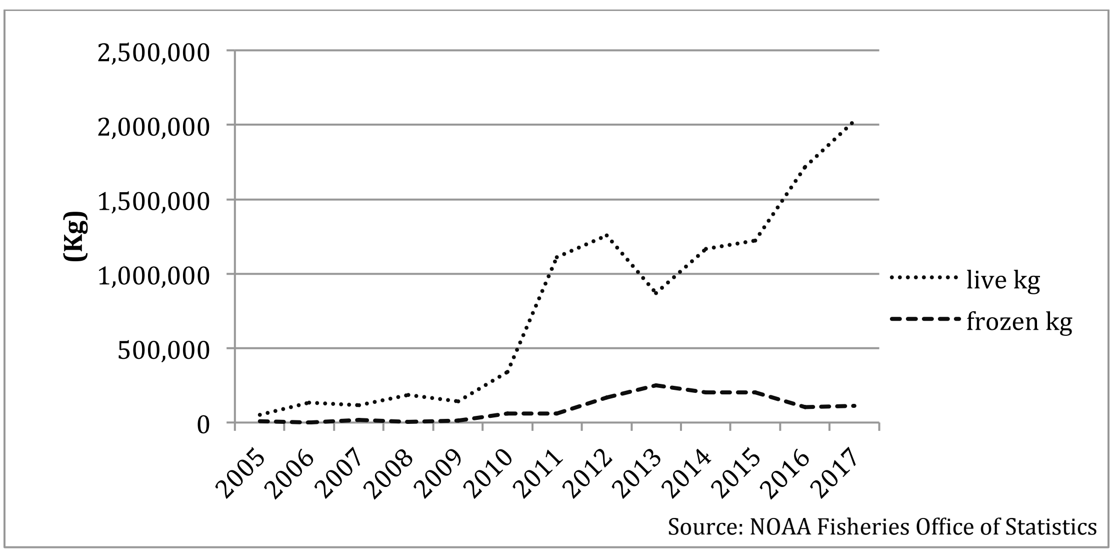

Figure 4.11 U.S. annual lobster exports to Hong Kong 2005 - 2017

4.5.1 Empirical Model Results & Discussion

The following regression models were run to explain the determinants and factors influencing wholesale price and ex-vessel price in the Maine lobster fishery:

$$lnXP_t^{US} = \delta_0 + \delta_1 GDP + \delta_2 \mathrm{SD1} + \delta_3 \mathrm{SD2} + \delta_4 \mathrm{SD3} + \delta_5 LAG\_QT + \delta_6 QT + \delta_7 LN\_QCAN\_Z + \delta_7 LN\_QCAN\_NZ + \varepsilon$$

Variable definitions and descriptive statistics are shown in Tables 4.1 and 4.2 for the pre-2011 and post-2011 periods respectively. Variables were log transformed to allow for the range of variation observed and to account for different scales within the data. Our models performed well, and accounted for a significant proportion of the variance observed. We analyzed model performance using AIC score to improve on the fit.

Table 4.1 Variable definitions and descriptive statistics for the period pre-2011

Variable	Definition	Mean	Std Dev
LN_P	Ex-vessel price per pound	1.34	0.258
LN_QT	Lbs. of Maine lobster landed	15.08	1.155
LAG_QT	Lagged lbs. of Maine lobster landed	15.08	1.155
GDP	Gross Domestic Product	10,580	3134
LN_QCAN_Z	Lbs. Canadian frozen imports to U.S.	9.22	0.3093
LN_QCAN_NZ	Lbs. Canadian non-frozen imports to U.S.	14.56	0.9940
SD1	Seasonal Demand Dummy 1 (yes=1/0)	0.5	0.25
SD2	Seasonal Demand Dummy 2 (yes=1/0)	0.25	0.25

Table 4.2 Variable definitions and descriptive statistics for the period post-2011

Variable	Definition	Mean	Std Dev
LN_P	Ex-vessel price per pound	1.41	0.23
LN_QT	Lbs. of Maine lobster landed	15.41	1.06
LAG_QT	Lagged lbs. of Maine lobster landed	15.41	1.06
GDP	Gross Domestic Product	17,107	3120
LN_QCAN_Z	Lbs. Canadian frozen imports to U.S.	14.47	0.521
LN_QCAN_NZ	Lbs. Canadian non-frozen imports to U.S.	15.14	0.7520
SD1	Seasonal Demand Dummy 1 (yes=1/0)	0.5	0.25
SD2	Seasonal Demand Dummy 2 (yes=1/0)	0.5	0.25

For our pre-2011 time period analysis, the reduced model was first applied to establish a baseline of seasonal landings to volume relationships coupled with consumer confidence measures of well-being and based on in-season effort, and catch rates. The results of our regression are shown in Table 4.3, model 1. This model fit the data well based on AIC score, and our estimated parameter for the effect of in-season quantity of product available was 0.138, which indicates that a 1% increase in the quantity of in-season landings contributes to a 13.8% decrease in price. The model also included seasonal demand shifters, dummy variables, which were both found to be significant and in keeping with expectation that certain months of the year will command a higher price; SD1 and SD2 coefficients were estimated at -0.08 and -0.07 and account for seasonal demand peaks contributing an 8% and 7% respectively, price improvement during the months associated with seasonal demand over non-seasonal demand months.

For model 2 we then included the lagged quantity parameter, which is presented in Table 4.3. This variable is intended to capture the effect of over-supply against market demand, which would lead to inventory holdings. The estimated parameter, -0.06, reflects the negative correlation with price as expected, and we also observed a decrease in the SD1, SD2, and QT parameters with the addition of the lagged quantity variable. In model 3 we included the Canadian export quantities to the U.S., and found an overwhelming influence of the Canadian live lobster, which is exported according to a regular annual trade pattern as observed in figures 4.2 through 4.6. This trend is felt in the LN_QCAN_NZ model parameter coefficient of 2.126, with model performance improving significantly over prior estimations as a result of the inclusion of this parameter. This was a surprise, but also shows that the incoming product from Canada in historical times was a positive influence on price in the U.S., likely because the increased marketing activities on the part of the Canadians in the U.S. also bore a benefit on the U.S. product demand, where supply did not historically outpace demand. All but one set of parameters in our analysis emerged as significant variables at the 5% confidence level, and our model accounts for 75.3% of the observed variability in ex-vessel price.

Among the models, we also observe a trade-off between the seasonal demand shifter dummy variables, which were significant as parameters in our study initially in model 1, as were the quantity of U.S. product landed initially. In model 2, this was then offset against the lagged landings variable in our analysis, which became significant, and accounts for a greater proportion of the variation observed than the seasonal demand shifters. Model 3 indicates that supply volume drivers associated with combined U.S. and Canadian product landings overwhelmingly outweigh the market demand influences on ex-vessel price and multiple sources of product substitutions correlate with this negative relationship to ex-vessel price.

The variable definitions for our post-2011 analysis are found in Table 4.2, and model run parameters estimations are presented in Table 4.4. Our models performed well, and accounted for a significant proportion of the variance observed. We analyzed model performance to improve on the fit, using AIC score. Model 3 outperformed the other models based on the AIC score of -310.62. The reduced model 1 was first applied to establish a baseline of seasonal landings to volume relationships coupled with our seasonal demand and consumer confidence measures of well-being and based on in-season effort, and catch rates. This model fit the data well and suggests that a 1% increase in the quantity of in-season landings contributes to a 15.3% decrease in price. The model also included seasonal demand shifters, dummy variables, which were both found to be significant and in keeping with expectation that certain months of the year will command a higher price; SD1 and SD2 coefficients were estimated at -0.20% and -0.167% and account for seasonal demand peaks. As compared to the pre-2011 models, we see a significant increase in the relative strength of the seasonal demand parameters, which show an order of magnitude increase over pre-2011 estimations. This demonstrates a significant change in supply to demand relationship between the two time periods in our study.

For model 2 we then included the lagged quantity parameter LN_LAG_QT, which was significant with an estimated coefficient of -0.065 and similar to the pre-2011 analysis results, captures some of the variance previously captured in the seasonal demand dummies. Model fit was also strong, as evaluated with AIC score comparison.

Table 4.3 Price Model Parameter Estimation Results pre-2011 (1990 – 2010)

	Model 1			Model 2			Model 3			Model 4		
Variable	Coefficient	t -value		Coefficient	t -value		Coefficient	t -value		Coefficient	t -value	
(Intercept)	2.960	18.65	***	3.199	18.17	***	-13.570	-7.81	***	-13.680	-7.85	***
LN_QT	-0.138	-11.71	***	-0.093	-5.00	***	-0.100	-7.49	***	-0.106	-6.43	***
LN_LAG_QT				-0.066	-3.07	**	-0.080	-5.90	***	-0.085	-4.54	***
GDP	-.0005	15.58	***	-.0005	16.19	***	-0.0002	-7.19	***	0.0002	-7.24	***
LN_QCAN_NZ							2.126	9.82	***	2.165	9.83	***
LN_QCAN_Z							-0.002	-2.55	*	-0.003	-2.74	
SD1	-0.079	-2.53	*	-0.021	-0.57					-0.029	0.87	
SD2	-0.084	-3.04	**	-0.008	-0.21					-0.007	0.21	
AIC	-239.23			-245.48			-310.62			-306.52		
df =	4			4			5			7		
F-statistic	122.8			122.8			160.8			114.6		
R^2 =	0.6479			0.6479			0.753			0.7521		

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

Table 4.4 Price Model Parameter Estimation Results post-2011 (2011 – 2016)

Variable	Model 1 Coefficient	t -value		Model 2 Coefficient	t -value		Model 3 Coefficient	t -value		Model 4 Coefficient	t -value	
(Intercept)	2.013	6.28	***	2.234	2.23	***	4.157	7.69	***	4.168	-7.85	***
LN_QT	-0.152	-8.82	***	-0.129	-0.10	***	-0.133	-4.86	***	-0.148	-6.43	***
LN_LAG_QT				-0.065	-0.06	*	-0.100	-4.42	***	-0.086	-4.54	**
GDP	0.000	7.15	***	0.000	7.34	***	0.000	8.86	***	0.000	7.24	***
LN_QCAN_NZ							-0.097	-2.84	***	-0.093	-2.58	***
LN_QCAN_Z							-0.061	-2.18	**	-0.071	-2.16	**
SD1	-0.207	-3.79	***	-0.133	-0.13	*				-0.032	0.87	
SD2	-0.167	-3.15	***	-0.074	-0.07					-0.056	0.21	
AIC	-73.642			-77.102			-86.165			-83.178		
df =	4			5			5			7		
F-statistic	68.53			59.3			69.03			48.62		
R^2 =	0.7919			0.6479			0.8273			0.8244		

Significance codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1

In model 3 we incorporate the influence of the Canadian live and frozen lobster, which is imported according to a regular annual trade pattern as observed in figures 4.2 through 4.6. This is captured in the LN_QCAN_NZ, and LN_QCAN_Z model parameter coefficients, which previously were a positive contribution to the price in the pre-2011 model, and now emerge as negative parameters at -0.097 and -0.061 respectively, with model performance improving significantly over prior estimations as a result of the inclusion of these parameters based on improved AIC score. This model was statistically different relative to the base model and supports our hypothesis that post-2011 price is now responding negatively to the additional supply incoming from Canada as a result of over-supply. All but one set of parameters in our analysis emerged as significant variables at the 5% confidence level, and our model accounts for potentially 82.73% of the observed variability in U.S. ex-vessel price.

We again in all of the model runs observe a trade-off between the seasonal demand shifter dummies, which were significant as parameters in our study initially in model 1, and then offset against the lagged landings variables in our analysis, and the incoming Canadian supply, which accounts for a greater proportion of the variation observed than the seasonal demand shifters. Our model indicates that supply volume drivers overwhelmingly outweighed the market demand influences on ex-vessel price post 2011 and multiple sources of product substitutions correlate with this negative relationship to ex-vessel price. This differs from the pre-2011 analysis when a positive effect was felt due to the different supply sources. These results provide an insight into the effects of climate mediated changes in lobster landings patterns, and suggests significant changes in the demand to supply function for the U.S. lobster industry that will lead to continued price effects.

In 2016, researchers unveiled new forecasting tools and prediction in February, which called for an early season and repeat landings pattern to 2012, and prices immediately dropped sharply with dealers citing a devaluation of their inventories associated with a high volume forecast. The subsequent season ex-vessel prices within the 2016 did not follow the pattern observed in 2012, instead rebounding and sustained over the long term, despite the record setting harvest levels of the fishery at 131 million pounds for 2016. We examine these two scenarios, and hypothesize that stored inventories in response to late season increased landings drive a significant portion of the ex-vessel price paid to harvesters. The use of forecasting tools can aid harvesters in their ability to plan and manage their effort, and in turn causes a re-valuation of inventory holdings. The counter-intuitive impact of this scenario is to improve the financial profitability of the harvesting sector, as they improve their leverage with dealers and purge latent inventory impacts caused by frozen or pounded product but at lower cost to the dealer. Because the harvester benefits, the resource extraction rate is then likely to decrease, or stabilize, and in turn benefit of the lobster population.

4.6 Conclusions

Lobster landings have increased significantly since 1997, but for many years since 2004 the market did not absorbed the expanded supply and the economic downturn was particularly difficult for the lobster market, resulting in lower price per pound. The Maine lobster industry has faced extraordinarily strong "buyer power" as all players struggle to sell the same undifferentiated and commoditized product and maximize revenue through volume, and a strong rivalry among various lobster industry constituents confounds efforts to address market challenges to the industry. This has had a negative price effect and hurt the overall profitability of the U.S. lobster industry in a highly competitive worldwide marketplace.

The State funded Marketing Initiative has the potential to change this pattern, and trade relations with Asia and Europe can also invigorate demand for Maine's staple export, but without stabilization of the overall supply of lobster, it is expected that any further expansion of the supply in the peak months, especially in the second quarter (April – June), and then again in the fourth quarter (Oct – Nov), is likely to result in further price deflation and have a further negative effect on individual profitability. Further research into the price and market integration of U.S. Maine caught and Canadian lobsters is warranted, where New Zealand and Australia experienced a similar trend as they compete to supply emerging Asian markets. Harvest policy reforms, such as output controls, might also offer a solution with many advantages.

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5. APPLYING A RETROSPECTIVE ANALYSIS TO ESTIMATE FUTURE VESSEL PROFITABILITY RATES IN MAINE'S LOBSTER FISHERY

5.1 Abstract

This analysis quantifies the potential economic impact of changes in resource abundance and spatial distribution in Maine's American lobster fishery associated with climate change where declines in settlement rates and projected to lead to a decline in landings. We specifically analyze the projected changing spatial harvest patterns and volumes on firm level short-run profitability (i.e. the lobster vessels) with sunk capital, and evaluate overall industry profitability rates and implications for Maine lobster fishery management. In this research we have created a series of scenarios with changes to lobster firm production inputs, providing an inter-disciplinary complement to the ecological modeling and abundance forecasts of other researchers. We have looked at a five-year horizon from 2016 to assess future fleet wide and vessel-level profitability. We examine three vessel classes, across seven Maine lobster zones at the producer level, and also in aggregate for the State of Maine. We provide several point-in-time profiles over different regional scales, to inform the discussion around community adaptation strategies both within communities, and at the State level. Our analysis reveals that future individual vessel level profits are highly sensitive to projected changes in landings patterns, ex-vessel price, and fleet participation rates. Our modeling of future profitability indicates that while 95% of the fleet has operated above break-even up through 2015, as much as 65% of the active Maine lobster fleet may operate at below break-even by the year 2020 if declines occur as expected. The distribution of fleet profitability changes are not uniform across all vessel categories and Maine lobster zones however, and vessels with a high degree of capital investment, and those located in lobster Zones west of Penobscot bay Maine appear more vulnerable to changes. Our modeling suggests that the most resilient vessel category is the traditional 35 – 39' vessel with no loans and operating with one crewman, where smaller vessels (< 34') will struggle to overcome operating costs under lower future landings projections, and the larger vessel category (> 39 ft.) will be hampered by over-capitalization. These findings have implications for fisheries managers, seeking to balance ecological resource conservation with economic return on resource extraction.

5.2 Introduction

The dynamic environment of fisheries offers a unique glimpse into the long term effects of anthropogenic changes in our environment (Perry et al. 2011; Perry et al. 2005), and we are observing both large and small changes from historical patterns (Kleisner et al. 2016; Ottersen et al. 2013; Walsh et al. 2015; Bell et al. 2015; Pinsky et al. 2011), as our world adapts to new inputs and stressors (Hobday et al. 2016; Popova et al. 2016; Wernberg et al. 2011). Change and uncertainty have become the norm. Forecasting techniques, and learning to proactively respond to future perils are skills we must develop (Ogier et al. 2016; Pinsky and Mantua 2014; Scheffer et al. 2018; Miller et al. 2018; Ford et al. 2011; Hare et al. 2016), and communities would do well to engage in difficult discussions and adapt ahead of time (Verweij et al. 2010; Stoll et al. 2017). Natural variability in the natural environment has long held patterns upon which we build our human economies; the past three decades however have seen an increase in episodic events such as hurricanes and storms, winter warming and icing events, extreme heat and vanishing water resources, and changes in ocean temperature and chemistry, all of which have become more frequent and intense (Hobday, et al. 2016; Thomas et al. 2017; Chen et al. 2014). Ecosystems rebuild after these events and anomalies, but over time we see that our natural environment never quite returns to the previous state, a slight alteration occurs (Johnson et al. 2011; Madin et al. 2012). A cumulative impact of these small adjustments, ultimately leads to a new expectation of normal (Pecl et al. 2017).

Prior research has shown that ecosystems can withstand changes, but will tend to lose some resilience and resist returning to the previous state even as the stressors, such as climate shifts, or in the case of fisheries resource management, over-fishing (Daskalov et al. 2007), are removed (Fu et al. 2001). Long term changes can then occur in an ecosystem when a threshold has been exceeded, and can lead to a cascade of habitat changes (Frank 2005), life history response such as changes in fishery age structure (Ying et al. 2011; Pershing et al. 2015; Le Bris et al. 2015) or evolutionary decrease in average age of maturity (Ottersen et al. 2013; Kleisner et al. 2016). Permanent ecosystem restructuring and regime shifts can also occur, with changes in abundance of species, the immigration and emigration of species in an ecosystem (Daskalov et al. 2007; Johnson et al. 2011; Perry et al. 2005; Link et al. 2011), as well as new speciation events (Rose et al. 2001). Long-term changes in the human component response also include the migrations that may be permanent resettlements closer to the fishing resource (McIlgorm et al. 2010) or engaging in community–based conservation efforts to ensure resource sustainability such as protections for spawning stock and egg bearing females (Le Bris et al. 2018). Other changes in policy and governance may be needed support of economic diversity include: re-training, professional pluralism, and out-migration (McIlgorm et al. 2010; Ogier et al. 2016; Pinsky and Mantua 2014; Miller et al. 2018; Perry et al. 2011).

In this research we examine the Maine lobster stock and fishery as an example of a physical ecosystem and assemblage of species on the brink of change (Nye et al. 2009; Anderson et al. 2013; Bell et al. 2015; Thomas et al. 2017; Wernberg et al. 2011; Johnson et al. 2011). Development of Maine's fisheries up through the early 1990's showed a large diversified fleet and harvest, enabling fishermen to vary their gear configurations between summer and winter months and enjoy year-round operations and income (Stoll 2017; Thunberg 2007). However, declines in the Gulf of Maine ground fishery, sardine, northern shrimp, urchin, and cod fisheries have caused changes in Maine's economy, such as the closure of Maine's sardine canning industry for example, and many fishermen now specialize and focus almost exclusively on harvest of American lobsters (*Homarus americanus*) since the late 1990s (Steneck and Wahle 2013). The American lobster fishery now dominates Maine's marine economy, and the outlook for fishermen, and the State's economic welfare, is deeply intertwined with the future of this iconic fishery. Since 2011, more than 70% of the all fishery landings values of Maine's fisheries are generated by the lobster fishery, and the economic diversity of the fishery is in it's lowest in the past 50 years (Maine Department of Marine Resources).

Lobstering provides a critical social construct and source of jobs in Maine, and understanding the inputs to the harvest production process is important to understanding factors influencing long-term sustainability of the industry (Dayton and Sun 2012). The Maine lobster fishery provides a study system for evaluating the impacts of climate variability on a fishery and offers important insights into how policies can help communities adapt. Since the 1990's, the American lobster fishery has seen over three decades of steadily increased landings. Of the total American lobsters landed in the U.S., approximately 90 percent have historically been caught in Maine, which has seen dramatic landings increases in the last two decades, rising from an annual average of 20 million pounds from 1950 to early 1990, to and average 50 million pounds in the end of 1990s. Lobster landings have continued to rise, and peaked in 2016 with a total harvest of 136 million pounds and a market value of $536 million (Maine Dept. of Marine Resources), propelling this fishery to the second largest fishery by value in the U.S.

According to the Atlantic States Marine Fisheries Commission's (ASMFC) most recent assessment, the stock is currently not overfished and overfishing is not occurring (ASMFC 2002, ASMFC 2015) but, there remains uncertainty about the future robustness of the stock due to underlying ecological and climate factors (Mills et al. 2013). Despite the landings volume increases in recent decades, the net profitability of the fishery has been questioned at both an individual and State level (Holland 2011). Many have cited the fishery as an example of fishery management twin ills, suggesting unsustainable harvest rates, and economic inefficiency (Steneck et al. 2011).

Scientists have expressed concerns over stock assessment risks (Chen and Wilson 2002) and potential future stock recruitment failure (Chang et al. 2016), and early indicators have identified changes in larval settlement patterns, which will affect future harvest levels and spatial and temporal patterns (Oppenheim et al. 2017 in progress). Economists have expressed concern over the profitability and economic sustainability of the industry (Steneck and Wahle 2013; Thunberg 2007) due to a number of factors, including: an increase in capitalization rates, the potentially unrecognized market integration with Canada leading to price response (Sun et al. 2015; Norman-López et al. 2014; Béné et al. 2000; Barten and Bettendorf 1989) and changes in the industry's input costs such as fuel and bait (Sumaila et al. 2008; Thunberg 2007). These underlying issues can be further compounded through increases in fishing effort. Additional entry is sought into the fishery; long waiting lists for a lobster license have fueled debate at the legislative level regarding fairness and equity of access. Managers continue to be concerned about the threat of excessive effort associated with management policies, as they do not limit resource extraction rates effectively and increases in effective effort are possible (Dayton and Sun 2012). Climate variability and changes in ecosystem structure further present question for the health of the underlying resource, and impact the species in yet to be fully understood ways.

The lobster resource has already declined precipitously in Long Island Sound and Southern New England (Pearce and Balcom 2005). In Southern New England the lobster resource is estimated to be at low abundance and low recruitment. The depleted stock abundance, low recruitment, and high fishing mortality rates over the past few years have led to consideration of additional harvest restrictions. Decreased recruitment and abundance have also been estimated in Massachusetts Bay and Stellwagen Bank (Dodoti 2012). In Long Island Sound shell disease has been observed in areas of high lobster densities (Tanaka et al. 2017; Tlusty et al. 2008), and in combination with other conditions has decimated the lobster population, suggesting that suitable habitat may be disappearing with other large scale environmental processes (Tanaka et al. 2017; Chang et al. 2010; Tlusty et al. 2008). In Southern New England, lobsters have succumbed to a shell disease during the same period that landings have fallen to less than one half of what they were four years ago. There is evidence that the same shell disease may be on the increase in Northern Gulf of Maine, although incidents currently still remain low overall (Reardon personal communication, Maine Fisherman's Forum 2017).

The social structure of the lobster industry is tight, and management of the fishery reflects the traditional social fabric of the lobster industry, extensively described by prior anthropologists (Acheson 1975). A co-management system implemented in the form of a Lobster Advisory Council guides the decision-making, and industry associations play a key role in communications to help fishery managers balance resource conservation (Le Bris et al. 2018) with the welfare of the community, and economic benefit (Acheson and Gardner 2012; Acheson and Acheson 2010). This provides for regional flexibility along the very large Maine coast, and aims to preserve the diversity of the lobster fleet and coastal community infrastructure, protect the small boat operators from consolidation pressures, and yet allow large-scale operations to operate under the same governing laws. In 1997 the Maine lobster industry began governance reform (Lobster Advisory Council 1999), and more potential management changes have already been identified to amend harvest and licensing strategies (Steinback et al. 2008; Cheng and Townsend 1993), but a lack of quantitative assessment and weak industry buy-in has stymied discussions in recent years. Maine’s fishing industry operates in an economic environment that provides limited opportunities for alternate employment with declining timber, paper, and other natural resource harvest professions, which have anchored the economy for two centuries. The opportunity cost of lobstering also varies along the coast, and reflects the economics of the localized county economies.

The management of fisheries has evolved in other regions, and the toolkit of managers has expanded (Australia 2009b; Australia 2009a; Yandle 2006; Yandle et al. 2011). In Maine however, management focuses primarily on various forms of effort controls, and so fishery policy adaptation has the opportunity to provide lasting frameworks for community structure in a changing environment. Much attention has been paid to the development of tools to evaluate the underlying health of the lobster population resource (Fogarty and Gendron 2004; Berger et al. 2009; Chang et al. 2016; Jiao et al. 2005; Wahle et al. 2009; Wahle et al. 1991; Steneck and Wahle 2013). In recent years more attention has been paid to co-management strategies and evaluating these strategies (Reid et al. 2013; Gardner et al. 2014). Economic modeling of fisheries is becoming increasingly relevant as well as it relates to both the cultural and financial well being of the fishing industry, and often drives observed behaviors (Thunberg et al. 1998; Anderson 1980; Anderson 1973; Sumaila et al. 2011). The complexities of future questions asked, coupled with the complex issues facing fisheries such as the Maine lobster fishery, demand an integrated and inter-disciplinary approach to ensure that we balance resource management with a robust policy platform to support human endeavors (Lehuta et al. 2014). The fusion of economic, biological, and ecosystem modeling disciplines has gained recent popularity in fisheries yielding new insights and approaches (Le Bris et al. 2018; Le Bris et al. 2015).

We apply retrospective analysis in this research to produce potential future scenarios associated with the impacts of climate change facing the Maine Lobster fishery and stimulate proactive governance discussions.

5.3 Background

Of the total American lobsters landed in the U.S., approximately 90 percent have historically been caught in Maine. American lobster landings in Maine increased dramatically in the last two decades, rising from an annual average of 20 million pounds from 1950 to early 1990, to 50 million pounds in the end of 1990s. Landings peaked in 2016 at 137 million pounds with a market value of $530 million (Maine Dept. of Marine Resources). During the summer of 2012, record warm seawater temperatures resulted in soft-shelled lobsters coming on the market a month early (Mills et al. 2013) and the market was unable to absorb the volume of low-meat yield “shedder” lobster, thereby significantly depressing ex-vessel prices. Overall, during the period 2008 – 2014, the industry experienced a 33% reduction in price per pound with a 64% percent increase in landings (Maine Dept. of Marine Resources).

Changes in input costs have challenged the economic efficiency of the lobster fleet. Where hard-shell lobsters command a higher price, they also require more effort to harvest as they are typically found offshore in winter months (Chang et al. 2010). Fuel and bait cost associated with targeting those lobsters that have migrated farther away from shore, either to deeper warmer bottom during harsher winter months or colder temperatures during the summer months, have changed the input ratio of the traditional lobster fishing operation and have called for an increase in managerial skill and capitalization rates (Sumaila et al. 2008).

In 2012, an unprecedented confluence of events led to more than 80% of Maine lobster landings occurring during June to October (Maine Dept. of Marine Resources), focused primarily on soft shell product, which is highly vulnerable to harvest injuries and subsequent transport mortality. Of that, more than 60% of U.S. soft-shell landings were exported to Canada for processing and then largely exported back to the U.S. and distributed into the U.S. frozen and canned lobster meat markets. Historically, this initial export of the annual soft-shell lobsters to Canada typically increases sharply in July, peaks in September, and drops again in December, matching the seasonality of U.S. landings, and complimenting the Canadian lobster season, which is open from November to June. In 2012 however, the shift in timing of the U.S. landings caused an overlap in the harvest of the two countries, specifically in June, and created an unprecedented landings volume during a compressed time period. The excessive demand for truck transportation, and excessive amount of product competing for limited processing capacity at the peak of the season created tensions in trade relations between the two countries, and as a result prices responded negatively to the oversupply. Fishermen on both sides of the border suffered significant financial losses, and individual fishermen reported significant personal losses (personal communication), even if the direct aggregate impact on the Maine economy was difficult to detect (Sun et al NAREA.)

Four years after the episodic heat wave event the Maine Fishery has seen a reprieve. The lobster landings have increased steadily in the past 5 years, and a recent confluence of events since 2014 have helped to push individual profits to a stable platform upon which to invest in capital such as new (often bigger) boats and trucks. Reduced fuel costs have allowed for small reprieve from capital layout required to set and bait lobster traps and begin fishing, and as of 2016, fishermen in Maine have seen relatively steady conditions in their fishery, with increasing volume and modestly improving ex-vessel prices. Maine has further invested in its fishery with a generic advertising campaign designed to spur summer product sales when the new shell season peaks and fishing operations are least costly. This strategy is aimed at bolstering overall product demand and enhancing consumer awareness. The recent reduction in fuel expenses has offset other increases such as bait cost, and has helped to improve the industry's profitability (Dayton and Sun, 2012), perhaps masking underlying weakness in reproductive health and other density related issues, as well as market structural issues, and weight of the very complex lobster supply chain.

Research into the species continues through oceanographic larval transport modeling (Incze et al. 2010; Xue et al. 2008), forecasting of biological abundance has several approaches including molt time predictions (Staples 2017), ecosystem modeling (Le Bris et al. 2018; Le Bris et al. 2015), and direct sampling programs such as the American Lobster Settlement Index (ALSI) (Wahle et al. 2009), which has for years provided a consistent sample methodology for larval Lobster Stage 4 Settlement assessment delivering a wide scale trend-based index to inform future lobster fisheries recruitment. From time of Stage 4 settlement to recruitment into the lobster fishery represents a period of biological production that has a lag period of 4 – 6 years before lobsters reach full size. The ALSI region wide scale sampling effort for early life history indicators provides an early indicator of future trouble or success, a sentinel. The sampling effort is implemented as a consortium of academic and research institutions, and extends from Southern New England, the Gulf of Maine, the Bay of Fundy, Nova Scotia, Prince Edward Island, and the Gulf of St. Lawrence. An annual compilation of the findings is used to compare year over year settlement within the range and characterize shifts in larval settlement volume, transport mechanisms, and phenology patterns. These data have been used to inform future commercial harvest landings patterns and recently further modeled to specific yields by Maine lobster Zone (Oppenheim et al. 2017 in progress). This landings prediction information provides a primary input assumption to our profitability modeling and scenarios.

Other climate based predictions and bio-economic models for the Maine lobster fishery have been developed (Xui 2015, Le Bris et al. 2018, Holland 2011). Our bioeconomic modeling framework presenting in this essay provides a tool for the comparison of the economic impacts of each potential outcome, and provides a discussion framework for key assumptions around fishery participation rates, and ex-vessel price along with a discussion of how it will impact specific individuals in the fishery, and which vessel classes are more resilient than others.

5.4 Materials and Methods

We developed a vessel level profit forecasting model based on our original 2010 cost survey of the Maine lobster industry (Dayton and Sun 2012), which was combined with the dealer data for landings and price. Linking this data to the licensing data (i.e. number of fishermen per landings class), we are able to apply an expansion factor using the current number of license holders within each representative vessel class and lobster zone. We created a statewide and fleet wide perspective of representative vessel categories and estimate the impact of different scenarios on overall fleet profitability, and estimate what proportion of the fleet will operate above or below break-even.

We have chosen to run three scenarios through our modeling framework, examining short-run profits, which include operating costs primarily (bait, fuel and labor) and other operating expenses. We have four vessel landings classes, stratified by vessel annual landings and the seven Maine lobster management zones, referred to as zones A through G (Dayton and Sun 2014), and each modeled individually. The historical fleet harvest patterns as reported in the dealer data are used to allocate simulated total Zone landings among the different vessel sizes. Our price model assumed all exogenous factors and market categories remain constant. Fishery profitability is assed through a set of accounting relationships, as uncovered in our survey. Input assumptions are discussed in further detail below.

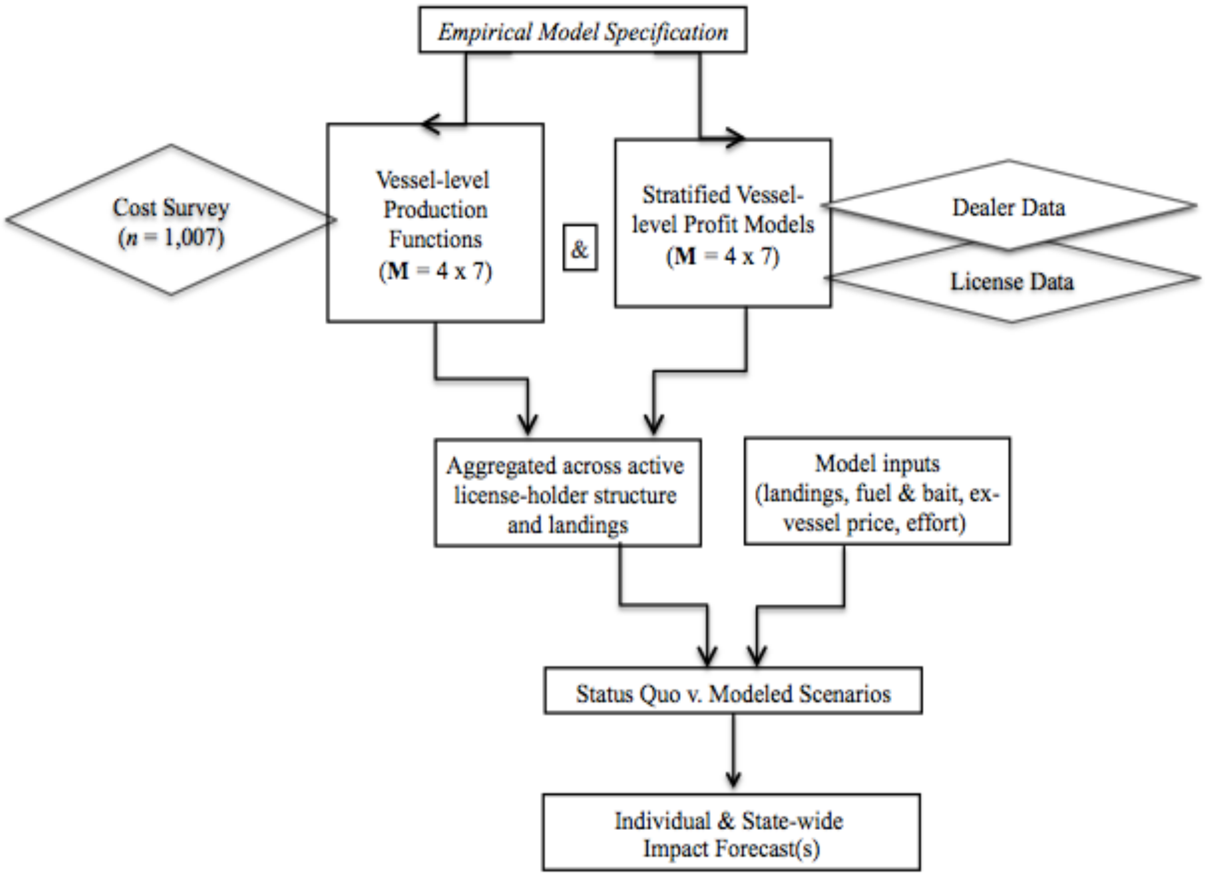

Figure 5.1 Lobster industry profitability modeling framework

Theoretical Economic Model

The model estimates the net revenue $NetRev_{ij}$ for each vessel i in lobster management zone j and $GrossRev_{ij}$, which is $NetRev_{ij}$ less the variable fuel and bait costs (v_{ij}). The model further estimates profit ($\boldsymbol{\pi}_{ij}$), which is the $NetRev_{ij}$ less the fixed annual and monthly costs of fishing (f_{ij}), and the crew share. Here, the fixed (f_{ij}) and variable costs of fishing (v_{ij}) are fleet and area specific, where variable costs are incurred linearly with effort (E_{ij}) and fixed costs are a function of the underlying firm's capitalization structure as reported in our survey. We applied mean variable costs by vessel category. This detailed information allows for a robust analysis of the profitability of the fleet and allows us to characterize differences among firms, which other analyses of this nature have previously been unable to specify (Holland 2011; Thunberg 2007, Sun and Franklin 2017) and recommended for future research. Vessel class specific differences in costs may represent distance from a fleet's homeport to a particular area, vessel size, engine efficiency, crew size, and other costs.

The gross revenue function $GrossRev_{ij}$, for vessel in class *i* in area *j* with quarterly time periods *t* is given by:

$$GrossRev_{ij}(t) = \sum_{t=1}^{4} \alpha C_{ijt} * \beta P_t \qquad (1)$$

where C_{ij} is the quarterly vessel level catch as reported in the dealer data for 2012, and scaled according to assumption α. This allows us to vary the resource production input to our model for each area *j* as a percent change in lobster catch from our baseline time periods, as predicted by the American Lobster Settlement Index lobster recruitment based fishery modeling. P_t is defined as the price for landed product class at time *t*, scaled by β, and selected in accordance with the inverse demand relationship of the lobster fishery as shown by (Holland 2011; Norman-López et al. 2014).

The net revenue function $NetRev_{ij}$ for vessel class *i* in area *j* with quarterly time periods *t*, is given by:

$$NetRev_{ij}(t) = \sum_{t=1}^{4} (\alpha C_{ijt} * \beta P_t) - v_{ijt} \qquad (2)$$

Where v_{ijt} is defined as a vector of variable costs calculated by calendar quarter based on effort, and then aggregated to annual variable cost component of each firm, in this case lobster vessel, including bait cost, fuel cost, and crew costs.

This model differs from prior studies, we have focused our attention on detailing the vector of cost variables with primary survey data, so as to estimate the vessel level characteristics and provide improved estimates of the previously lumped average cost data sets (Holland 2011; Thunberg 2007).

For our simulations, cost parameters were allowed to vary as a simulation of potential business and natural environments, specifically: cost per gallon fuel with the assumption of similar fishing effort levels and fuel consumption year over year, vary crew percent of gross based on number of crew employed, bait cost percent increase or decrease from previous year. It's important to note that although our data were collected to allow for a trap haul based and trip based cost profile, our outreach revealed that data collected at quarterly calendar year increments would provide maximum insight.

We further estimate the annual profit function (π_{ij}) for vessel in class *i* in area *j* with time periods *t* as given by:

$$\pi_{ij} = \sum_{t=1}^{4}\left\{ (C_{ijt} * P_t) - v_{ijt}\right\} - f_{ij} \qquad (3)$$

Where f_{ij} is defined as a vector of fixed annual costs such as license fees, equipment and boat repair and replacement expenses, insurance, wharf & mooring, truck costs, interest on loans and accounting expenses. We assume that each vessel class is a profit maximizer, and also takes the actions of the fleet for vessel class *i* in area *j*. We finally define, Π_f as the total annual fleet profit for the sum of all sub-fleet vessels in class *i* and all area *j*:

$$\Pi_f = \sum_{f=1}^{q} \pi_{ij} * n_f \qquad (3)$$

where n_f represents the number of licensed vessel for each sub-fleet, as reported by Dept. of Marine Resources (2012) and representative vessel profit is indicated by π_{ij} per equation (2) above.

Bioeconomic Model

To provide a baseline for comparison, in late 2015, we took our cost survey based vessel-level profitability models (Dayton, A. 2017), which were constructed with the 2010 cost inputs, retrospective as of Jan 2016, and validated with year-by-year hind casts for the known years

2010 – 2015 to assess the model's ability to capture dynamics of the fleet. This was validated in person with the accounting inputs from lobstermen in Maine through a series of outreach meetings, small presentations, and one on one working sessions over the years 2016 – 2017. This scenario for fishing year 2015 is presented in the results below as a measure of current state of the industry at the time of this publication and to allow for meaningful comparison with projections and scenarios, developed through changes to operational inputs as follows.

Lobster catch. Projected landings by Maine lobster zone for year 2015 – 2020 (Oppenheim et al. 2017) were provided as inputs to the profitability forecast model. These estimates were provided by the American lobster settlement index (Wahle et al. 2009), as presented in figure 4.3, and represent a direct estimate of recruitment changes in the fishery and the intended sole source of variability in our series of scenarios presented. We have not further evaluated stock-recruitment relationships, where this is implicit in the settlement index provided by ALSI.

Stock dynamics. We held catch composition constant when predicting harvest levels in future years 2015 – 2020, thereby smoothing potential effects associated with changes in product quality or age structure/size. The underlying harvested product for the prior two decades consists of 85% lobsters that have gone through their first molt into legal harvest size, with some small proportion of second molt (Steneck and Wahle 2013). Older, larger lobsters are not deemed a significant proportion of the catch, where these forecasts are focused on the inshore component of the fishery harvest. This assumption may be over-simplified however, given the potential metabolic changes associated with climate variation leading to earlier size at maturity, and increased growth rates (Le Bris et al. 2018).

Ex-vessel price. Although we see a variety of lobster product grades brought to market, only two market categories are recorded in the statistics of the fishery. We have assumed a stable proportion of market categories in the scenarios provided, which may be an oversimplification of the underlying ecological response over time, and we acknowledge this shortcoming in our analysis. Economic theory would suggest a price response associated with changing supply market conditions, and we have applied an inverse relationship with volume in accordance with findings of prior research (Barten and Bettendorf 1989).

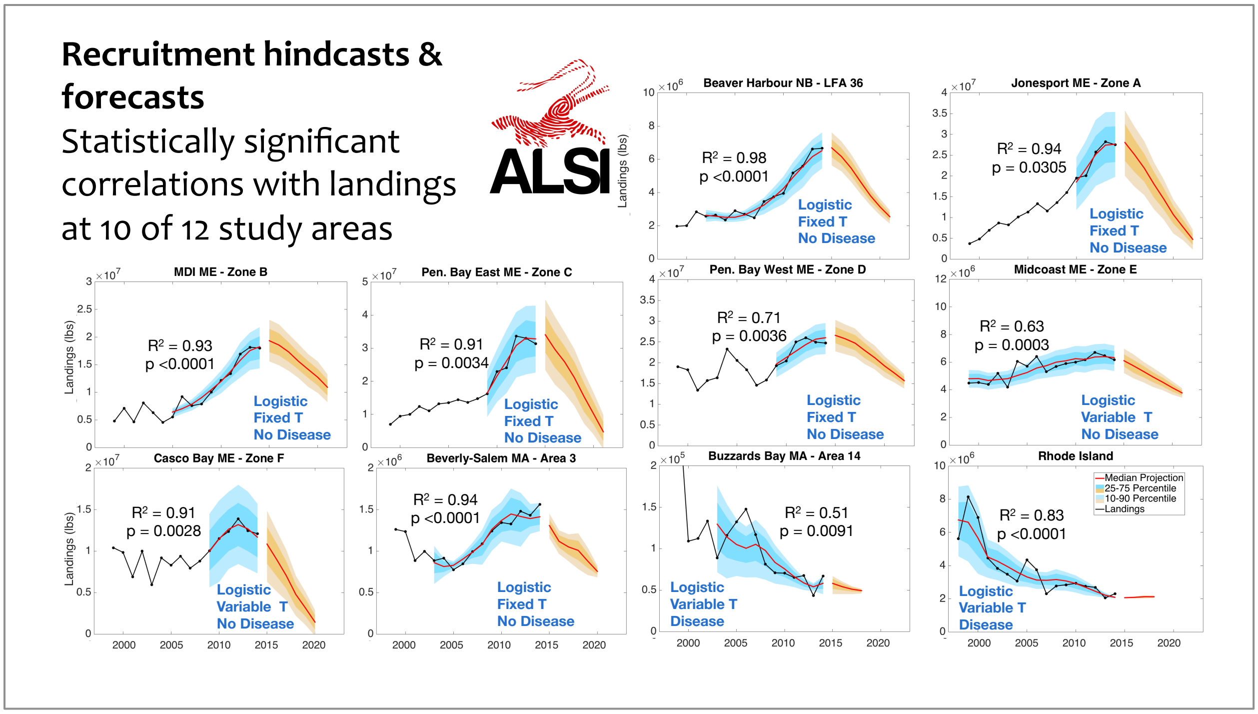

Figure 5.2 Landings projection provided by Oppenheim et al. 2017.

We also consider the active efforts to create new markets for lobster product both domestically and internationally, and reflect a constraint on supply in years where volume decline may be coupled with an increase in market demand. As well, periods of excessive inventory can create a market lag, which is hypothesized to decrease price in the following season and can further confound ex-vessel prices. For these modeling scenarios, a constant price was rejected because it was deemed too simplistic and ignores the volume relationship that has been clearly observed (Sun 2011); we have applied assumptions to the ex-vessel price increases per year, based on the aggregate rate of resource harvest decline, with possible seasonal gluts and a stable or growing market demand, as noted in Table 5.1.

Bait and Fuel. For these direct operational inputs, we build from the example of the Taiwan mackerel fishery, which observed a 10% increase in fuel consumption and a minimum of a 10% increase in bait costs during a period of declining catch rates (Sun et al. 2006) a pattern that would be expected in the Atlantic herring fishery, the primary source of bait for Maine lobstermen. Current rationing measures, affecting the Atlantic herring fishery in late 2015, have reverberated throughout the bait market however, and current bait rates passed on to the lobster harvest sector have been closer to 50% above bait prices in 2010. Prior research has estimated that upward of 70% of the herring catch is re-deployed as bait in the lobster fishery (Grabowski et al. 2010) and so our bait cost assumptions may be optimistically low. Fuel prices in 2015 stand at a historic low point for the decade and presently the oil price is $48 per barrel. Domestic oil production in the U.S. has increased and this trend is projected to continue, barring climate driven episodic weather events that impact refineries and other fuel-producing firms. We have therefore applied a small fuel increase of 5% in keeping with observed historical patterns in the early 2000's.

Fishing Effort. The observed economic benefits of an ex-vessel price increase, combined with reduced shrinkage in shipping and handling costs to new markets such as China, could become an even more attractive business for new entrants from the student and apprentice programs. In addition, many others hold licenses and have since shifted to other economic activities, but under improving short-run firm level profitability, an increase in the number of firms is predicted by neo-classical economics (Deacon et al. 2011) and market behavior. In the case of the Maine fishery, this could be observed as the activation of latent fishing effort. Game theory has also been applied to the Maine lobster fishery to bolster fleet and individual participation and specific predictions by season, the results of which support our microeconomics based approach (Wilson 2016). Short-run consumer price theory and short-run marginal cost benefit analysis would indicate both an improvement in short-run marginal profitability, followed by an increase in the number of firms participating in the market, with potential lagging observation of eroded profitability due to increase in number of firms.

In the State of Maine, there exists 30% latency of lobster trap tags held by active lobstermen, and eligible for immediate issuance in the fishery, as well as a 10-year waiting list for new entrants over age 18 representing new effort. These entry and exit issues appear inexorably linked with each other, and individual business profitability and current fisheries policy drive the rates of participation in the fishery. It's very difficult to project whether latent effort will become active effort, and it's even harder to know if one might see increased traps per person, or additional firms entering the fishery. Based on the results our previous study on lobster licensing (Dayton and Sun 2012), it is highly likely that some additional effort will enter the fishery under current licensing framework whether through additional trap hauling or new entrants. Given the concerns raised by fishermen for the already high number of traps in their region, it is further likely to decrease catcheability per trap due to congestion effects.

The range of technical expertise and skill as outlined in our production frontier analysis also indicates that significant efficiency and technical gains remain available to the current fleet. Therefore, for our economic modeling purposes, participation and effort rates in the fishery are deemed sufficiently dense at baseline (Wilson 2007) that any increase in active effort will only add to operating cost baselines and sunk capital. We anticipate that additional harvest contributions to the fishery will be non-incremental, given that the current fleet already lands 95% of harvestable year class. For our economic model, we do not increase effort to reflect new entrants, given the current limited entry restrictions; this is likely then to understate the potential impact of effort increases. However, we do apply a catcheability coefficient decrease of 20%, to account for a congestion effect associated with more frequent hauling of traps and or additional trap deployment on the part of existing fishermen.

Crew costs. A large degree of variability exists in the number of crew per vessel, seasonal crew hiring, and calculation of payment method (hourly wage, percent of gross revenue, percent of net revenue). We have found that the majority of the fleet however applies remuneration based on landings value, after deductions for fishing expenses including ice, bait and fuel. We have held this method constant in our analyses, and crew costs scale directly with revenue across the underlying relationships associated with the specific vessel class.

Simulation Methods

For our first forward looking scenario, all lobster vessel operating and fishing behavior factors are held constant, including effort variables (# hauls, # trips and operating costs), and we assumed no changes in participation in the fishery, market response or ex-vessel price.

In our second scenario, we add an inverse demand price response, where a decrease in landings is projected lead to an increase in price. We applied stepwise increases in price for years 2016 through 2020. We also have assumed a lag effect between resource decline beginning gradually in 2016, and subsequent price response. A confluence of events is poised to drive a sharp increase in ex-vessel prices several years after the landings decline is observed. We also vary the operational input costs for bait and fuel.

Table 5.1 Profitability forecast modeling assumptions and scenario inputs[2]

Year	Zone A	Zone B	Zones C+D	Zone E	Zone F	Zone G	Total Lbs.	Fuel	Bait	Price	Catch-ability
2008	-60%	-23%	-24%	-3%	-39%	-20%	-29%	20%	0%	20%	0%
2009	-34%	-12%	-11%	-2%	-11%	-8%	-14%	-18%	0%	0%	0%
2010 (lbs)	14.8m	11.8m	45.8m	7.9m	11.6m	3.5m	95.5m	$3.00	$48	$3.82	Base
2011	19%	14%	13%	0%	9%	4%	12%	28%	0%	5%	0%
2012	39%	30%	28%	3%	13%	6%	25%	32%	0%	-3%	0%
2013	57%	45%	36%	3%	9%	5%	33%	31%	0%	5%	0%
2014	63%	59%	40%	1%	0%	3%	36%	11%	0%	5%	0%
2015	55%	61%	41%	-2%	-11%	-2%	34%	-21%	5%	5%	0%
2016	37%	56%	33%	-7%	-30%	-10%	24%	-25%	5%	5%	0%
2017	14%	47%	23%	-12%	-50%	-19%	11%	-5%	5%	5%	0%
2018	-11%	37%	11%	-17%	-70%	-28%	-3%	10%	20%	35%	0%
2019	-39%	25%	-3%	-22%	-89%	-38%	-18%	15%	20%	35%	0%
2020	-66%	13%	-17%	-27%	-100%	-46%	-34%	25%	20%	35%	-20%

In our third scenario, we further simulate activation of increased fishing effort and technical skill on the part of the existing fleet, by applying the decrease in catcheability. New entrants have not been incorporated into this scenario, where the limitations associated with current limited entry law are assumed to be constant. The average age of the licensed fishing population will likely increase by close to one year annually, although some exit of older individuals may be observed and will likely to be offset then by younger new entrants. We have conservatively modeled this as a net zero effect, although in practice the new entrants are likely to possess greater energy and expend more effort than retiring captains.

[2] Changes noted in our assumptions are relative to the base year 2010 survey data; additional years modeling was performed retrospectively and as a forecast in 2015.

5.5 Results

When applied to a baseline condition, our model suggests that most of the fleet was profitable in 2010 (Fig 5.3) and profitability further increases for 2015 (Fig 5.4). These represent the baseline for comparison of the different scenarios. We note that our simulation statistics do not reflect the full uncertainty associated with model projections. Biological characteristics such as growth rates, natural mortality rates, or habitat availability are not fully specified in the landings projections. Uncertainties in market and price response, as well as product form and size and weight have also been assumed to be stable relative to prior time periods. The results must therefore be interpreted in light of these limitations.

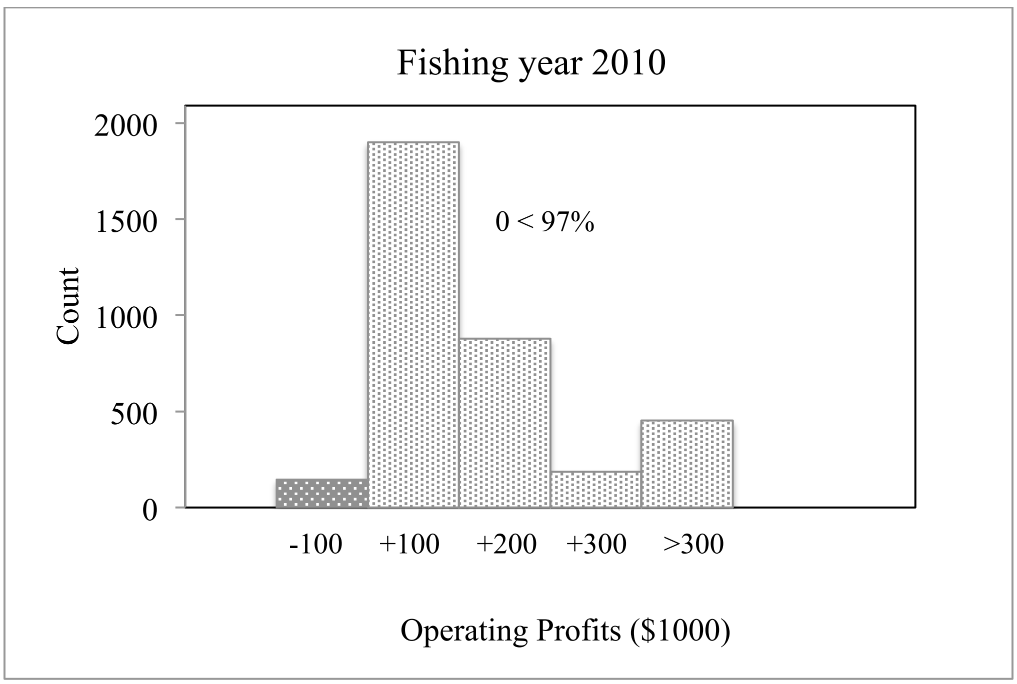

Figure 5.3 Distribution of estimated fleet profitability for fishing year 2010

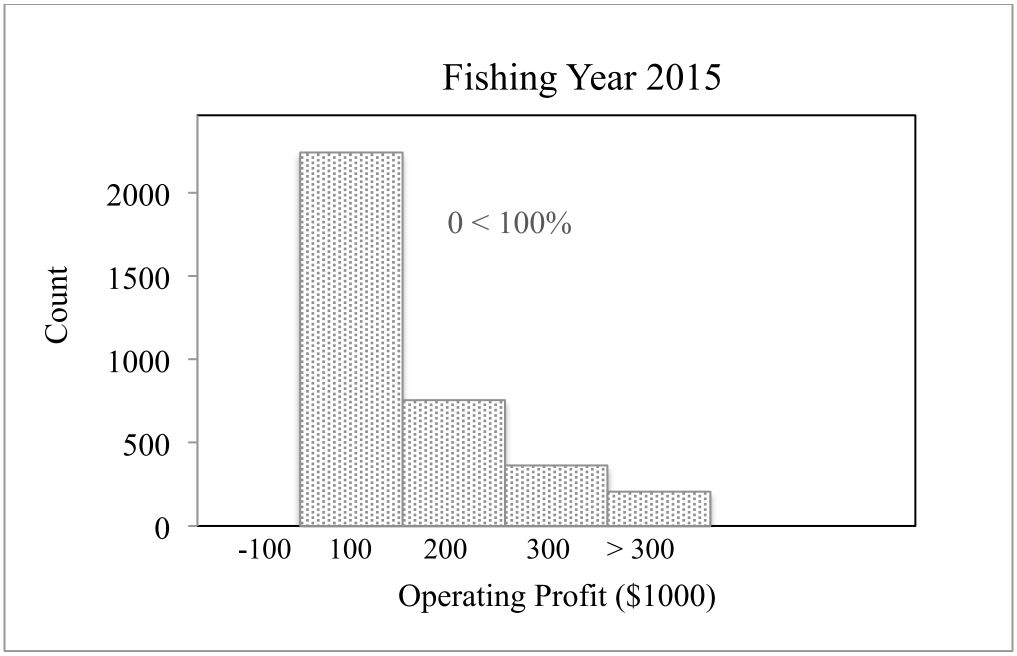

Figure 5.4 Distribution of estimated fleet profitability for fishing year 2015

For 2015, our model indicates 100% of fleet operates above break-even due to lower operating costs such as fuel, and increased landings with marginal price improvements over base year. When aggregated over the fishery, we see that while landings have shown an upward trend, profits have increased as well, but at a faster rate than landings (Fig 5.5); the fleet bears an amount of structural overhead in the form of loans, and other fixed costs which, once overcome, lead to a higher profit margin for the incremental revenue. This presents a very favorable situation for the Maine lobster fleet.

We next consider the profitability under projected landings declines out to 2020 under different market and participation scenarios.

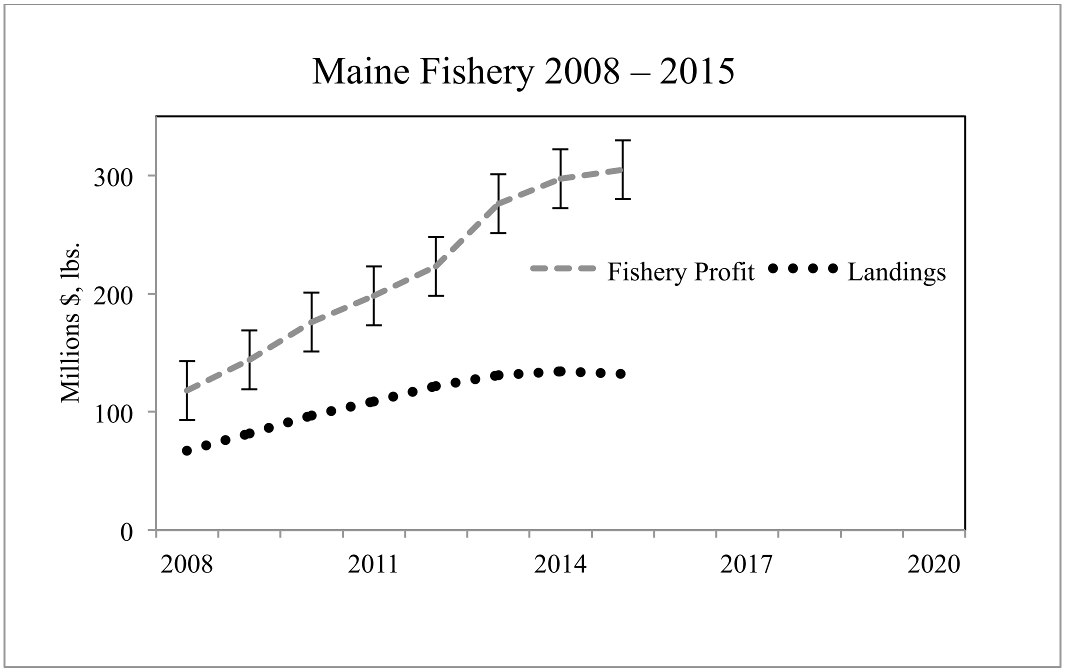

Figure 5.5 Landings and modeled fishery profit for fishing years 2008 - 2015

For our first scenario, where we have used the modeled regional declines in the lobster landings per the projections from the ALSI, and we note that the modeled profitability of the varying vessel classes follows similar trends over the period. Each of the three vessel classes shows a decline in profits by the year 2020 (Fig 5.6), and 45% of the fleet is projected to operate below break-even (Fig 5.7), and comprises largely the smallest vessel class, those with the lowest landings typically, who will be most impacted by the decline. The middle and larger vessel operators will also experience reduced profits, but they are likely to continue to operate above break-even. In aggregate, fleet profitability is projected to decline (Fig 5.8).

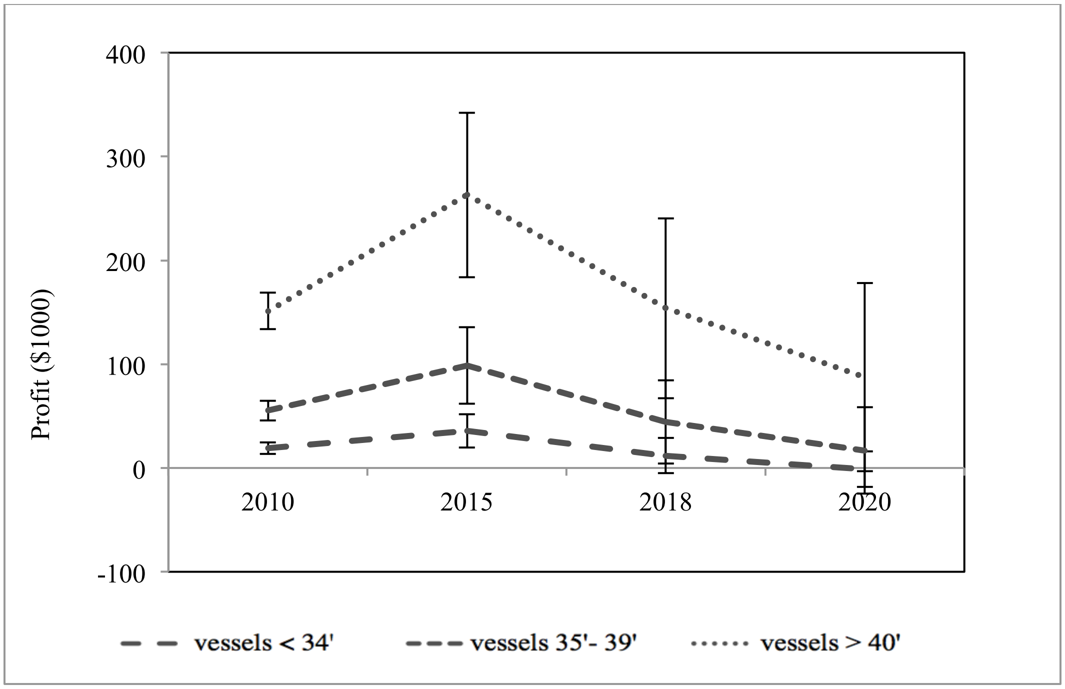

Figure 5.6 Projected vessel level profit for fishing years 2016 - 2020 (Scenario #1)

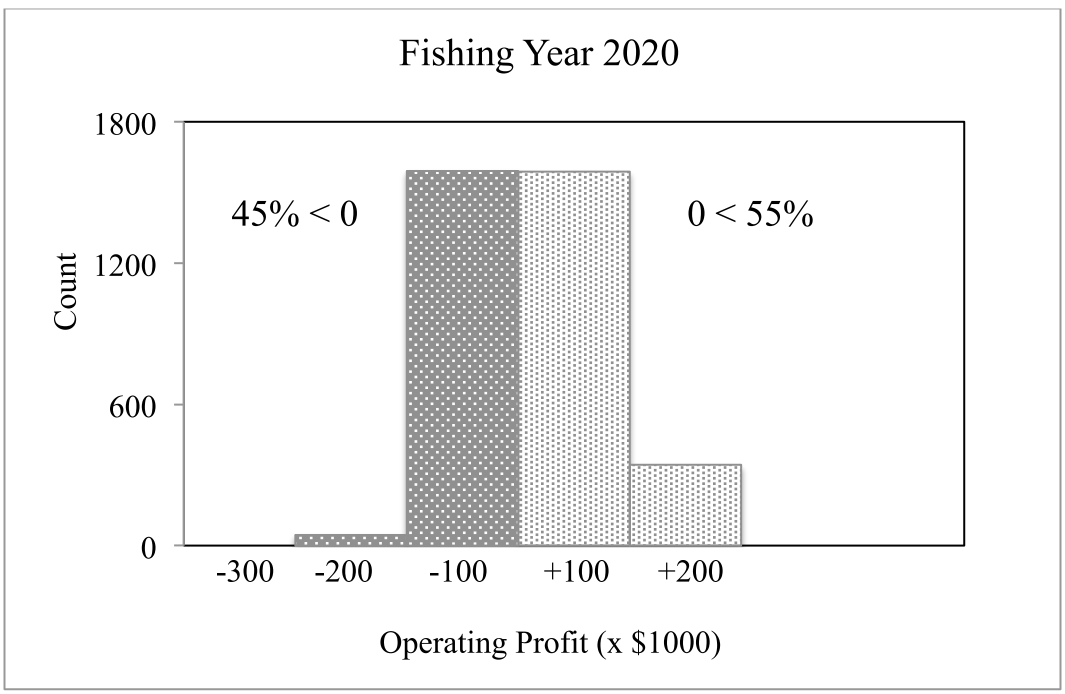

Figure 5.7 Distribution of estimated fleet profitability for fishing year 2020 (Scenario #1)

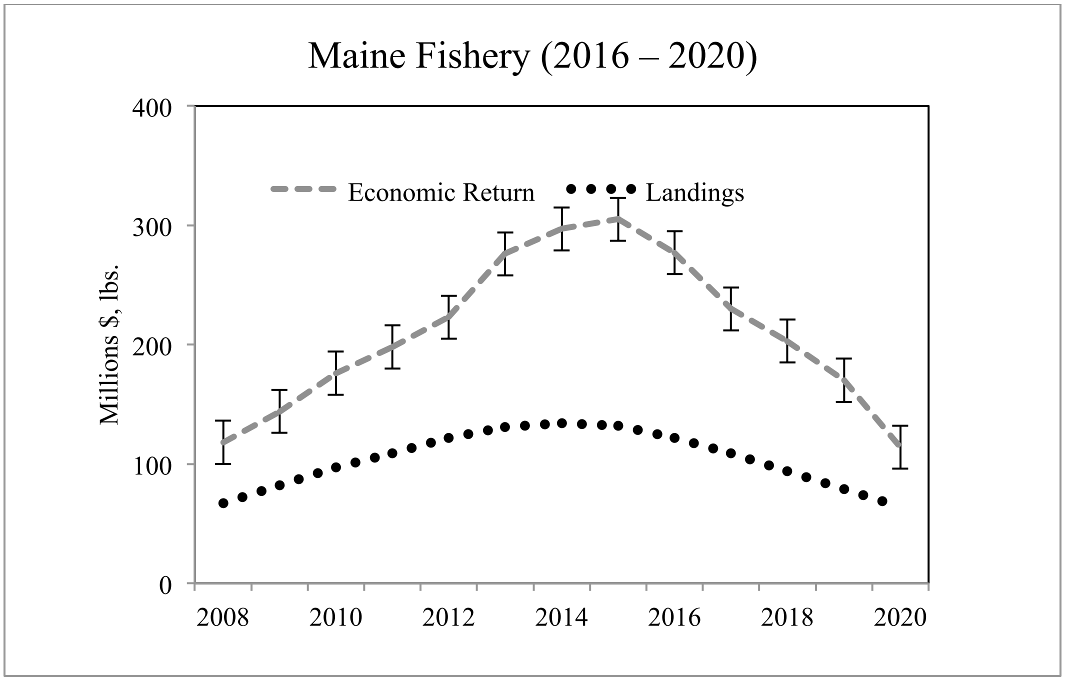

Figure 5.8 Projected total fleet profit for fishing years 2016 - 2020 (Scenario #1)

For our second scenario, we have added in a price response to reflect potential market forces associated with declining supply, and at minimum stable demand.

The effect of the price increase is quite significant on all vessel classes, and our model projects that it will offset the decline in landings for many vessels (Fig 5.9), where an additional 9% of the fleet is likely to benefit and operate above break-even (Fig 5.10). In aggregate, fleet profitability also declines (Fig 5.11) but we see that price response may dampen the impact of the decline in landings.

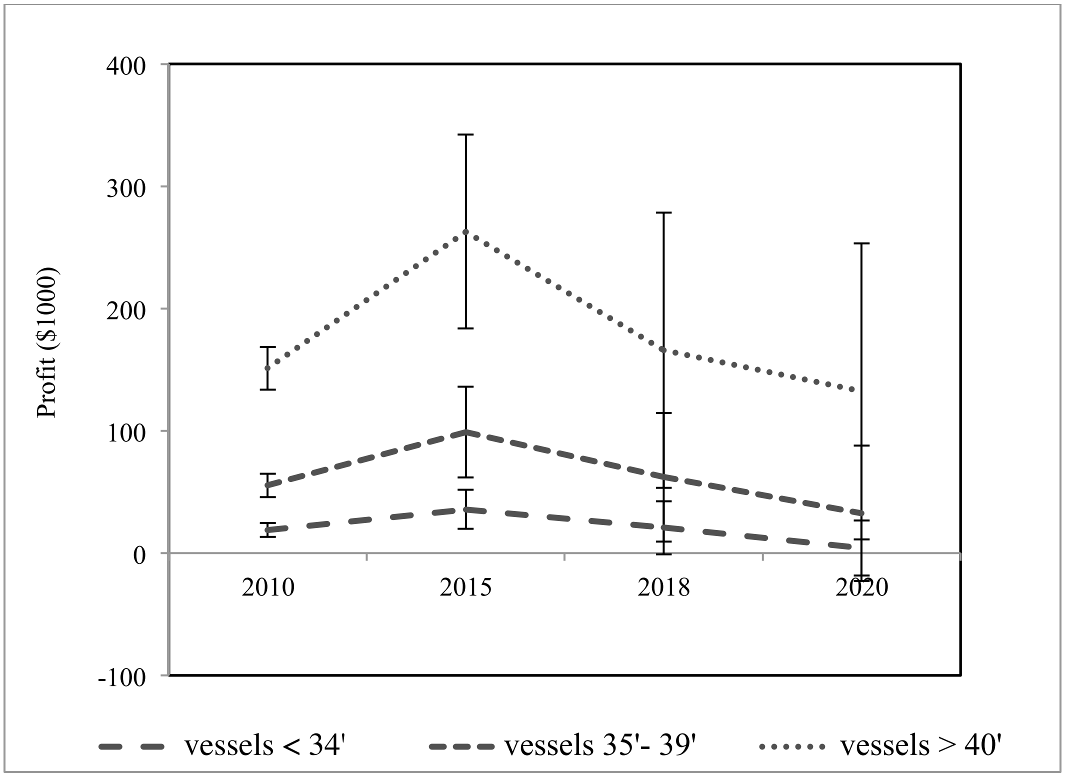

Figure 5.9 Projected vessel level profit for fishing years 2016 - 2020 (Scenario #2)

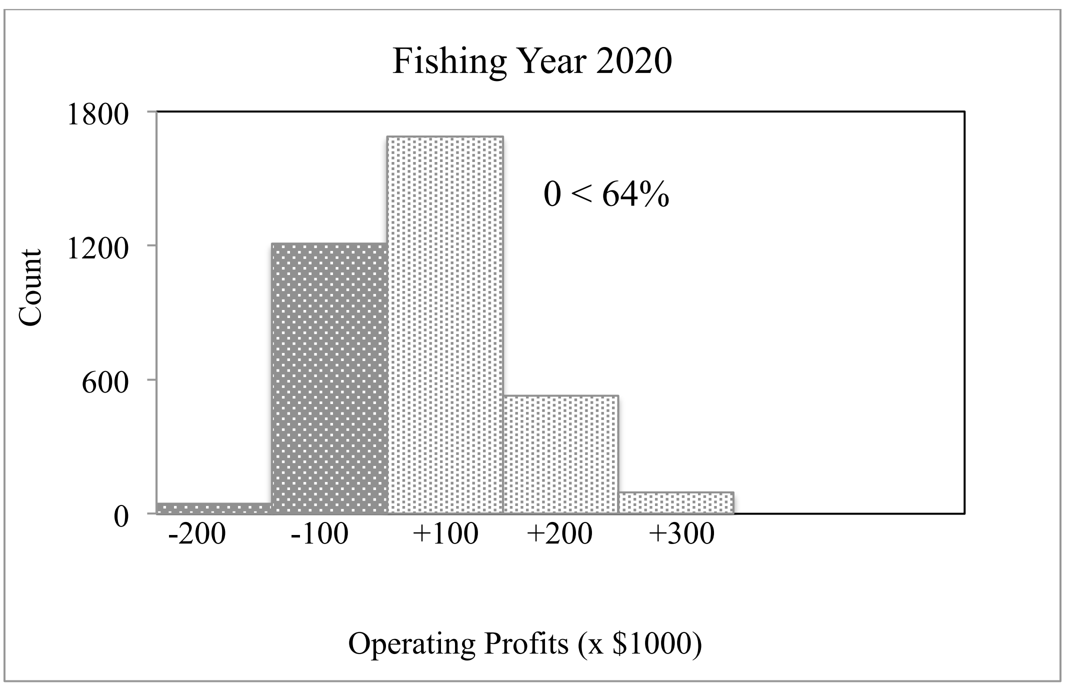

Figure 5.10 Distribution of estimated fleet profitability for fishing year 2020 (Scenario #2)

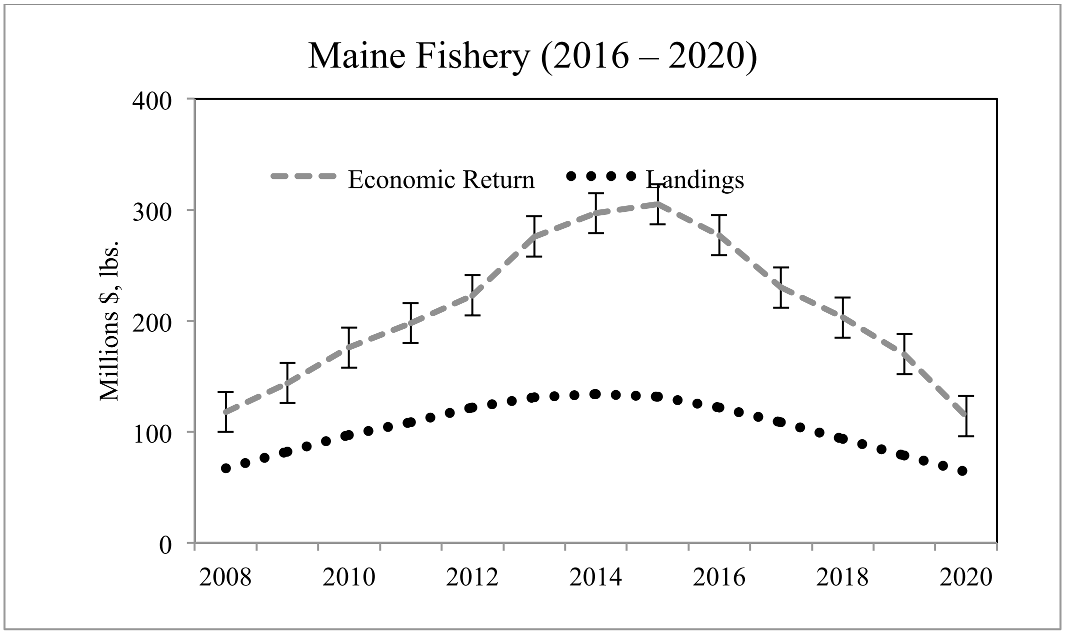

Figure 5.11 Projected total fleet profit for fishing years 2016 - 2020 (Scenario #2)

For our third scenario, we have added in an increase in harvester fishing effort, through activation of latent effort in the form of increased participation rates in the fishery, or an increase in trap hauls on the part of existing fishermen.

The results of scenario 3 show a divergence in the trends for the primary dimensions analyzed versus the previous scenarios. If we compare the individual profitability (Fig 5.12), we note that the two larger vessel classes are now also affected, in addition to the smaller vessel class. Activation of latent effort would potentially cause approximately 60% of the fleet to operate at below break-even (Fig 5.13). This represents a significant impact at the vessel level profitability, and jobs and living wages will be impacted. Interestingly, the aggregate perspective for the fleet as a whole remains relatively unaffected. The aggregated fishery profit in scenario 3 (Fig. 5.14) does not appear to have marked differences from aggregated fishery profit in scenario 2 (Fig. 5.11) and suggests the impacts are less likely to be felt at the level of the Maine state economy, and much more likely to be felt at the individual harvester level. This issue could potentially create very different perceptions of the health of the fleet and the fishery, and could confound efforts to respond to changes and shifts in productivity of the underlying biological resource.

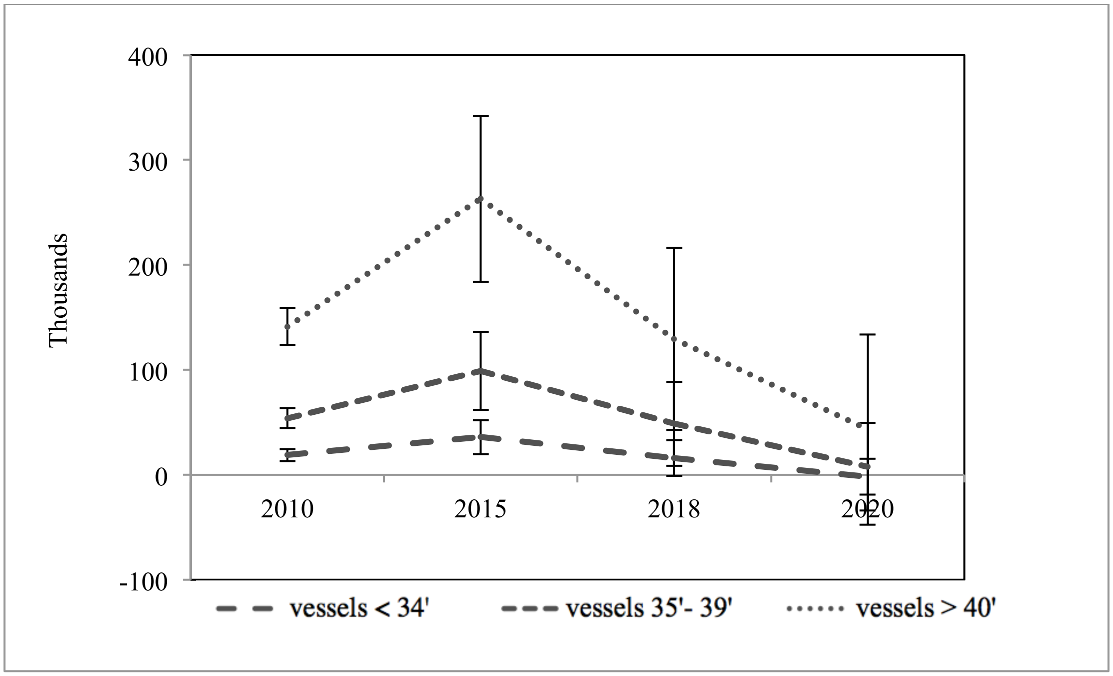

Figure 5.12 Projected vessel level profit for fishing years 2016 - 2020 (Scenario #3)

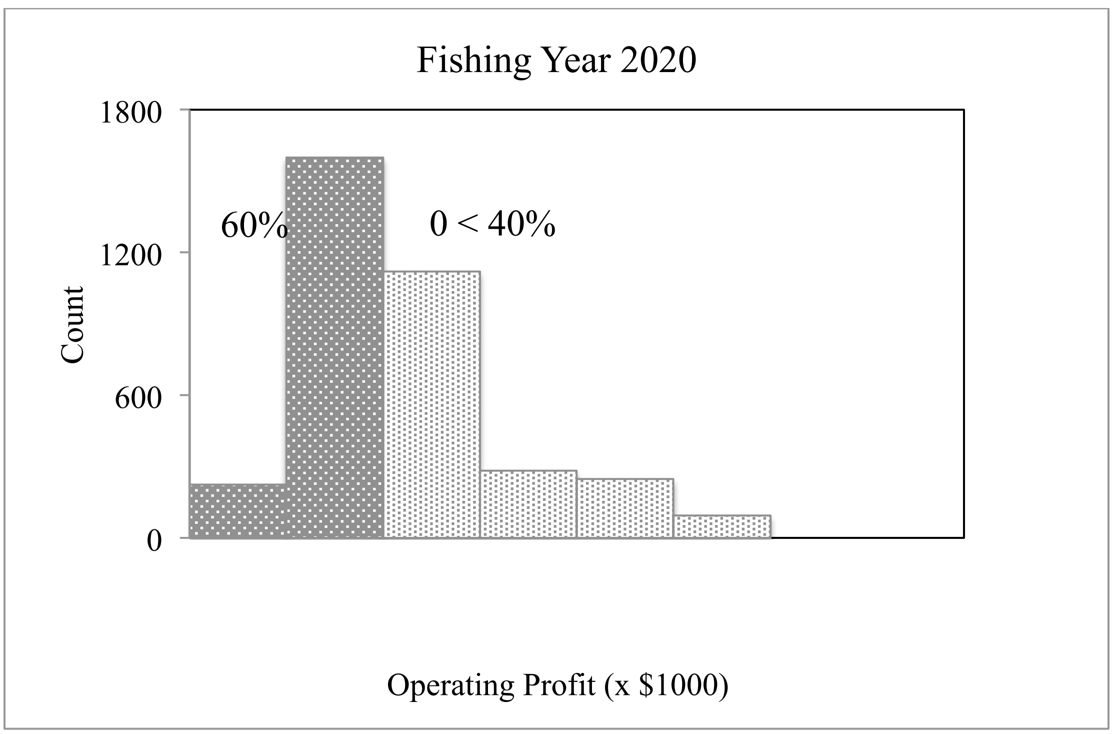

Figure 5.13 Distribution of estimated fleet profitability for fishing year 2020 (Scenario #3)

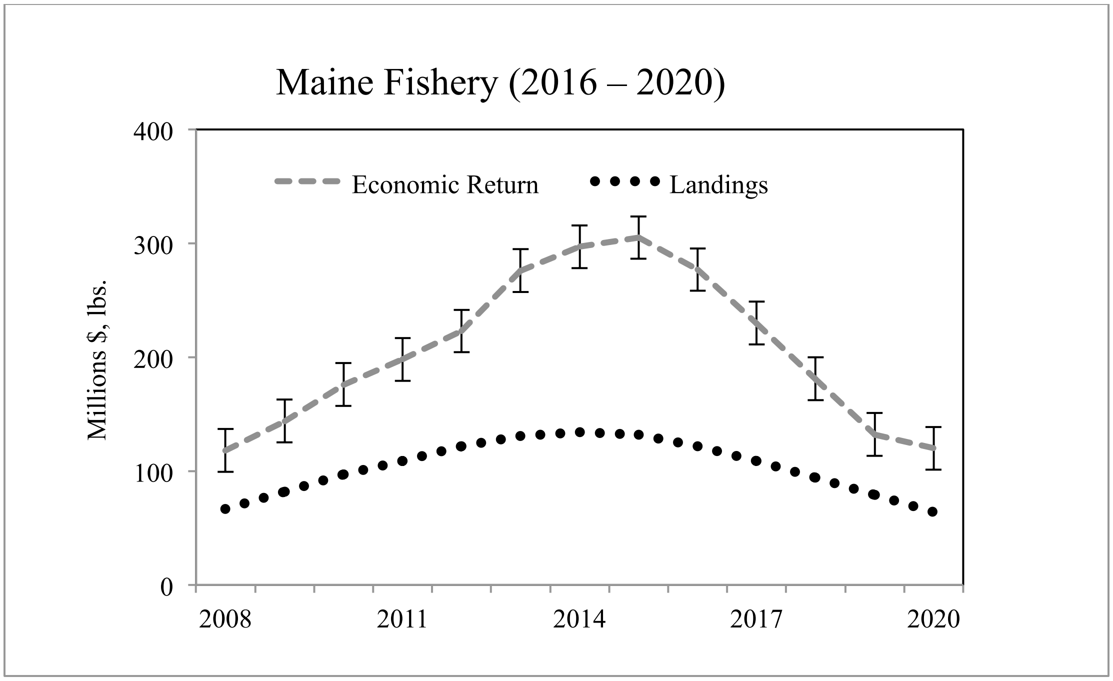

Figure 5.14 Projected total fleet profit for fishing years 2016 - 2020 (Scenario #3)

5.6 Conclusions

Change in the fishery is inevitable. Climate related ecosystem shifts are already being observed in the Gulf of Maine, with warming temperatures and altered thermal habitats (Nye et al. 2014; Friedland et al. 2013; Saba et al. 2015). Phenology is changing (Thomas et al. 2017; Anderson et al. 2013), shifting predator prey dynamics and altering food supplies (Henderson et al. 2017; Morse et al. 2017). Changes in the habitat suitability for lobster are expected (Tanaka and Chen 2015; Tanaka and Chen 2016; Alexander et al. 2018), and changes in molt patterns likely to continue (Staples 2017). We have already observed a decline in settlement (Oppenheim et al. 2017 in progress), portending a decline in landings.

Lobster landings have increased significantly since 1997, and the market has also grown in that time, absorbing the expanded supply more so in 2017 than it was able to in 2004, but ex-vessel price per pound has continued to respond inversely to increased volume. Without changes in the overall market demand for lobster, it is expected that any further expansion of the supply, especially in the second quarter (April – June) and based on our analysis of inventory holdings fourth quarter late season landings may also be impacting ex-vessel prices in the following season as hold over inventory; this trend of late summer landings then is likely to result in further price deflation with a delayed effect, which could have a further negative effect on individual profitability despite beneficial in-season conditions. Conversely, landings volume decreases and market development activities should lead to higher demand and price increases, but in turn may lead to increased participation and activation of latent effort, and so over-fishing is possible.

This analysis suggests that the predictions of climate driven changes such as those which are likely to cause a decrease in landings, or a return to historical landings patterns of the early 1990s, a large proportion of the fleet, as much as 60%, could be facing unprofitable fishing conditions. Effort in the fishery could increase despite the marginal or even negative profits being derived by existing lobstermen. The relationships within the supply chain and the lobster co-management structure will benefit from adapting as well, with science advice and forecasting tools to help inform the discussion. For capital restrictions as modeled here, the ease of substitution among suppliers implies excessive effort, which is consistent with excessive labor inputs. Although rents are dissipated, some stakeholders may see this as a positive outcome because it delivers higher employment in Maine's fishing community (Hilborn 2007).

Prior research (Boyce 1994; McIlgorm et al. 2010) provides an examination of governance choices for fisheries to explain why suboptimal controls such as input restrictions and entry limitation persist in fisheries management. The inefficiency we demonstrated in our research is consistent with these prior findings, and suggests that suboptimal controls such as limited entry benefit input suppliers by transferring rents from the fishery resource to the owners of inputs permitted to operate. Inefficient regulation appears entrenched in Maine, which based on our analysis are to prevent rent dissipation and rent benefit transfer, which is so common and durable, particularly in the U.S. where fishery management councils are heavily influenced by resident input suppliers with organized, entrenched lobbying power.

Similar to other fisheries, Maine may need to consider community support, such as vessel buy back scheme or capital asset taxation, and possible incentives associated with property rights. Biological reference points and harvest control rules (Zhang et al. 2011) based on expected CPUE may also provide some additional tools for managers, so as to protect and preserve the lobster population and the economic engine of Maine's fishery. Further research is suggested around target fleet capacity and optimum yield for the fishery (MEY) (Reid et al. 2013), as a precursor to possible change in the Maine lobster fishery and we the analyses provided herein as baseline for comparison.

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6. CONCLUSION

In this thesis, we examined the Maine Lobster fishery as an example of an ecosystem on the brink of change. Over the past twenty years, lobster governance in Maine has undergone many small adjustments in response to fishery, economic, and ecosystem changes, and adapted in keeping with the goals of the community. Maine has built a model of self-governance and regional management, that reflects the heritage upon which is has been built. The limited-entry licensing program, which guides policy-making, has retained an owner operator provision, and stock conservation efforts such as V-notching of berried females have protected the fishery and the fishermen. Long-standing cooperative relationships along the supply chain have ensured stable market conditions and strong and positive diplomatic and scientific relations with neighboring Canada have allowed for an efficient and cooperative trade. Ensuring livelihoods and protecting the next generation also feature prominently in the goals of the Maine lobster community, and an apprenticeship has provided a mechanism for knowledge-transfer and safety of the fleet. This ecosystem has adapted to small stresses and withstood change, but the research provided in this thesis would suggest that the Maine lobster fishery may have lost some resilience, and may be vulnerable to a complete restructuring as a result of observed climate shifts. This research provides a series of intertwined analyses to aid in the process of answering complex questions about ecosystem adaptation to climate driven changes.

Our research has uncovered weaknesses in the ability of fisheries resource management to protect from over-fishing and ensure continued stability in supply and demand relationships, exposing fishermen to large swings in ex-vessel price. Long term changes are poised to occur as the water temperatures in the Gulf of Maine continue to increase and approach the lobster threshold of 20.5 degrees Celsius, leading to a continued cascade of habitat changes, such as the life history response to increase metabolic and growth rates, which already appears to be resulting in an evolutionary decrease in average age of maturity (Wahle at al. 2013).

Permanent ecosystem restructuring and regime shifts, with changes in abundance of historical key species such as ground fish, scallops, and shrimp, are already being observed including the immigration of black sea bas, and squid and emigration of shrimp and cod (Frank 2005). Long term changes in the human component response also include the migrations are showing fishermen take on migrant worker habits, often traveling long hours on land to then board a fishing vessel in a different location. Young people find it increasingly difficult to derive a full wage in certain portions of the state of Maine, and an ageing of the fleet has been observed. Some fishermen from the Maine lobster fleet have permanently resettled closer to the fishing resource, others have taken multiple jobs, reflecting a start to pluralism, as predicted and observed in other research (Hobday et al. 2016).

To help inform continued adaptation on the part of the community, I have evaluated four dimensions of the Maine lobster coupled human and natural ecosystem, to uncover opportunities and threats to the fishery, and build on our collective knowledge of how fisheries respond to large ecosystem changes. In this research I applied a variety of inter-disciplinary techniques to look at the complex fishery in a holistic way, such as non-market valuation techniques including surveys and contingent valuation methods, which originally were developed in support of other natural resources such as agriculture, and production efficiency analysis, typically used in fisheries aquaculture producer settings and with growing application for wild and trap fisheries. I also employed bio economic modeling techniques to build on growing body of knowledge in tis area, and I applied a unique blend of econometric and social engagement techniques, where data collection is combined with field interviews to derive meaning.

In chapter 2, I have provided a series of production function performance baselines for future comparison, and to demonstrate potential efficiency gains on the part of lobstermen. Empirical results highlight the differences in technical inefficiency among vessel classes, and signal that societal benefits associated with employment levels have characterized the lobster production environment, over firm-level efficiency. We note a latent potential capacity increase on the part of existing lobstermen, through increases in skill and technical efficiency, and where this fishery places restrictions on number of traps, but not trap hauls or total removal quantity. This fishery, which is managed by input controls, has a 30% latent capacity and effort escalation is poised to occur.

In chapter 3, I look closely at current Maine limited entry licensing policies, and community goals, which resoundingly focus on the practice of ensuring the entry of young people as apprentices, ensuring the stability of the number of licenses and trap tags, and ensuring financial viability for existing Maine lobster businesses. This research also determined that if licenses were transferrable, incoming new entrants would be willing to pay an average of $16,665 for a Maine lobster license, and an average of $1,896 per trap tag, with those individuals seeking full time fishing willing to pay more than average.

Landings patterns have changed in the Maine fishery, and routes to market and market response underpin the determinants of price. We found ex-vessel price in the Maine lobster fishery varies according to an inverse demand price response. Lobster landings volume tends to be based on the underlying ecological conditions as well as environmental factors, stock status, and input control regulatory limits, and not by price. Volumes of landings and projected volumes of landings then serve as a proxy for the total expected volume for the fishery and this in turn provides the basis for ex-vessel pricing. This research demonstrates that the recent addition of late season harvest contributes to excessive dealer inventory holdings over the winter, not just for the U.S. dealers, but neighboring Canadian processors as well. The combined effect of these product volumes has a direct negative effect on in-season ex-vessel price and introduces uncertainty in the business of lobstering.

I applied a retrospective analysis against a baseline year to evaluate future profitability and economic performance in the fishery, under potential changing conditions facing the coupled natural and human system. We looked at both the individual harvester level impacts and compared this to the statewide impact of change. The production functions suggest overcapitalization in the Maine Lobster fishery, which is likely to confound efforts to effectively manage the resource in times of changing harvest patterns, and in light of variability in supply and changes in market demand. The fleet capitalization has implications and non-malleability of human and operating capital.

Further research is recommended to build on the research methods applied in this thesis and enhance the resolution and applicability of the findings. An optimization question remains for the

Maine lobster fishery fleet capacity, and a simultaneously simulated bio economic model would allow for iterative modeling and better estimation of uncertainties associated with our models. More broadly, fisheries managers would benefit from specifically looking to enhance Maine's unique limited entry system and developing further options for foundation change that will support what is likely to be major ecosystem restricting in the years to come (Dietz et al. 2003). Lessons and findings from other similar fisheries around the globe and linking with current ongoing research in Maine, much of it with lobster fishermen as collaborative partners, provides a basis for adaptation planning and community discussion. Industry-partnered independent fishery surveys, with specialized gear to capture ecosystem parameters over time also enhances the dialog around mitigation and behavior change, where all parties trust in the data provided. Or building on recent work to develop a harvest control framework for Maine lobster (Zhang et al. 2011), and establishing thresholds for action according to in-season indices. This would create a nimble and rapid response to compliment traditional stock assessment methods, which at times lag behind observed trends due to data quality. Combined these yield a robust management framework. Further research into mechanisms to stabilize product volume spikes through supply chain collaboration, continued market development and trade relations with Canada, could bolster Maine's return from the lobster fishery. Researchers in Australia have shown favorable results with management strategy evaluation that incorporates maximum economic yield concepts and metrics (Reid et al. 2013). This could in turn provide stability to the community upon which young families and the next generation can plan a future.

In conclusion, the dynamic environment of the Maine lobster fishery in the Gulf of Maine offers a unique study system to evaluate the short and long term effects of anthropogenic changes in our environment, such as those associated with climate change. The lobster fishery has observed both large and small changes from historical patterns, with temperature rising faster in the Gulf of Maine than other bodies of water, and will need to continue to adapt to new inputs and stressors and change in an ecosystem where uncertainty and high variability have become the norm.

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APPENDIX A: INDUSTRY COST SURVEY DESIGN AND RESPONSE

In collaboration with Maine Lobsterman's Association, we conducted a comprehensive survey of the New England Lobster Industry. The target population consisted of all lobster permit holders in Maine, New Hampshire, and Massachusetts who fish in Lobster Management Area 1 (LMA 1) and landed at least 1,000 pounds of lobster in 2010. The goal of was to conduct a census among this group of lobstermen, and capture input and outputs associated with lobstering businesses, as well as demographics of the industry.

Sample Frame

The list of potential respondents was generated using lobster license lists provided by Maine, New Hampshire, and Massachusetts, and our overall survey response rate was 43%. Throughout the course of this research all 7,346 lobstermen included on the list were contacted by one or more of the following methods: mail, email, or phone (Dillman 1991).

Table A.0.1 Summary of industry survey response rates

	Response Rate	Cooperation Rate	Completion Rate
Maine	44%	81%	98%
New Hampshire	37%	84%	100%
Massachusetts	35%	74%	96%
Total	43%	80%	98%

* Cooperation rate indicates they responded and began the survey; completion rate indicates the number who completed the entire survey.

Respondents were given the option to take the survey online or by telephone. Data collection began on April 11, 2011 and was completed by June 16, 2011. A total of 1,001 active lobstermen were interviewed during this period including 163 who completed the survey online and 838 who completed the survey over the telephone. Lobstermen were called up to 15 times by telephone until a contact was made and the lobstermen completed the survey or expressed that they were not interested in 2011 Lobster Industry Study and taking the survey. Most respondents did not require all 15 calls. On average 5.4 calls were made to each number in the sample list.

Respondents provided a great deal of information about their lobster business. The goal was to obtain accurate information about the lobster business while limiting the time commitment required of the respondent. On average, the 1,001 interviews required 23.3 minutes each. While it was difficult to get an eligible participant on the phone, once a potential respondent was on the phone they were likely to cooperate and once they began the survey they were almost guaranteed to complete the survey.

Our survey penetration by Maine lobster Zone shows an average 23% of total potential lobstermen were surveyed. Survey coverage of Zones C and F was slightly less than the overall average at 18% and 19% respectively, and overall the number of responses within each zone provided sufficient statistical power to perform the analyses included in this report. These penetration rates were used to weight responses in our analyses.

Table A.0.2 Maine LCMA I survey penetration rate by Maine lobster zone

	Total # Licenses*	# Survey Responses	% Penetration
Zone A	721	177	25%
Zone B	395	93	24%
Zone C	653	118	18%
Zone D	720	187	26%
Zone E	272	81	30%
Zone F	494	92	19%
Zone G	241	92	38%
Overall	3,496	840	23%

* Includes LC1, LC2, and LC3 license holders only
*who land more than 1,000 lbs. of lobster per year.

Table A.0.3 Survey responses by vessel category

Vessel Length Category:	Overall Average	34 and below	35 to 39 feet	40 and above
Vessels w/lbs. > 1,000 (#)	3,496	1,641	1,218	637
Total Surveyed (#)	1,001	461	373	167
Survey population (%)	29	28	31	26

Data Collected Through the Survey

The survey questionnaire that was used in the 2011 Lobster Industry Study was developed in collaboration with the Maine Lobstermen's Association, and input from other industry representatives and associations such as Massachusetts Lobstermen's Association. The basic components of the 2011 survey gathered information from active lobstermen fishing inshore in the designated area LMA 1 on the following areas of their fishing operations:

- Vessel Characteristics
- Lobster Business Financing
- Lobster Fishing Effort by Quarter
    a. Maximum Traps Fished
    b. Trap Configuration
    c. Number of Traps Hauled per Day
    d. Soak Time
    e. Time Spent on each Fishing Trip
    f. Days per Week Spent Fishing
    g. Number of Sternmen Taken on each Trip
    h. Steam Time to Fishing Grounds and Fuel Used
- Time Spent on Gear Maintenance and Repair
- Time Spent on Paperwork for Lobster Business
- Other Fishing Activities Besides Lobster Fishing
- Total Pounds of Lobster Landed
- Revenue Generated by Lobster Business
- Type, Amount and Cost of Bait Used for Lobster Fishing
- Other Lobster Business Expenses
    a. Fuel
    b. Oil Changes
    c. Crew
    d. Gear and Vessel Maintenance and Repair
    e. Other Gear Purchases

f. Insurance
g. Costs of Storing and Hauling Vessel
h. Cost of Other Vehicles Used for Business
i. Administrative Costs (office supplies, association dues, etc.)

- Percentage of Household Income from Lobster Business

Data Preparation and Audit Process

Any survey process can result in erroneous reporting or recording of data. To ensure the accuracy of the data, we conducted data consistency checks on the data files. As a part of the data file preparation and analysis, the first stage of this process involved checking all data to insure that responses were consistent. This process involves insuring that respondents were asked appropriate questions based upon earlier responses to variables, skip patterns were followed based upon appropriate responses to earlier items, and that respondents provided consistent answers to questions on related concepts.

The initial steps of data consistency checks were programmed into the survey instrument themselves. The programmed data checks insured that respondents were directed to appropriate questions and that answers to some key issues were verified. The next step involved using notes gathered during the interview that indicated different answers to those given. For example, some lobstermen provided responses that they then changed by the end of the survey. Instead of going back to the original question they simply added information at the end of the survey describing their updated response and these were coded into the data. Finally, data were analyzed for inconsistencies between related questions and corrected. If it was possible to deduce an unanswered question from answers to other questions then the original question was modified to reflect those other responses. For example, if a lobsterman said they were active during a particular quarter and then provided 0's for all follow-up responses the questions were amended to be consistent. In the case of the above example, the lobsterman was considered as not active during the quarter in question. In general, however, unless responses were clearly inconsistent between two related questions responses were left as the respondent indicated during the survey.

Additional Data Used In the Analysis

The survey gathered quarterly cost and effort data from individual lobstermen and to ensure maximum participation rates did not collect corresponding quarterly harvest output data. So that we could analyze the data quarterly and generate estimated quarterly profitability, we secured permission to link this survey data with the mandatory dealer reports, and aggregated this at a broad scale to ensure confidentiality of individual harvesters. The data were stratified first by State, and within Maine again refined by Maine Lobster Zone, which provided regional perspective on the survey findings. We also stratified the data according to lobster vessel length category, and also by calendar quarter. Survey penetration rates were used to weight the responses when generating overall averages for the entire population.

Survey Results and Summary

Fishing Effort

The estimate of the number of lobster traps deployed along the coast of Maine has been the subject of many debates. The number of sea surface marker buoys certainly makes the coast appear densely fished, at the same time GPS technologies, grapple hooks and new trawling up requirements mean there is less visible evidence of the true effort underway. It has become a younger man's job -- for the pace is rigorous, and hauling and baiting a full string of traps is hard work.

Our survey reveals that during the 1st quarter of 2010 (January to March) three in ten active lobstermen had landings. In the 1st quarter, on average, lobstermen had a maximum of 530 traps in the water (versus 450 traps in 2005), made two trips per week where they hauled traps, and hauled about 260 traps during each trip. Active lobstermen who fished during the 1st quarter reported landing just over 700 pounds of lobster on average, as compared to a similar study in 2005 when they reported landing just under 900 pounds of lobster on average.

During the 2nd quarter of 2010 (April to June) our survey shows three-quarters of active lobstermen had landings. In the 2nd quarter, on average, lobstermen had a maximum of 575 traps in the water (versus 480 traps in 2005), made three trips per week where they hauled traps, and hauled about 252 traps during each trip. Active lobstermen who fished during the 2nd quarter reported landing about 2900 pounds of lobster on average, no change from 2005.

During the 3rd quarter of 2010 (July to September) our survey shows 9 out of 10 active lobstermen had landings. In the 3rd quarter, on average, lobstermen had a maximum of 630 traps in the water (versus 557 traps in 2005), made four trips per week where they hauled traps, and hauled about 256 traps during each trip. Active lobstermen who fished during the 3rd quarter reported landing about 17,500 pounds on average, which is up significantly from 2005 when they reported landing 10,900 pounds of lobster on average.

During the 4th quarter of 2010 (October to December) our survey shows 8 in 10 active lobstermen had landings. In the 4th quarter, on average, lobstermen had a maximum of 624 traps in the water (versus 550 traps in 2005), made four trips per week where they hauled traps, and hauled about 258 traps during each trip. Active lobstermen who fished during the 4th quarter reported landing about 11,200 pounds of lobster on average, which is up from 2005 when they reported landing 10,500 pounds of lobster on average.

As a medium-term effort comparison, it is interesting to note that these effort reports trend closely with the survey responses provided in similar studies conducted in prior 5-year period. This suggests that on average fishing effort levels and fishing behavior have remained relatively constant over this 5 year period of time, although fishing locations may have changed and the average number of traps deployed per person increased in aggregate in all calendar quarters.

In our survey, we observed differences between vessel classes across the calendar quarters, which provides insight the differences in fishing techniques and skill that result in different levels of quarterly catch, revenue, and in turn annual profits for each type of fishing operation.

Table A.0.4 Fishing effort expended within each quarter

Vessel Length Category:	Overall Average	34 and below	35 to 39 feet	40 and above
Quarter 1				
Actively Fishing (%)	28	14	35	54
Number of trips (#/qtr)	29	29	27	30
Soak Time (days)	7.53	7.07	7.59	7.91
Max Traps (#/qtr)	482	362	536	692
Traps Hauled (#/trip)	243	204	259	315
Steam Time (hrs/trip)	1.17	0.78	1.18	1.55
Quarter 2				
Actively Fishing (%)	77	73	81	82
Number of trips (#/qtr)	46	47	45	45
Soak Time (days)	4.69	4.62	4.71	4.72
Max Traps (#/qtr)	531	414	594	718
Traps Hauled (#/trip)	234	193	247	313
Steam Time (hrs/trip)	0.66	0.47	0.61	0.90
Quarter 3				
Actively Fishing (%)	94	94	95	93
Number of trips (#/qtr)	55	53	56	56
Soak Time (days)	3.67	3.65	3.71	3.64
Max Traps (#/qtr)	592	474	665	756
Traps Hauled (#/trip)	238	197	252	320
Steam Time (hrs/trip)	0.57	0.49	0.49	0.74
Quarter 4				
Actively Fishing (%)	85	78	92	90
Number of trips (#/qtr)	50	48	51	52
Soak Time (days)	4.37	4.08	4.89	4.11
Max Traps (#/qtr)	582	466	648	758
Traps Hauled (#/trip)	239	198	253	322
Steam Time (hrs/trip)	0.81	0.57	0.77	1.08

We first note a large number of similarities among vessel classes, for those vessels which are active in the quarter we see a similar average number of trips, and the soak time per trap fished in the quarter do not vary widely across the vessel categories. As well, active fishermen tend to haul through a similar percentage of their traps with each trip. We have concluded that these variables do not account for the observed differences in profitability. However, the variable Traps Hauled (#/trip) and Steam Time (hrs/trip) (with which a distance traveled variable was created) provide good insight into distinguishing features of each vessel category and helps to explain observed variation in profitability, which is further explored in this analysis.

Table A.0.5 Maine household dependence on lobstering and opportunity cost of labor

Zone:	A	B	C	D	E	F	G
Household income %	77%	77%	81%	74%	64%	61%	69%
Alt. Earnings/hr.	$13	$17	$15	$16	$28	$20	$39

The State dependence on lobstering as a profession is captured in table 2.5, where we see between 60% and 81% average dependence household on lobstering. The wage that individuals could earn if not lobstering also ranges greatly, from a low of $13 in the more rural and eastward portions of the State, to as high as $39 for western-most zones in the State. These values inform our profitability and economic return assessments, by zone.

Operating Expenses

Fishing expenses include the startup costs and licensing fees but on an ongoing basis fisherman incur expenses associated with labor, fuel & bait, annual vessel operations and maintenance, and business operations. These expenses on average show labor as 19% of gross income, bait at 15% of gross, fuel at 10% of gross, vessel & gear maintenance expenses at 24% and administrative expenses at 6%. The details of each expense type are explored in greater detail in the following sections.

Bait Usage

The price of herring bait has significantly increased from $25 per barrel in 2000 to $150 per barrel in 2010, a 500% increase (Acheson and Acheson 2010). Furthermore, the herring industry faces a strict regulatory environment, with decreasing catches and increasing demand from Thailand, and eastern Asia.

In our survey we collected information on the types of bait fished during the calendar quarters, and the cost expended on bait, and also units of bait purchased. Information was provided in great detail and collected in free text form, to retain as much value to the analysis as possible.

However, the variability in how much volume each of these bait units represents by bait type, and region of purchase, has *confounded our efforts to derive bait quantity* deployed from our survey. We therefore focus our analysis on bait types *and bait costs, as a proxy bait quantity* deployed.

The bait types used vary significantly by region, reflecting the localized nature of this component of the industry. Herring remains the most widely used and efficient bait type, and the industry dependence on the continued availability of this pelagic species is deemed very high, and represents approximately 85% of the bait used. In Southern regions of the state pogies have become available as an alternative bait source, and redfish have become a choice for certain mid-coast fishermen and sparsely in southern Maine. Racks, once very popular bait are now only seen used in New Hampshire fishing operations. Most experienced fishermen create a mix of bait, which they believe is more efficient and appealing to discerning lobsters.

Table A.0.6 Bait type used by Maine lobster zone for fishing year 2010

	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	Zone G	MA	NH
Herring	90%	86%	73%	73%	84%	37%	75%	76%	60%
Pogies	3%	2%	0%	15%	14%	39%	11%	13%	4%
Redfish	1%	8%	12%	4%	1%	19%	8%	0%	0%
Racks	1%	2%	1%	2%	0%	1%	1%	6%	26%
Alewives	1%	1%	0%	1%	0%	0%	0%	0%	0%
Other	4%	2%	13%	5%	0%	4%	4%	4%	9%

Fuel

The price of diesel fuel has increased from $1.50 per gallon in 2004 to as high as $4.70 per gallon in 2008, $4.00 per gallon in 2013 and back down to $2.50 per gall on 2016 (U.S. Energy Information Administration). This cost is passed along the entire supply chain, making transportation one of the biggest expenses facing the lobster industry. Engine oil is another area of expense and time, and in our survey we found differences in the cost of an oil change, ranging from $85 to $186, and averaging $118 each time. Lobstermen typically change their oil 5 to 6 times per year, and so this expense can be significant.

Table A.0.7 Average fuel consumption per fisherman by calendar quarter

Vessel Length Category:	Overall Average	34 and below	35 to 39 feet	40 and above
Quarter 1 Fuel (gal/trip)	44	21	41	71
Quarter 2 Fuel (gal/trip)	30	14	27	48
Quarter 3 Fuel (gal/trip)	26	14	27	48
Quarter 4 Fuel (gal/trip)	33	16	30	54

The strong seasonal differences in fuel and oil consumption reflect the weather conditions, distance traveled and spatial distribution of the lobster resource. Larger vessels are able to overcome these structural cost differences in the winter months, and fish profitably. In summer months none of the vessel categories experience a benefit, and the larger vessels may be over capitalized to profitably fish closer to shore.

Labor

One of the biggest expenses lobstermen can chose to incur or not is that of a crew. Most of the large vessels report bringing 2 crew per trip year round. More than half of the smaller vessels tend to fish without a sternman, although we see an increase in crew size for the third quarter of the year when the peak volume is landed, for all vessel categories.

Table A.0.8 Vessel level crew and labor expenses

Vessel Length Category:	Overall Average	34 and below	35 to 39 feet	40 and above
Average Crew Share (%)	20	20	20	20
Average Annual Crew Cost ($)	9,954	6,074	8,515	23,878
Quarter 1				
Actively fishing (%)	28	14	35	54
w/Crew aboard (%)	24	8	31	53
Crew earnings ($/trip)	822	462	693	2,105
Quarter 2				
Actively fishing (%)	77	73	81	82
w/Crew aboard (%)	55	38	67	76
Crew earnings ($/trip)	1,020	814	941	1,771

Quarter 3				
Actively fishing (%)	94	94	95	93
w/Crew aboard (%)	68	52	79	89
Crew earnings ($/trip)	1,184	983	1,130	1,861
Quarter 4				
Actively fishing (%)	85	78	92	90
w/Crew aboard (%)	63	43	77	86
Crew earnings ($/trip)	1,181	930	1,114	2,026

Crew wages are largely based on a percent of the revenue, after fuel and bait expenses have been deducted. Crews are typically paid extra for time on gear maintenance, vessel maintenance and other related tasks. Typical crew earnings reported in our survey are approximately $9,954 per year and range typically from $6,000 to $25,000, with some crew earning more or less than this. Zones A, B, and C have few other economic opportunities, and the wage earning potential outside of lobstering is low, with Zone A reporting a $13/hour potential alternate wage. Conversely, southern regions, especially those with strong tourism such as Zone G, offer more economic opportunity and the potential wage reported is much higher, at $39/hour. Compared to a similar study in 2005, dependency on the fishery increased across all regions as other job opportunities decreased.

Maintenance

Lobstermen work hard, and lobstering is a full-time year round job when all aspects of the business are included. Gear maintenance and repair often represents a significant investment of time and effort on the part of the fisherman. Average annual equipment repair expenses total $30,433, of which $24,000 is related to the vessel and gear, and another $6,000 is related to administrative expense. In our survey, fishermen report expending significant amounts of time on gear maintenance, specifically: 17 hours per week in Q1 and Q2 when foul weather can damage gear and traps whereas they expend and average of 5 to 7 hours per week in each of Q3 and Q4 when weather tends to be more favorable.

Table A.9 Annual vessel-level operating cost summary

Vessel Length Category:	Overall Average	34 and below	35 to 39 feet	40 and above
Bank Fees ($)	860	392	1,266	1,245
Boat Hauling & Storage ($)	606	455	618	994
Safety Equipment ($)	909	501	1,070	1,677
Equipment Maintenance ($)	8,468	4,705	10,150	15,101
Equipment Taxes ($)	1,268	976	1,351	1,885
Mooring and Wharf Fees ($)	702	383	895	1,150
Office Supplies ($)	350	231	382	613
Permits & Tags ($)	778	671	840	937
Trap Replacement ($)	760	570	850	1,060
Vehicle Costs ($)	4,752	3,901	5,450	5,545
Vessel Maintenance ($)	7,792	4,254	9,346	14,087
Vessel Operations ($)	907	461	987	1957
Vessel Insurance ($)	2,282	1,537	2,515	3,819
Total Expenses ($)	30,433	19,040	35,722	50,072
Vessel Maintenance Total ($)	23,975	14,514	27,773	41,608
Admin Costs Total ($)	5,963	4,524	7,098	7,403

Vessel Performance Measures

Based on the data collected net return was positive for all vessel size classes ranging from a low of 26% of gross revenue to a high of 29% of gross (Table 2.11). While net returns above variable and fixed costs were all positive they do not account for the opportunity cost of capital or the opportunity cost of the owners labor. These opportunity costs provide a measure of whether capital would be better used in an alternative investment and whether the vessel owner would be financially better off in an alternative occupation.

Table A.10 Annual vessel-level operating profits by vessel category

Vessel length category:	Overall Average	34 feet and Under	35 – 39 feet	40 feet and Over
Gross Revenue ($)	97,333	56,132	114,331	173,103
Bonus Amount[1]	12,304	6,499	13,037	26,693
Variable Costs ($)[2]	42,810	24,223	51,795	74,053
Variable Costs % Gross	44%	43%	45%	43%
Fixed Costs ($)[3]	29,676	18,468	34,870	49,011

Table A.10 continued

Fixed Costs % Gross	30%	33%	30%	28%
Net Return ($)	24,847	13,440	27,666	50,040
Net Return % Gross	26%	24%	24%	29%
Cost of Capital ($)	10,186	6,722	10,744	18,504
Capital % Gross	10%	12%	9%	11%
Opportunity Cost[4] Labor ($)	36,015	29,379	43,381	37,887
Economic Return ($)	-33,897	-29,601	-41,088	-29,699
Economic Return % Gross	-31%	-47%	-32%	-15%

[1] End of year bonus is collected as a separate income at year's end.
[2] Variable costs include bait, fuel, labor only.
[3] Fixed costs include all other operating costs including vessel operations, insurance and vehicle expenses, as well as safety equipment, administrative expenses, and fees.
[4] Opportunity cost represents the potential earnings if not lobstering.

In our analysis we calculated opportunity cost of capital by multiplying the market interest rate of 2% for 2010 by the reported capital investment by each vessel owner; the opportunity cost of labor was based on the survey respondent's self-assessment of what could be earned in an alternative occupation. After taking these economic costs into account net returns for all vessel classes is negative.

Catch-per-unit-effort

The differences in catch and revenue between the vessel classes appear to lie in the vessels themselves, the number of traps hauled per trip, and the average steam time per trip -- from which we have further derived a new quarterly variable, distance traveled, using steam time as a basis for calculating this, and which appears to have significant explanatory power for catch-per-unit-effort ("CPUE").

We see that CPUE is significantly higher for the larger vessel classes than the smaller vessel class, as is the revenue per unit effort. These trends are observed, despite relatively uniform price per pound across vessel classes. We attribute the increases in pounds caught to the total distance traveled, and the total number of trap hauls per trip (versus haul through % or number of traps in the water). Our survey shows that a 50% increase in the distance traveled in Q1 for example, corresponds to a 650% increase in the catch per trap haul. This relationship remains positively correlated, in all quarters but the returns are lower in the other three calendar quarters. The production functions are explored in greater detail in Chapter 3.

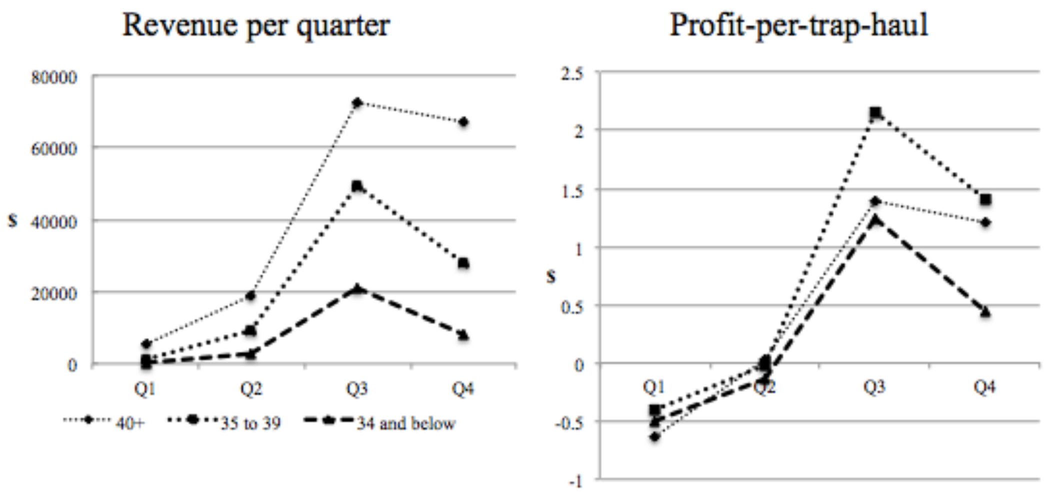

Figure A.1 Quarterly revenue by vessel class, and associated quarterly operating profits

The efficiency of this strategy however is less clear, and so we take a closer look at the catch per fuel gallon expended in each calendar quarter. Here we see that in Q1 for example a 238% increase in gallons of fuel per trip is able to generate the 650% increase in the catch, but in the highly productive Q3 time period when the lobsters are closer to shore, a 185% increase in fuel per trip, leads only to a 47% increase in the catch. With the bulk of the lobster landings occurring in this time Q3 time period, the overall net effect of this strategy is to erode profitability.

Revenue-per-trap also varies by size vessel and also by zone, which is higher for fishermen who fish in Zones A, B, C and D, and appears to be a function of average number of trap hauls, which is closely related to total traps fished, but can also be a function of a fisherman's skill and effort. This suggests that it may be difficult to predict individual profitability based on number of trap tags purchased, since the number of trap hauls and the particular habitat may be a better indicator of financial success.

Table A.11 Quarterly vessel-level productivity measures

Vessel Length Category:		Overall Average	34 and below	35 to 39 feet	40 and above
Price Per Pound					
	Q1	4.07	4.09	4.04	4.09
	Q2	3.78	3.68	3.85	3.91
	Q3	3.01	3.00	3.00	3.03
	Q4	3.55	3.56	3.53	3.58
Catch per unit effort[1]					
	Q1	0.06	0.02	0.08	0.15
	Q2	0.21	0.13	0.26	0.34
	Q3	1.11	0.89	1.31	1.31
	Q4	0.66	0.38	0.80	1.11
Revenue per unit effort					
	Q1	0.26	0.09	0.32	0.60
	Q2	0.81	0.49	0.99	1.34
	Q3	3.35	2.66	3.93	3.97
	Q4	2.35	1.37	2.83	3.97
Distance Traveled[2]					
	Q1	16	12	18	23
	Q2	9	7	10	14
	Q3	8	8	8	12
	Q4	12	9	12	17
Catch per gallon fuel					
	Q1	0.42	0.26	0.51	0.66
	Q2	2.19	1.88	2.45	2.46
	Q3	12.64	12.59	13.43	11.04
	Q4	6.04	5.00	6.79	7.25

[1] One unit of effort is defined as one trap haul.
[2] Distance traveled is measured in miles.

As we saw in the profitability analysis for harvesters above, the profit margin associated with the harvester side of lobstering can be relatively low, favoring operations of scale, or larger vessels those landing more than 90,000 lbs. per year. Increases in operating costs, coupled with deflated landed boat price, have caused lobstermen to increase their annual catch further as a means of maintaining a certain level of operating income. This increase in supply without the increase in product demand, has a further negative effect on the boat and market price, and also places additional fishing pressure on the resource.

Survey of Maine Harvesters and Dealers

In conjunction with the cost survey administered to Maine Lobstermen in 2011, a separate in-depth survey was conducted as a series of interviews with individual prominent Maine lobster dealers from the Maine coastal area. Through these survey interviews, we compiled a general process upon which to develop our pricing assumptions, and these are described as a supply chain continuum from the vessel to the market place (Plagányi et al. 2014), with identified transaction points but we did not extend our analysis to quantify these relationships with a model.

Maine's lobster supply chain starts with the individual fishermen, who lands product at their home dock or a designated wharf and offers the product for sale to a first station buyer, as a bulk quantity of lobsters in a mixed quality and size called a "run". The survey results indicate that on average 89% of product has been landed in this way, with some distinction by Maine zone, with Maine Zone D landing the most "run" product at 94% on average. Massachusetts and New Hampshire tend to have lower "run" product percentages, at 82% and 85% respectively. Harvesters are searching for ways to improve their product value and sorting and grading offers one such opportunity.

Table A.12 Ex-vessel price by fishing area for year 2010

	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	Zone G	MA	NH
Product "run" (%)	86	88	90	94	91	87	85	88	82
Avg ex-vessel price ($)	3.55	3.30	3.24	3.01	3.17	3.47	3.32	3.69	3.74
Adj ex-vessel price[1] ($)	3.98	3.57	3.61	3.44	3.44	3.64	3.52	3.81	3.74

[1] Includes returns associated with end of year of coop bonus.

Conversely, the larger scale operations and areas where the resource abundance and catch rates may be higher such as Maine Zone C, we see a higher percentage of their product sold as a "run", in our survey we saw an 95% run rate for these operations. Implications from these figures relate to meat yield, and inventory perishability.

Table A.13 Product grade and reported price for 2011

Vessel Length Category:	Overall Average	34 and below	35 to 39 feet	40 and above
Product grade "run" (%)	89	86	91	90
Reported Boat price ($)	3.78	3.68	3.85	3.91
Adjusted Boat price[1] ($)	4.07	4.09	4.04	4.09

[1]Includes annual end of year bonus payment

The dockside buyer, also referred to as a dealer or Cooperative ("Co-op"), takes this largely undifferentiated product from the harvester at a "boat price". To attract the needed volume of product, the Dealer can be organized as a fisherman's Cooperative structure, and provide for an annual per pound bonus between $0.50/lb. and $0.75/lb. to incentivize harvesters.

The dealer then sorts, grades, and makes a decision about the route each piece of inventory will take, based on quality. This dealer is often competing with other dealers for the same markets, and so volume is required to overcome structural costs of labor, wharf, credit, and administrative overhead to perform the product differentiation, buying & selling, and arranging the transport. In addition, the dealer owns the product inventory and accepts 100% of the risk the associated shrink, which can be as high as 20% for shedders, or as low as 5% for hard shell product. Reduced lobster mortality, or shrink, provides an important opportunity for all segments to improve yield and reduce costs. It also offers an important biological consideration, and how this prematurely harvested product could help to ensure the longer-term population remains stable, with consistently high harvest yields in the future.

Thirteen local industry owned cooperatives are major players in terms of buying direct from harvesters in Maine, but most sell directly to a dealer/processor as a primary buyer. Other buyers are dock owners or dealers. In some areas, harvesters have access to more than one buying station dock to sell their lobster catch. For example, in Beal's Island, harvesters have access to more than 5 buying stations on any given day. This may be true for several more areas, but for many fishermen it can be the opposite – however accessibility rather than the availability of the dock is an issue and harvesters may have issues trying to reach a buying station that is not readily available.

One or several dealers may serve buying stations, and some wholesalers have moved into the dealer space in an effort to increase their overall business. However, dealers and wholesalers do not appear to dominate geographically to a sufficient scale to become price-setters. While there may be limited dealers serving any individual buying station, or even a group of stations in an area, there are no explicit contracts restricting access. Existing relationships or other informal arrangements may be present that affect the decision-making process. The harvester typically gets 70 to 75% of the export price or that first wholesale price.

APPENDIX B: A SURVEY TO UNCOVER ATTITUDES AND GOALS FOR LIMITED ENTRY LOBSTER LICENSING

Survey Overview

A separate survey was developed for the license holder and non-license holder groups. Data collection took place between August 10, 2012 and September 10, 2012. Potential respondents from the sample list were mailed a survey along with a cover letter stating the purpose of the research, and a business reply mail envelope for easy return. The number and instructions on how to access the phone line were included in the cover letter as well.

Sample Frame

The sample files consisted of commercial lobster license holders as well as those not holding a commercial license but are on waiting lists to acquire a license or who are completing training. Lists consisted of 5,195 commercial lobster license holders and 1,572 non-license holders (1,276 in training programs and 296 on a waiting list). Sample files contained addresses for mailing. Survey data were collected on 1,416 license holders and 313 non-license holders. A breakdown of response rates is provided in the table below:

Table B.1 Survey Response Rates

Type of Survey	Total Surveys Mailed	Returned as Bad Address	Total Completed Surveys Returned	Response Rate
License Holder	5,195	27	1,416	27.4%
Non-License Holder	1,572	20	313	20.2%
Total	*6,767*	*47*	*1,730*	*25.7%*

A total of 44 comments were collected by phone. According to the distribution of population, the distribution of our sample by zones is relative similar to the distribution of the population, such as shown in Figure 1.

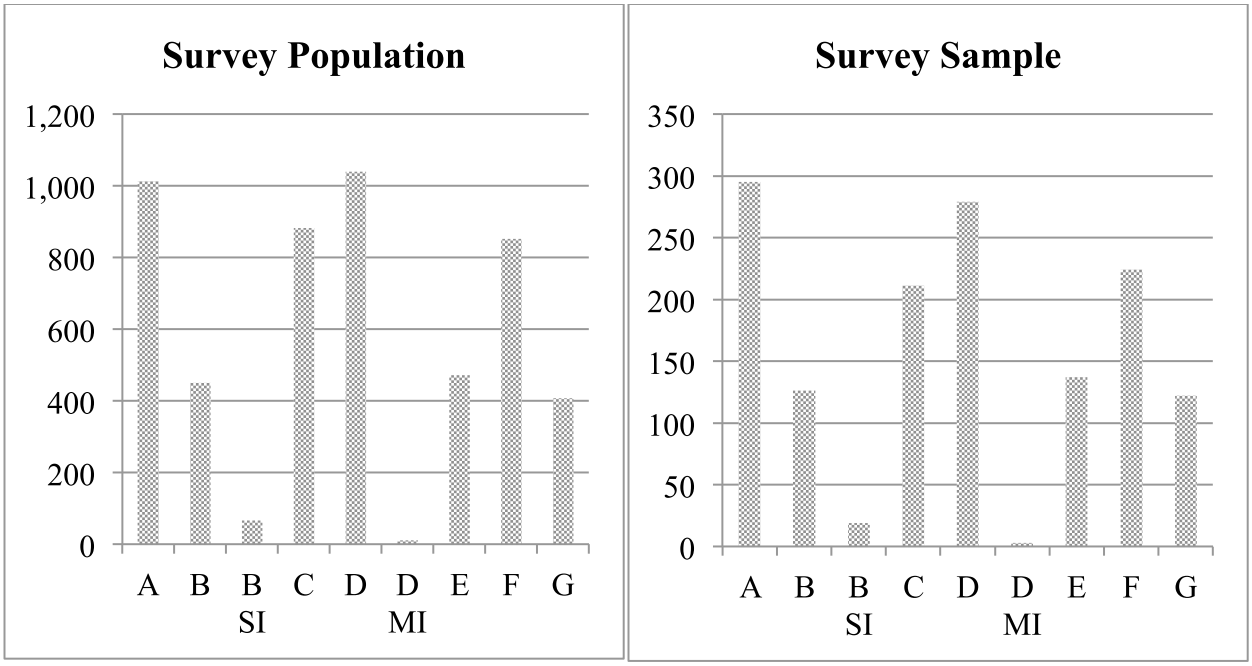

Figure B.1 Survey penetration rates by Maine lobster zone

Results

We present the survey summary, goals and attitudes responses, as well as contingency table results of all the questions presented in each of two surveys; first for the individuals who hold a lobster license and a second section for the survey of those individuals who do not hold a lobster license. We also look at the sources of new entrants to the fishery in Table 7.2 below as context for the attitudes and outcomes uncovered in our surveys.

Table B.2 An Analysis of entry sources for Maine lobster license holders

Include All Zones

Year:	Existing Apprentice and Student Licenses over 18 years old (LA)	New LC123 Licenses off Waiting over 18 years old	% of LA group to awarded LC123	Existing Student Licenses (LCS) under 18 years old	New LC123 Licenses under 18 years old	% of LCS under 18 years old group awarded LC123	Total	% of all new entrants started as apprentice > 18	% of all new entrants started as student < 18
	(A)	(B)	(B)/(A)	(C)	(D)	(D)/(C)	(B)+(D)	(B)/(B+D)	(D)/(B+D)
2005	420	81	19%	602	65	11%	146	55%	45%
2006	317	61	19%	535	67	13%	128	48%	52%
2007	251	56	22%	550	43	8%	99	57%	43%
2008	229	50	22%	534	31	6%	81	62%	38%

2009	193	30	16%	504	26	5%	56	54%	46%
2010	174	31	18%	475	26	5%	57	54%	46%
2011	209	36	17%	520	27	5%	63	57%	43%
Average '08 - '11	**201**	**37**	**18%**	**508**	**28**	**5%**	**64**	**57%**	**43%**
Zone A Entry Only									
2005	114	11	10%	120	24	20%	35	31%	69%
2006	62	9	15%	92	26	28%	35	26%	74%
2007	53	13	25%	95	11	12%	24	54%	46%
2008	40	10	25%	97	6	6%	16	63%	38%
2009	27	5	19%	87	5	6%	10	50%	50%
2010	25	6	24%	83	6	7%	12	50%	50%
2011	37	4	11%	99	7	7%	11	36%	64%
Average '08 - '11	**51**	**8**	**18%**	**96**	**12**	**12%**	**12**	**50%**	**50%**
Zone B Entry Only									
2005	41	4	10%	80	2	3%	6	67%	33%
2006	29	6	21%	60	9	15%	15	40%	60%
2007	30	8	27%	61	6	10%	14	57%	43%
2008	22	4	18%	62	5	8%	9	44%	56%
2009	15	0	0%	68	5	7%	5	0%	100%
2010	9	2	22%	76	5	7%	7	29%	71%
2011	5	2	40%	78	6	8%	8	25%	75%
Average '08 - '11	**13**	**4**	**20%**	**69**	**5**	**8%**	**7**	**25%**	**75%**
Zone C Entry Only									
2005	54	27	6%	104	6	6%	33	82%	18%
2006	54	18	6%	95	10	11%	28	64%	36%
2007	44	8	3%	99	3	3%	11	73%	27%
2008	54	11	5%	98	1	1%	12	92%	8%
2009	51	18	9%	85	4	5%	22	82%	18%
2010	41	14	8%	84	2	2%	16	88%	13%
2011	64	22	11%	88	3	3%	25	88%	12%
Average '08 - '11	**52**	**17**	**7%**	**93**	**4**	**4%**	**21**	**81%**	**19%**
Zone D Entry Only									
2005	83	11	13%	149	11	7%	22	50%	50%
2006	61	8	13%	132	8	6%	16	50%	50%
2007	39	9	23%	125	9	7%	18	50%	50%
2008	26	10	38%	117	10	9%	20	50%	50%
2009	29	3	10%	103	3	3%	6	50%	50%
2010	22	3	14%	87	3	3%	6	50%	50%
2011	28	2	7%	100	2	2%	4	50%	50%
Average '08 - '11	**41**	**7**	**17%**	**116**	**7**	**5%**	**13**	**50%**	**50%**
Zone E Entry Only									
2005	31	3	10%	58	6	10%	9	33%	67%

2006	24	4	17%	49	6	12%	10	40%	60%
2007	18	3	17%	55	6	11%	9	33%	67%
2008	19	5	26%	50	2	4%	7	71%	29%
2009	12	1	8%	41	3	7%	4	25%	75%
2010	13	1	8%	37	4	11%	5	20%	80%
2011	13	2	15%	40	2	5%	4	50%	50%
Average '08 - '11	**19**	**3**	**14%**	**47**	**4**	**9%**	**7**	**39%**	**61%**
Zone F Entry Only									
2005	51	14	27%	69	9	13%	23	61%	39%
2006	51	12	24%	76	7	9%	19	63%	37%
2007	40	11	28%	85	3	4%	14	79%	21%
2008	42	6	14%	78	4	5%	10	60%	40%
2009	32	3	9%	83	3	4%	6	50%	50%
2010	42	2	5%	74	2	3%	4	50%	50%
2011	44	3	7%	81	6	7%	9	33%	67%
Average '08 - '11	**43**	**7**	**16%**	**78**	**5**	**6%**	**12**	**57%**	**43%**
Zone G Entry Only									
2005	83	11	13%	120	7	6%	18	61%	39%
2006	61	4	7%	92	1	1%	5	80%	20%
2007	39	4	10%	95	5	5%	9	44%	56%
2008	26	4	15%	97	3	3%	7	57%	43%
2009	29	0	0%	87	3	3%	3	0%	100%
2010	22	3	14%	83	4	5%	7	43%	57%
2011	28	1	4%	99	1	1%	2	50%	50%
Average '08 - '11	**41**	**4**	**9%**	**96**	**3**	**4%**	**7**	**48%**	**52%**

License Holders Survey Results Detailed

Question number 4a of the survey for current lobster license holders states "*What do you believe should be the goals of a lobster limited entry system*?" Table Q4-1 shows the survey responses of current lobster license holders in regard to the listed eight limited entry lobster license system goals.

Respondents were asked to select all goals that apply. The clear favorite among respondents is the goal of having a system work as a mechanism for young people to obtain a lobster license. The nearly 23% margin of selection advantage it holds over the goal choice of having a system work as a mechanism for adults to obtain a lobster license may reflect the desire of lobstering families to ensure entry possibilities for the next generation. While slightly more than half of all respondents included financial viability of existing license holders by limiting participation as a goal, their least popular choice, at 36.1%, was to reduce the number of license holders. This may be indicative of there being a greater concern among lobstermen about who gets a license as opposed to how many licenses are given.

Table B.3 Tabulated Responses to Goals Question by License Holders

	# Yes	%YES
Mechanism for young people to obtain a lobster license	888	62.7
Stabilize the number of license holders	743	52.5
Protect the lobster resource from depletion	711	50.2
Financial viability of existing license holders by limiting participation	709	50.1
Stabilize the number of traps fished	649	45.8
Reduce the number of traps fished	630	44.5
Mechanism for adults to obtain a lobster license	564	39.8
Reduce the number of license holders	511	36.1
Other	293	20.7

Question number 4b of the survey for current lobster license holders states "*Does the current system achieve these goals*?" Respondents were asked to give their opinion by way of choosing a number on a scale of 1 to 5, with 1 meaning strongly disagree and 5 meaning strongly agree. Figures Q4-1 through Q4-8 below illustrate the survey responses to this series of questions.

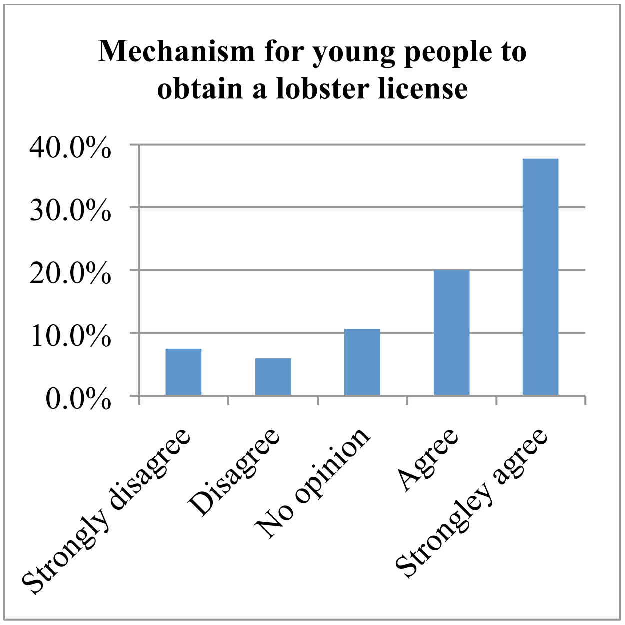

Figure Q4-1 Lobster License Holder Opinions of Making a system a Mechanism for Young People to Obtain a License

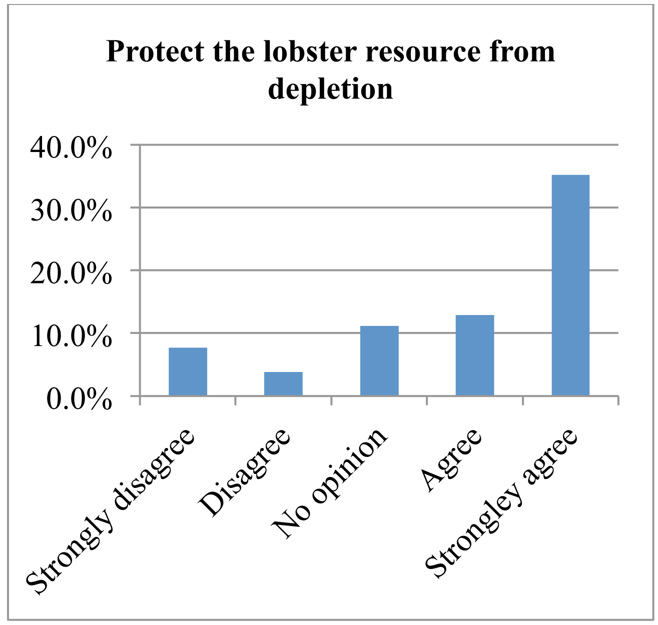

Figure Q4-3 Lobster License Holder Opinions of the Goal of Having a system Protect the Lobster Source from Depletion

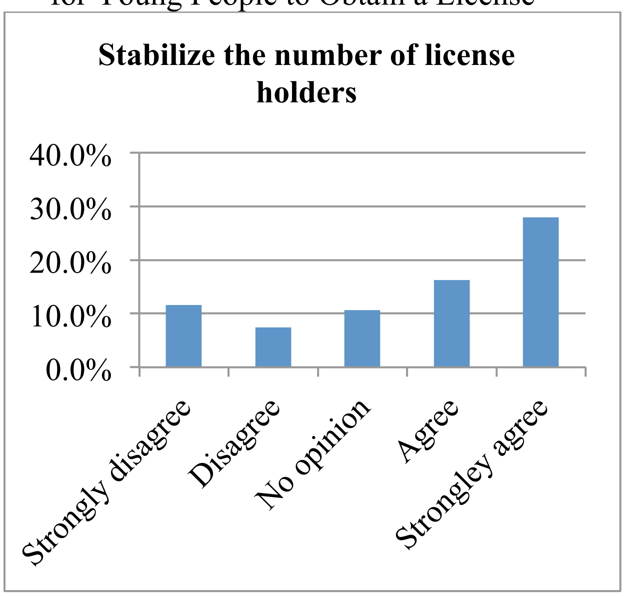

Figure Q4-2 Lobster License Holder Opinions of the Goal of Having a system Stabilize the Number of License Holders

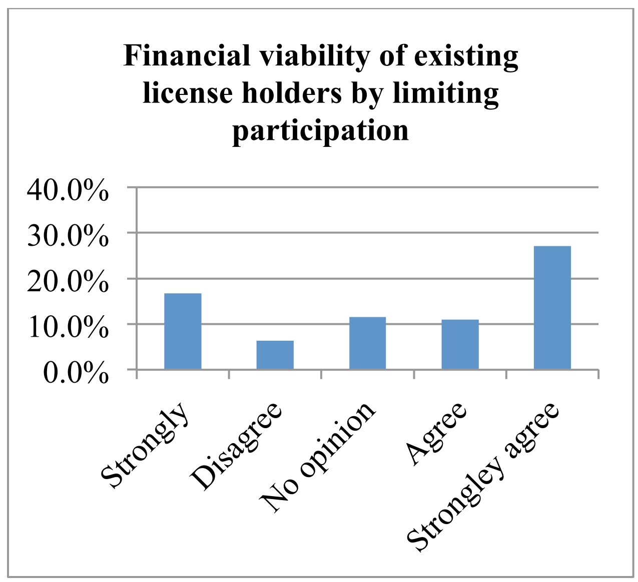

Figure Q4-4 Lobster License Holder Opinions of the Goal of Having a system Achieve the Financial Viability of Existing License Holders by Limiting Participation

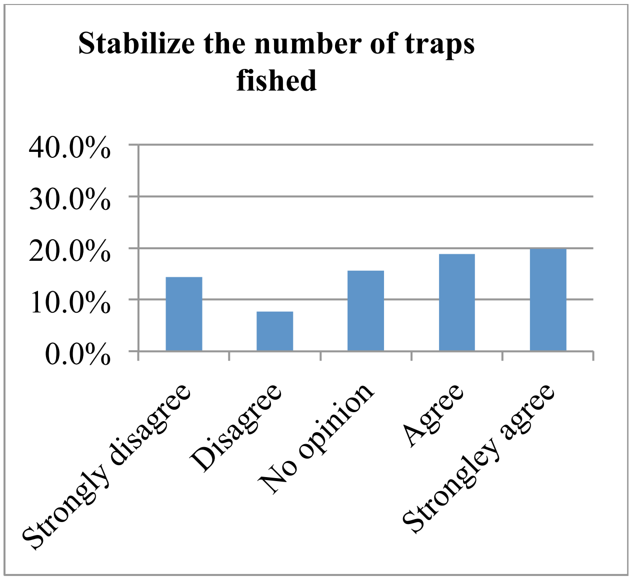

Figure Q4-5 Lobster License Holder Opinions of the Goal of Having a system Stabilize the Number of Traps Fished

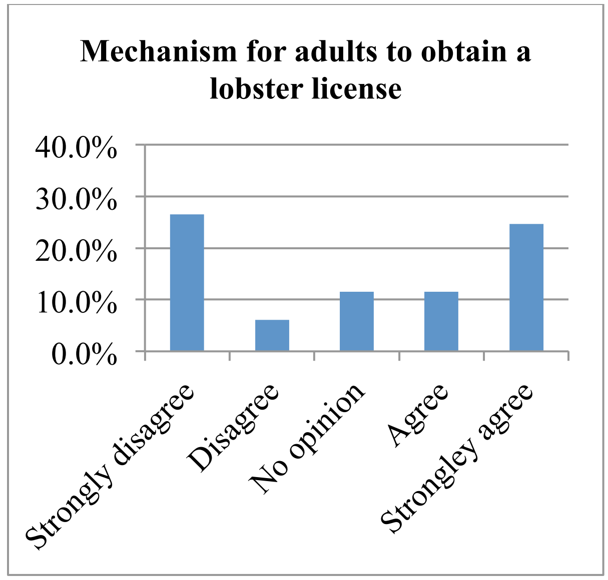

Figure Q4-7 Lobster License Holder Opinions of the Goal of Having a system be a Mechanism for Adults to Obtain a License

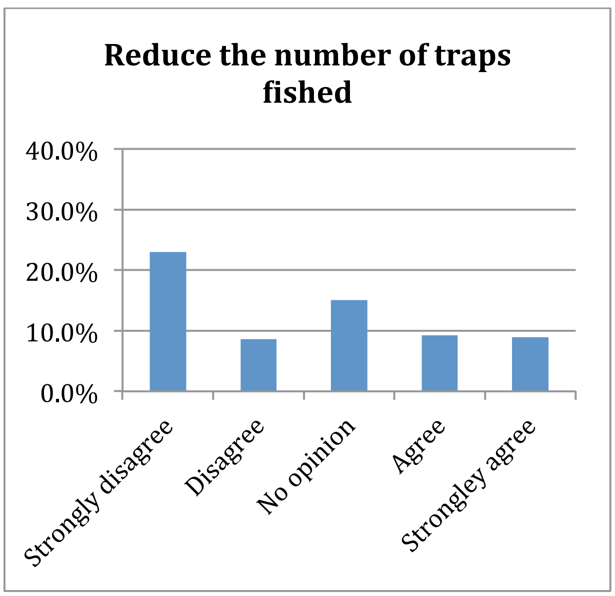

Figure Q4-6 Lobster License Holder Opinions of the Goal of Having a system Reduce the Number of Traps Fished

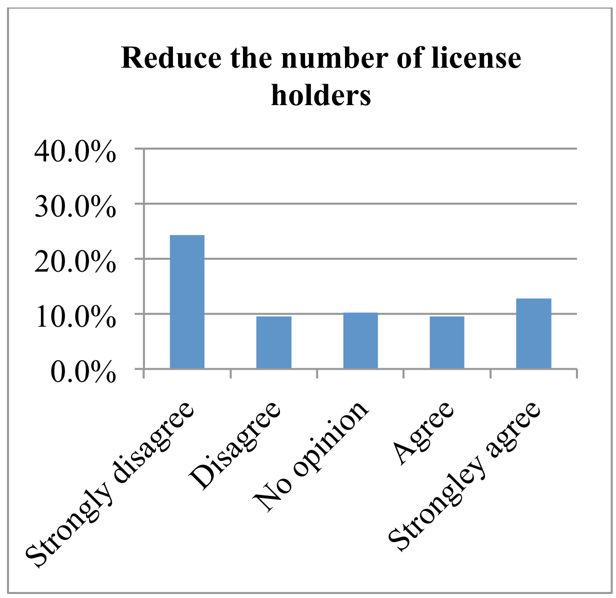

Figure Q4-8 Lobster License Holder Opinions of the Goal of Having a system Reduce the Number of License Holders

Question Three: "How worried are you about the number of traps fished in your zone?"

Responses are generally uniform across zones, tag numbers, and landings, with roughly one third or respondents not worried, one third somewhat worried, and slightly under one third very worried. There are two notable exceptions. A lower proportion of respondents in Zone C said they were very worried than in all other zones. In Zone F, a higher proportion said that they were very worried, and a larger majority said that they were either somewhat or very worried. It may also be noted that least worried categories of respondents in terms of landings are the lowest bracket and the two highest brackets.

Question Five: "Do you favor a change to the current trap limit per person in your zone?"

There was universally small support among respondents for increases in trap limits. Most support for increasing the limit is found among the two highest levels of tags issued. A majority of respondents supports no change in all zones except in Zone F, where the most common response favored a decrease in the trap limit.

Question Six: "If the trap limit were changed, do you favor a proportional adjustment or an across-the-board trap limit per person?"

Support for a proportional change was very low in all tag and landings groups except for the highest trap bracket and highest landings bracket. The majority of respondents in all zones favor across-the-board changes.

Question Seven: "Do you support the current regulations that allow students under age 18 who have completed the apprentice requirement to get a commercial license without going on the waiting list?"

A majority of respondents favor the current system in Zones A, B, C and E. The margin is widest in Zones B and C. In Zone D, respondents are almost equally split between supporting and not supporting. In Zones E and G, a majority does not support the current system. Both the highest trap bracket and the highest landings bracket favor the current system by wide margins.

Question Eight: "Do you support the current entry or exit ratio based on tags retiring in your zone?"

A majority agrees with current entry ratio in all categories. Only a small minority support more entrants in any category. The highest proportion of respondents that support allowing more entrants is found in zone A. There is also marginally higher support for more entrants in the lowest landings bracket. Zone F has the highest proportion of respondents who support allowing fewer entrants.

Question Nine: "Do you favor eliminating latent effort in the form of trap tags that are not issued?"

The majority of individuals in the lowest landings bracket do not wish to eliminate unissued tags. Individuals in with landings from ten to thirty thousand pounds per year are about evenly split, and individuals in the two highest landings brackets show the most support for eliminating unissued tags. In Zones B, C and E, the most common response was in favor of eliminating unissued tags. Zones A, D, and G are the opposite.

Question Ten: "Do you support eliminating latent effort in the form of removing licenses not being fished?

Responses were almost evenly split in all zones. Eliminating unused licenses found the least support among those with less than 500 tags or less than a thousand pounds of landings.

Question Eleven: "Do you support eliminating latent effort in the form of removing trap tags that are issued but not fished?

In all zones, the majority of respondents are against removing issued but unused tags. This preference was especially strong in Zone G. Elimination was highly unfavorable to lower landings and tags brackets but was the most common response among the highest landings bracket.

Question twelve: "Do you believe licenses and or tags should be transferable?"

The majority of respondents were in favor of transferable licenses in all zones and all tag ranges. Transferable tags were not as popular as licenses and did not receive majority support in any category.

Question Fifteen: "Do you support an overall limit on total lbs. of lobster landed in Maine per year?"
In all categories, respondents overwhelmingly did not support an overall state limit.

Question Sixteen: "Do you support a quota on pounds of lobster landed per zone per year?
In all categories, respondents overwhelmingly did not support an overall zone limit.

Question Eighteen: "Do you support a quota on pounds of lobster landed per fisherman per year?
In all categories, respondents overwhelmingly did not support an individual quota.

Table B.4 Contingency tables for license holders survey responses all questions

Q01: What percentage of your total household income comes from your lobster business?

		Total	
		Count	%
Q01: What percentage of your total household income comes from your lobster business?	80% - 100%	732.0	51.7%
	50% - 80%	260.0	18.4%
	25%- 50%	146.0	10.3%
	Less than 25%	244.0	17.2%
	NO ANSWER	34.0	2.4%
	Total	1416.0	100.0%

Q02: How many traps did you fish last year (maximum # in the water at once)?

		Total	
		Count	%
Q02: How many traps did you fish last year (maximum # in the water at once)?	0	62.0	4.4%
	1	2.0	.1%
	2	2.0	.1%
	3	1.0	.1%
	6	1.0	.1%
	9	1.0	.1%
	10	3.0	.2%
	12	1.0	.1%
	15	4.0	.3%

	16	1.0	.1%
	18	1.0	.1%
	20	10.0	.7%
	25	7.0	.5%
	26	1.0	.1%
	28	1.0	.1%
	30	7.0	.5%
	35	2.0	.1%
	40	9.0	.6%
	50	26.0	1.8%
	53	1.0	.1%
	55	1.0	.1%
	60	4.0	.3%
	70	2.0	.1%
	75	7.0	.5%
	78	1.0	.1%
	80	7.0	.5%
	82	1.0	.1%
	90	1.0	.1%
	100	33.0	2.3%
	115	1.0	.1%
	120	4.0	.3%
	125	5.0	.4%
	130	1.0	.1%
	135	2.0	.1%
	140	1.0	.1%
	150	26.0	1.8%
	160	2.0	.1%
	165	1.0	.1%
	170	2.0	.1%
	175	1.0	.1%
	180	2.0	.1%
	190	2.0	.1%
	200	40.0	2.8%
	220	1.0	.1%
	230	2.0	.1%
	235	1.0	.1%
	250	19.0	1.3%
	270	1.0	.1%

	275	2.0	.1%
	280	2.0	.1%
	300	57.0	4.0%
	320	1.0	.1%
	325	1.0	.1%
	330	3.0	.2%
	340	2.0	.1%
	350	22.0	1.6%
	355	1.0	.1%
	360	1.0	.1%
	370	1.0	.1%
	385	1.0	.1%
	400	67.0	4.7%
	410	3.0	.2%
	425	1.0	.1%
	440	1.0	.1%
	450	19.0	1.3%
	460	1.0	.1%
	475	12.0	.8%
	490	1.0	.1%
	500	62.0	4.4%
	505	1.0	.1%
	510	1.0	.1%
	520	2.0	.1%
	525	1.0	.1%
	531	1.0	.1%
	535	1.0	.1%
	537	1.0	.1%
	540	1.0	.1%
	550	11.0	.8%
	570	3.0	.2%
	575	3.0	.2%
	580	3.0	.2%
	585	1.0	.1%
	600	126.0	8.9%
	621	1.0	.1%
	625	2.0	.1%
	630	1.0	.1%
	640	1.0	.1%

		Count	%
	650	11.0	.8%
	670	1.0	.1%
	675	1.0	.1%
	700	41.0	2.9%
	704	1.0	.1%
	720	5.0	.4%
	730	2.0	.1%
	745	1.0	.1%
	750	20.0	1.4%
	760	3.0	.2%
	780	5.0	.4%
	781	1.0	.1%
	784	1.0	.1%
	785	1.0	.1%
	787	1.0	.1%
	790	2.0	.1%
	800	542.0	38.3%
	900	1.0	.1%
	1200	1.0	.1%
	5555	1.0	.1%
	REF	38.0	2.7%
	Total	1416.0	100.0%

Q03: How worried are you about the number of traps fished in your Zone?

		Total	
		Count	%
Q03: How worried are you about the number of traps fished in your Zone?	Very	411.0	29.0%
	Somewhat	494.0	34.9%
	No Worries	422.0	29.8%
	No Opinion	64.0	4.5%
	NO ANSWER	25.0	1.8%
	Total	1416.0	100.0%

Q05: Do you favor a change to the current trap limit per person in your zone?

		Total	
		Count	%

Q05: Do you favor a change to the current trap limit per person in your zone?	Yes - Increase	94.0	6.6%
	Yes - Decrease	552.0	39.0%
	No Change	755.0	53.3%
	NO ANSWER	15.0	1.1%
	Total	1416.0	100.0%

Q06: If the trap limit were changed, do you favor a proportional adjustment or an across-the-board trap limit per person?

		Total	
		Count	%
Q06: If the trap limit were changed, do you favor a proportional adjustment or an across-the-board trap limit per person?	Proportional	396.0	28.0%
	Across-the-board	802.0	56.6%
	No Opinion	153.0	10.8%
	NO ANSWER	65.0	4.6%
	Total	1416.0	100.0%

Q07: Do you support the current regulations that allow students under age 18 who have completed the apprentice requirement to get a commercial license without going on the waiting list?

		Total	
		Count	%
Q07: Do you support the current regulations that allow students under age 18 who have completed the apprentice requirement to get a commercial license without going on the waiting list?	Yes	724.0	51.1%
	No	563.0	39.8%
	No Opinion	111.0	7.8%
	NO ANSWER	18.0	1.3%
	Total	1416.0	100.0%

Q08: Do you support the current entry or exit ratio based on tags retiring in your zone?

		Total	
		Count	%
Q08: Do you support the current entry or exit ratio based on tags retiring in	Yes - keep it as is	732.0	51.7%
	No - allow fewer entrants	300.0	21.2%
	No - allow more entrants	198.0	14.0%

		Count	%
your zone?	No Opinion	149.0	10.5%
	NO ANSWER	37.0	2.6%
	Total	1416.0	100.0%

Q09: Do you favor eliminating latent effort in the form of trap tags that are not issued?

		Total	
		Count	%
Q09: Do you favor eliminating latent effort in the form of trap tags that are not issued?	Yes	431.0	30.4%
	No	509.0	35.9%
	No Opinion	417.0	29.4%
	NO ANSWER	59.0	4.2%
	Total	1416.0	100.0%

Q10: Do you support eliminating latent effort in the form of removing licenses not being fished?

		Total	
		Count	%
Q10: Do you support eliminating latent effort in the form of removing licenses not being fished?	Yes	582.0	41.1%
	No	663.0	46.8%
	No Opinion	144.0	10.2%
	NO ANSWER	27.0	1.9%
	Total	1416.0	100.0%

Q11: Do you support eliminating latent effort in the form of removing trap tags that are issued but not fished?

		Total	
		Count	%
Q11: Do you support eliminating latent effort in the form of removing trap tags that are issued but not fished?	Yes	419.0	29.6%
	No	802.0	56.6%
	No Opinion	158.0	11.2%
	NO ANSWER	37.0	2.6%
	Total	1416.0	100.0%

Q12: Do you believe licenses and or tags should be transferable?

		Total	
		Count	%
Q12: Do you believe licenses and or tags should be transferable?	Yes - Tags	71.0	5.0%
	Yes - Licenses	285.0	20.1%
	Yes - Both	511.0	36.1%
	No - Neither	488.0	34.5%
	No Opinion	44.0	3.1%
	NO ANSWER	17.0	1.2%
	Total	1416.0	100.0%

Q13: If tags were transferable, how many traps would you ideally fish (max # in the water at once)?

		Total	
		Count	%
Q13: If tags were transferable, how many traps would you ideally fish (max # in the water at once)?	0	20.0	1.4%
	3	1.0	.1%
	4	1.0	.1%
	6	1.0	.1%
	9	1.0	.1%
	11	1.0	.1%
	15	1.0	.1%
	16	1.0	.1%
	18	1.0	.1%
	20	2.0	.1%
	25	3.0	.2%
	35	1.0	.1%
	40	2.0	.1%
	50	12.0	.8%
	60	1.0	.1%
	80	5.0	.4%
	100	25.0	1.8%
	120	2.0	.1%
	135	1.0	.1%
	150	16.0	1.1%
	200	22.0	1.6%
	225	1.0	.1%

	250	9.0	.6%
	300	44.0	3.1%
	350	12.0	.8%
	360	1.0	.1%
	400	77.0	5.4%
	450	16.0	1.1%
	475	5.0	.4%
	500	63.0	4.4%
	503	1.0	.1%
	550	4.0	.3%
	575	1.0	.1%
	600	147.0	10.4%
	650	11.0	.8%
	700	19.0	1.3%
	750	6.0	.4%
	760	1.0	.1%
	777	1.0	.1%
	790	2.0	.1%
	800	326.0	23.0%
	900	23.0	1.6%
	1000	41.0	2.9%
	1050	1.0	.1%
	1100	3.0	.2%
	1200	67.0	4.7%
	1300	1.0	.1%
	1350	1.0	.1%
	1400	1.0	.1%
	1500	4.0	.3%
	1600	25.0	1.8%
	1800	1.0	.1%
	2000	7.0	.5%
	2500	1.0	.1%
	3000	1.0	.1%
	4000	1.0	.1%
	5000	1.0	.1%
	6000	1.0	.1%
	9997	1.0	.1%
	REF	368.0	26.0%
	Total	1416.0	100.0%

Q14: If tags or licenses were transferable, what restrictions should be applied to transfers?

		Total	
		Count	%
Q14	Inter-family direct relation	694.0	49.0%
	Within a Harbor	76.0	5.4%
	Within a Fishing Cooperative	21.0	1.5%
	Inter-family distant relations	215.0	15.2%
	Within a Zone	369.0	26.1%
	No Restrictions	215.0	15.2%
	Owner-operator only	439.0	31.0%
	Within Island Communities	115.0	8.1%
	Other	101.0	7.1%
	NO ANSWER	112.0	7.9%
	Total	1416.0	100.0%

Q15: Do you support an overall limit on total lbs. of lobster landed in Maine per year?

		Total	
		Count	%
Q15: Do you support an overall limit on total lbs. of lobster landed in Maine per year?	Yes	90.0	6.4%
	No	1262.0	89.1%
	No Opinion	46.0	3.2%
	NO ANSWER	18.0	1.3%
	Total	1416.0	100.0%

Q16: Do you support a quota on pounds of lobster landed per zone per year?

		Total	
		Count	%
Q16: Do you support a quota on pounds of lobster landed per zone per year?	Yes	76.0	5.4%
	No	1272.0	89.8%
	No Opinion	50.0	3.5%
	NO ANSWER	18.0	1.3%

		Count	%
	Total	1416.0	100.0%

Q17: Do you support a quota on pounds of lobster landed per fisherman per year?

		Total	
		Count	%
Q17: Do you support a quota on pounds of lobster landed per fisherman per year?	Yes	102.0	7.2%
	No	1250.0	88.3%
	No Opinion	47.0	3.3%
	NO ANSWER	17.0	1.2%
	Total	1416.0	100.0%

Q18: If quota were transferable, what restrictions should be applied?

		Total	
		Count	%
$Q18	Inter-family direct relation	476.0	33.6%
	Within a Harbor	69.0	4.9%
	Within a Fishing Cooperative	18.0	1.3%
	Inter-family distant relations	137.0	9.7%
	Within a Zone	263.0	18.6%
	No Restrictions	299.0	21.1%
	Owner-operator only	344.0	24.3%
	Within Island Communities	66.0	4.7%
	Other	115.0	8.1%
	NO ANSWER	221.0	15.6%
	Total	1416.0	100.0%

Non-license Holders Survey Responses

Question number 12a of the survey for non-license holders states "*What do you believe should be the goals of a lobster limited entry system*?" Table Q12-1 shows the survey responses of non-license holders in regard to eight limited entry lobster license system goals. Respondents were asked to select all goals that apply. As also evidenced in the license holder survey, the clear favorite among respondents is the goal of having a system work as a mechanism for young people to obtain a lobster license. In contrast to the non-license holder survey, the goal choice of having a system work as a mechanism for adults to obtain a lobster license is ranked much more highly. This quite likely reflects the opinions of adult non-license holders. The two goal choices promoting reducing the number of license holders and limiting participation received the least support among non-license holders. This is easily understandable from the point of view of someone waiting to get a lobster license.

Table B.5 Non-License Holder Responses to Goals questions

	# Yes	%Yes
Mechanism for young people to obtain a lobster license	198	63.3
Stabilize the number of license holders	125	39.9
Protect the lobster resource from depletion	161	51.4
Financial viability of existing license holders by limiting participation	73	23.3
Stabilize the number of traps fished	130	41.5
Reduce the number of traps fished	61	19.5
Mechanism for adults to obtain license	160	51.1
Reduce the number of license holders	49	15.7
Other	54	17.3

Question number 12b of the survey for non- license holders states "*Does the current system achieve these goals*?" Figures Q12-1 through Q12-8 below illustrate the survey response to this question.

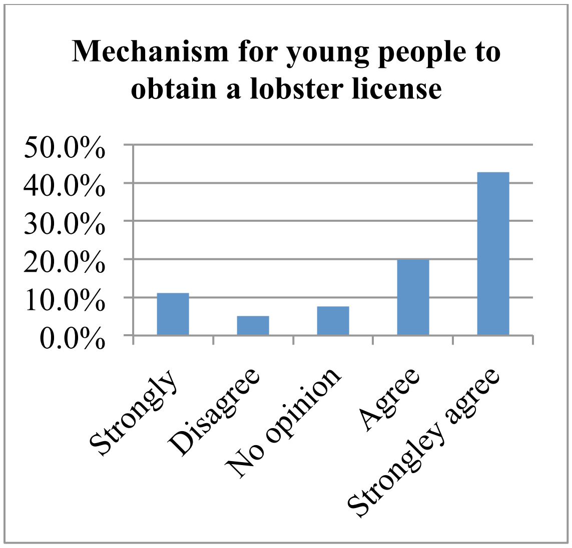

Figure Q12-1 Non-License Holder Opinions of Making a system a Mechanism for Young People to Obtain a License

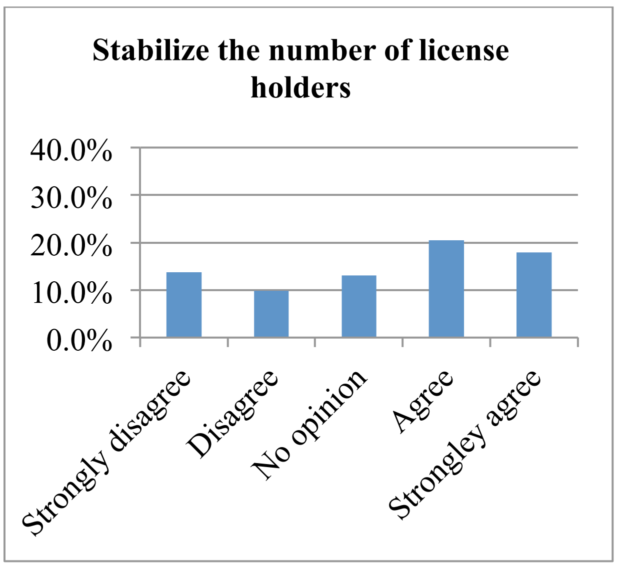

Figure Q12-2 Non-License Holder Opinions of the Goal of Having a system Stabilize the Number of License Holders

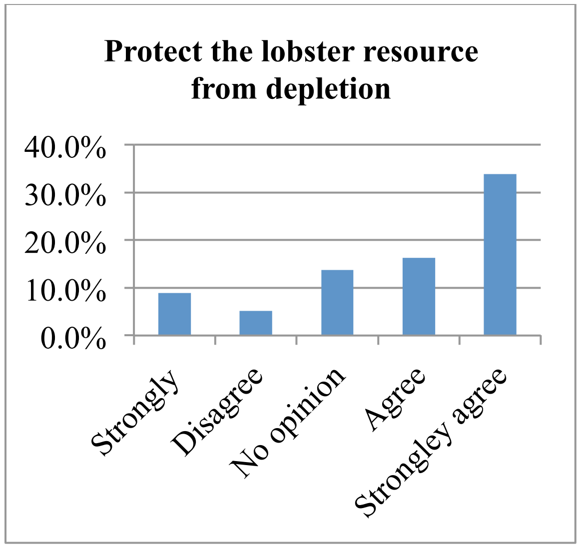

Figure Q12-3 Non-License Holder Opinions of the Goal of Having a system Protect the Lobster Source from Depletion

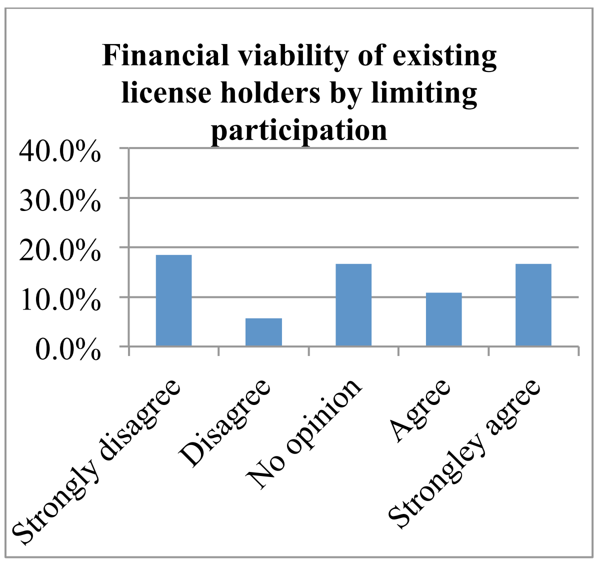

Figure Q12-4 Non-License Holder Opinions of the Goal of Having a system Achieve the Financial Viability of Existing License Holders by Limiting Participation

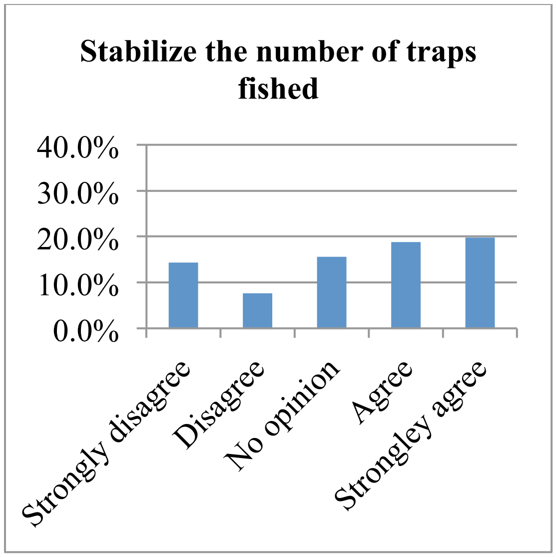

Figure Q12-5 Non-License Holder Opinions of the Goal of Having a system Stabilize the Number of Traps Fished

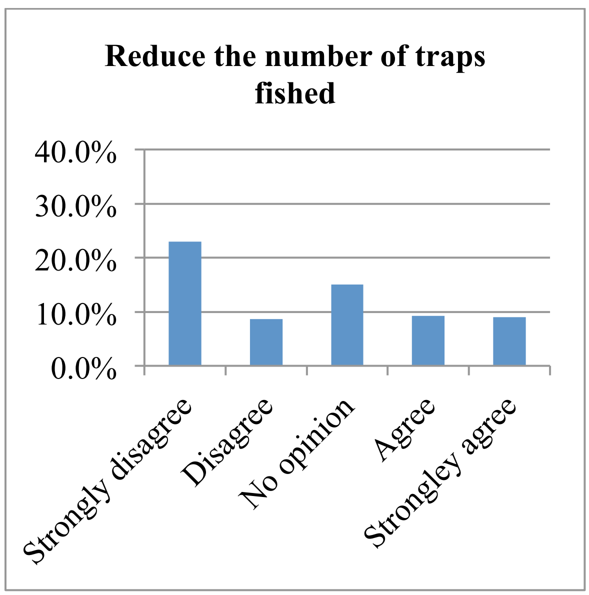

Figure Q12-6 Non-License Holder Opinions of the Goal of Having a system Reduce the Number of Traps Fished

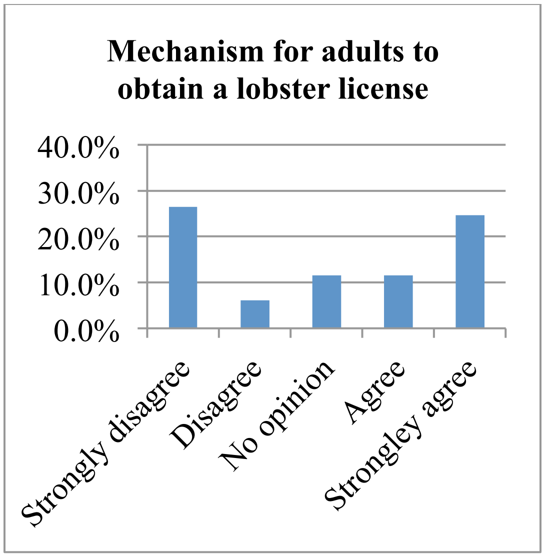

Figure Q12-7 Non-License Holder Opinions of the Goal of Having a system be a Mechanism for Adults to Obtain a License

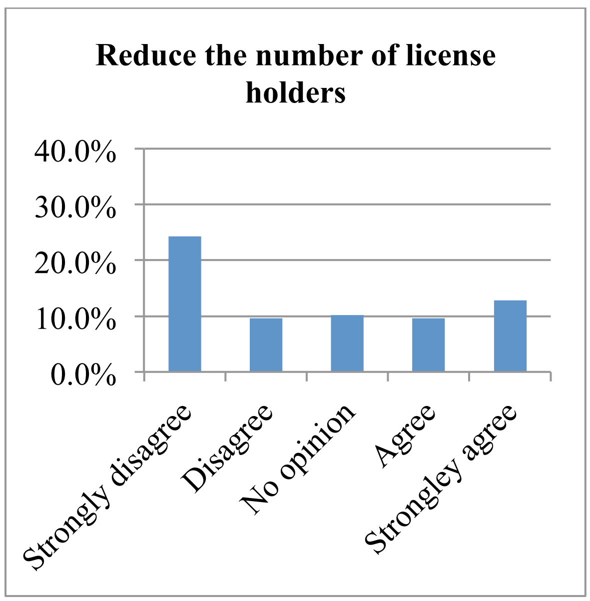

Figure Q12-8 Non-License Holder Opinions of the Goal of Having a system Reduce the Number of License Holders

Table B.6 Contingency tables for non-license holders survey responses

Q01: What is your current employment status?

		Total	
		Count	%
Q01: What is your current employment status?	Employed Full time (Fishing)	82.0	26.2%
	Employed Full time(Other)	44.0	14.1%
	Employed Part time (Fishing)	44.0	14.1%
	Employed Part time (Other)	13.0	4.2%
	Unemployed less than 6 months	15.0	4.8%
	Retired	3.0	1.0%
	Unemployed more than 6 months	8.0	2.6%
	Student	102.0	32.6%
	NO ANSWER	2.0	.6%
	Total	313.0	100.0%

Q02: What is your educational background?

		Total	
		Count	%
Q02: What is your educational background?	Some High School	56.0	17.9%
	High School/GED	109.0	34.8%
	College - Associates, technical, or other 2-yr	42.0	13.4%
	College - Bachelor's degree	32.0	10.2%
	College - Graduate degree	12.0	3.8%
	Other/None	55.0	17.6%
	NO ANSWER	7.0	2.2%
	Total	313.0	100.0%

Q03: Approximately, how much do you currently earn per year?

		Total	
		Count	%
Q03: Approximately, how	$0 - $9,999 £	127.0	40.6%

		Count	%
much do you currently earn per year?	$10,000 - $24,999	55.0	17.6%
	$25,000 - $39,999	66.0	21.1%
	$40,000 - $59,000	34.0	10.9%
	$60,000 - $79,999	12.0	3.8%
	$80,000 +	11.0	3.5%
	NO ANSWER	8.0	2.6%
	Total	313.0	100.0%

Q04: Why are you interested in getting your own lobstering license?

		Total	
		Count	%
$Q04	Add another species to my existing fishing business	16.0	5.1%
	Take over the family lobstering business	125.0	39.9%
	Get back into the business after leaving for a while	58.0	18.5%
	Only job I've ever done, want my own business	133.0	42.5%
	Supplemental income	66.0	21.1%
	Switch Careers	39.0	12.5%
	NO ANSWER	9.0	2.9%
	Total	313.0	100.0%

Q05: Do you intend to go lobstering:

		Total	
		Count	%
Q05: Do you intend to go lobstering:	Full Time	187.0	59.7%
	Part time all year	28.0	8.9%
	Hobby/Recreational	5.0	1.6%
	Part time seasonal	90.0	28.8%
	NO ANSWER	3.0	1.0%
	Total	313.0	100.0%

Q06: How many traps do you wish to fish per year?

		Total

		Count	%
Q06: How many traps do you wish to fish per year?	0	3.0	1.0%
	5	1.0	.3%
	10	4.0	1.3%
	12	1.0	.3%
	20	1.0	.3%
	30	1.0	.3%
	40	1.0	.3%
	50	9.0	2.9%
	70	1.0	.3%
	75	1.0	.3%
	100	9.0	2.9%
	150	21.0	6.7%
	200	12.0	3.8%
	250	3.0	1.0%
	300	14.0	4.5%
	350	1.0	.3%
	400	15.0	4.8%
	450	1.0	.3%
	475	6.0	1.9%
	500	15.0	4.8%
	600	43.0	13.7%
	700	2.0	.6%
	800	130.0	41.5%
	1000	1.0	.3%
	2000	1.0	.3%
	NO ANSWER	16.0	5.1%
	Total	313.0	100.0%

Q07A: How much do you currently have invested in lobster traps?

		Total	
		Count	%
Q07A: How much do you currently have invested in lobster traps?	0	84.0	26.8%
	5	1.0	.3%
	10	1.0	.3%
	100	6.0	1.9%
	150	2.0	.6%

	200	5.0	1.6%
	250	5.0	1.6%
	300	2.0	.6%
	400	3.0	1.0%
	500	11.0	3.5%
	560	1.0	.3%
	600	4.0	1.3%
	750	1.0	.3%
	800	2.0	.6%
	1000	24.0	7.7%
	1170	1.0	.3%
	1200	1.0	.3%
	1400	1.0	.3%
	1500	5.0	1.6%
	2000	16.0	5.1%
	2200	1.0	.3%
	2500	8.0	2.6%
	3000	13.0	4.2%
	3500	2.0	.6%
	4000	8.0	2.6%
	4500	1.0	.3%
	5000	18.0	5.8%
	5500	2.0	.6%
	6000	6.0	1.9%
	7000	2.0	.6%
	7500	3.0	1.0%
	8000	2.0	.6%
	9000	1.0	.3%
	10000	9.0	2.9%
	12000	6.0	1.9%
	13000	1.0	.3%
	14500	1.0	.3%
	15000	4.0	1.3%
	20000	3.0	1.0%
	28000	1.0	.3%
	30000	1.0	.3%
	40000	1.0	.3%
	50000	1.0	.3%
	51000	1.0	.3%

		Count	%
	51750	1.0	.3%
	NO ANSWER	40.0	12.8%
	Total	313.0	100.0%

Q07B: How much do you currently have invested in Lobster boat?

		Total	
		Count	%
Q07B: How much do you currently have invested in Lobster boat?	0	102.0	32.6%
	400	1.0	.3%
	500	6.0	1.9%
	800	1.0	.3%
	1000	7.0	2.2%
	1500	9.0	2.9%
	2000	3.0	1.0%
	2700	1.0	.3%
	3000	10.0	3.2%
	3500	5.0	1.6%
	4000	7.0	2.2%
	4500	1.0	.3%
	4600	1.0	.3%
	5000	15.0	4.8%
	5500	1.0	.3%
	6000	8.0	2.6%
	7000	9.0	2.9%
	8000	2.0	.6%
	9000	1.0	.3%
	9500	2.0	.6%
	10000	17.0	5.4%
	10500	1.0	.3%
	12000	3.0	1.0%
	15000	5.0	1.6%
	16000	1.0	.3%
	18000	1.0	.3%
	18500	1.0	.3%
	20000	9.0	2.9%
	22000	1.0	.3%
	25000	5.0	1.6%
	27000	2.0	.6%

		Count	%
	28000	2.0	.6%
	30000	3.0	1.0%
	34000	1.0	.3%
	40000	3.0	1.0%
	45000	1.0	.3%
	50000	2.0	.6%
	60000	2.0	.6%
	70000	1.0	.3%
	80000	2.0	.6%
	90000	1.0	.3%
	100000	1.0	.3%
	120000	2.0	.6%
	160000	2.0	.6%
	NO ANSWER	52.0	16.6%
	Total	313.0	100.0%

Q08A: How much do you plan to invest in lobster traps?

		Total	
		Count	%
Q08A: How much do you plan to invest in lobster traps?	0	8.0	2.6%
	150	1.0	.3%
	200	1.0	.3%
	250	1.0	.3%
	300	2.0	.6%
	500	3.0	1.0%
	900	1.0	.3%
	1000	7.0	2.2%
	1500	1.0	.3%
	2000	5.0	1.6%
	2100	1.0	.3%
	2500	5.0	1.6%
	3000	5.0	1.6%
	3500	1.0	.3%
	4000	3.0	1.0%
	4500	1.0	.3%
	5000	18.0	5.8%
	6000	8.0	2.6%
	6400	1.0	.3%

		Count	%
	6500	1.0	.3%
	7000	1.0	.3%
	7500	1.0	.3%
	8000	2.0	.6%
	10000	30.0	9.6%
	12000	3.0	1.0%
	13000	1.0	.3%
	15000	12.0	3.8%
	18000	1.0	.3%
	20000	20.0	6.4%
	24000	2.0	.6%
	25000	8.0	2.6%
	30000	16.0	5.1%
	35000	1.0	.3%
	36000	1.0	.3%
	40000	6.0	1.9%
	50000	14.0	4.5%
	57000	2.0	.6%
	60000	12.0	3.8%
	64000	1.0	.3%
	72000	1.0	.3%
	80000	12.0	3.8%
	100000	5.0	1.6%
	As much as I need to/Whatever I can afford	21.0	6.7%
	NO ANSWER	66.0	21.1%
	Total	313.0	100.0%

Q08B: How much do you plan to invest in Lobster boat?

		Total	
		Count	%
Q08B: How much do you plan to invest in Lobster boat?	0	15.0	4.8%
	400	1.0	.3%
	1000	5.0	1.6%
	1500	1.0	.3%
	2000	3.0	1.0%
	4000	1.0	.3%
	4500	1.0	.3%

	5000	7.0	2.2%
	6000	1.0	.3%
	6500	1.0	.3%
	8000	1.0	.3%
	9000	1.0	.3%
	10000	21.0	6.7%
	11000	1.0	.3%
	15000	5.0	1.6%
	20000	15.0	4.8%
	25000	7.0	2.2%
	30000	7.0	2.2%
	35000	4.0	1.3%
	40000	12.0	3.8%
	45000	1.0	.3%
	50000	32.0	10.2%
	60000	11.0	3.5%
	70000	3.0	1.0%
	75000	5.0	1.6%
	80000	2.0	.6%
	85000	1.0	.3%
	90000	1.0	.3%
	95000	1.0	.3%
	100000	18.0	5.8%
	125000	1.0	.3%
	130000	1.0	.3%
	150000	10.0	3.2%
	160000	1.0	.3%
	175000	1.0	.3%
	200000	7.0	2.2%
	230000	1.0	.3%
	250000	2.0	.6%
	300000	3.0	1.0%
	450000	1.0	.3%
	999999	1.0	.3%
	As much as I need to/Whatever I can afford	18.0	5.8%
	NO ANSWER	81.0	25.9%
	Total	313.0	100.0%

Q09: If you were able to get a license, how many sternmen would you employee?

		Total Count	Total %
Q09: If you were able to get a license, how many sternmen would you employee?	None	45.0	14.4%
	One	216.0	69.0%
	Two	48.0	15.3%
	NO ANSWER	4.0	1.3%
	Total	313.0	100.0%

Q10: Do you support the current entry or exit ratio based on tags retiring in your zone?

		Total Count	Total %
Q10: Do you support the current entry or exit ratio based on tags retiring in your zone?	Yes - keep it as is	91.0	29.1%
	No - allow fewer entrants	9.0	2.9%
	No - allow more entrants	171.0	54.6%
	No Opinion	33.0	10.5%
	NO ANSWER	9.0	2.9%
	Total	313.0	100.0%

Q11: How much longer do you expect to have to wait to obtain a license?

		Total Count	Total %
Q11: How much longer do you expect to have to wait to obtain a license?	0	10.0	3.2%
	1	26.0	8.3%
	2	31.0	9.9%
	3	24.0	7.7%
	4	17.0	5.4%
	5	29.0	9.3%
	6	11.0	3.5%
	7	13.0	4.2%
	8	9.0	2.9%
	9	4.0	1.3%
	10	35.0	11.2%
	11	1.0	.3%

		Count	%
	12	3.0	1.0%
	14	2.0	.6%
	15	10.0	3.2%
	16	1.0	.3%
	20	17.0	5.4%
	24	1.0	.3%
	25	5.0	1.6%
	26	1.0	.3%
	30	5.0	1.6%
	35	1.0	.3%
	39	1.0	.3%
	40	8.0	2.6%
	50	5.0	1.6%
	Forever/a long time	8.0	2.6%
	NO ANSWER	35.0	11.2%
	Total	313.0	100.0%

Q13: Do you support the current regulations that allow students under age 18 who have completed the apprentice requirement to get a commercial license without going on the waiting list?

		Total	
		Count	%
Q13: Do you support the current regulations that allow students under age 18 who have completed the apprentice requirement to get a commercial license without going on the waiting list?	Yes	188.0	60.1%
	No	106.0	33.9%
	No Opinion	14.0	4.5%
	NO ANSWER	5.0	1.6%
	Total	313.0	100.0%

Q14: Do you support the current requirement that someone who has previously been licensed as a lobsterman must go through the apprenticeship program to re-obtain a license?

		Count	%
Q14: Do you support the current requirement that	Yes	122.0	39.0%
	No	161.0	51.4%

someone who has previously been licensed as a lobsterman must go through the apprenticeship program to re-obtain a license?	No Opinion	23.0	7.3%
	NO ANSWER	7.0	2.2%
	Total	313.0	100.0%

Q15: Do you support a quota on pounds of lobster landed per fisherman, per year?

		Total	
		Count	%
Q15: Do you support a quota on pounds of lobster landed per fisherman, per year?	Yes	32.0	10.2%
	No	258.0	82.4%
	No Opinion	20.0	6.4%
	NO ANSWER	3.0	1.0%
	Total	313.0	100.0%

Q16: Do you believe licenses and/or tags should be transferable?

		Total	
		Count	%
Q16: Do you believe licenses and/or tags should be transferable?	Yes - Tags	15.0	4.8%
	Yes - Licenses	56.0	17.9%
	Yes - Both	142.0	45.4%
	No - Neither	80.0	25.6%
	No Opinion	12.0	3.8%
	NO ANSWER	8.0	2.6%
	Total	313.0	100.0%

Q17: If tags or licenses were transferable, what restrictions should be applied to transfers?

		Total	
		Count	%
$Q17	Inter-family direct relation	175.0	55.9%
	Within a Harbor	34.0	10.9%
	Within a Fishing Cooperative	6.0	1.9%

	Inter-family distant relations	71.0	22.7%
	Within a Zone	117.0	37.4%
	No Restrictions	39.0	12.5%
	Owner-operator only	46.0	14.7%
	Within Island Communities	29.0	9.3%
	Other	15.0	4.8%
	NO ANSWER	19.0	6.1%
	Total	313.0	100.0%

Q18: If licenses were transferrable, how much would you be willing to pay for one?

		Total	
		Count	%
Q18: If licenses were transferrable, how much would you be willing to pay for one?	0	36.0	11.5%
	1	4.0	1.3%
	10	1.0	.3%
	50	1.0	.3%
	60	1.0	.3%
	70	1.0	.3%
	100	4.0	1.3%
	132	1.0	.3%
	150	3.0	1.0%
	167	1.0	.3%
	200	5.0	1.6%
	250	1.0	.3%
	300	4.0	1.3%
	400	1.0	.3%
	500	11.0	3.5%
	600	1.0	.3%
	800	1.0	.3%
	1000	16.0	5.1%
	1500	3.0	1.0%
	2000	4.0	1.3%
	2500	1.0	.3%
	3000	3.0	1.0%
	5000	22.0	7.0%
	6000	1.0	.3%

		Count	%
	10000	30.0	9.6%
	15000	6.0	1.9%
	16000	1.0	.3%
	20000	15.0	4.8%
	25000	3.0	1.0%
	30000	4.0	1.3%
	40000	1.0	.3%
	50000	6.0	1.9%
	75000	1.0	.3%
	100000	9.0	2.9%
	1000000	1.0	.3%
	As much as it takes/market value	12.0	3.8%
	NO ANSWER	97.0	31.0%
	Total	313.0	100.0%

Q19: If tags were transferrable how much would you be willing to pay for one?

		Total	
		Count	%
Q19: If tags were transferrable how much would you be willing to pay for one?	0	38.0	12.1%
	1	64.0	20.4%
	2	16.0	5.1%
	3	1.0	.3%
	5	15.0	4.8%
	6	1.0	.3%
	9	1.0	.3%
	10	16.0	5.1%
	20	6.0	1.9%
	25	2.0	.6%
	30	1.0	.3%
	40	1.0	.3%
	50	5.0	1.6%
	100	8.0	2.6%
	200	1.0	.3%
	500	4.0	1.3%
	1000	1.0	.3%
	5000	2.0	.6%
	10000	2.0	.6%

	50000	1.0	.3%
	100000	3.0	1.0%
	As much as it takes/market value	13.0	4.2%
	NO ANSWER	111.0	35.5%
	Total	313.0	100.0%

Survey Package: License Holders

(Presented as legal size format in original mail package)

*****

2012 Lobster Limited Entry System Questionnaire for Existing License Holders

We would like to get your feedback on how to address the issues surrounding the licensing system, and its impacts on the fishery. Please answer the questions below as accurately as possible. We recommend reading through all the questions first. **Thank you!**

1. What percentage of your total household income comes from your lobster business?
   a. 80% - 100%
   b. 50% - 80%
   c. 25%- 50%
   d. Less than 25%

2. How many traps did you fish last year (maximum # in the water at once)?
   # ________________

3. How worried are you about the number of traps fished in your Zone?
   a. Very
   b. Somewhat
   c. No Worries
   d. No Opinion

4. What do you believe <u>should be</u> the goals of a lobster limited entry system? Please answer both parts of the question below:

4. a.) Which of these should be goals of the system? (Check all that apply)

4. b.) Does the current system achieve these goals (circle your choices below)

Mark with "√"		***Strongly Disagree*** ***No Opinion*** ***Strongly Agree***
	a. Stabilize the number of license holders in the fishery	1 2 3 4 5
	b. Reduce the number of license holders in the fishery	1 2 3 4 5
	c. Stabilize the number of traps fished in the fishery	1 2 3 4 5

	d. Reduce the number of traps fished in the fishery	1 2 3 4 5
	e. Protect the lobster resource from depletion	1 2 3 4 5
	f. Ensure the financial viability of existing license holders by limiting participation	1 2 3 4 5
	g. Ensure that there is a mechanism for young people to obtain a lobster license	1 2 3 4 5
	h. Ensure that there is a mechanism for adults to obtain a lobster license	1 2 3 4 5
	i. Other: ____	1 2 3 4 5
	h. Other: ____	1 2 3 4 5

5. Do you favor a change to the current trap limit per person in your zone?
   a. Yes – Increase
   b. Yes - Decrease
   c. No Change

6. If Yes to #5, do you favor a proportional adjustment (every lobsterman increases/decreases by the same percentage) or an across-the-board trap limit per person:
   a. Proportional
   b. Across-the-board
   c. No Opinion

7. Do you support the current regulations that allow students under age 18 who have completed the apprentice requirement to get a commercial license without going on the waiting list?
   a. Yes
   b. No
   c. No Opinion

8. Do you support the current entry/exit ratio based on tags retiring in your zone?
   a. Yes – keep it as is
   b. No – allow more entrants
   c. No – allow fewer entrants
   d. No Opinion

9. Do you favor freezing the number of tags at current levels for each license holder?
   a. Yes
   b. No
   c. No Opinion

10. Do you support eliminating latent effort in the form of removing <u>licenses</u> not being fished?
   a. Yes
   b. No
   c. No Opinion

11. Do you support eliminating latent effort in the form of removing <u>trap tags</u> that are issued but not associated with an active license?
   a. Yes

b. No
c. No Opinion

12. Do you believe licenses and/or tags should be transferable?
    a. Yes - Tags
    b. Yes - Licenses
    c. Yes - Both
    d. No - Neither
    e. No Opinion

14. If tags were transferable, how many traps would you ideally fish (max # in the water at once)?
    # ______________

14. If tags or licenses were transferable, what restrictions should be applied to transfers (check all that apply)?
    - ❑ Inter-family (direct relation ie. child/parent, sibling, spouse)
    - ❑ Inter-family (distant relations ie. uncle/nephew, cousin, in-law)
    - ❑ Free Market unlimited
    - ❑ Within a Harbor
    - ❑ Within a Zone
    - ❑ Within Island Communities
    - ❑ Within a Fishing Cooperative
    - ❑ Owner-operator only
    - ❑ Other: ___________________________________

15. Do you support an overall limit on total lbs. of lobster landed in Maine per year?
    a. Yes
    b. No
    c. No Opinion

16. Do you support a quota on pounds of lobster landed <u>per zone</u> per year?
    a. Yes
    b. No
    c. No Opinion

17. Do you support a quota for pounds of lobster landed <u>per fisherman</u> per year?
    a. Yes
    b. No
    c. No Opinion

18. If quota were transferable, what restrictions should be applied (check all that apply)?
    - ❑ Inter-family (direct relation ie. child/parent, sibling, spouse)
    - ❑ Inter-family (distant relations ie. uncle/nephew, cousin, in-law)
    - ❑ Free Market unlimited
    - ❑ Within a Harbor
    - ❑ Within a Zone
    - ❑ Within Island Communities
    - ❑ Within a Fishing Cooperative
    - ❑ Owner-operator only
    - ❑ Other: ___________________________________

Comments (please indicate what question your comment(s) refer to if applicable):

Lobster and Crab License number:

Your license number is needed to verify your eligibility and to ensure a representative number of fishermen.
Your license number will be cut off for confidentiality and your responses will not personally be associated with you.

Survey Package: Non-license Holders

2012 Lobster Limited Entry System Questionnaire for Non-License Holders

We would like to get your feedback on how to address the issues surrounding the lobster licensing system, and its impacts on the fishery. Please answer the questions below as accurately as possible. We recommend reading through all the questions first. **Thank you!**

5. What is your current employment status?

☐ Employed Full time (Fishing) ☐ Employed Part time (Fishing) ☐ Unemployed less than 6 months ☐ Unemployed more than 6 months

☐ Employed Full time (Other) ☐ Employed Part time (Other) ☐ Retired ☐ Student

2. What is your educational background?

☐ Some High School ☐ College – Associates, technical, or other 2-yr ☐ College – Graduate degree

☐ High School/GED ☐ College – Bachelor's degree ☐ Other/None

3. Approximately, how much do you currently earn/yr?

☐ $0 - $9,999 ☐ $25,000 - $39,999 ☐ $60,000 - $79,999

☐ $10,000 – $24,999 ☐ $40,000 - $59,000 ☐ $80,000 +

4. Why are you interested in lobstering (check all that apply)?

☐ Add another species to my existing fishing business ☐ Get back into the business after leaving for a while ☐ Supplemental income

☐ Take over the family lobstering business ☐ Only job I've ever done, want my own business ☐ Switch Careers

5. Do you intend to go lobstering:

☐ Full Time ☐ Part time all year ☐ Hobby/Recreational ☐ Part time seasonal

7. How many traps do you wish to fish per year (maximum # in the water at once)? # _______________

8. How much do you currently have invested:
   a. lobster gear? $ ___________________ b. Lobster boat? $ ___________________

9. How much do you plan to invest?
   a. lobster gear? $ ___________________ b. Lobster boat? $ ___________________

10. If you were able to get a license, how many sternmen would you employee?

☐ One ☐ Two ☐ None

11. Do you support the current entry/exit ratio based on tags retiring in your zone?

☐ Yes – keep it as is ☐ No – allow fewer entrants

☐ No – allow more entrants ☐ No Opinion

12. How much longer do you expect to have to wait to obtain a license? # years ____________________

13. What do you believe should be the goals of a lobster limited entry system? Please answer both parts of the question below:

12. a.) Which of these should be goals of the system? (Check all that apply)

12. b.) Does the current system achieve these goals? (Using the 1-5 scale below, circle your opinion)

Strongly Agree ← No Opinion → Strongly Disagree

☐	Stabilize the number of license holders in the fishery	1 2 3 4 5
☐	Reduce the number of license holders in the fishery	1 2 3 4 5
☐	Stabilize the number of traps fished in the fishery	1 2 3 4 5
☐	Reduce the number of traps fished in the fishery	1 2 3 4 5
☐	Protect the lobster resource from depletion	1 2 3 4 5
☐	Ensure the financial viability of existing license holders by limiting participation	1 2 3 4 5
☐	Ensure that there is a mechanism for young people to obtain a lobster license	1 2 3 4 5
☐	Ensure that there is a mechanism for adults to obtain a lobster license	1 2 3 4 5
☐	Other: ________________________________	1 2 3 4 5

13. Do you support the current regulations that allow students under age 18 who have completed the apprentice requirement to get a commercial license without going on the waiting list?

☐ Yes ☐ No ☐ No Opinion

14. Do you agree that someone who has previously been licensed as a lobsterman must go through the apprenticeship program to re-obtain a license?

☐ Yes ☐ No ☐ No Opinion

15. Do you support a quota on pounds of lobster landed per fisherman, per year?

☐ Yes ☐ No ☐ No Opinion

16. Do you believe licenses and/or tags should be transferable?

☐ Yes - Tags ☐ Yes - Licenses ☐ Yes - Both

☐ No - Neither ☐ No Opinion

17. If tags or licenses were transferable, what restrictions should be applied to transfers (check all that apply)?

☐ Inter-family direct relation (i.e. child/parent, sibling, spouse)
☐ Within a Harbor
☐ Within a Fishing Cooperative
☐ Inter-family distant relations (i.e. uncle/nephew, cousin, in-law)
☐ Within a Zone
☐ No Restrictions
☐ Owner-operator only
☐ Within Island Communities
☐ Other: ___________

18. If licenses were transferrable, how much would you be willing to pay for one? $ ___________________

19. If tags were transferrable how much would you be willing to pay for one? $ ___________________

Comments (please indicate what question your comment(s) refer to if applicable):

____

____

____

____

BIOGRAPHY OF THE AUTHOR

Alexa M. Dayton was born in Ann Arbor, MI and lived in the U.S., Germany, and France as a child. She graduated from the Wooster School in Danbury CT, where and went on to pursue a B.S. in Electrical and Computer Engineering from the University of Michigan. From there, she went on to hold several career positions including General Dynamics, MapInfo Corporation, and L.L. Bean, where she held the role of Sr. Forecast Analyst for nearly a decade. After a period of family leave, she went on to pursue a M.S. in Biological Sciences from the University of Southern Maine, in Portland, Maine, where she has been a long time resident. Her master's research focused on the biological control of Eurasian water milfoil, an aquatic fresh water invasive species. She also performed research in salt marsh ecology at the Rachel Carson Preserve in Wells, ME. She was awarded a National Science Foundation Fellowship for Science Corps teaching, and received a trustee award for merit. Upon graduation, she went on to contribute to the creation of Maine Huts & Trails, as an economic resource based development in western Maine, and then accepted a role at the Gulf of Maine Research Institute, where for the past 8 years she has held the position of Program Manager and Principal Investigator of the Marine Resource Education Programs. In her current role, she has developed a portfolio of grants-based collaborative projects aimed at improving fisheries science and management, through the development of industry leadership capacity. She has served on the Boards of several non-profits including: Winter Kids Maine, and Fishing Into The Future. She belongs to several societies, including the Society for Women in Marine Science (SWMS), and North American Association of Fisheries Economists (NAAFE) and she is Member-friend of the Maine Lobsterman's Association. She has had the privilege to work with collaborators from a broad array of fishing fleets around the country, and the world, forming lasting collaborations with fishermen scientists and regulators from various federal agencies and academic institutions. In an effort to better understand and contribute to the complex word of fisheries management, and more generally the sustainability of natural resource extraction policies balanced with community welfare and economy, she has embarked on a journey to better understand the foundation principals of resource valuation and policy implementation, with the humble recognition that the more we learn, the more we realize we have yet to learn. She is a candidate for the Doctor of Philosophy degree Interdisciplinary in Marine Science, Policy and Resource Economics from the University of Maine in May 2018.