Condos, Connectivity, and Catch: Analyzing the State of the Bahamian Spiny Lobster Fishery.

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CONDOS, CONNECTIVITY, AND CATCH: ANALYZING THE STATE OF THE BAHAMIAN SPINY LOBSTER FISHERY

By

Karlisa Alicia Callwood

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CONDOS, CONNECTIVITY, AND CATCH: ANALYZING THE STATE OF THE
BAHAMIAN SPINY LOBSTER FISHERY

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Caribbean spiny lobster (*Panulirus argus*) is a heavily exploited seafood throughout its range and supports the primary fishery in The Bahamas. However, its long pelagic larval duration and, thus, potential for long-range dispersal increases the difficulty in determining the origins of local populations and complicates management. In recent years, the Bahamian fishery has transitioned to the use of condos (or casitas) as the primary fishing method. Condos are relatively inexpensive to construct and deploy, and it is estimated there are now over a million deposited throughout the Bahama banks. Collectively, these factors, coupled with an increased level of effort in the form of new fishers and more boats, have contributed to increased levels of competition for an already limited resource, further complicating the development of adequate and sustainable management strategies. The potential for human-induced changes to the ecosystem due to the proliferation of condos highlights the need for an interdisciplinary investigation of the fishery that takes into account both natural and anthropogenic impacts. This project utilizes an interdisciplinary approach that examines the biophysical forces that impact spiny lobster coupled with the chief human activities. Data from a biophysical model, a bioeconomic
model, and surveys and interviews are used to help create a robust assessment of the fishery and aid in the proposal of viable management strategies. The integration of interdisciplinary methodologies provides an example of how these merged tools can help understand ecological processes while assisting management decisions.

Simulations of larval dispersal for Bahamian spiny lobster populations indicate dispersal distances (or dispersal kernel) of 200-400 km, with a 25% probability of successful settlement. Surveys and semi-structured interviews of Bahamian fishers revealed five popular areas for condo placement. Further connectivity assessments of these locations indicate higher rates of settlement success for 4 sites. Two of these locations demonstrated a narrower dispersal kernel, suggesting self-recruitment. However, the 3 remaining locations appear to depend on subsidies from other spiny lobster populations throughout the Caribbean. These differences in connectivity suggest each location should be evaluated individually to determine spatially-dependent management actions, and to effectively develop and implement condo-related policies that will be supported by local communities.

A bioeconomic analysis, completed by incorporating data on condo effort obtained through the surveys and interviews, revealed the fishery is operating beyond Open Access levels. The model revealed that the fishery has the potential to increase its profits if operated at the maximum economic yield. However, survey responses indicate fishers may be more amenable to a fishery managed towards the maximum sustainable yield, particularly if operating at
MEY results in a drastic reduction of condo effort. This analysis revealed the necessity for additional management controls within the fishery, as well as filling the gaps that exist in the fishery data.

An examination of the increased condo usage, and the implications of this use on how the fishers define, perceive, and adhere to access and property rights is achieved through a political ecology lens. This case is amenable to such an analysis due to the heavy interdependence of ecology and human factors throughout the fishery, allowing for an assessment of how the ecological, social, and economic elements interact to create and define the fishery, including the implications of this convergence on the overall management. Surveys and semi-structured interviews of Bahamian fishers and other stakeholders revealed many conflicting views about the fishery, particularly around ownership of the condos and the lobster within them. A further examination of the data highlighted the emergence of several political ecology themes within the fishery, as well as the importance of considering both internal factors, such as social pressures, local norms, and voluntary agreements, and external ones, including demand and market value defined by a global market, when determining how to sustain and successfully manage the fishery.
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Chapter 1: Review of the Bahamian Spiny Lobster Fishery

Introduction

*Panulirus argus*, known commonly as the Caribbean or Florida spiny lobster, is a popular, and heavily exploited seafood throughout its range. It constitutes the primary fishery in many Caribbean countries, and is probably one of the Caribbean’s most economically important species, valued at nearly $1 billion US dollars annually (Ehrhardt *et al.* 2010). FAO reports that fishery landings of Caribbean spiny lobster were approximately 37,000 metric tons in 2012, comprising nearly 80% of the total catch for all spiny lobsters globally (FAO 2014).

According to Cascorbi (2004), *P. argus* “reaches its greatest abundance, fastest growth, and greatest fecundity” within the waters of The Bahamas, contributing to the high catches reported in the region. Referred to as “crawfish” by Bahamians, spiny lobster is the number one food export and supports the primary fishery in the country (Ehrhardt *et al.* 2009). This fishery is responsible for 2% of the Gross National Product of the country and 94% of the total value of its fisheries exports (CRFM 2003).

With one of the longest pelagic larval durations of any marine species, *P. argus* possess the possibility for long range dispersal, thus increasing the difficulty of determining the origins of local adult populations. Understanding population connectivity and local retention of *P. argus* is important for the conservation of this species and for the management of the valuable fishery that it supports.
In recent years, the use of artificial aggregation habitats as a fishing method has increased within The Bahamas. These structures, commonly referred to in The Bahamas as condos and elsewhere throughout the Caribbean as casitas or habitats, are used to concentrate lobsters in large numbers (Lozano-Álvarez et al. 1991, Sosa-Cordero et al. 2008), as they are believed to help boost production in order to meet the increased market demand for the species (Baisre 2000; Cruz and Phillips 2000; Eggleston et al. 1992; Losada-Tosteson and Posada 2001; Briones-Fourzán et al. 2000; Deleveaux and Bethel 2002). Although The Bahamas is one of many Caribbean nations utilizing condos, the ecological, social, and management implications of condo usage have not yet been fully evaluated. Ecologically, the large quantities of condos on the bank are potentially creating new habitats for the spiny lobster. Sociologically, they create a new dynamic of approaches to lobster fishing that forces us to re-evaluate the notions of property rights, raising some concerns in regards to defining access and property rights for Bahamian lobsterfishers, especially as it relates to where the condos are placed and who can fish from them.

There is often a lack of a comprehensive theoretical framework to understand the population and community processes, as well as the biological, physical, and social ones, that can affect the success of various fishery management strategies. Species with long dispersal ranges, like Caribbean spiny lobster, and changes within the fishery itself, as seen with the introduction and proliferation of condos, can further complicate attempts at adequate
management. As such, there is a great need to study and understand the intersections that occur between species dynamics, human behavior, and social interactions, and what the confluence of these factors means for developing and implementing effective policy measures. The use of an interdisciplinary methodology, by coupling tools from various fields, can aid in the design of these strategies.

Fisheries are best understood when they are viewed as a system that incorporates ecological, biophysical, economic, social, and cultural factors, including how these various perspectives interact. Unfortunately, this has not always been the case in fisheries science. Often times, fisheries management efforts have failed, either because complex ecological connections were not considered or the resulting human responses or impacts were not expected (Arlinghaus 2014). Interdisciplinary methods help to bridge these seemingly disparate factors, emphasizing the need for integration and allowing for a richer and more holistic exploration of these systems. Incorporating more holistic views of fisheries management, particularly for small-scale and artisanal fisheries, is expected to help improve sustainability efforts (Hughes et al. 2005).

Acknowledging broader perspectives allows for considerations of the effects of market forces (Jacquet et al. 2010a), exploring the success of management techniques (Pollnac et al. 2010; McClanahan et al. 2006; Pollnac et al., 2001), determining the social and economic drivers of fishing strategies (Cinner and McClanahan 2006) and management impacts (Sanchirico et al.}
2008), and the social and ecological benefits for management strategies

Purpose

The goal of this dissertation is to further examine the ecological, social, and economic impacts of connectivity/dispersal and the use of condos as a fishing strategy in The Bahamian Spiny Lobster Fishery, utilizing an interdisciplinary methodology, then evaluate the findings in the context of marine resource management approaches. Emphasis will be placed on an analysis of the increased usage of condos from the perspectives of key actors, including assessing the social, bioeconomic and management impacts on the fishery, estimating the effects of condo placement on lobster dispersal characteristics, and weighing the implications of defining and enforcing access and property rights in the face of changing management regimes.

An important consideration for managing Caribbean spiny lobster fisheries is that of the role of metapopulation dynamics. Metapopulations relate to assemblages of local populations that inhabit spatially distinct habitat patches within a landscape (Sanchirico and Wilen 2005). Many species, both terrestrial and marine, occur as metapopulations whose dynamics are affected by the spatial configuration of the landscape in which the species exists. For most metapopulations, it is often difficult to predict the outcomes of implemented management scenarios; this tends to result in an incomplete understanding of the spatial characteristics involved and how they operate (Kritzer and Sale 2004). For successful management to occur, managers need to first be able to
recognize the spatial scales that characterize connectivity processes and then align management strategies appropriately (Botsford et al. 1997, Palumbi 2004, Kaplan 2006). Shifting to a metapopulation view, particularly for marine species, has been encouraged by recent technological innovations, such as connectivity modeling, that help to increase our understanding of spatial distribution, population abundances, the contributions of oceanographic processes, and the drivers of ecological interactions.

Despite this, one of the core challenges to connectivity is determining how it contributes to issues of conservation and management (Bode et al. 2012). Since connectivity implies that local processes and populations may be dependent on processes occurring elsewhere (Grober-Dunsmore and Keller 2009), local management initiatives may be ineffective for providing adequate protection or localized benefits. Additionally, if connectivity across large spatial scales occurs, as is believed to be the case with Caribbean spiny lobster, there is no doubt that these populations are also crossing political boundaries along their journey, meaning that decisions made in one country could impact ecosystems elsewhere. It may be necessary to increase the scale of management, as well as the levels of transnational collaborations, to adjust for these issues. Clearly, development of coherent management strategies to ensure sustainability of entire ecosystems is complex and will require more interdisciplinary work than is currently being done.

In the past few decades, biologists have begun to consider the implications of space when creating population models (Sanchirico and Wilen
Spatial bioeconomics allows for the incorporation of more realistic features and parameters of the populations being studied. Real populations are often distributed heterogeneously; integrating spatial dimensions can generate new insights that encompass the intricacies of biological and ecological processes. As Sanchirico and Wilen point out, "space matters in interesting and complicated ways" (1999). When researchers ignore the contributions of space they often miss important behavior, as well as relevant characteristics of the resource and how it is used. This is especially true when changes in the landscape occur, either due to natural processes or human interventions, such as the introduction of condos. Assessing the population, the fishery, or the best strategies for management without considering the role these structures play spatially, ecologically, and economically is key if sustainability and ecosystem health are to be maintained. The interconnectedness of the environment further highlights the importance of considering all aspects of a system, including the role that space plays, before any decision-making can occur. The incorporation of spatial dynamics into a bioeconomic study will help to better inform ecosystem-based management by examining the intersection of spatial scales, species dynamics, and economic behavior.

The multiple dimensions encountered in a fishery, from the habitat and the targeted species to the fishers and the consumers, create a complex system where all aspects need to be understood in order for the system to function correctly. These systems need to be evaluated and studied in such a way that all parts, ecological and human, are considered equally. Political Ecology (PE) is
one discipline that does this by attempting to create a picture “where nature and society are undivided” (Robbins 2004: xvii). PE integrates natural and social science approaches to understanding human and ecological relationships using holistic methods. PE also seeks to examine how power relations impact human-environmental relations, including how social inequalities become a part of the environment and how the environment becomes part of systems of injustice. Both play a role in understanding why some actors have access to natural resources while others do not.

In recent years, conservation and environmental issues have been at the forefront of many debates. The concepts of conservation, biodiversity, and sustainable development are all part of an increasingly globalized understanding of the various relationships people have to nature (Quiroga 2009). As these issues become more prominent in local, national, and international affairs, many are paying more attention to the underlying politics and to the defined power relations influencing the interactions between humans and their environments. With this in mind, political ecology gives more attention to the environmental knowledge and practices of local social groups (Gezon and Paulson 2005), instead of focusing on interpretations of environmental issues made by those perceived to be “outsiders”. As Paulson et al. (2005) note, political ecology focuses on framing research in such a way that it spans across different spaces, scales, and social groups while conceptualizing the politics in environmental studies.
The rise in the use of condos has led to an increasing level of concern about how to sustainably manage the fishery in the face of a wide population range, inadequate regulations, and limited enforcement, while keeping pace with the demands of the global market. As such, the Bahamian spiny lobster fishery provides an excellent opportunity to examine the various biological, physical, ecological, economic, and social interactions taking place within an interdisciplinary context by combining methodologies from the disciplines noted above.

The remainder of this chapter will serve to present background on the Bahamian Caribbean Spiny Lobster Fishery and utilize responses obtained from surveys and interviews to provide a view of the current state of the fishery from the perspectives of various stakeholders. This will be followed by a description of the remaining chapters of this dissertation.

Background

Caribbean Spiny Lobster

Caribbean spiny lobster sustains one of the most economically important fisheries in the Caribbean, behind the penaeid shrimp fishery (CRFM 2011). The species inhabits tropical and subtropical waters of the Atlantic Ocean, Caribbean Sea and the Gulf of Mexico. It is distributed throughout the western Atlantic Ocean, from Brazil up to North Carolina, as well as Central America, Bermuda, and The Bahamas (Marx and Herrnkind 1986; Herrnkind 1980). Spiny lobsters typically inhabit shallow waters and can be found in any habitat that offers them protection, such as on reefs, among rocks, and in seagrass beds. A primarily
nocturnal animal, this organism hides in crevices and under ledges during the day. They are solitary until they reach their juvenile stage; at this point, they begin to congregate around more protective habitats in nearshore areas (Cascorbi 2004).

Caribbean spiny lobsters have a complex life cycle comprised of four phases: planktonic phyllosome larvae, swimming postlarval pueruli, benthic juveniles, and adults (Marx and Herrnkind 1986). The spawning season occurs April through September in the southeast United States and throughout the year in the Caribbean; females can produce 500,000 to 1.7 million eggs per spawning (CFMC 1981). Reproduction tends to be higher during the months of March through July (Arce and de Leon 2001). Once released, larvae can be carried for thousands of miles by currents until they settle in shallow nearshore areas among seagrass and algae beds (Marx and Herrnkind 1986). The phyllosoma float in the upper 100 meters of the water column, with a pelagic larval duration (PLD) that ranges from 6-12 months, until they settle to become puerulii. Settlement is often triggered by physical and chemical cues from macroalgal rich hard-bottom, usual from the genus Laurencia (Butler et al. 1997). Pueruli molt to become juveniles when they encounter suitable inshore substrates such as mangrove roots or seagrass beds. Although the benthic juveniles are primarily solitary, they begin to aggregate and migrate offshore where they seek reef habitats and eventually develop into adults (Marx and Herrnkind 1986).

The distribution of adults is dependent on the duration of larval life and the currents that transport the larvae (Ingle et al. 1963). DNA analysis of the
Caribbean spiny lobster indicates that there is a single stock structure (Silberman and Walsh 1994). This suggests high levels of gene flow due to long-range larval dispersal throughout the Caribbean. Additionally, the lengthy PLD of this species contributes to a high degree of larval connectivity in the Caribbean.

Spiny Lobster Fishing and Management

Spiny lobster sustains one of the most economically successful fisheries in the Caribbean, supporting approximately 50,000 fishers and an additional 200,000 people within the lobster fishing industry (Gittens and Braynen 2003) and generating over $450 million US per year (Ehrhardt 2005). The main resources for this species are located on the larger continental shelf reef areas of Belize-Mexico, Brazil, Florida, Honduras-Nicaragua, The Bahamas, and south of Cuba (Ehrhardt 2001). These locations correspond to the countries reporting the largest harvests of spiny lobster: Cuba, Brazil, Nicaragua, The Bahamas, and the United States (Figure 1.1). Over the past 10 years, The Bahamas has been a major producer.

Despite the economic gains in this fishery, management remains a difficult task. Many of the management issues stem from difficulties in defining the units of stock due to the long-range dispersal of the larvae. With a potential pan-Caribbean population structure, it is likely that many countries are recruiting from other, possibly distant areas (Cochrane and Chakalall 2001). This level of connectivity throughout the Caribbean creates an ecological bridge that helps to underscore the need for cooperation in the management and conservation of these stocks in order to ensure sustainable use (Claro et al. 2001). The stocks
throughout the Caribbean have been divided into four groups based on biogeography and the prevailing currents. These are the Northern Stock (northern Cuba, USA, Bahamas, Turks and Caicos, Bermuda), North-Central Stock (Mexico, Belize, southern Cuba), Southern stock (Brazil, Venezuela, Dominican Republic, Lesser Antilles), and South-Central Stock (Colombia, Nicaragua, Honduras, Jamaica) (CRFM 2011). It is the belief that The Bahamas’ geographic position contributes to their dominance in the Caribbean spiny lobster market (Cascorbi 2004).

The Bahamas Fishery

The Commonwealth of the Bahamas (Figure 1.2) is an archipelago of over 700 islands and 2,400 uninhabited islets and cays that covers an area over 259,000 km² (Deleveaux and Bethel 2001). The 19 major islands of the Bahamas comprise a total area of 13,935 km²; these islands and cays are spread over a shelf area of about 153,000 km² of shallower water banks with an average depth of 9 m. (FAO 2009).

The fishing industry in the Bahamas is the country’s third largest source of (legal) revenue, following tourism and banking (FAO 2009). While The Bahamas has several fishery resources, including conch (*Strobus gigas*), grouper (*Epinephelus* and *Mycteroperca* spp), snapper (*Lutjanus* spp), stone crabs (*Menippe mercenaria*), and other shallow and deep water scalefish (*Caranx* spp, *Haemulon* spp, *Slar* spp) (Deleveaux and Bethel 2001; Gittens and Braynen 2003), *P. argus* supports the primary fishery (Figure 1.3). It is estimated that approximately 95% of Bahamian fishermen target the species (Gittens 2004).
The commercial lobster fishery, in existence for about 100 years, began as small, local bait fisheries positioned around population centers, where the catch was sold locally. As the industry grew, so did the fishery. The sponge collapse in the late 1930s opened the door for lobster export, allowing for a strong market to develop in the 1940s (Moe 1991). Since then, the Bahamian spiny lobster fishery has grown into one of the largest and most valuable international fisheries in the western and central Atlantic (Ehrhardt et al. 2009).

Sixty-one percent (61%) of the total fishery landings in The Bahamas come from spiny lobster (FAO 2014). Sixty percent (60%) of these spiny lobster landings go to the United States; a large percentage is exported to the European Union, particularly France, with smaller numbers of exports to Canada, Barbados, and Japan (Gittens & Braynen, 2003). Project Global (2011) valued these exports at $62.7 million Bahamian.

The Bahamian spiny lobster fishery is comprised of both artisanal and commercial fishers. The fishery is based on the extensive shallow water banks, with much of the fishing effort concentrated primarily on the Little Bahama Bank and the Great Bahama Bank. Commercial fishing vessels vary in size, ranging from 10 ft to 100 ft. Within the fishery are “motherships” that work in conjunction with 8-10 smaller boats. The motherships tow the smaller boats out and often possess sleeping quarters, a kitchen, and large freezer storage (some with a capacity of holding 10-40,000 lbs), creating a floating operations base and allowing the fishers to stay at sea for weeks at a time. Artisanal fishers work off smaller boats, like dinghies, and typically make day trips. (CRFM 2011) These
“day boats” are often smaller than 20 feet and use an outboard engine. Due to their size, these boats lack freezers. Coupled with the cost of fuel and the seaworthiness of the vessels, these fishers are limited in their ability to journey far and/or travel for extended periods of time. Gear used in the fishery include spears, hooks, compressors, traps and condos (Figure 1.4), with the latter two representing the main gear (Moe 1991). Lobster divers search reefs and artificial habitats (including condos) to locate the lobster. Often times, the diver is provided air from a compressor aboard the boats. Traditionally, lobster fishers free-dived the reefs; however, compressor diving has now become more commonplace. Almost all landings are just the tails, with the head and legs wasted (Gittens 2004). While some of the commercial fishers primarily target spiny lobster, many of the smaller scale fishers target other species based on the season, including conch and scalefish such as snapper and Nassau grouper.

Status of the Bahamian Lobster Fishery

The Bahamas Department of Marine Resources (DMR) is the agency responsible for fisheries regulations, under which the Caribbean spiny lobster fishery is regulated through the Fisheries Act. Regulations in the fishery include a closed season (April 1 – July 31); minimum size limits (carapace length of 3.25 inches, tail length of 5.5 inches) and carrying a measurement gauge; trap permits, including labeling each trap and marking with buoys (currently, neither permits nor the identification of the structure’s owner are required for the use of condos); specified materials for the traps, allowing them to disintegrate over time; prohibition on capture, possession, and sale of berried females or the removal of
eggs from a female; and prohibition on possession of an individual with the swimmerettes removed. Additionally, all commercial fishing vessels within The Bahamas’ exclusive fishery zone must be fully owned by Bahamian citizens who are also Bahamian residents. (CRFM 2011; Bahamas.gov 2014)

While the fishery is subject to management through government regulations, enforcement is weak due to the size and spread of The Bahamas compared to the number of available fisheries officers (Deleveaux and Bethel 2001). Illegal, unregulated, and unreported fishing (IUU) is also a primary concern within the fishery, as it is estimated that 36% of all the landings fall within this category (Medley and Gittens 2012). Other concerns for the fishery include its apparent open access nature, the inability to control effort, and the increase in diving accidents due to the use of compressed air hoses (referred to as “hookahs”) (Martinez et al. 2007 and CRFM 2011). Despite these concerns, the fishery has been evaluated by Seafood Watch and ranked yellow, suggesting that lobster from this fishery are good alternatives when the “best choices” are not available, but buyers should be aware that there are some sustainability concerns within the fishery (MBA Seafood Watch 2013).

In 2010, the Bahamas Spiny Lobster Fisheries Improvement Plan (FIP) was implemented to assess the local lobster fishery. Led by the Bahamas Marine Exporters Association (BMEA) in collaboration with DMR, the World Wildlife Fund (WWF), and The Nature Conservancy (TNC), this project serves as a strategy to improve the fishery by promoting more sustainable management practices. It is the hope that the FIP will allow the fishery to perform at a level
consistent with the sustainability standards set by the Marine Stewardship Council (MSC).

The MSC provides certification and eco-labeling for sustainable seafood by recognizing and rewarding sustainable fishing practices, while at the same time providing consumers and other buyers with the assurance the seafood has been obtained and managed in a sustainable way. The program has aggressive standards, requiring that governments, private companies, stakeholders, and consumers (including local populations) all support sustainable practices. While MSC certification is a goal of many marine fisheries, there are serious critiques about the process of certification that will be addressed later in this chapter.

Preliminary assessments of the Bahamian spiny lobster fishery have indicated it currently falls short of the standards, as it needs to meet 80% compliance within the selected criteria to obtain the certification. While countries typically attempt to achieve this certification only for certain areas within their jurisdiction, The Bahamas hopes to obtain the certification for the entire country, further increasing the difficulty of this task.

*Lobster Condos*

In recent years, The Bahamian spiny lobster fishery has seen an increase in the use of condos (referred to as “casitas” throughout the Caribbean), artificial habitats used to aggregate lobsters in large numbers for easy capture (Lozano-Álvarez *et al.* 1991, Sosa-Cordero *et al.* 2008). The Bahamas is one of many Caribbean nations that has utilized condos as a way to concentrate lobsters to boost production in the fishery and meet the increased market demand for the

The use of condos as a spiny lobster fishing method gained popularity in the Caribbean over 50 years ago. It is believed the method was developed by Cuban lobster fishers, who created raft-like structures made of palm logs and placed them in shallow areas where natural refuges were scarce (Cruz and Phillips 2000; Baisre 2000). These “pesqueros” concentrated hundreds of lobster at a time, which were then easily caught. Fishers in the Yucatan Peninsula soon followed suit with similar structures they called “casitas cubanas” (Sosa-Cordero et al. 2008; Miller 1982; Moe 1991; Briones-Fourzan et al. 2000). The success of the method led to its use in other areas in the Caribbean, the U.S. (in Florida, where they are now banned), and other parts of the world such as Africa (Herrnkind and Cobb 2008; Conrad and Danoff-Burg 2011; Quinn and Kojis 1995; Okechi and Polovina 1995). It is believed that the ease of deployment of condos, coupled with their relatively low costs, have helped to revolutionize lobster fishing throughout the Caribbean (Seijo et al. 1991).

There are several benefits to introducing condos to spiny lobster fisheries. Condos can be used to mitigate the loss of natural habitats and shelters (Davis 1985; Butler et al. 1995; Herrnkind et al. 1999) and to reduce fishing impacts to reefs by redirecting efforts away from fragile habitats to minimizing environmental damage from divers and boats (Conrad and Danoff-Burg 2011). Condos also provide protection from predators (Lozano-Alvarez 1995), which in turn can help
increase the survival of juveniles (Eggleston and Lipcius 1992, Briones-Fourzán et al. 2007) and potentially contribute to the increase in lobster populations (Nonaka et al. 2000; Briones-Fourzan et al. 2000). Additionally, condos provide an efficient way for fishers to demonstrate some selectivity in the maturity and size of the individuals collected during harvesting, helping to ensure they are abiding to regulations (López and Consejo 1986, Lozano-Álvarez et al. 1993, Sosa-Cordero et al. 1998, Ley-Cooper and Chávez 2009).

**Condos in The Bahamas**

While lobster fishers in The Bahamas still use a variety of methods for harvesting, most lobsters in this fishery are caught through the use of condos (CRFM 2011). It is believed this shift in popularity, from traps and spears to condos, occurred during the late 1980s (Bethel et al. 2001). Despite their widespread use, it is still unknown exactly how many of the structures are deployed. In 2001, it was estimated there were approximately 650,000 condos placed throughout The Bahamas (Deleveaux and Bethel 2001); in 2009, the estimate rose to about 800,000 (Ehrhardt et al. 2009). Currently, anecdotal estimates place the quantities of these structures at over a million. It is difficult to estimate the exact number of condos as some are lost due to storms or theft (and tend to be replaced without recovering the lost structures) and many of the fishers choose to be secretive about how many they have set out and/or fish from. These condos are located on the shallow water banks, particularly on the Great Bahama Bank and the Little Bahama Bank. Once the condos are placed,
they last an average of 5 years (FAO 2009). Most of these condos are not removed, and even fewer are relocated.

Issues and Uncertainties with Condos

Despite the potential benefits mentioned previously, the long-term effects of condo usage on lobster, the surrounding and nearby habitats where they are deployed, and the fishery, including the fishers, have not yet been fully examined or understood. This creates many concerns, especially as the use of condos continues to increase, coupled with an upsurge of new individuals entering the fishery (Gittens 2004). For example, the high densities of individuals found in the structures can facilitate disease transmission (Evans et al. 2000; Briones-Fourzan et al. 2012; Candia-Zulbaran et al. 2012). While concentrating the lobster may offer some level of protection, particularly for juvenile, the large numbers of individuals may also attract predators such as snapper, grouper, nurse sharks, and lionfish (Mintz et al. 1994; Arce et al. 1997; Henderson and Cote 2011), potentially increasing predation (Herrnkind and Butler 1986; Smith and Herrnkind 1992; Herrnkind et al. 1999). Additionally, the placement of the condos may result in seagrass die offs, and it is still uncertain how removing lobster from the reefs might impact the ecosystem services they provide for that community. And although they can lead to better efficiency for fishers, there is data to suggest condos may contribute to overfishing (Briones-Fourzan et al. 2000) and tend to lead to a larger percentage of juvenile individuals being caught in many of the fisheries where they are used (Chakalall & Cochrane 2007). It is also still unclear how moving these individuals from their natural habitats might
influence migratory and connectivity patterns. Another large uncertainty is whether the condos are resulting in an increase in lobster production or are simply aggregating many individuals in one place.

Despite the large number of landings through the use of condos, there are few regulations and policies regarding them. As will be discussed later in this chapter, it seems most of the fishers believe that since the structures are under the water, on the seabed, and unmarked (by a buoy or otherwise), the condos belong to no one, regardless of who built and distributed them; the same reasoning goes for the lobsters (and other organisms) found utilizing the condos as habitats. This notion of property rights is quite different from that regarding lobster traps, which are registered and labeled with the owner’s information; any lobster found within a registered trap belong to that owner. In the case of condos, however, whoever gets to one first gets the catch – a classic “race to fish”. Thus, there is no surprise that some conflicts do arise, especially when fishers intersect. It’s also interesting to note that although the condos provide artificial habitats (for lobsters and a host of other species), DMR currently does not view the structures as “artificial reefs”, which have strict regulations for their use and placement.

The high reproductive potential of spiny lobsters in The Bahamas coupled with the relatively low-tech and inexpensive nature of condos has contributed to the stocks remaining relatively stable when compared to other lobster fisheries throughout the Caribbean (Ehrhardt 2009). However, although the Bahamian fishery produces 5-6 million pounds of frozen tails per year, recent fishing
mortality rates indicate the stock might be nearing full exploitation (Gittens and Braynen 2003; Chakalall and Cochrane 2007; WECAF 2007). Despite this, the number of fishers has increased as the catches by each fisher decreases (Gittens, Personal communication). As the size of the fishery increases, both in terms of effort and entry, its management will remain a complex task. Some of this complexity is due to the biology of the species (Ehrhardt et al. 2009; Marx and Herrnkind 1986); however, most of the management complications arise from the inability to efficiently manage the large area over which the population is fished, the uncertainties surrounding the use of the condos, and the seemingly open access nature of the fishery.

**MSC Certification of the Bahamian Lobster Fishery**

In recent years, there have been encouraging strides towards creating a sustainable lobster fishery within The Bahamas, by attempting to certify the fishery through the Marine Stewardship Council (MSC). Their mission is to contribute to ocean health by using the certification to reward sustainable fishing practices and by using the eco-label to help influence the choices made when purchasing seafood (MSC 2010). Through this process, fisheries are able to increase their transparency, as well as traceability of the catch. Certified fisheries are subsequently rewarded through consumer choices, thereby having the opportunity to maximize their profits by receiving price premiums on or increases in the market shares of their products (Gudmundsson and Wessells 2000; Wakamatsu 2014).
Several markets have declared they would only source MSC certified products, beginning with an announcement made by Walmart in 2006 (Zwerdling 2013; MSC 2014). Similar declarations were made by other large food distribution and service companies, such as Sysco and the Compass Group, as well as by the European Union, which has pledged to sell only MSC certified fish by 2015.

The MSC certification process represents the emergence of a global market for sustainable fish (Ponte 2008; Gulbrandsen 2009; Auld and Gulbrandsen 2010; Hallström and Boström 2010; Gale and Haward 2011). As one of over 30 certified labels for fishery products, the MSC eco-label currently holds the rank as the most recognized and fastest growing (Parkes et al. 2010; Roheim 2009). MSC began as a collaboration between the World Wide Fund for Nature (WWF) and Unilever to help promote long-term sustainability of well-managed marine fisheries (MSC 2015). Currently, there are 200 fisheries with the certification, 103 are being assessed, and 22 have failed the certification process or withdrawn from the program (MSC 2015).

The “MSC standard” is based on three principles: the fish stocks must be healthy, the surrounding ecosystem must not be harmed by the fishery, and management regimes in place must ensure the longevity of the fishery resource (MSC 2010). Fisheries wishing to obtain the certification must undergo a review process where their sustainability is assessed under 31 performance indicators grouped under the three principles. The indicators are then scored on a scale of 1-100, with the key benchmarks of sustainability defined by the scores 60
A minimum score of 60 must be achieved for each performance indicator in order to qualify for the certification. As the scores increase towards 100, there is greater certainty that the fishery will be more resilient to both ecosystem changes and fishing pressure, as well as possess a lower risk of falling below the minimum score. Although fisheries are not required to achieve an 80 on all 31 indicators for certification, they must receive an average score of 80 within each of the 3 principles. Any performance indicator with scores below 80 must be improved during the course of the fisheries certification, helping to further promote positive changes. Once certification is obtained, the fishery must be audited annually and undergo a complete reassessment every 5 years.

Fisheries that seek to complete a pre-assessment or want to move from the pre-assessment stage to a full assessment for certification can engage in a Fishery Improvement Plan (FIP), which will allow the fishery to develop a strategy for improving their performance within the certification standards. (MSC 2010)

**MSC in The Bahamas**

The Bahamian fishery underwent the pre-assessment process in February 2009, identifying several performance indicators that, if the fishery was placed under a full assessment, would only pass with conditions (achieving scores between 60-80) or would likely fail by receiving scores below 60. Some of the issues leading to non-compliance include: lack of data regarding the status of the
stock, lack of defined reference points for the stock, lack of fishery specific
harvest controls, limited ability to monitor and evaluate fishery impacts on the
stock, the unknown impacts of condos on the habitat, lack of limits on the
quantity of traps and condos in use, limited information on the level of risk the
fishery poses to lobster habitats or to the trophic structure and function of the
ecosystem (Wakeford 2013).

Based on information obtained during the pre-assessment, it was
determined the fishery would most likely fail to achieve certification and that it
should not move forward with the process until significant changes were made.
As such, an FIP action plan was developed in October 2009, with plans for
implementation to begin in June 2010. Since it was put into the place, the fishery
has achieved several benchmarks and made numerous improvements, including:
a stock assessment, development and approval of harvest control rules, a study
on IUU fishing within The Bahamas, dissemination an outreach and education
program through the “Size Matters” campaign developed by the Friends of the
Environment organization in Abaco, and establishment of a data collection
system utilizing catch certificates.

Although there are still key activities awaiting implementation, it is believed
that through the cooperation of the numerous stakeholders involved, the fishery
will complete the full assessment and earn the certification by the end of 2017.
Receiving the MSC certification will allow the fishery to expand to additional
markets, particularly those seeking to deal only in “sustainable” products. This
would be especially profitable, as The Bahamas would be one of 5 “certified
sustainable” spiny lobster fisheries globally, and the second in the Caribbean (Figure 1.5), ensuring the broadest possible market for export.

Benefits and Criticisms of MSC Certification

The MSC has succeeded in promoting “sustainable fish” by certifying many fisheries and creating markets for these products in just over a decade. Through the assessment process, the MSC has allowed certified fisheries to emerge from their traditional markets and enter into markets where there is less competition, a price premium on their labeled products, and potentially new consumers. This was seen in the Kyoto Danish Seine Fishery Federation, a small fishery that received immediate benefits from its certification by being able to break away from markets dominated by larger fisheries and essentially dominating its own, new market as the products were now viewed to be “different” (Wakamatsu 2014; Loureiro and Hine 2002).

The purchasing preferences generated by the sustainable fish market create the incentives needed for fisheries to want to move forward with the assessment necessary to join the program. These same incentives also influence those who operate their fisheries at levels below the MSC standard to revise and improve their practices to become as sustainable and ultimately, as competitive as those possessing the certification (Martin et al. 2012; Tlusty 2012). It is through these incentives and competitiveness that the MSC program can potentially play a role in helping to shape fisheries by encouraging their management to evolve over time. By undergoing the certification process, fisheries have created new protected areas to help limit impacts, developed
methods to help reduce bycatch, changed fisher and manager behaviors, and even seen their resource stocks rebuild (MPI 2012; MRAG, 2011a, b; Richard et al., 2011; Field et al. 2013, Watkins et al. 2008).

In addition to creating new markets, the certification process can also have an effect on who has access to the resource, the fishery, and the resulting markets. This was examined by Foley (2012), who reviewed the certification process of a shrimp fishery in the Province of Newfoundland and Labrador, and how acquiring the certificate became a strategic move in terms of resource access. Foley argues MSC certification allows those holding the certificates, “the fishery client”, to control access to the fishery resource (with the potential to decide who can fish and where) and to control the production relations, i.e. all the social relationships people need to develop for survival, within the fisher. A fishery client can be an “individual, organization or group of organizations” who have “some influence over the management of the fishery, or the ability to be able to implement any conditions raised by the certification body” (MSC 2010).

The ability to control access, either to a valuable resource, or in this case, to utilizing a valuable eco-label to reach more viable markets, provides the owner with a distinct advantage and influence over the relationships that are developed and/or changed as the decisions are made, especially considering this same owner might lack property rights. This further underscores the importance in being able to make the distinction between the right to benefit (property) vs. the ability to benefit (access), as it could be argued that one might have an advantage over the other.
Much of the criticism of the MSC has been in regards to the low number of certifications gained by fisheries in the developing world. Some argue the market incentives generated by MSC certification promote the certification of more capital-heavy fishery operations over smaller-scale fisheries that are less intensive and invasive due to selective, low-impact techniques (Jacquet et al. 2010b; Jacquet and Pauly, 2008; Gulbrandsen, 2009; Ponte, 2012), fisheries common in the Global South. As new markets are being created, these fisheries and the small-scale fishers they support are seeking access into these elusive markets. Many times, this is not possible due to the financial (with the estimated cost of assessment between $15,000-$120,000 (Christian et al. 2013)), administrative, and organizational burdens created by participation in the assessment process (Gulbrandsen 2013; Jacquet and Pauly 2008). In The Bahamas, these burdens were eased through the collaboration taking place between various government agencies, NGOs, exporters, fishers, and other stakeholders. Additionally, the Bahamian Marine Exporters Alliance (BMEA) was able to assist with the financial needs by dedicating a small percentage of all sales to certification efforts (Personal Communication). Yet, these may not be options for other fisheries in the Global South in their current states. Bush et al. (2013) suggests that in order for the MSC to maintain credibility, they must work towards improving accessibility to these fisheries, as well. They also argue that as certification and certified products become more mainstream, the uniqueness on the market will be dampened and any associated price premiums will be lost, forcing fisheries to find new opportunities to create added value.
Critics have also expressed concern about the subjective nature of the third-party certifiers (Jacquet et al., 2010b; Stokstad, 2011), as well as the effectiveness of the process (Jacquet and Pauly, 2007; Ward, 2008; Gulbrandsen, 2009; Jacquet et al., 2010a; Marko et al., 2011; Froese and Proelss, 2012; Ruddle, 2012). Some believe that the certifiers are generous in their interpretations of the principles and in their assignment of scores, particularly since the MSC itself is funded by the certification fees. These factors may lead to the certification of fisheries that may not, in fact, be sustainable, as well as conflicts of interest when reassessing sustainability.

Methods

In the summers of 2010, 2011, 2012, and 2013, in person interviews and surveys were conducted in The Bahamas with fishers, government officials, NGOs, exporters, and other stakeholders within the Bahamian spiny lobster fishery. Surveys (Appendix A) were conducted with lobster fisherman on several of the islands with major lobster fishing settlements, including New Providence Island, Grand Bahama, Abaco, Andros, Long Island, and Spanish Wells. Utilizing the snowball method (Singleton and Straits 2010), fishers were identified through recommendations from local contacts, approaching individuals on fishing docks, boats, or markets, and requesting contact information for additional individuals at the end of each interview. The survey contained 125 questions and included a variety of topics including general demographics; fishing practices; vessel and gear information, including usage of condos; decision
making; and opinions about condo use, the lobster population, the general marine environment, fisheries management strategies, and property rights.

Each survey lasted 45 minutes to 2 hours, based on the amount of additional anecdotal information fishers were willing to provide. For individuals who expressed concern over the time commitment required, semi-structured interviews (Singleton and Straits 2010) were conducted, following the general format of the surveys; these interviews were typically 20-30 minutes. Sixty-six (66) fishers were surveyed, while thirty-six (36) participated in semi-structured interviews.

Semi-structured interviews were also conducted with the other stakeholders in the fishery. Groups interviewed included fisheries officers; buyers; NGO staff from the Bahamas National Trust (BNT), The Nature Conservancy (TNC), and the Bahamas Reef Environmental Education Foundation (BREEF); the founder of the Bahamas Commercial Fishers Alliance (BCFA); and the members of the Bahamas Marine Exporters Association (BMEA). These interviews focused on the current state of the lobster fishery and expected changes, perceptions on condo usage and perceived impacts of their utilization, reasons for and opinions about engaging in the Marine Stewardship Council (MSC) certification (an internationally recognized eco-label awarded to fisheries that have been deemed environmentally well-managed and sustainable (MSC Executive 2005)) process, including their role in the process, if any, and general concerns about the fishery.
In order to probe the existence of differences among the fishers, responses were evaluated based on various groups. Fishers were characterized based on age (20-29 years of age, 40-45 years of age, 46-50 years of age, 51-57 years of age, and 58 years of age and older), experience level (<15 years, 16-30 years, and >31 years), island (Abaco, Andros, Grand Bahama, Long Island, Spanish Wells, and New Providence), position of fisher (captain, crew), primary occupation (fisher, fishing guide, and other), and generation of the fisher (first, second, and third). Survey responses were compared between these groups. For categorical response variables, comparisons were made using a chi squared test for independence (Hampton and Havel 2006). For continuous response variables, comparisons were made using a one-way analysis of variance (ANOVA).

Results

Fisher Demographics

Of the 102 total fishers surveyed and/or interviewed, the largest percentage lived in Andros, Long Island and Spanish Wells (Figure 1.6). All fished for lobster; 92% focused primarily on lobster, while 15% exclusively fished for lobster. The fishers ranged in age from 24 to 81 years old, with a mean age of 49 (SE=1.42). Experience levels ranged from 6 years to 73 years, with a mean of 26 (SE=1.54) years of experience. Neither the ages nor experience levels of fishers were significantly different among the islands. All the fishers are first (37.1%), second (33.9%), or third (29.0%) generation fishers. Additionally, more than half (68.2%) reported their primary occupation as fisher; the remainder
were either fishing guides (10.6%) or focused on other jobs outside of the fishing industry (21.2%), such as farming, caretaking, tourism, carpentry, and engineering. Table 1.1 provides a summary of the fisher demographics.

*Use of Condos*

When asked about their primary method for harvesting lobster, 75% (n=64) of the fishers responded condos (Figure 1.7). Of these fishers, some indicated they use condos equally with traps (4.69%) and with diving (7.81%), while 62.5% report using condos exclusively. The remainder (25%) primarily dive for their lobster. Of all the fishers surveyed (n=66), only 6.25% reported not using condos at all. There was a significant difference in responses to the method used between islands (p=.034), with only fishers from Long Island utilizing all three methods, and fishers from Abaco solely using condos (Figure 1.8). Of the fishers who do use condos (n=60), 60% don’t actually build or deploy any condos at all. Additionally, 71% admit to fishing from condos set by other fishers. Both of these are also significantly different between islands (p=.001 and p=.003, respectively), with fishers from Andros most likely not to set condos while still harvesting from them, and fishers from Spanish Wells most likely to set and fish from condos they build. Consequently, 68% of the fishers also report being involved in conflicts arising from the use of the condos, with fishers from Andros and Spanish Wells significantly more likely to be involved in condo-related conflicts (p=.001). The same was true for those who also owned the boat they fished from (p=.002).
On average, the first year of condo use reported was 1994 (SE=0.89). Although the earliest reported year for use was 1978, most of the fishers began utilizing this method in 1992 (Figure 1.9). There was a statistically significant difference in the first use of condos between the islands (p=.002), with fishers from Abaco and Spanish Wells most likely to begin using condos at an earlier date (Figure 1.10). Fishers from Abaco also reported condo use 6 years prior to any of the other islands discovering condos.

Despite 62.5% of fishers using condos as their exclusive method for harvesting lobster, 60% of the fishers admit to not building or setting any condos. For those who do, the amount they set per season ranges from 0 to 4000, with an average of 419 (SE=156.42) set each season. Spanish Wells fishers, as part of their boat cooperatives, set a mean of 1716.7 condos (SE=576.4) per season, significantly higher than the mean number of condos set per season by fishers from the other islands (p=.001; Figure 1.11). The total number of condos set by these fishers ranges from 0 to 25,000, with an average of 3400 (SE=776.98) condos in total. Fishers with less than 15 years experience were significantly more likely (p=.016) to set fewer condos (Figure 1.12). Fishers from Andros were also significantly more likely to set fewer condos, while those from Spanish Wells tend to set larger quantities (p=.000; Figure 1.13). The cost for these condos ranges from $10 to $500 per condo, with an average cost of $50-$60 (SE=10.53). The condos are placed in a variety of habitats, with the largest percentage (60%) ending up in seagrass areas, followed by a mixture of grassy, sandy, and hardbottom substrates (Figure 1.14). When asked about the factors
used to determine placement, the fishers indicated they were mostly looking for areas with low boat traffic, but still provided a high catch (Figure 1.15). The fishers reported typically finding 100-200 individuals per condo (about 40-60 lbs).

When asked if condo use influences the way they fish, the majority of the fishers indicated yes (54.5%; Figure 1.16). For many, collecting from condos allowed them to increase the lengths of their trips, while also traveling further and covering a wider area. Additionally, condo use enabled them to decrease their crew size, thus allowing more profits for those still left. Most of the fishers also answered yes (69.8%) when asked if the cost of condos influences the number they set out (Figure 1.17). Many agree they would place more condos if the overall costs (materials, gas, time, etc.) were cheaper: “If you put them down and they don’t hit, it’s a lot of cost to pull them up and move them” (Personal communication). Fishers also mentioned the lower ex-vessel price for lobster in recent years is also a factor in how many condos they could afford to place. For those who answered “no”, they feel there is such a high number of condos in Bahamian waters that it is not necessary to spend money making or setting more. As one fisher recounted, “I don’t put out condos because they cost; but there are so many condos out there and so many people working them” (Personal communication).

Fishers Perceptions of the Bahamian Spiny Lobster Fishery

When asked about their opinion in regards to the status of the Bahamian lobster population, a large percentage (90%) of the fishers responded they thought the population was doing very well. The general consensus is that there
is “no shortage of lobster”, as “there are so many there is no end to them” (Personal communication). Those who answered that there are some issues with the population believe there have been some changes over the years and report seeing fewer lobsters, particularly in the shoals and reefs. However, 86.4% of the fishers do believe that The Bahamas is an important site for lobster, due to the banks and the presence of a variety of habitats, and 72% believe The Bahamas acts as a source of lobster for the rest of the Caribbean. Responses to the importance of The Bahamas as a lobster site were significantly different between islands (p=.004) and fisher’s position (p=.009), with fishers from Andros and boat owners more likely to believe in the importance of the areas. Fishers from Andros were also significantly more likely to believe that the Bahamian habitats are an important lobster source for the Caribbean (p=.040).

When asked about the condition of lobster habitat generally in The Bahamas and near their local settlements, 66.1% and 63.5% of the fishers felt the habitats, respectively, were in very good condition. Perceptions on the condition of the habitat were significantly different between islands (p=.025), with Long Island fishers more likely to believe the condition of the marine habitat is fair. A similar amount of fishers (60.3%) also felt that locally, the fishing levels were not excessive, compared to 44.3% who felt the same about The Bahamas as a whole. Third generation fishers were significantly more likely to believe local fishing levels are too high (p=.019), while boat owners were most likely to deem that fishing is being done at correct levels (p=.040). There was no significant
effect of the various fisher groups on responses regarding the levels of fishing for the entire Bahamas.

The fishers believe the largest threat to the lobster population is poaching, followed by illegal harvesting (Figure 1.18). Fishers from Spanish Wells and those who are boat owners were significantly more likely to respond that poaching is the biggest threat to Bahamian lobster (p=.017 and p=.010, respectively). When asked about the top impacts to their local areas, poaching was again the most frequent response, followed by pollution (Figure 1.19). These responses did not differ significantly between the various groups.

Fishers’ Views on Condos

Most of the fishers (87%) believe condos have an impact on the environment (Figure 1.20). A large proportion of these fishers (73%) feel the presence of condos is good for the environment (Figure 1.21), as they help to provide additional habitat, shelter, and food for the lobster, while also serving as nursery sites for many other species, including grouper and snapper. The remainder viewed these impacts as negative, as they've noted the die-off of seagrass in areas where condos are placed. For those who still fish on the reefs, they also report seeing less lobster, and they posit the condos are preventing the lobster from reaching their natural habitats. Although there was no significant difference in response to the presence of impacts among the groups, fishers from Long Island were more likely to perceive that condo use had a negative impact on the environment (p=.000).
When asked about the impact of condos on the lobster populations, 82% believe there are impacts, with 69% perceiving the impacts as positive, describing reasoning similar to those in the paragraph above, and 23% believing there are negative impacts on the population (Figure 1.22; Figure 1.23). These fishers feel the condos attract more juveniles and condo use is contributing to killing the shoals and reefs as there are fewer lobsters in these habitats to fulfill their intended ecosystem function. A small percentage (8%) feel there are both positive and negative impacts on the population because they believe that while condos may be good at attracting lobster and other organisms, they are also contributing to more pressure being placed on the fishery. Boat owners and Andros fishers were more likely to perceive the presence of impacts from the use of condos on the local lobster populations (p=.001 and p=.011, respectively), with Andros fishers were also significantly more likely to respond that these impacts were negative (p=.033).

Fishers’ Views on Condos and Associated Rights

When fishers were asked who they thought owned the condos, more than half (52%) believed ownership belonged to the person who set the condo (Figure 1.24). Table 1.2 describes some additional statements made by the fishers in regards to this question. When asked who owns the lobster inside the condos, 66% of fishers responded this right belongs to no one (Figure 1.25). These fishers contend the person who gets to the condo first, despite whether they made and/or set the condo is entitled to whatever catch is there. The remaining fishers believe whoever invests in the materials to make the condos and expends
the resources to build and deploy them within the habitats, have a claim to any of the lobster residing beneath the structures. Table 1.3 lists some of the statements made by fishers in response to this question. Spanish Wells fishers were significantly more likely to agree that the person who sets the condo owns the condo and owns the lobster found in the condos (p=.000 for both); alternately, fishers from Andros were more likely to answer that no one had ownership rights to condos or the catch generated from them.

When asked if they should be allowed to collect from other fishers’ condos, 76% (n=62) of the fishers answered “Yes” (Figure 1.26). Responses to this question were significantly different between islands (p=.000), with fishers from Andros and Long Island most likely to agree that collecting from others’ condos should be allowed (Figure 1.27). A small percentage of the fishers (5%) confirmed that while they do currently fish from condos that are not theirs, they believe they should not be allowed to do so.

*Fishers’ Views on Condo Regulations*

The large majority (88%) of fishers surveyed consider the level of local enforcement within The Bahamas, especially in regards to fisheries regulations, to be inadequate. More than half the fishers (55%) also agreed condos needed some sort of government regulations. Figures 1.28 and 1.29 summarize the condo use and placement restrictions suggested by the surveyed fishers. Suggested regulations included licenses and fees (21%), limits on number of condos per boat/fisher (42%), limit on types of materials used to build condos (32%), implementation of shorter seasons (9%), closure of certain areas to
lobster fishing (72%), and a ban on all condo use (6%). Fishers from Andros and Long Island (p=.001), as well as 1st generation fishers (p=.046), are more likely to support the institution of protected areas. Material and number restrictions for condos were also significantly more likely to be championed by fishers from Long Island (p=.027 and p=.001, respectively) and by boat owners (p=.000 and p=.023, respectively). Despite the desire for more condo regulations, most of the fishers (82%) disagree that condos should be removed after the season. They feel this option would be too costly for both the fishers and the government, and that condos should only be removed if they are damaged. This view did not differ significantly between the various groups.

**Views from Non-Fishers**

Many of the individuals/groups interviewed on Nassau are involved in the movement to obtain MSC certification for the Bahamian spiny lobster fishery. As part of this process, the FIP was conceived with input from many of these stakeholders. They all view the FIP as a means to promote positive changes in the management of the fishery, increasing the transparency of the industry and the traceability of the catch. They also hope gaining the MSC certification, which will allow the fishery to expand to additional markets, will help the fishery earn more profits.

The stakeholders also expressed concern in condo usage throughout the fishery in recent years, and the potential impacts on the lobster, the surrounding environment, and the fishery overall. All of the interviewees communicated interest in learning more about how condos are used, where they are being
placed, and in what quantities. They also spoke of the necessity for policies related specifically to managing the use of the condos. However, the fisheries officers noted the government is hesitant to institute any new regulations before gaining a deeper understanding of condo distribution and the fishers’ perceptions of current and potential policies. Many are worried that if these condo-related concerns are not addressed they will have a bearing on the evaluation scores assigned during the MSC certification process.

Buyers interviewed discussed the recent changes they’ve seen in the fishery since the quest for MSC certification began. They noted a firmer stance by the processors and exporters on enforcing purchasing policies with regards to undersized lobster and keeping accurate catch records for each boat and/or settlement area. The BMEA expressed the importance of all the exporters coming together to stand firm on issues like this, as they believe it helps to send a clear message to the fishers on what will and won’t be accepted. They were ecstatic about the collaboration between the exporters, who are normally competitors, which allowed them to implement zero tolerance policies in an attempt to eliminate some of the harmful practices within the fishery, like the acceptance of undersized individuals. Many of the interviewees also spoke of the increased level of cooperation over the past few years amongst the various stakeholders in the fishery. One of the members of the BMEA stated he never thought he would be sitting and collaborating with NGOs, DMR, and other exporters to discuss the state of fishery, but that “the [certification] process has
allowed us to come together on a common platform to work collectively as a team” (Personal communication).

Discussion

Despite the sentiment of “we are all Bahamians” (expressed by almost every fisher I spoke to), the islands are quite different. Grand Bahama, situated near the northern extent of the country, hosts small communities of fishers in both the East End and West End settlements. They use easily obtainable materials, such as local pine and scrap metal, to construct their condos. Many of the fishers also still use lobster traps. Grand Bahama fishers focus most of their efforts on the Little Bahama Bank, where there is less competition from the larger commercial fishers, utilizing small boats to make day trips to check their condos. Andros fishers are also day fishers, spending 8-12 hours daily harvesting lobster on their small boats with nothing but a couple coolers on board. Some of the fishers from Central and South Andros may take longer trips of up to 2 or 3 days, where they camp on the local cays surrounding the islands. These fishers are from small and extremely isolated settlements, where the economic opportunities are limited. Many of the fishers, particularly those from South Andros, live Spartan lives with few extravagances. If they do make condos, they typically utilize simple or discarded materials. Due to the lack of access to resources, most of these fishers don’t own much gear, and they admit to fishing from condos belonging to others. Abaco also has small isolated settlements where the fishers work in small family groups. Unlike the Androsian’s, these fishers place much effort into building and using condos. They set large numbers throughout the
Banks, with most of their condos concentrated on the Little Bahama Bank and the habitats near the Berry Islands. Long Island fishers, on the other hand, mostly focus their efforts on the habitats within the southern regions of the Great Bahama Bank, spending 1-2 weeks on the water. They typically fish in groups of 8-10 fishers, utilizing a small mothership and a few dinghies. Like the fishers from Grand Bahama, Long Island fishers also tend to use a combination of condos and traps to harvest lobster. All the fishers from the islands mentioned thus far were black Bahamians, with the exception of Long Island and Abaco, which both have fishers representing multiple races. However, the fishers from Spanish Wells are all white Bahamians. The small island of Spanish Wells has long been considered the spiny lobster capital of The Bahamas. These fishers work in family collectives, using a large mothership with 5-6 associated boats. Although a few of these fishers still utilize traps, the majority have transitioned to using only condos. During the closed season, they spend their time preparing for the next August by purchasing large quantities of wood and metal to repair and/or replace their many condos. These supplies can be seen stacked up along the sides of the roads. Once the season opens, only women and children are left on the island, as most of the men leave to fish for 4 to 6 weeks at a time, harvesting until their large freezers on board the motherships are filled. They then return for a week or two to unload and restock their supplies before heading out again. While the fisheries on the other islands are primarily small-scale, the Spanish Wells fishery represents a large portion of the industrial fishing fleet, with
typical trips resulting in 30,000 to 40,000 pounds of lobster tails harvested on average.

Almost all of the fishers surveyed use condos to harvest lobster. Although condo usage began as early as the late 1970s most of the fishers discovered this technique in the 1990s. The Abaconian fishers appeared to be the first to use condos; this is consistent with the interviews, as most fishers from the other islands said they learned about the method from the Abaconians.

Many of the fishers use additional fishing methods; however, the vast majority utilize condos exclusively. Despite this, most admit they don’t build any condos, instead choosing to harvest from condos built and placed by others. This is believed, anecdotally, to be the cause of the increasing conflict among lobster fishers in recent years. Clear differences emerged between islands and age group in terms of which fishers were building condos and which were solely utilizing them, with fishers from Spanish Wells more likely to the do the former and those from Andros more likely to do the latter; additionally, fishers with less than 15 years experience were also more likely to use condos without building them. These differences between islands were further reflected in the reports of conflicts, as a higher proportion of both Spanish Wells and Andros fishers were involved in condo-related conflicts.

Even with the increase in conflicts, the fishers seem to value their use of condos as they view the method as a way to increase their harvest, while at the same time lowering their effort and limiting their crew size. As one fisher stated, “now that we have condos, fishing is a sure thing” (Personal communication).
Additionally, the use of condos has helped some fishers to fetch better prices. It was noted that the absence of visible spear holes in the lobster tails “helped change the rating of the lobster they produced from second rate to first rate” (Lobster exporter, Personal communication), which subsequently raised the price. However, the cost of the materials, and more specifically, setting the condos, has been a bit prohibitive for both those who choose to construct condos and those who don’t.

With large numbers of condos currently placed throughout the banks, and hundreds to thousands of additional condos being set per season, concerns have risen about the ability of The Bahamas population to adequately sustain rising catch levels exhibited in the area (Figure 1.30). Although the fishers believe the Bahamian lobster population is doing very well, the interviews revealed that they are greatly concerned about the level of poaching and illegal harvesting seen in recent years, as “people are taking everything they see” (Personal communication).

Much of this concern is levied against non-Bahamian citizens, particularly fishers from the Dominican Republic, with fishers citing “there are too many fishermen from other places” (Personal communication). Bahamian fishers have reported seeing foreign boats within Bahamian territorial waters with increasing frequency over the past few years, both during lobster season and after the season has closed. These fishers “do not respect the environment” and “they have no regards for the laws of our country,” state two of the local fishers (Personal
communication). The fishers also worry that the limited levels of enforcement also contribute to the rise of these foreign poachers.

With the increasing number of condos throughout The Bahamas, there has also been some debate as to their impact on the environment and the lobster population. While almost all the fishers agree there is an impact, most believe this impact is positive and helps support the lobster population, as well as the community of organisms that share the “condo habitat”. As one fisher pointed out, “condos are definitely helping the lobster population. Hundreds of small baby lobsters are produced from condos and this gives them a long time to develop, which they need. If they were in small rocks [the shoals or reef], the nurse sharks would get them” (Personal communication). This echoed the sentiments of another fisher who stated, “now that the crawfish are in condos, fish can’t eat them, so they live longer and grow bigger” (Personal communication). Other fishers describe the importance of the condos for organisms besides lobster: “They are good for other species as well. When we close the season, lots of things live there; spawn” (Personal communication).

The remainder, particularly fishers from Long Island and Andros perceive the impacts to be negative. One main issue is seagrass die-off because the “condos kill the area they cover” (Personal communication). Fishers also worry the condos attract too many juveniles as “people may be catching more juveniles or killing babies” (Personal communication). Other fishers show concern about the increase in harvesting pressure throughout the fishery: “Condos may be destroying the population. It’s so much easier and faster to catch the crawfish;
they have nowhere to hide” (Personal communication). Fishers from Andros, a large number of whom still fish regularly from the reefs (more so than fishers from other islands), have described seeing drastic changes in the numbers of lobster found on the reefs over the last decade. They attribute this loss to the rapid increase in condos during this time period. “I know for a fact that it doesn’t make much sense to go out and fish shoals anymore….I will find more crawfish in the condos than in the shoals. This has an impact on the shoals because they keep the shoals clean.” (Personal communication) Other fishers agree with this sentiment, as “once the crawfish come to the shoals, the shoals stay clean and other fish come back. But when there’s no crawfish, moss grows and everything leaves” (Personal communication).

**Condos and Associated Rights**

While about half of the fishermen surveyed believe that the person who builds and sets a condo is the rightful owner of the condo, a higher percentage of the fishers believe that no one has a claim to the lobster or other organisms found within them. Many of these fishers are the same fishers who believe in ownership of the condos. It’s these conflicting views that seem to be the most challenging for the fishers: while the condos themselves may be perceived as private property, once the structures are set in traditional fishing areas, they become open and available to everyone. Statements like “The guy who put it [the condo] there owns the material, but he don’t own the spot” and “I’d feel a little bad if someone was working my condo, but I know it’s a part of the game” (Personal communication) help to substantiate this viewpoint.
These findings link to the common assumption made throughout the fishery that anyone who finds a condo can, and commonly will, take the catch as their own, regardless of who put the condo out there. As one fisher eloquently stated, “yours is mine and mine is mine” (Personal communication). Many of the fishers describe it as a classic race to fish; a large percentage of them say something along the lines of whoever gets there first can claim the catch. This practice is so common that fishers who build condos themselves expect to lose a portion of their catch, and will often times build extra structures to help account for those losses (Personal communication). Also, most of the fishers attempt to conceal their condos by “priming” them just offshore of their settlements, where the tops can become overgrown with seagrass and algae, making it easier to camouflage the structures. One fisher also notes the “condos need to get a little mossy before the crawfish will approach them” (Personal communication), so preparing them in this manner serves a dual purpose. Fishers also tend to be extremely secretive about the locations of their condos, so much so that of all the fishers interviewed and surveyed, only one chose to disclose a GPS map with the specific locations of “his” 3000 condos (Figure 1.31), none of which were actually built by him! All the other fishers only pointed to general swathes of the Bahamian banks. Fishers also often explained that they utilize elaborate patterns and spacing when setting the condos to help prevent other condo users from locating all of their condos, even if they should happen to find a few.

Although fishers from Spanish Wells are more likely to agree that that the person who sets the condo owns both the condo and the organisms found
beneath it and those from Andros generally tended to believe the exact opposite, it’s interesting to note that fishers from South Andros settlements were more likely to agree with the Spanish Wells fishers. While the South Androsians admit to not building condos and freely collecting from the condos of others, most do believe that condos should be private property. The main stated reason they choose to use the condos of other fishers is because they cannot afford the costs of building and setting their own, coupled with their perception that fishers from other islands are setting their condos near the reefs where South Andros fishers dive, resulting in fewer lobsters on their reefs. Similarly, while the majority of Bahamian fishers agree they should be able to collect from other condos, a small percentage of this group also agree that they legally should not be able to do so.

Views on regulations

Fisheries enforcement throughout The Bahamas is a difficult task, and almost all the fishers surveyed acknowledge that the current level of enforcement is not enough. A fisher from Andros stated, “there are only two of them [fisheries officers] for this whole island. It’s impossible for them to man this whole island” (Personal communication). Despite this, only about half of the fishers called for more specific regulations where condos are concerned. Presently, the Department of Marine Resources (DMR) does not have regulations on condos; DMR also doesn’t consider the structures as “artificial reefs”, despite condos providing artificial habitats for lobster and many other species and despite the existence of strict regulations for the use and placement of artificial reefs. Of all the suggested regulations, the majority of fishers, particularly those from Andros
and Long Island champion the closing of some areas to lobster fishing. Long Island fishers typically mentioned the importance of having protected areas during their interviews, believing these areas are important for helping to maintain a healthy ecosystem. Androsian fishers tended to be more interested in closing areas near their settlements in order to ban condo use where they have traditionally (and still to this day) dived for lobster. The other popular regulations requested included creating limits on the number of condos set per boat and/or fisher and on the types of materials used to build the condos, as well as implementing licenses and fees for their use. Almost all the fishers had no interest in seeing condo use banned, nor being required to remove their condos at the end of the ach season.

**Significance of Study**

Bahamian lobster, as in most Caribbean spiny lobster fisheries, is a common pool resource. All Bahamians have the right to the use the resource; yet, every fisher has the incentive to maximize his catch. In light of the fact that this is a valuable, un-owned resource, each fisher strives to capture the lobster in a given area before other fishers can do so. It follows, then, that in order to sustain the resource, users must be excluded or limited in some way (Bish 1977). For commercial lobster fishers in The Bahamas, exclusion was mainly achieved through the requirement of licenses for traps. As the licenses and construction of traps both incurred a cost, they served to help limit entry into the fishery. However, when resources are depleted, fishers tend to overinvest in harvesting technology in an attempt to sustain their level of catch. This can be seen in the
increased usage of condos, which currently have no regulations and are relatively low cost to construct. Increased effort has also been seen in the amount of boats, the sizes of boats, and a greater number of traps and condos in use. Collectively, these have helped to increase the number of fishers entering the fishery as well as to increased levels of competition for an already limited resource.

The introduction of condos as a fishing method may have significant effects on the lobster population, as well as on the fishers, especially as there is little management or enforcement on where the units can be placed and who can collect from them. Conflicts arising from this method will continue to increase until appropriate management that ensures some type of property rights is put into effect (Lozano-Alvarez 1995). Furthermore, the use of condos to increase fisheries production remains controversial, as it is not clear whether their use will lead to long-term sustainable use or towards a decline of the stock (Eggleston et al. 1992; Briones-Fourzan et al. 2000; Lipcius and Eggleston 2000). As the construction and use of condos continue to increase, so do the questions and concerns about their possible impacts on the species, on the surrounding environment, and on the fishery overall.

The use of condos in the Bahamian lobster fishery has contributed to some interesting interactions among users, especially in terms of both access (who has the ability to benefit from these condos) and property (who has the right to benefit from these condos), including how access and property are developed, assigned, or even assumed in light of the lack of rules/regulations and
ownership. This will become a major point of contention for DMR as they seek to put policies in place that will directly focus on condo usage, as they must consider how fishers’ perceptions, assumptions, and values about access and rights will align or conflict with any implemented regulations, thus creating implications for how new access or property regimes are theorized and enforced. As Beitl (2012) suggests, when designing and implementing conservation and management strategies for governing the commons, the importance lies in understanding the access and property systems, including the emerging relations produced by these systems, from all likely perspectives.

Even without the concerns enumerated above, fisheries management is a complex process. Successful management requires the integration of resource biology and ecology with the social, economic, and institutional factors affecting the behavior of fishers, policy makers, and the other stakeholders involved. As such, this dissertation shall utilize biophysics, the interactions between biological traits and physical properties of the environment, bioeconomics, the study of the dynamics of living resources through the integration of economic and biological processes, and political ecology, the examination of the relationships between political, economic, and social factors with regards to environmental issues, to assess the Bahamian spiny lobster fishery.

**Overview of Dissertation Chapters**

Chapter 2 focuses on the modeling of lobster connectivity and its use to predict the spatial scales over which lobster travel within, and beyond, The Bahamas. This will allow for a further examination of the sustainability of the
fishery based on the dispersal characteristics of spiny lobster. I will also present an interdisciplinary approach to guiding the management process and assess how this strategy can assist in the difficulties of designing sustainable management for spiny lobster in The Bahamas. Emphasis is placed on the integration of anthropological and biophysical modeling techniques, providing an example of how these merged tools can help understand ecological processes while assisting management decisions.

In Chapter 3, a bioeconomic model is developed with the intention of supporting decision making processes for the Bahamian lobster fishery. The model uses data collected as part of the anthropological study, coupled with other fisheries data, to determine the economic optimum of the fishery. These values are compared to current levels in the fishery, followed by an examination of the implications of continuing at present levels versus shifting towards what would be economically and sustainably viable.

Chapter 4 features an analysis of the Bahamian lobster fishery within a political ecology (PE) context, allowing for an assessment of how the ecological, social, and economic factors come together to create and define the fishery, including the implications of this convergence on management. A PE framework holds the key to gaining a better understanding of all the relationships at play. The chapter will also explore the increased usage of condos in the fishery, and the implications of this use on how the fishers define, perceive, and adhere to access and property rights through a political ecology lens.
Chapter 5 synthesizes the work from the previous chapters in order to explore the implications of this interdisciplinary approach for developing guiding principles for spiny lobster fishery management. This will include a further examination of the current management strategies utilized by the Bahamian government with regards to the condo use, as well as the suggested paths forward based on the conclusions from the previous chapters. Focus is placed on understanding what it means to manage fisheries, like this one, responsibly and sustainably, and the ecological, economic, and social implications of doing so. Ultimately, this will serve as an example for how an interdisciplinary framework can be used to inform policy decisions.

This work will pair the biophysical forces that impact spiny lobster together with the chief human activities involving lobster. It is the hope that this project will utilize data from the biophysical model, the bioeconomic model, and the surveys and interviews together to help create a robust assessment of the fishery, especially considering how the use of condos figures into each (Figure 1.32), while also proposing some potential viable management strategies for maintaining the sustainability of the fishery.
Figure 1.1 Spiny Lobster Capture Data. Top 10 Fisheries in the Caribbean, 2002-2012 (FAO 2014)
Figure 1.2 Map of the Bahamas

http://www.bvsde.paho.org/powww/eva2000/Bahamas/informe/Fig-01.gif
Figure 1.3 Bahamas Fisheries Capture Data, 2012 (FAO 2014). Percentages based on a total quantity of 19,746.83 tonnes reported for all Bahamian fisheries in 2012. Caribbean spiny lobster represents the highest quantity captured (12,051 tonnes), followed by conch (6,413 tonnes).
Figure 1.4 Lobster Fishing Gear. Bahamian fishers utilize a variety of methods to harvest spiny lobster including: (A) Traps, (B) Hawaiian Slings, (C) Hookah/Compressors, (D) Condos/Casitas.

Figure 1.5 Map of MSC certified spiny/rock lobster fisheries around the world. The circled fishery is currently the only certified Caribbean Spiny Lobster.
Figure 1.6 Islands Represented by the Fishers Surveyed (n=66).

Table 1.1 General Demographics of Fishers’ Surveyed.

<table>
<thead>
<tr>
<th></th>
<th>Abaco</th>
<th>Andros</th>
<th>Grand Bahamas</th>
<th>Long Island</th>
<th>New Providence</th>
<th>Spanish Wells</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Fishers</td>
<td>5</td>
<td>25</td>
<td>7</td>
<td>17</td>
<td>2</td>
<td>10</td>
<td>66</td>
</tr>
<tr>
<td>Surveyed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Age</td>
<td>47.0</td>
<td>48.9</td>
<td>41.7</td>
<td>48.5</td>
<td>53.5</td>
<td>55.7</td>
<td>49.0</td>
</tr>
<tr>
<td>(8.12)</td>
<td>(13.65)</td>
<td>(9.88)</td>
<td>(9.95)</td>
<td>(2.12)</td>
<td>(9.62)</td>
<td>(11.5)</td>
<td></td>
</tr>
<tr>
<td>Mean years of Experience</td>
<td>30.2</td>
<td>25.9</td>
<td>17.6</td>
<td>25.1</td>
<td>15.0</td>
<td>33.9</td>
<td>26.0</td>
</tr>
<tr>
<td>(9.93)</td>
<td>(15.4)</td>
<td>(3.69)</td>
<td>(10.14)</td>
<td>(9.89)</td>
<td>(8.91)</td>
<td>(12.47)</td>
<td></td>
</tr>
<tr>
<td>Mean Generation of Fisher</td>
<td>2.4</td>
<td>2.0</td>
<td>1.9</td>
<td>1.8</td>
<td>2.0</td>
<td>1.6</td>
<td>1.9</td>
</tr>
<tr>
<td>(0.89)</td>
<td>(0.86)</td>
<td>(1.07)</td>
<td>(0.68)</td>
<td>(1.41)</td>
<td>(0.53)</td>
<td>(0.82)</td>
<td></td>
</tr>
<tr>
<td>Primary Occupation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fisher</td>
<td>2</td>
<td>16</td>
<td>2</td>
<td>16</td>
<td>1</td>
<td>8</td>
<td>45</td>
</tr>
<tr>
<td>Guide</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>14</td>
</tr>
</tbody>
</table>
Figure 1.7 Primary Fishing Method for Harvesting Spiny Lobster in The Bahamas. Natural refers to fishers diving the reefs or shoals.

Figure 1.8 Harvesting Method Preferred by Fishers Based on Island.
Figure 1.9 First Use of Condos in The Bahamas Reported by Fishers Surveyed.

Figure 1.10 Box Plot: First Use of Condos by Island. Fishers from Abaco and Spanish Wells began utilizing condos earlier than fishers from other islands.
Figure 1.11 Box Plot: Condos Set Per Season by Island. With the exception of fishers from Spanish Wells, most fishers only add a relatively small number of new condos (from 0 to a couple hundred) at the start of each lobster season.

Figure 1.12 Box Plot: Condos Currently Set Based on the Fisher’s Level of Experience. Recent entrants to the fishery tend to have less condos.
Figure 1.13 Box Plot: Condos Currently Set Based on Island. Fishers from Spanish Wells report having 10,000-20,000 condos currently deployed throughout the banks.

Figure 1.14 Preferred Habitat for Deploying Condos. “Mixture” refers to fishers with no specific preference, choosing to set their condos in a variety of habitats.
Figure 1.15 Factors Determining Where Condos are Placed. (n=33)

- Water flow: Light yellow bar
- Prey availability: Medium yellow bar
- Size of lobster in the area: Light yellow bar
- Less movement: Light yellow bar
- Low traffic: Dark yellow bar
- Highest catch: Medium yellow bar

# of Responses
0 2 4 6 8 10 12 14 16

Figure 1.16 Fisher Responses to: Does Condo Use Influence How You Fish? (n=22)

- Yes: 55%, Light yellow sector
- No: 45%, Light blue sector

No 45%
Yes 55%
Figure 1.17 Fisher Responses to: Does Condo Cost Influence the Number You Set? (n=53)

Figure 1.18 Fishers’ Perceptions on the Biggest Threats to the Spiny Lobster Population. Fishers identified themselves, illegal harvesting (fishing outside of sanctioned regulations), and poaching (fishers from other countries or fishers stealing from condos) as the main sources of threats.
Figure 1.19 Fishers’ Perceptions on the Top Impacts to Their Local Areas.
Fishers identified poaching and pollution (particularly in regards to oil drilling and the use of bleach on reefs to aid in fishing) as the key impacts.

Figure 1.20 Fishers’ Response to: Do Condos Impact the Environment? (N=62)
Figure 1.21 Fishers’ Views on Whether the Impacts of Condos on the Environment are Positive or Negative. (N=51)

- Pos: 73%
- Neg: 27%

Figure 1.22 Fishers’ Response to: Do Condos Impact the Lobster Population? (N=62)

- Yes: 85%
- No: 15%
Figure 1.23 Fishers’ Views on Whether the Impacts of Condos on the Lobster Population are Positive or Negative. (N=58)

- Positive: 69%
- Negative: 23%
- Both: 8%

Figure 1.24 Fishers Responses to: Who Owns the Condo? (N=63)

- No One: 46%
- The person who set it: 52%
- The Government: 2%
<table>
<thead>
<tr>
<th>The person who set it</th>
<th>&quot;It's not yours&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;the guy who put it there owns the material; but you don't own the spot&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;I set the condo, I own the condo&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;they put the money and equity into the condo&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;if someone wants to fish from condos, they should set them&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;they set it, they know they put it down, they marked it in their gps&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;they did the work and invested&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;belongs to the person who pays for and build it&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;the person who paid for it, built it, and set it&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;The government lets me put it down, so it should be mine.&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;they pay a lot of money for the condos and sometimes owe money for them, so they own it &quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;the guys will come and let you know it's their condo&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;He invested the money to put it here.&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;provisions need to be made to outlaw stealing from other condos&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;They paid for the materials, and invested the money to do it&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;we go to the bank every year to finance these condos; all other fishermen have the same rights to set them, but prefer to reap the benefit of our hard work.&quot;</td>
<td></td>
</tr>
<tr>
<td>No One</td>
<td>&quot;no one should be allowed to own them:&quot;</td>
</tr>
<tr>
<td>&quot;it's just like pushing something overboard and leaving it&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;they are not marked; if someone claims it is his, hard to prove or disprove&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;once you throw the condo over, you're doing something illegal&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;It's an artificial reef. Anyone who finds it can work it&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;it doesn't belong to anyone; there is no license&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;first come, first served&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;if I owned it, my name would be on it&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;nobody owns the ocean. It's free for everyone.&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;It's a free for all. There is nothing much you can do if someone is fishing from it.&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;everyone who finds it can use it&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;no one owns something that is set down on government land&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;the sea is there for everybody. Fishermen searching for crawfish can find them anywhere, even in condos.&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;Once it's down there, it's fair game.&quot;</td>
<td></td>
</tr>
<tr>
<td>The Government</td>
<td>&quot;once it's on the bank, it belong to the Bahamas government&quot;</td>
</tr>
</tbody>
</table>
Figure 1.25 Fishers’ Responses to: Who Owns the Lobster Inside the Condo? (N=61)

- No One: 66%
- The person who set it: 34%
Table 1.3 Quotes Made by Fishers in Regards to Who Owns the Lobster Found in a Condo

<table>
<thead>
<tr>
<th>The person who set the condo</th>
<th>“the person spent money”</th>
</tr>
</thead>
<tbody>
<tr>
<td>“that's my money on the ocean floor”</td>
<td></td>
</tr>
<tr>
<td>“they [lobster] went in the condo so they belong to the person who built the condo”</td>
<td></td>
</tr>
<tr>
<td>“I put the condo there to attract the lobster, I should get to be the one to work it”</td>
<td></td>
</tr>
<tr>
<td>“his [condo], his crawfish”</td>
<td></td>
</tr>
<tr>
<td>“We set the trap, so we should own the crawfish in the trap – you paid for it, you set it. We consider harvesting from someone else’s condo stealing.”</td>
<td></td>
</tr>
<tr>
<td>“the person who paid for the condo should have the rights to the lobster in the condo”</td>
<td></td>
</tr>
<tr>
<td>“To me, the lobster can come and go on their own, but if it crawls into my condo, to me they are mine”</td>
<td></td>
</tr>
<tr>
<td>“If I park in Disneyworld, the car is still mine, the things in the car are still mine.”</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No One</th>
<th>“if you don't own the condo, you don't own the lobster”</th>
</tr>
</thead>
<tbody>
<tr>
<td>“the person who owns the condo doesn't know how many were there before”</td>
<td></td>
</tr>
<tr>
<td>“If I find it, I take it; if you find it, you take it.”</td>
<td></td>
</tr>
<tr>
<td>“they [lobster] belong to whoever gets there first”</td>
<td></td>
</tr>
<tr>
<td>“the condo doesn’t have a bottom; if you lift it or remove the condo, the lobster are still there”</td>
<td></td>
</tr>
<tr>
<td>“they come and go in god’s ocean”</td>
<td></td>
</tr>
<tr>
<td>“whoever comes across the condo since they are just dropped down and not registered; they’re illegal.”</td>
<td></td>
</tr>
<tr>
<td>“whoever finds the lobster owns it”</td>
<td></td>
</tr>
<tr>
<td>“The man who set the condo may not be happy that you're diving it, but you can dive it”</td>
<td></td>
</tr>
<tr>
<td>“once it's on the ocean bed, it [the lobster] is technically yours.”</td>
<td></td>
</tr>
<tr>
<td>“belongs to everyone”</td>
<td></td>
</tr>
<tr>
<td>“belongs to all Bahamians”</td>
<td></td>
</tr>
<tr>
<td>“According to the laws of the Bahamas, anything in the sea belongs to all Bahamians”</td>
<td></td>
</tr>
<tr>
<td>“Bahamians as a whole own the lobster”</td>
<td></td>
</tr>
<tr>
<td>“We are all Bahamians”</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1.26 Fishers’ Responses to: Should you be able to Fish from Other Fishers’ Condos? (N=62)

- Yes: 76%
- No: 24%

Figure 1.27 Fishers’ Responses to “Should you be able to Fish from Other Fishers’ Condos?” by Island

- Abaco: No: 70%, Yes: 30%
- Andros: No: 80%, Yes: 20%
- Grand Bahama: No: 90%, Yes: 10%
- Long Island: No: 80%, Yes: 20%
- New Providence: No: 70%, Yes: 30%
- Spanish Wells: No: 60%, Yes: 40%
Figure 1.28 Condo Use Restrictions. Potential restrictions for utilizing condos within the Bahamian spiny lobster fishery proposed by fishers during interviews.

<table>
<thead>
<tr>
<th>Restrictions</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limit Quantity</td>
<td>25</td>
</tr>
<tr>
<td>Limit Locations</td>
<td>25</td>
</tr>
<tr>
<td>Shorter Season</td>
<td>10</td>
</tr>
<tr>
<td>Licenses</td>
<td>8</td>
</tr>
<tr>
<td>Ban All Condos</td>
<td>5</td>
</tr>
<tr>
<td>None Necessary</td>
<td>10</td>
</tr>
</tbody>
</table>

Figure 1.29 Condo Placement Restrictions. Restrictions on where condos can be deployed based on fisher responses during interviews.

<table>
<thead>
<tr>
<th>Locations</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protect Areas</td>
<td>2</td>
</tr>
<tr>
<td>Spawning Grounds and Nurseries</td>
<td>16</td>
</tr>
<tr>
<td>Where Locals are Fishing Near Settlements</td>
<td>10</td>
</tr>
<tr>
<td>In or Near Natural Habitats</td>
<td>14</td>
</tr>
</tbody>
</table>
Figure 1.30 Bahamas Spiny Lobster Capture Data 1955-2012 (FAO 2014).
Figure 1.31 GPS Map of Condo Locations. Flags identify the 999 condos fished by an Androsian fisher. This is one of his 3 GPS units that he utilizes to find the condos he harvests from each year. None of these condos were constructed by him.
Figure 1.32 Interdisciplinary Framework for Dissertation. Data from each of these sources will help to create a robust assessment of the Bahamian Spiny Lobster Fishery.
Chapter 2: Condos and Connectivity: Developing an Interdisciplinary Approach to Guide Caribbean Spiny Lobster (*Panulirus argus*) Fisheries Management within The Bahamas

**Background**

Dynamics within marine populations have important considerations for fisheries management. Most of these populations are not isolated, instead existing within complex ecosystems that involve impacts from biological, physical, chemical, and geological forces, as well as from humans. This variability makes it challenging to provide adequate management for fisheries resources. As many worldwide fisheries continue to decline or struggle to maintain sustainability, we must reevaluate traditional management tools and how these tools can be improved to provide for effective fisheries management strategies.

Many marine populations are spatially distributed metapopulations (assemblages of local populations that inhabit spatially distinct habitat patches within a landscape (Sanchirico and Wilen 2005)). This increases the difficulty in predicting outcomes from implemented management scenarios, as there tends to be an incomplete understanding of the spatial characteristics involved and how they operate (Kritzer and Sale 2004). The result is a mismatch between natural spatial scales and appropriate scales of management. As such, for successful management to occur, fisheries managers need to be cognizant of the spatial scales that characterize dispersal processes and align management scales appropriately (Botsford *et al.* 1997, Palumbi 2004, Kaplan 2006). This highlights
the importance for not only understanding the processes of connectivity, but also for incorporating connectivity within proposed management strategies.

Caribbean spiny lobster (*Panulirus argus*) is a popular and heavily exploited seafood throughout most of its range. The species supports the primary fishery in many Caribbean countries (FAO 2006), where it is harvested both commercially and recreationally, and is valued at nearly $1 billion US dollars annually (Ehrhardt *et al.* 2010). This is especially true in The Bahamas, which reports one of the highest catches and where spiny lobster is the number one food export (Ehrhardt *et al.* 2009).

Spiny lobster have a complex life cycle: they begin as planktonic larvae that develop in the open ocean during dispersal; they then settle to coastal macroalgal-rich habitats; after, they molt to become juveniles, then move to inshore habitats such as mangroves and seagrass beds; and eventually, as adults, they inhabit coral reefs, which provide the crevices and ledges that allow them protection to hide during the day (Marx and Herrnkind 1986; Lipcius and Cobb 1994; Butler *et al.* 1997). The long pelagic larval dispersal (PLD) of 5-9 months allows for spiny lobster larvae to disperse throughout the Caribbean (Ehrhardt 2005), and creates the opportunity for high levels of gene flow. Genetic analysis indicates there is a single metapopulation for spiny lobster (Silberman and Walsh 1994; Diniz *et al.* 2005; Naro-Maciel *et al.* 2011), supporting the Pan-Caribbean Theory of population structure for the stock (Lyons 1980).
Understanding population connectivity and local retention of spiny lobster is important for the conservation and management of the valuable fishery it supports. However, the ability for wide-range dispersal, due to the lengthy PLD, increases the difficulty in determining the origins of local adult populations and can complicate management attempts. Despite the long-range potential of this species, findings have indicated high proportion of spiny lobster offspring settle relatively close to their spawning sites (Black 1993; Butler et al. 2005). Yet, several studies have also provided evidence that connectivity patterns do exist among spiny lobster populations throughout the Caribbean and may have implications for the species’ management (Chavez 2012; Kough et al. 2013). One of the core challenges to connectivity is determining overall how connectivity contributes to issues of conservation and management (Bode et al. 2012). Since connectivity implies that local processes and populations may be dependent on processes occurring elsewhere (Grober-Dunsmore and Keller 2009), local management initiatives may be ineffective for providing adequate protection or localized benefits. Additionally, if connectivity across large spatial scales is indeed the case, there is no doubt that these populations are also crossing political boundaries along their journey, allowing for decisions made in one country to possibly impact ecosystems elsewhere. It may be necessary to increase the scale of management to account for these issues. However, development of management strategies to ensure sustainability of entire ecosystems is complex and will require more interdisciplinary work than what is currently being done.
Exploration of the impacts of these connections, whether local or distant, is imperative, especially for countries like The Bahamas, where spiny lobster is an important commodity and management of the fishery is difficult. Attempts at managing this species must take into account the recruitment locations of the larvae, where the larvae settle, how far the adults move and where they end up. Identifying the spawning and settling sites will help provide fishery managers a better perspective of the areas that should be considered for protection locally or those areas abroad that can lead to cooperation between nations to promote effective use and management of the resource.

In recent years, The Bahamian spiny lobster fishery has seen an increase in the use of condos (referred to as “casitas” throughout the Caribbean), artificial habitats used to aggregate lobsters in large numbers for easy capture (Lozano-Álvarez et al. 1991, Sosa-Cordero et al. 2008). The Bahamas is one of many Caribbean nations using condos to concentrate lobsters to boost production in the fishery and meet the increased market demand (Baisre 2000; Cruz and Phillips 2000; Eggleston et al. 1992; Losada-Tosteson and Posada 2001; Briones-Fourzán et al. 2000; Deleveaux and Bethel 2002). Condos have also effectively created additional spiny lobster habitat, especially in The Bahamas, where the structures tend to be placed in locations with sandy or grassy bottoms instead of near reefs, the ecological habitat of choice for adults.

While the use of condos has increased greatly throughout Caribbean spiny lobster fisheries, the ecological, social, and management implications of their use have not been fully evaluated. Condo studies have focused on their
design (Briones-Fourzán et al. 2000; Cruz and Phillips 2000; Sosa-Cordero et al. 1998; Nedimyer et al. 2001; Seaman 2000; Losada-Tosteson and Posada 2001; Sherman et al. 2001), stock assessments and population enhancement (Ley-Cooper et al. 2011; Behringer and Butler 2006; Cruz and Borda 2013); disease transmission (Behringer et al. 2012; Lozano-Alvarez et al. 2008; Briones-Fourzan et al. 2012; Candia-Zulbaran et al. 2012; Cruz Quintana et al. 2012; Huchin-Mian et al. 2013); impacts on juvenile populations (Arce 1997; Eggleston et al. 1992; Smith and Herrnkind 1992; Childress and Herrnkind 1994), suitability as additional habitat in areas lacking adequate natural refuges (Miller 1982; Briones et al. 1994; Spanier and Zimmer-Faust 1988; Eggleston et al. 1990; Spanier 1994; Mintz et al. 1994; Butler and Herrnkind 1997; Sosa-Cordero et al. 1998; Briones-Fourzan and Lozano-Alvarez 2001); and their influence on lobster predation (Mintz et al. 1994; Butler and Herrnkind 1997; Sosa-Cordero et al. 1998; Behringer and Butler 2006; Eggleston et al. 1990; Eggleston and Lipsius 1992; Briones-Fourzan et al. 2007; Lozano-Alvarez et al. 2009). Few studies have focused on the impact of condos on lobster fisheries and their management (Cruz and Phillips 2000; Briones-Fourzan et al. 2000; Losada-Tosteson and Posada 2001; Henderson and Cote 2011; Ley-Cooper 2013) and even fewer have assessed the role of condos on dispersal characteristics (Eggleston and Lipscius 1999) or how these characteristics might influence management of the fishery and vice-versa (Ley-Cooper et al. 2014; Gonzalez and Wehrtmann 2011). Additionally, to date, none of these studies have incorporated anthropological
methods to determine how condo use might impact dispersal and ultimately spiny lobster fishery management.

With these factors in mind, there is a need to not only determine natural patterns of connectivity, but to learn how to sustain these patterns (McCook et al. 2009) while also protecting the population, especially in the face of changing perspectives and fishing strategies, such as the increased use of condos. As the construction and addition of these structures continue to occur, so, too, do the questions and concerns about their impacts on the species and the fishery, and what those impacts mean for sustainable management. Moreover, development of management strategies to ensure sustainability of an entire, and potentially Caribbean-wide ecosystem, will be difficult without utilizing interdisciplinary approaches. While biophysical models have been used to evaluate management strategies based on connectivity (Kough et al. 2013; Botsford et al. 2009), coupling these spatially explicit models with additional tools, such as anthropological research and social science methods, can aid in the assessment of some of the aforementioned challenges, allowing for management decisions based on a range of factors (ecological, social, economic, etc.) to result in the design of appropriate, more holistic, strategies.

**Goals and Objectives**

The purpose of this study is to examine the sustainability of the Bahamian spiny lobster fishery based on the dispersal characteristics of Caribbean spiny lobster. Emphasis is placed on modeling lobster connectivity to predict the spatial scales over which the lobster travel within, and beyond, The Bahamas,
and then coupling the connectivity results with anthropological data gathered from Bahamian fishers. This pairing of data allowed for the examination of how these two methodologies can be used to predict locations that might either help to optimize condo placement or identify those locations requiring additional management considerations. Specific objectives of this project include:

1. Determining the average dispersal distance among habitat sites to estimate the level of connections among sites in the Bahamas and between Bahamian sites and other sites throughout the Caribbean;

2. Identify sites within The Bahamas that serve as good sink locations (areas with high levels of imports), good source locations (areas with high levels of successful exports), and good connectors that help to link habitats and populations throughout the network; and

3. Coupling connectivity and anthropological data to examine how pairing can be used to predict locations that might either help to optimize condo placement or identify those habitats needing additional management considerations.

Significance

Caribbean spiny lobster supports one of the most important fisheries throughout its range. Over the last 50 years, these fisheries have seen a steady increase in lobster landings, leading to concern in regards to the sustainable use of the species (Cochrane and Chakalall 2001). Although spiny lobsters are not currently considered to be threatened or endangered, they are recognized as an organism that could be in that position sometime in the near future (Cascorbi...
Because of their status as a highly sought after species, if high fishing pressures persist without proper management, populations could become at risk for decline.

While there have been encouraging strides towards creating a sustainable spiny lobster fishery within The Bahamas (Wakeford 2012), management of the fishery remains a complex task. The PLD of the species provides the opportunity for its larvae to travel thousands of kilometers from their spawning site, contributing to a high degree of connectivity in the Caribbean. Thus, understanding the levels of connectivity, as well as the ability for local retention, is an important consideration for the conservation of the species.

Connectivity is crucial for marine organisms for several reasons. Because of the nature of water and how it moves, organisms can be transported between locations, sometimes for vast distances, and thus contribute to the maintenance of habitat corridors. These habitats link various life stages of species and are vital for healthy ecosystem functions. Most importantly, though, connectivity can serve as a dominant factor in ensuring the resilience of marine ecosystems. The process allows for the “reseeding” of populations after major disturbances (Hughes et al. 2003; Jones et al. 2007; Birrell et al. 2008) and for the maintenance of life cycles and trophic connections (Nagelkerken et al. 2001; Dorenbosch et al. 2007; Jones et al. 2007; Almany et al. 2009; Botsford et al. 2009). Steneck (2006) argues that understanding what drives connectivity within areas/habitats considered to be metapopulations, and ultimately what keeps the distances between the various connected habitats small enough, will aid in a
better understanding of resilience, especially as there is not much known about what controls the recovery of populations and habitats or the role of larval connectivity in this process (Jennings 2001; Russ and Alcala 2004; Mumby and Steneck 2008). In order to be resilient, ecosystems need to maintain connectivity within and between similar habitats, as well as between habitat types (Cappo and Kelly 2001; Mumby 2006; Mumby and Hastings 2008). There is currently not enough knowledge to provide for adequate strategies to protect these patterns, thus creating a critical gap in understanding how to manage for resilience, especially in coastal fisheries.

This potential for widespread larval dispersal is also important for the effective management of the stock (Cochran and Chakalall 2001; Kough et al. 2013). Larval dispersal determines where recruits to a particular area originate from, helping to establish the boundaries of each stock. And because the pelagic stage can last for so long, many of the stocks might rely on recruitment from other areas, and possibly other countries. This creates the potential for transboundary issues, as any ecological problems (or successes) in one region, as well as any management actions implemented in that region, may have considerable impacts on the stocks located elsewhere.

Despite these crucial factors, there remain several core challenges to connectivity. These include: determining the spatial-temporal scaling of connectivity; explaining the full range of processes underlying larval dispersal and connectivity; gaining a better understanding of the impacts of connectivity on population structure and dynamics; and determining overall how connectivity
contributes to issues of conservation and management (Bode et al. 2012). Because of this, population connectivity has been increasingly recognized as a key conservation objective due to its importance to population persistence and resilience (Roberts et al. 2006; Salm et al. 2006). Yet, connectivity is one of the least effectively used concepts in current management practices (Sale et al. 2010). Understanding how marine populations, like spiny lobster, are connected spatial and temporally will provide an essential component not currently present within the management of marine resources (Werner et al. 2007). A better understanding of spatial linkages over populations will also contribute to the understanding of the immense variability that occurs, particularly in fisheries (Hjort 1914).

Several studies have attempted to get at this problem. Cowen et al. (2006) utilized a connectivity model that operated at several spatial scales to identify the subregions within the Caribbean with different levels of larval subsidies and self-recruitment. They found that larval subsidies are quite limited in some regions, suggesting managers should directly manage their reefs on a local scale instead of depending on potential subsidies from distant sources. This correlates with Warner and Palumbi (2003), who demonstrated larvae are capable of maintaining close links to their home base, despite their proximity to long-range currents.

Bustamante and Paris (2008) questioned the understanding that "we are all connected", referring to the long-held theory that the Caribbean is one large unit of biological connections. They use connectivity to propose ecoregional
scenarios throughout the Caribbean. They also note that if larval dispersal is more restricted than previously thought, management decisions based on open population models or long dispersal scenarios may, in fact, be overestimates of the levels of exchange. Steneck et al. (2008) reconsider the linkages among networks created by connectivity, and the role habitat receptivity plays in linking larval dispersal to population persistence. Unlike the former studies, they proposed utilizing a broader spatial scale of management beyond what is currently used or proposed for MPAs in order to capture all the possible habitat associations. Regardless of the scales, the disparity in the lengths highlights the uncertainty that remains. In order for adequate management strategies to be put in place, these questions must be seriously considered and answered.

There is no doubt that demographic connectivity should be a key component in fishery management agendas. Coupled with spatially explicit models, it can be quite useful for designing and assessing management strategies by determining the degree to which populations are connected, as well as the estimates of the exchange between areas. And while these patterns of connections have long been recognized as important to fisheries management concerns (Roberts 1997), it hasn’t been until the past decade that connectivity has been considered as a relevant and important tool for management decisions. When the field of connectivity originally began to flourish, there was not much interest in utilizing the work for management purposes. For instance, as the work in genetic connectivity progressed, it showcased connectivity over multiple generations. While this was important research, it was not viewed as relevant by
fisheries managers, as they are more concerned about changes that occur over short time periods that can lead to direct impacts on management objectives. However, as the field continues to progress, including the techniques and tools necessary to determine short term scales of connectivity, this type of modeling can be used purposefully by managers to create effective strategies.

Over the past few decades, marine protected areas (MPAs) have emerged as a tool for protecting marine resources and managing the ways in which these resources are utilized. MPAs are being used in both fisheries management and biodiversity conservation to enhance ecosystem resilience, as well as to safeguard ocean resources for future generations. MPAs provide mechanisms to increase the reproductive potential of fisheries species inside the protected areas (Harrison et al. 2012) and to enhance fish production outside the borders through spillover or recruitment subsidy (Kritzer and Sale 2004; Sale et al. 2010). Despite this, knowledge concerning the extent to which offspring are exported and the contribution of protected areas to recruitment is still quite limited (Gaines et al. 2010; Sale et al. 2005; Botsford et al. 2003; Hastings and Botsford 2006).

The spatial scale of connectivity and its resolution is important for the management of many marine species, especially when MPAs are considered. The resolution of connectivity also has important implications when trying to gain a fundamental understanding of the structure and dynamics of these communities or when trying to determine the appropriate scales to implement management strategies (Sale et al. 2010). If larvae are mostly retained at local
scales, then local management would be effective; yet, if larvae disperse beyond those scales, management will need to scale up appropriately to achieve effectiveness. Understanding the dispersal mechanisms, rates, and distances can help to determine the optimal size, configuration, and location of MPAs (Levin 2006).

Previous modeling studies have indicated how larval dispersal and the spatial configuration of MPAs interact to promote population persistence (Crowder et al. 2000; Botsford et al. 2001; Kaplan et al. 2006; Bode et al. 2012). While these interactions are clear in modeling results, attempts at applying these conclusions to assess and design effective protected areas have been hindered by the uncertainty surrounding larval dispersal (Stockhausen et al. 2000; Botsford et al. 2001).

The growing importance of the interconnectedness of marine habitats and their associated processes has highlighted the need for moving beyond individual MPAs to networks of MPAs, as it is the belief that such larger-scale approaches are imperative if the protection and conservation of these processes is to be effective. MPA networks have been identified as key conservation strategies for coral reefs (Roberts et al. 2006; Jones et al. 2007; Wood et al. 2008). They have been advocated for the conservation of biodiversity, protection against natural and anthropogenic disturbances, and as a tool to increase resilience of ecosystems while also enhancing their ability to adapt to major environmental shifts, like climate change (Sale et al. 2010).
Connectivity can allow a set of MPAs in a given region to operate ecologically as a network with individual organisms dispersing from one protected area to another or to another surrounding area (Sale et al. 2010). Again, details of the patterns of dispersal are critical to determining the appropriate scale of a network. MPAs within a network must be close enough to allow for the exchange of individuals. Connectivity between subpopulations would increase as distance between populations or protected areas decrease. Connectivity among the MPAs in the network will allow for resilience in individual populations similar to how dispersal processes within a metapopulation imparts greater resilience to local subpopulations (Sale et al. 2010). Approaches to this management strategy highlight the importance of keeping these areas close enough so the levels of connectivity between them are sufficient. In order for this to occur, designing networks that adequately protect connectivity will also require an understanding of larval dispersal processes (Almany et al. 2009).

Though there has been a charge towards shifting to networks of MPAs for optimal fisheries and biodiversity management, the expected benefits are tough to anticipate, due in part to the lack of comprehensive data on connectivity. Many of the existing networks have been created without incorporating larval dispersal into the design, failing to capture the main objectives of protecting connectivity and biodiversity, as well as not ensuring for population persistence (Almany et al. 2009). As such, networks should not be designed without reference to important demographic issues; Sale et al. (2009) write, "it is regrettable that the use of MPAs as fishery management tools has proceeded as
far as it has with so little concern about the lack of sound demographic science to underpin it, but there are excellent opportunities to work towards redressing this problem in the course of improving reef fishery management”.

Historically, there have been few estimates of larval dispersal distance that can be integrated into the design of MPA networks (Almany et al. 2009). This lack of information has inhibited the development of specific design criteria for the protection of connectivity (McCook et al. 2009). For this reason, any data on larval dispersal can provide the opportunity to enrich network design principles while evaluating existing networks. Much of the theory on MPA networks is based on the expectation that connectivity among the protected areas included within the network will result in resilience comparable to that of a metapopulation. If true, protected areas within the network would be less susceptible to decline if other factors, such as overfishing, happen to impact populations outside the MPAs’ borders.

Studies that address the influences of larval dispersal on MPA network design for the purpose of fisheries management illustrate the dependence of optimal reserve location, size, and spacing on larval dispersal (Botsford et al. 2001; Lockwood et al. 2002). Jones et al. (2007) contribute to this by describing the three main issues of larval dispersal and connectivity that influence reserve location: source/sink populations, isolated populations, and spawning aggregations. Determining the factors that establish whether an MPA will function as a source or sink population is directly relevant to the science and design of networks (Sale et al. 2010). While these factors have yet to be clearly
identified, certain preconditions, such as a consistent oceanographic pattern that occurs regularly, may help categorize locations as one or the other.

Social connectivity, the flow of information among people (Steneck et al. 2009), and social networking also play a role here. Social connectivity includes the management activities that bring communities together, reduce social conflicts, create a conservation ethic, and help to maintain high compliance to instituted regulations (Sala et al. 2002; White et al. 2006). Social connectivity is just as important as demographic connectivity in the creation of fisheries management strategies, including protected areas, because it’s the socioeconomic and political factors that ultimately drive not only the regulations proposed, but compliance as well (McClanahan 1999; Alcala and Russ 2006). It follows then, that the management of marine species is primarily a management of people (Sale et al. 2010). Fisheries management must account for the impacts, both positive and negative, humans can have on the species and habitats of concern. As most fisheries are exploited heavily by a variety of users, it creates additional complexity for designing appropriate strategies. Management must then be implemented in such a way that it incorporates user’s perspectives and encourages modifications in their behaviors they are willing to abide by, thus changing the way they view, use and impact the environment. Managers must also be aware of the impact of their management plans on the community. Before there can be connectivity networks among protected areas, there must be social networks created among the stakeholders (Johannes 2002; Alcala and Russ 2006) who must ultimately buy into the concept first in order for
them to work. Social networks facilitate learning and the coordination of administration and planning of marine protected areas by linking people and institutions (IUCN-WCPA 2008). Social networks can also be considered “learning networks”, where communities of practitioners, locally and internationally, come together to determine what makes projects successful and share lessons learned (MPA News 2004).

Methods

Surveys

Responses from the survey (Appendix A) described in Chapter 1 were used to determine the locations throughout The Bahamas where fishers catch lobster. Additionally, at the end of each survey, fishers were shown a map of The Bahamas (Figure 2.1) highlighting the habitat areas used as polygon habitats within the connectivity model (model described below). Fishers were asked to identify locations on the map where they have either deployed condos or fished from condos. While exact locations were not given by any fisher, they were able to provide general locations for condos.

Connectivity Modeling System

The open-source coupled biophysical model of Lagrangian transport, the Connectivity Modeling System (CMS; Paris et al. 2013), simulated the probabilistic connections between spiny lobster populations around the Caribbean. The CMS enables seamless multiscale nesting between general ocean circulation models to maximize the temporal and spatial resolution of ocean currents. The CMS has been verified against empirical data and
successfully described the ocean dispersal of fish larvae (Spoungale et al. 2012), lobster larvae (Kough et al. 2013), and oil plumes (Paris et al. 2012). In addition, the performance of HyCOM has been verified and it is a widely used and powerful general ocean circulation model (Cassignet et al. 2007; Bleck 2002). The 3D currents within the top 100m of both the Global HyCOM and the higher-resolution Gulf of Mexico HyCOM were used for larval transport simulations of spiny lobster.

Spiny lobsters spawn at the edge of coral reef habitats around the Caribbean and settle on a variety of habitats, including the hard-bottom algal beds in proximity to reefs. In these simulations, appropriate habitat for both spawning and settlement was contained within 3,202 sites at coral reef locations (Holstein et al. 2014). Spawning occurred daily from the centroid of each 8km x 8km reef site. The magnitude of spawning, 500 larvae per site per day, was enough to saturate potential connections and probabilistically describe dispersal (Kough and Paris 2015). Lobster larvae spend a long time as planktonic wanderers; advances in aquaculture have given an estimate of between 5 and 9 months for spiny lobster PLD (Goldstein et al. 2008). In the simulation, lobster larvae reached competence at 152 days and were no longer tracked after 196 days. During their pelagic journey, lobster larvae have ontogenetic vertical migration and daily vertical migration. The ontogenetic vertical migration described through larval collection trawls and laboratory experimentation (Butler et al. 2011) was included in the simulation. (See Table 2.1.)
Data Analysis

The likelihood of larval exchange between any two sites in the network are represented using a probability matrix. Paths of exchange from an origin location ("i") follow a row in the matrix to each other habitat location ("j"), which are the columns. The probability (probability of dispersal from "i" to "j") was obtained by dividing export (larvae with an origin in "i" that settled in "j") by the total export (sum of all successfully settling larva with an origin in "i"). Distances between habitat sites were calculated using the haversine great circle formulation using the coordinates of each site’s centroid. Mean dispersal distances were calculated by combining the probability of dispersal with a distance matrix and therefore represent a Euclidean distance rather than a pathlength. The spatial scales of larval linkage were calculated by subsampling and counting unique connections, or tabulating probabilities, in 100km bins from 0 through 4,500km away from each habitat site. Betweenness centrality is a measure of how important a given habitat location is to the entire connectivity network. It was formulated by calculating how many times a given habitat location is involved in the most probable pathway of larval exchange between any other two locations in the network. The inverse of the probability matrix was used as an edge weight, to assess the shortest distance (in units of connection probability) between two locations. Calculations were made using the BGL Toolbox developed by Gleich (2006). The betweenness centrality was normalized to the maximum of the sampled network to place habitat sites into logical tiers.
Four connectivity factors were used to help determine the importance of individual habitat polygons in terms of the role they play in maintaining connectivity of the local spiny lobster population: betweenness centrality - sites with the highest number of shortest paths passing through them and serve as important connectors for the entire population network; diversity of connections - sites with the highest number of unique incoming connections with other sites and serve as important sinks, as they provide the opportunity for distant populations to subsidize local ones; self-recruitment - the probability a site will export larvae back to itself, providing the potential for these habitats to serve as both good sinks and sources; and successful settlement of larvae - the percent of larvae exported from a site that settle successfully anywhere within the network, representing habitats that may represent good sources. Roberts et al. (2006) and Salm et al. (2006) affirm that resilient source populations can provide larvae to revive other depleted populations. However, those sites that function solely as sources must have substantial self-replenishment to persist, especially while subsidizing other areas (Jones et al. 2007). There have been arguments made that those populations functioning mostly as sinks must rely on larvae from elsewhere in order to persist, and therefore should be considered low conservation priorities (Almany et al. 2009). While these sinks may not be able to replenish other populations like sources can, they may be important for genetic diversity, especially if they receive larvae from multiple sources. Additionally, if sinks respond in different ways than sources to environmental changes, including them in reserve networks can contribute to population resilience and persistence,
especially if those responses are positive. Isolated populations also have high conservation values, especially when they harbor endemic species and/or unique assemblages (Jones et al. 2002; Perez-Ruzafa et al. 2006; Roberts et al. 2006). The low connectivity that creates the isolation also contributes to less resilient populations. This places isolated populations at greater risks of both extinction and inbreeding (Reed 2005), placing further importance on protecting their habitats.

Using this as guidance, the habitat polygons were evaluated to determine the top and/or best habitats within each of the four connectivity factors listed above. Next, a rating system was implemented with the intention of creating a system for determining which areas should be evaluated further for additional management considerations. Habitats examined within the connectivity model received a rating from 1 through 10 within betweenness centrality, diversity of connections, and successful settlement, with 10 indicating the habitat should be considered a high priority for additional management considerations and 1 indicating the habitat should have a lower priority. Individual data from each factor were entered into ArcGis for comparison, followed by combination of the data through a raster analysis to provide a final ranking to help identify those locations that should be a top priority of focus for managers. Once the final ranking for each habitat was determined, the analysis was coupled with the results obtained from the survey data to provide recommendations for spatial management of the Bahamian spiny lobster fishery.
Results

Summary of Lobster Habitats/Identified Condo Locations

Of the 3,202 habitat polygons identified throughout the Caribbean and used within the CMS model, 848 are within The Bahamas. During interviews, fishers identified 44.7% (n=379) of the polygons as locations where they have either placed or fished from condos. Survey responses to the question, “Where in The Bahamas is the best place to catch lobster”, returned a variety of answers; however, the most frequent responses were Cay Lobos (n=12), the Great Bahama Bank (n=10), the Tongue of the Ocean (n=9), the Jumentos (n=7), the Little Bahama Bank (n=6), the Berry Islands (n=6), the Ragged Islands (n=6), and Cochinos (n=6). These responses where coupled with the locations identified on the habitat map to delineate 5 main areas of condo placement and use within The Bahamas (Figure 2.2): the Little Bahama Bank (LBB), the Berry Islands and North of Andros (BI), the Tongue of the Ocean (TOTO), the Great Bahama Bank (GBB), and the Jumentos and Ragged Island Chain (JRI). Table 2.2 describes the number of habitat polygons located within each of these areas, as well as the number of those polygons that potentially contained condos. JRI has the highest number of potential condo polygons, whereas LBB area has the least. It is also important to note that over 95% of the habitat polygons within JRI, BI, and TOTO are identified as potential condo locations. These are also areas where the number of habitat polygons per area is the densest.
**Exchange between Spiny Lobster Populations**

**Caribbean Wide**

The simulations reveal connections between lobster populations within The Bahamas and other areas throughout the Caribbean (Figure 2.3). Bahamian sites demonstrate larval export to the Gulf of Mexico, the Turks & Caicos, Cuba, Hispaniola, Puerto Rico, Jamaica, the Cayman Islands, and Mexico (see Table 2.3). Conversely, The Bahamas receives recruits from all of the areas throughout the Caribbean, with high levels of imports from the Turks & Caicos, Hispaniola, Puerto Rico, the Leeward and Windward Islands, parts of Cuba and Florida. Despite these international connections, the lobster populations within The Bahamas have a high probability for self-recruitment, signifying domestic connectivity.

The dispersal kernel (DK) for the spiny lobster population throughout the entire Caribbean (Figure 2.4) displays a skewed distribution to the left, signifying a shorter distance of travel on average. This indicates the probability of survival for the population is highest between 200-400 km, with approximately 13% of recruits settling successfully. Those populations originating within The Bahamas exhibit a similar dispersal kernel distance (Figure 2.5), however the probability of survival at this distance was doubled (25%).

**Within the Bahamas**

A closer examination was taken of the connectivity in the five popular condo locations identified by the Bahamian fishermen (Figure 2.6). These habitats also demonstrated local and international connections, with populations
within TOTO dominated by self-recruitment, while the populations in the other 4 sites are largely dependent on subsidies from areas outside The Bahamas.

The DKs for these areas were similar to The Bahamas as a whole (Figure 2.7), with LBB and TOTO populations demonstrating narrower kernel distances, and GBB populations demonstrating a wider DK. Differences are also apparent in the probabilities of successful recruitment, with the populations originating in the GBB decreasing their probability of recruits to 17%, while populations within the other four areas increased their recruit survival rate. Populations within TOTO demonstrated the highest probability of successful recruitment at 36%. A summary for all the dispersal kernels has been provided in Table 2.4.

Spatial Scales of Linkages

Betweenness centrality, diversity of connections, self-recruitment, and successful settlement were used to help determine the importance of individual habitat polygons in terms of the role they play in maintaining connectivity of the local spiny lobster population. Over 35% of the top habitat sites within each of the aforementioned categories were also locations where condos are most likely placed.

Habitats within The Bahamas demonstrated betweenness centrality scores ranging from 0 to 452,005, the highest score for the entire Caribbean, almost 450% greater than the next highest score of 82,227 in Jamaica. Sites within the GBB and BI, as well as areas near Cay Sal, east of Andros, south of Abaco, and Long Island, show high potentials for serving as important connectors for habitats within the Caribbean-wide network (Figure 2.8). More
than 50% of sites in the GBB and all of the sites in BI are also possible condo locations.

The quantity of unique incoming connections also has a wide range for Bahamian habitats, starting from only 4 connections and reaching to 2,746 connections, again, the greatest for all the sites in the Caribbean. Over 70% of the habitats displaying high levels of connections with other sites all throughout the Caribbean are habitats within The Bahamas, with areas in LBB and BI receiving larvae through the largest number of unique links (Figure 2.9). Sixty-nine (69) percent and 100 percent, respectively, of these habitats also serve as condo sites. Other areas with high levels of connection include GBB, JRI, Cay Sal, Long Island, the Exumas, and Eleuthera. None of the habitats in TOTO were identified as top sites for diverse connections.

The percent of successful settlement of exported larvae from polygon habitats within The Bahamas ranges from 0.5% to 50.4%. Despite not having the highest proportion of habitats with successful settlers in the Caribbean, over 80% of Bahamas habitats have a successful settlement rate of 20% or higher, with LBB, BI, TOTO and JRI producing the best settlers (Figure 2.10). While none of the LBB habitats identified here are also condo locations, all of the habitats in BI and TOTO are.

The probability of self-recruitment within The Bahamas ranges from 0 to 0.1257, with 80% of the sites receiving some level of returned larvae. Medium to higher rates of domestic connectivity are demonstrated in BI, the southern areas
of GBB, and TOTO. (Figure 2.11). TOTO displayed the highest quantity of sites demonstrating any self-recruitment.

Appendix B provides a list of the Top 100 sites, Caribbean wide, for each of the connectivity factors described above.

**Final Ranking Scores for Habitats**

Each Bahamian habitat polygon was assigned a score of 1 to 10 within the 4 factors, with a 10 indicating there should be higher considerations for further management actions within a habitat and a 1 indicating the area should have a lower priority for management actions. Figure 2.12 describes the final management priorities for each of the habitat polygons based solely on the connectivity factors. Habitat polygons with scores greater than 20, received a ranking of “High Priority”, indicating the area should have the highest consideration for additional management scenarios; polygons with scores between 15-20 should have “Medium Priority” for additional management considerations; and scores below 15 should have a “Low Priority”.

Most of the polygon habitats in The Bahamas fall under the “medium priority” for closing (Figure 2.13), suggesting other factors (including how the fishers use the habitats, their perceptions about the state of the habitats, interactions between fishers, etc.) should be evaluated before a final decision is made on whether to impose new management scenarios. This is true for the 5 main fishing areas as well, with the exception of the LBB, where 63% of the habitats obtained a rating for low consideration. Each of these popular areas also contain sites with a high consideration rating (n=144), ranging from 4% in
LBB to 40% in the GBB. Of these sites 65% (n=94) are currently locations where condo placement occurs in each of the 5 areas except for the LBB.

**Discussion**

The connectivity simulations indicate larval exchange does occur between Caribbean spiny lobster populations. Although the DK is narrow, at only 200-400 km, many particles successfully traveled longer distances, at times reaching beyond 4,500 km. This allowed for many of these connections to cross international lines, a result similar to those obtained by Kough *et al.* (2013).

Probabilistic exports and imports of larvae originating from and settling within The Bahamas, respectively, demonstrate that exchanges between populations in The Bahamas and other countries also occur. Despite this, The Bahamas does tend to retain most of its larval exports with a higher probability for survival than when compared to Caribbean-wide populations, suggesting that lobster spawned within The Bahamas settle and thrive there as well.

Although Bahamian fishers deploy condos all over the Bahama Bank, five main areas emerged as clear favorites for most of the fishers. These areas (the Little Bahama Bank, the Berry Islands and North of Andros, the Tongue of the Ocean, the Great Bahama Bank, and the Jumentos and Ragged Island Chain) encompass a variety of habitats, including those critical to the attraction of the pueruli at the end of the larval journey and to the survival of the juveniles (Gittens 2004). Examining the probabilistic imports and exports for these areas highlights their connections to other local areas within The Bahamas, as well as to populations elsewhere in the Caribbean. With similar dispersal kernels to the
one obtained for The Bahamas population as a whole, these areas are also exhibiting high levels of domestic connectivity for the region, with each site demonstrating greater rates of recruit survival, with the exception of the GBB area. This data suggests these areas have some importance for maintaining the populations that support the Bahamian spiny lobster fishery.

Based on fisher responses, the majority of habitat polygons in each of the popular fishing areas are most likely hosting condos as well. This is especially prevalent in the JRI, BI, and TOTO areas, where over 95% of the habitat polygons were also identified as condo locations. This may have important implications for how these sites are managed when the percentage of condos present in the areas are weighed against the areas’ importance for sustaining both the population and the fishery. The creation of protected areas may be an option to achieve this. Two of the factors that can influence the placement of reserve locations are the identification of source/sink and isolated populations (Jones et al. 2007), which can be extrapolated from the connectivity factors examined here.

It was revealed that GBB had the most sites with high betweenness centrality, followed by the BI area, suggesting these locations may have importance for securing connections between the populations within The Bahamas and across the entire Caribbean network. As such, it may be best to limit intense fishing within the habitats in these areas, as this may impact how individuals in the population move throughout the network. However, this is complicated by the presence of high quantities of condos in these locations, as
100% and 61% of the habitat polygons in the BI and GBB, respectively, are also preferred condo placement areas.

LBB and BI have the most habitats within the top 10% for diverse connections (greater than 2500 unique linkages with other sites Caribbean wide). The high number of unique incoming connections to these areas indicates these populations can be subsidized by others from various locales, ensuring a level of maintenance for the population and also potentially the sustainability of fishing operations within these areas. As such, these areas should have lower priorities for closure. While a large percentage of the LBB habitats (68%) are already condo sites, there may be additional habitats here that can possibly accommodate condos, especially if condo placement is limited in other highly popular areas.

This may be the case for TOTO. Although there are 27% of sites with 1000 or more unique connections, none of the habitats in TOTO fell in the top 10% for connection diversity. Despite this, TOTO was the one area displaying high levels of self-recruitment, with 29% of its habitats demonstrating a probability for self-recruitment of 0.01 to 0.12, compared to the 4-7% of habitats in the other 4 areas displaying a self-recruitment probability greater than .01. The quantity of highly self-recruiting sites in TOTO is 150% greater than the next best self-recruiting area in LBB. As such, TOTO habitats may have some importance for helping to maintain Bahamas populations. A closer examination of the larval exchange occurring between TOTO and the rest of the network reveals strong connectivity with other Bahamas sites, but relatively low
connectivity with other Caribbean habitats (Figure 2.6 (A)). This is supported by TOTO’s DK, which is narrower than the DK’s for the rest of the Bahamas, and has the highest probability of successful recruits (36%). These characteristics aid in further substantiating the notion that TOTO may be a self-sustaining system essential to the success of the Bahamian spiny lobster population.

LBB and BI also possessed the most habitats with the highest rates of larval particles that successfully settled somewhere within the network, followed by TOTO and JRI. This suggests lobsters being spawned in these areas are more likely to find suitable habitat at the end of their larval journeys, not only contributing to the strength of the ecological network, but to the sink populations as well. Limiting harvesting and/or the deployment of condos in these important source locations may be one suitable management option for these areas based on their potential as nursery habitats. Currently, none of the LBB habitats identified as potentially important nurseries, those along the south-east edge, were identified as popular condo locations. As such, there may be little disagreement if a management decision is made to close or impose harvesting limitations in these areas. However, the opposite is true for the BI nurseries, where 100% of the habitats are also condos sites. This may cause some contention should any limitations be imposed.

Management Recommendations

Self recruitment within the GBB ranges from low in the northern and western areas to high along the southern edge of the bank. Coupled with the southern area’s great potential as an important population connector, the habitats
in this location may be good candidates for closure, allowing the area as a whole to serve as a safe haven for both Bahamian and Caribbean-wide spiny lobster populations. These southern habitats are also locations where condo placement is extremely popular; however, based on the fisher interviews, the western edge is not currently a first choice for condo placement. It may be best to encourage fishers to place more condos within these habitats as a compromise for potentially limiting fishing in what is considered “prime” condo space in the southern GBB.

TOTO demonstrates high levels of successful settlement, as well as some diversity of connections with other habitats throughout the network. Factoring in its ability for high levels of domestic connectivity (higher than all the other habitats in The Bahamas), especially along the northern edge, TOTO habitats may be significant sites for supporting the Bahamian spiny lobster population and the fishery, with the potential for helping to subsidize the habitats in the other Bahamian areas. Despite this, the level of unique incoming connections to TOTO may not be enough to help subsidize the area should the population it supports collapses. This is a potential threat, as interviews indicate harvesting in this area, particularly through the use of condos, is high, suggesting the increased potential for the harvesting of juveniles based on the connectivity factors explored. As such, TOTO should be a principal focus for managers within The Bahamas, with particular considerations for how this area can serve primarily as a nursery.
Despite having one the highest average rates of successfully settling larvae, suggesting some importance as a nursery, JRI is not an area that serves as an important connector of habitats, nor does it have much importance in terms of diversity of connections. Condo usage in this area is also extremely popular, as 30.6% (n=19) of fishers mentioned placing or using condos all throughout this region. Therefore, it is suggested this area remains open. Managers may want to consider the potential for paying particular attention to some of the habitats along the southern edge that demonstrate higher rates of successful settlement; however, since self-recruitment is not particularly high in JRI, it is likely these larvae are leaving the Bahamas and settling elsewhere throughout the Caribbean (which may provide some additional opportunities for collaborative management amongst different countries sharing these populations). Couple this with the popularity of the area by industrial fishers and the potential limits within other popular areas, it may be best to not alter management of this area.

BI also had a medium consideration for closing due to a large number of habitats demonstrating importance for betweenness centrality and successfully settling larvae, but not for unique connections. Domestic connectivity for the entire area is average, with higher levels seen in the habitats surrounding the eastern edge, around the Berry Islands group. Further examination of this section reveals it also has a higher consideration for additional management opportunities when compared to the western portion. This suggests limiting fishing within the eastern part of this area might be best, allowing it to serve as a spawning and linking site that helps to facilitate the movement of larvae.
throughout the local and Caribbean-wide network. More fishing can be encouraged in the western section along the bank, where most of the connectivity factors have a lower importance and where condo placement tends to be favored.

Lastly, LBB was the only area to receive a low priority for management. It has relatively low betweenness centrality and diversity of connections, with average rates of larvae with successful settlement. However, high levels of self-recruitment are evident along the southeast edge. Most of this southern area also received a medium priority rating, indicating harvesting limitations here could be a viable option, especially as condo placement along this edge is not as popular as in the northern and western regions of this smaller bank. Despite the low priority rating for the area as a whole, limiting fishing in the southeastern section may be a good choice, as fishers may not oppose this decision.

Figure 2.14 provides a summary of the final management recommendations.

**Managing the Bahamian Spiny Lobster Fishery for Connectivity**

The resolution of connectivity has important implications for determining suitable scales of management (Sale et al. 2010). Local management alone can be effective if larvae are mostly retained locally, as may be the case for Bahamian spiny lobster populations; yet, when larvae travel beyond these scales, as is also the case for Bahamian spiny lobster populations, management must be scaled up appropriately to be the most effective. This is one of the
fundamental issues that continues to plague connectivity research, especially for species like lobster with long PLDs.

In order to effectively conserve biodiversity, as well as to efficiently manage the fishery, a management program is necessary across the entire network. This must include the space between the protected areas and the coastal marine ecosystems that might affect the network. Protected areas need to be large enough to retain a large portion of the larval dispersal, ensuring adequate self-recruitment. For fisheries enhancement, protected areas should be sized and spaced in such a way that dispersal to fished areas can occur, yet remain close enough to ensure connectivity between the areas is still maintained. This spacing should consider variation in dispersal distance, both within and among taxa (Palumbi 2004; Holstein et al. 2014). Information collected based on where fishers harvest can contribute to determining the spacing options.

However, if the protected areas are large enough to be substantially self-replenishing, then the distance between the areas may be of little consequence (Botsford et al. 2001; Jones et al. 2007). Spacing may be more important instead for recruitment subsidies outside the protected area boundaries (Almany et al. 2009) and to maintain genetic diversity (Palumbi 2004; Cowen et al. 2006; Frankham 1995). Despite all this, there still remains uncertainty as to whether the magnitude of larval supply from protected areas will be enough to offset increases in fishing pressures outside protected areas (Hilborn et al. 2004).

Ecosystem based management will be key to managing for connectivity within The Bahamas, where multiple factors are in play. Through the
identification of the functional factors within ecosystems, including humans, managers can begin to assess how best to maintain the connections between all the possible networks. When these connections are severely impacted or broken through population loss or decline, the overuse or destruction of key habitats, or drastic changes in resource use and/or user behavior, the ability for these systems to recover while still continuing to provide valued ecological utilities will also decline (Steneck *et al.* 2004; Hughes *et al.* 2005). Understanding how all these factors intersect is imperative; this work demonstrates that creating links between various methodologies may serve as one strategy to help achieve this.

In many tropical nations, fisheries management requires a community based approach, especially since the spatial scale of management tends to be defined by small customary marine tenure areas (Almany *et al.* 2013). Linking these areas via larval dispersal and connectivity can provide a solid foundation for cooperative management and community support (White and Costello 2011; Palumbi 2004). Support, however, will depend on how well community perspectives are incorporated in management decisions and on how well management efforts create and/or maintain benefits to all stakeholders. Steneck *et al.* (2009) suggest that social connectivity is also necessary for communicating results among stakeholders in order to develop those incentives for supporting the new ways of sustaining the ecosystem. This is supported by Agardy (2005) and Almany *et al.* (2013) who both demonstrated the incentive for compliance is highest in those communities that receive direct benefits from their actions. Pollnac *et al.* (2010) also suggest the key priorities for governments and
managers should be investments in the processes and conditions that would help to foster compliance.

While customary tenure areas are not necessarily the case throughout The Bahamas, responses during the surveys and interviews indicate many Bahamians are of the belief that although Bahamian marine resources are open to all Bahamians, the habitats directly adjacent to their settlements should be restricted for the use of that settlement’s residents. Many of the fishers also feel there is a lack of enforcement and utilizing the local communities to help regulate and enforce imposed management strategies would be helpful for sustaining both the ecosystem and the fishery. The implementation of protected areas, especially the closing of habitats near settlements, will need additional support from those residents if they are to be effective. Broad and Sanchirico (2008) discuss the importance of understanding local perspectives during the development and implementation of management strategies, such as the creation of protected areas. They note the danger in imposing a “one-size-fits-all conservation approach”, and argue managers should incorporate characteristics particular to local sites. Developing social connectivity in these areas will require involving fishers from these areas in the decision making process. This work attempts to take a first step at this, by using surveys and interviews to develop a better sense of how the fishers are utilizing the habitats spatially and considering their preferences for priority fishing areas, coupled with the demographic connectivity of the spiny lobster, before proposing where additional management considerations might be necessary. Further social connectivity can be achieved
by continuing to involve fishers in the process by collecting their opinions on the proposed management strategies and assessing what roles they might play in ensuring management success.

Another aspect requiring further consideration is the connection of the Bahamian lobster population and related habitats to the rest of the Caribbean. Creating a network of protected areas within The Bahamas may be inconsequential if the other populations that can potentially subsidize these areas are not protected as well. As such, social connectivity also needs to occur between managers from different locations. To date, there has been some action to link management initiatives across international borders through the help of organizations such as the Caribbean Community (CariCom), Caribbean Regional Fisheries Mechanism (CRFM), Gulf and Caribbean Fisheries Institute (GCFI), and Caribbean Marine Protected Area Network (CaMPAN). Since networks, too, might also cross many boundaries and jurisdictions, social networks become imperative to ensuring the survival and success of connected management areas. A similar level of social connection also needs to occur between scientists and researchers from different fields, and the aforementioned organizations can assist with this as well.

Ultimately, there is a need to be able to translate empirical findings into useful conclusions about the resource that can help to further guide spatial management. In order for any of this to happen, greater communication is required between those generating empirical estimates of dispersal and population, spatial modelers, and social scientists, especially in regards to the
social and economic factors that will have an influence on whether people accept instituted management regimes. Advancing the design and implementation of new networks within The Bahamas will require scientists and managers to work together in long-term processes in which setting up social networks become a way of testing these proposals and the effectiveness of the choices being made (Sale et al. 2010). Understanding how much and at what spatial scales local communities can benefit from management actions is key to designing effective strategies, obtaining and maintaining support for management, and providing incentives for compliance (Almany et al. 2013). Additionally, mapping connectivity patterns will assist with the identification of key management priorities and partnerships that can be created between managers and local fishers, and between The Bahamas and other countries. Furthermore, an overall awareness of connectivity, especially the potential for it to highlight how management decisions and the resulting human reactions in one location can lead to consequences, either positive or negative, in another location, provides an added boon for bolstering not only the use of social connectivity and networks, but for integrating ecosystem based management that has the capability to span the range of the Caribbean spiny lobster both within The Bahamas and throughout the Caribbean.
Figure 2.1 Bahamas Habitat Polygon Map. Each habitat is represented by an 8km x 8km polygon. There are 848 of these habitat polygons within The Bahamas.

Table 2.1 Summary of CMS Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceanography:</td>
<td>1/12 degree Global HyCOM+data assimilation. 1/25 degree HyCOM Gulf of Mexico.</td>
</tr>
<tr>
<td>Horizontal diffusion:</td>
<td>15m$^2$/s for Global, 10m$^2$/s for GoM</td>
</tr>
<tr>
<td>Integration Timestep:</td>
<td>2700s</td>
</tr>
<tr>
<td>Spawning Timespan:</td>
<td>1/1/2004 through 12/31/2008</td>
</tr>
<tr>
<td>Habitat:</td>
<td>3202 sites consisting of 8x8 km polygons overlaid on Caribbean coral reef habitat</td>
</tr>
<tr>
<td>Competency:</td>
<td>152 days</td>
</tr>
<tr>
<td>Maximum dispersal time:</td>
<td>196 days</td>
</tr>
<tr>
<td>Spawning Frequency:</td>
<td>Daily</td>
</tr>
<tr>
<td>Spawning Magnitude:</td>
<td>500 larvae per site per day</td>
</tr>
<tr>
<td>Vertical Migration:</td>
<td>ontogenetic migration</td>
</tr>
</tbody>
</table>
Figure 2.2 Preferred Lobster Fishing Areas. Areas circled represent the major locations fishers indicated they preferred to either deploy and/or fish from condos.

Table 2.2 Quantities of Habitat Polygons in Popular Locations. Habitat polygons within these areas potentially housing condos were estimated based on feedback from fishers during interviews.

<table>
<thead>
<tr>
<th></th>
<th>GBB</th>
<th>JRI</th>
<th>LBB</th>
<th>BI</th>
<th>TOTO</th>
</tr>
</thead>
<tbody>
<tr>
<td># of polygons</td>
<td>141</td>
<td>111</td>
<td>116</td>
<td>75</td>
<td>79</td>
</tr>
<tr>
<td># of condo polygons</td>
<td>71</td>
<td>105</td>
<td>51</td>
<td>75</td>
<td>77</td>
</tr>
<tr>
<td>% condos</td>
<td>50.4</td>
<td>94.6</td>
<td>44.0</td>
<td>100</td>
<td>97.5</td>
</tr>
</tbody>
</table>
Figure 2.3 Connectivity Matrix. Represents the likelihood of larval exchange between any two habitat sites in the Caribbean-wide network. The matrix depicts the probability of dispersal from source location (y-axis) to settlement location (x-axis). Dark blue (probability = 0) indicates there is likely no dispersal between a source and settlement site. There are 3,202 habitat polygons from throughout the Caribbean represented within the matrix. (A) Represents the probability of dispersal for the 848 habitats within The Bahamas. (B) Represents dispersal of larval particles released from habitats in The Bahamas. (C) Represents dispersal of larval particles settling within the habitats in The Bahamas.
Table 2.3 Summary of Matrix Locations. Each polygon in the model is represented by a number that identifies the location of the habitat by country.

<table>
<thead>
<tr>
<th>Country</th>
<th>Site ID #</th>
<th>Country</th>
<th>Site ID #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida</td>
<td>1-94</td>
<td>Panama</td>
<td>2384-2458</td>
</tr>
<tr>
<td>Bahamas</td>
<td>95-913</td>
<td>Nicaragua</td>
<td>2459-2598</td>
</tr>
<tr>
<td>Turks and Caicos</td>
<td>914-1010</td>
<td>Colombian Archipelago</td>
<td>2599-2676</td>
</tr>
<tr>
<td>Cuba</td>
<td>1011-1630</td>
<td>Jamaica</td>
<td>2677-2788</td>
</tr>
<tr>
<td>Hispanola</td>
<td>1631-1892</td>
<td>Cayman Islands</td>
<td>2789-2811</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>1893-1982</td>
<td>Honduras</td>
<td>2812-2923</td>
</tr>
<tr>
<td>Leeward Islands</td>
<td>1983-2107</td>
<td>Belize</td>
<td>2924-3041</td>
</tr>
<tr>
<td>Windward Islands</td>
<td>2108-220</td>
<td>Mexico</td>
<td>3042-3186</td>
</tr>
<tr>
<td>Venezuela</td>
<td>2221-2327</td>
<td>Gulf of Mexico</td>
<td>3187-3202</td>
</tr>
<tr>
<td>Colombia</td>
<td>2328-2383</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2.4 Dispersal Kernel: Caribbean. The dispersal kernel (DK) identifies the distance and probability that a larval particle will disperse and settle successfully within the network. The average dispersal kernel for the entire Caribbean is 200-400 km, with ~13% successful recruits.
Figure 2.5 Dispersal Kernel: Bahamas. The average dispersal kernel for The Bahamas 200-400 km, with ~25% successful recruits.
Figure 2.6 Connectivity Matrices: Popular Locations within The Bahamas. (A) Tongue of the Ocean (TOTO), (B) Jumentos and Ragged Island Chain (JRI), (C) Little Bahama Bank (LBB), (D) Great Bahama Bank (GBB), (E) Berry Islands and North of Andros (BI).
Figure 2.7 Dispersal Kernel: Popular Fishing Locations within The Bahamas.

- **DK_{TOTO} = 200-300 km**
  - Prob Recruits: ~36%

- **DK_{LBB} = 300-400 km**
  - Prob Recruits: ~28%

- **DK_{JRI} = 200-400 km**
  - Prob Recruits: ~31%

- **DK_{BI} = 200-400 km**
  - Prob Recruits: ~32%

- **DK_{GBB} = 200-500 km**
  - Prob Recruits: ~17%
Table 2.4 Summary of Dispersal Kernels and probabilities of successful recruits for the Caribbean, The Bahamas, and the 5 Popular Fishing Locations.

<table>
<thead>
<tr>
<th>Dispersal Kernel (km)</th>
<th>Caribbean</th>
<th>Bahamas</th>
<th>GBB</th>
<th>LBB</th>
<th>BI</th>
<th>JRI</th>
<th>TOTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>200-400</td>
<td>200-400</td>
<td>200-500</td>
<td>300-400</td>
<td>200-400</td>
<td>200-400</td>
<td>200-300</td>
<td></td>
</tr>
<tr>
<td>Probability of Successful Recruits (%)</td>
<td>13</td>
<td>25</td>
<td>17</td>
<td>28</td>
<td>32</td>
<td>31</td>
<td>36</td>
</tr>
</tbody>
</table>

Figure 2.8 Betweenness Centrality Habitat Rankings. Habitats with high scores have the highest number of shortest paths passing through them and are linked directly with the most habitats in the network. These locations are important connectors for the entire network.
Figure 2.9 Unique Incoming Connections Habitat Rankings. Habitats with low scores are settlement locations with diverse connections from other source habitats. These locations are heavily subsidized by other habitats within the network.
Figure 2.10 Successful Larval Settlement Habitat Rankings. Habitats with high scores are habitats with a high percentage of larval particles that exported and successfully settle anywhere in the network. These locations can serve as nurseries.
Figure 2.11 Domestic Connectivity Habitat Rankings. Habitats with high scores are locations with high probabilities for exporting larval particles back to themselves (self-recruitment).
Figure 2.12 Final Management Priority Rankings. Rankings from the connectivity factors were combined to identify management priorities for the individual habitat polygons. A ranking of “High Priority” indicates an area should have the highest consideration for additional management scenarios.
Figure 2.13 Quantity of Habitat Polygons within Each Management Priority Rating.
Figure 2.14 Final Management Recommendations. Recommendations based on the rankings of the four connectivity factors, coupled with responses from fishers on how they utilize the space, their interactions with other fishers, and their perceptions about the habitats.
Chapter 3: Bioeconomic Model of the Bahamian Spiny Lobster Fishery

Background

Humans play a dominant role in most ecosystem functions (Ellis 2013; Zalasiewicz 2010); we can induce changes in habitats, impact species composition, and contribute to the gain or loss of biodiversity. Whether from marine or terrestrial sources, the demand for ecosystem services is high and decisions related to the distribution, protection, and management of natural resources must be made. One tool that can aid in this decision making process is the combination of resource economics and management in the form of bioeconomics.

Bioeconomics is the economics of managing renewable resources. It focuses on the study of the dynamics of living resources through the linkage of biological and economic processes via quantitative relationships (Conrad and Smith 2012). By integrating population dynamics and economic value, bioeconomic modeling represents a system comprised of variables, each with logical and quantitative relationships that link them together and enable “reasoning within an idealized framework” (Prellezo et al. 2009). Bioeconomic models can serve as tools that aid in the identification of the costs and benefits of different allocation scenarios (Sanchirico 2011), providing a guide for how to achieve sustainability through natural resource policies. These models can be used to explain and quantify the impacts of regulation on harvest, stock size, effort, and profits. Through bioeconomics, it is possible to determine the level of socioeconomic activity for which a biological system can be used efficiently,
without impairing the system’s ability to rebound and remain sustainable (Mohammadian 2000).

In the past few decades, biologists have begun to consider the implications of space when creating population models (Sanchirico and Wilen 1999). Spatial bioeconomics allows for the incorporation of more realistic features and parameters of the populations being studied. Real populations are often distributed heterogeneously; integrating spatial dimensions can generate new insights to fully grasp the intricacies of biological and ecological processes. Thus, spatial bioeconomics seeks to better inform ecosystem based management by examining the intersection of spatial scales, species dynamics, and economic behavior.

With a complex life cycle (Marx and Herrnkind 1986; Lipcius and Cobb 1994; Butler et al. 1997) that includes a long pelagic larval duration (PLD) of 5-9 months, Caribbean spiny lobster possess the ability to disperse throughout the entire Caribbean (Ehrhardt 2005) and creates the opportunity for high levels of connectivity. This ability for wide-range dispersal tends to complicate attempts at creating sustainable management strategies for spiny lobster fisheries. Although some findings indicate a high proportion of spiny lobster offspring settle relatively close to their spawning sites (Black 1993; Butler et al. 2009), other studies have also provided evidence that strong patterns of connectivity do exist among spiny lobster populations throughout the Caribbean and may have implications for the species’ management (Chavez and Chaves-Hidalgo 2012; Kough 2013).
Exploration of the impacts of these connections, whether local or distant, is imperative, as attempts at managing the species must take into account the recruitment locations of the larvae, where the larvae settle, how far the adults move, and where they eventually end up (as examined in Chapter 2 of this dissertation). Coupling these biophysical factors with socio-economics will only serve to enhance the ability to adequately manage these fisheries. With the recent push towards more focused ecosystem based management, the old view in population biology of "homogenous, stable, predictable, and uniform" (Smith and Wilen 2000) populations no longer holds true and is a major issue that needs to be resolved.

In order to ensure the sustainable harvesting of a resource such as spiny lobster requires that the rate of harvest not exceed the growth rate of the species, i.e. where the maximum sustainable yield (MSY) would be met. This represents the biological optimum, as beyond this point, the harvesting becomes unsustainable and results in overfishing. Another possibility for ensuring sustainability is determining how best to achieve economic equilibrium by operating at the maximum economic yield (MEY).

Typically, fishers are often driven to maximize their profits in the short run. This is seen in the Bahamian fishery by an increase in effort, either in the amount of time spent harvesting or the quantities of condos utilized. If this continues in the long run, rent dissipation and/or overfishing are likely to occur, especially if proper management is not in place. Regulatory policies are necessary to ensure sustainability long-term, particularly when there are economic and sociological
incentives to continue high levels of fishing. To achieve this, the fishery needs to be managed in such a way that it is both ecologically sustainable and economically efficient.

**Goals and Objectives**

The goal of this analysis is to construct a bioeconomic model to help support the decision making processes for the Bahamian spiny lobster fishery. The model will be used to determine if the current fishing levels, based on condo effort, are biologically and economically sustainable. More specifically, the analysis will examine the trends in the fishery over time and explore its economic optimums. The implications of the current practices within the fishery will be examined and utilized to propose strategies for helping to promote and maintain its sustainability.

**Significance**

Bioeconomic models have been used to assess spiny and rock lobster fisheries in Hawaii, New Zealand, Mexico and the Caribbean (Breen *et al.* 1994; Clarke *et al.* 1992; Chavez and Gorostieta 2010; Vega-Velázquez *et al.* 2011; Seijo *et al.* 1991). The Gordon-Schaefer surplus production model has been utilized to study fisheries from around the world as it describes the long-run equilibrium conditions of collective action dilemmas, highlighting that open access situations, a characteristic common in many Caribbean spiny lobster fisheries, can be economically and biologically inefficient. Due to its simplicity and robust assumptions (Clark 1985), the model has also been used to study spiny lobster fisheries throughout Caribbean, including fisheries in Florida.
(Waters 1987; Milon et al. 1999), Cuba (Puga et al. 2005), Brazil (Seijo et al. 2000), and Jamaica (Morris 2010).

Although bioeconomic analyses of the Bahamian spiny lobster fishery have been completed in the past (Sanders 1995; Gittings and Braynen 2002), this study represents one of the first since the recent completion of a stock assessment (Medley 2015) on the local population. It also fills a gap in the research on the fishery as prior bioeconomic analyses did not incorporate the effects of condo usage. This analysis also utilizes data gathered from surveys and interviews of Bahamian fishers obtained through an anthropological methodology. While the incorporation of condos in this project does not reflect a true spatial bioeconomic analysis, utilizing estimates of the quantities of condos, coupled with descriptions of how and where they are deployed, provides some insights into how the potential changes in the habitat landscape caused by condo use are impacting the fishery.

**Methods**

**General Model**

The bioeconomic model utilized in this analysis is based on a Gordon-Schaefer surplus production model. The general bioeconomic functions include:

1. **Biomass Growth:**
   
   \[
   \frac{dx}{dt} = G(x) - h_t
   \]

   where, \( x \) is biomass, \( G(x) \) is growth as a function of biomass, \( h \) is the yield or harvest from fishing, and \( \frac{dx}{dt} \) is the change in biomass over time;

2. **Harvest Function:**

   \[ h = H(e,x) \]

   where total harvest, \( h \), is a function of effort, \( e \), and biomass, \( x \);
(3) Profit Function:  
(a) \( TR = p \, H(e,x) \)
(b) \( TC = C(h,e) + f \)
(c) \( \pi = R - TC \)

\[ \pi = p \, H(e,x) - [C(h,e) + f] \]

The profit function assumes there is a price, \( p \), that when multiplied by harvests will result in the revenues, \( TR \), from the fishery. Total costs (TC) includes the costs associated with fishing effort and harvest (\( C(h,e) \)) and fixed costs (\( f \)). Profits, \( \pi \), are obtained by subtracting the total costs from the revenue.

**Biomass Growth Function**

The growth function represents the net increase in the biomass over time. Biological production of the stock is assumed to follow the Schaefer surplus production model:

\[ G(x) = r \times (1 - \frac{x}{K}) \]

where \( r \) represents the intrinsic growth rate and \( K \), the carrying capacity. The function is density dependent, where the growth rate decreases as the population increases. By including harvest and time, the equation can help determine the effect of fishing on the population dynamics:

\[ \frac{dx}{dt} = r \, x_t \, (1 - \frac{x_t}{K}) - h_t \]

where \( h_t \) is the harvest at time \( t \). This can be written as:

\[ \dot{x} = \alpha \, x_t - \beta \, x_t^2 - h_t \]

where \( \alpha = r \) and \( \beta = r/K \). To estimate the change in biomass in discrete time, where biomass at time \( x_t \) minus the biomass at time \( x_{t-1} \) is equal to biomass growth minus the harvest, the following equation will be used:
(5b) \[ x_t - x_{t-1} = \alpha x_t - \beta x_t^2 - h_t \]

The equilibrium state, \( \dot{x} = 0 \), can then be represented by:

(5c) \[ h = x_t - x_{t-1} = \alpha x_t - \beta x_t^2 - h_t = 0 \]

**Harvest Function**

The harvest will also be based on a modified Schaefer equation:

(6) \[ h = q e x \]

where \( q \) (a constant) is the catchability coefficient. The catchability coefficient represents the proportion of the population that is caught over a defined unit of effort.

**Sustainable Yield Curve**

To determine the amount of harvest obtained without impacting the stock size, a sustainable yield curve will be determined. This curve looks at harvest as a function of effort by first assuming that the growth rate equals the harvest:

\[ G(x) = h \]

\[ r x (1 - \frac{x}{K}) = q e x \]

\[ r (1 - \frac{x}{K}) = q e \]

\[ (1 - \frac{h}{qeK}) = \frac{qe}{r} \]

(7) \[ SY(E) = h = q e K(1 - \frac{qe}{r}) \]

**Population Equilibrium Curve**

The population equilibrium curve (PEC) demonstrates the relationship between the long-run sustainable stock size and the fishery industry effort. It reflects the maximum effort that can be used year after year without decreasing
the stock size. Again using the assumption that the growth rate and harvest as equal, the population equilibrium curve is defined as a function of effort:

\[ r x \left(1 - \frac{x}{K}\right) = q e x \]

\[ r \left(1 - \frac{x}{K}\right) = q e \]

\[ 1 - \frac{x}{K} = \frac{q e}{r} \]

(8) \[ \text{PEC} = x = K \left(1 - \frac{q e}{r}\right) \]

**Economics**

The total cost function (3b) can be specified as:

(9) \[ TC = c \ e \]

where \( c \) represents the costs (constant) associated with the fishery.

A sustainable total revenue curve (STR) is used to determine how much is earned in the fishery based on the sustainable yield calculate in equation (7):

(10) \[ \text{STR} = p \ SY(E) \]

The profits from fishery are defined by equation (3c). From this, we can obtain the profit function:

(11) \[ \pi = \text{STR} - TC \]

(11a) \[ = p q e K \left(1 - \frac{q e}{r}\right) - c \ e \]

**Fishery Reference Points**

Static reference points for maximum sustainable yield (MSY), maximum economic yield (MEY), and the open access conditions (OA) will be determined using the models described above. Biomass at MSY can be obtained from:

(12) \[ X_{\text{MSY}} = \frac{\alpha}{2 \beta} \]
while the harvest at MSY can be obtained from

\begin{equation}
\text{H}_{\text{MSY}} = \frac{a^2}{4\beta} = \frac{rK}{4}
\end{equation}

The equilibrium effort at MSY (E_{\text{MSY}}) or for any other equilibrium (E_{\text{Eq}}) can be estimated from a combination of the harvest and biomass growth functions:

\begin{equation}
E_{\text{Eq}} = \frac{h}{q x}
\end{equation}

Therefore, E_{\text{MSY}} can be calculated from:

\begin{equation}
E_{\text{MSY}} = \frac{r}{2q}.
\end{equation}

Effort at MEY occurs when \(\frac{d\pi}{dE} = 0\). Using equation (12a):

\begin{equation}
\pi = p q e K (1 - \frac{q e}{r}) - c e
\end{equation}

\begin{equation}
= p q e K - \frac{p q^2 K e^2}{r} - c e
\end{equation}

\begin{equation}
\frac{d\pi}{dE} = p q K - \frac{2 p q^2 K e}{r} - c = 0
\end{equation}

\begin{equation}
\frac{2 p q^2 K e}{r} = p q K - c
\end{equation}

\begin{equation}
2 p q^2 K e = r (p q K - c)
\end{equation}

\begin{equation}
e = \frac{r (p q K - c)}{2 p q^2 K}
\end{equation}

\begin{equation}
E_{\text{MEY}} = \frac{r}{2q} - \frac{r c}{2 p q^2 K}
\end{equation}

\begin{equation}
E_{\text{MEY}} = \frac{r}{2q} \left(1 - \frac{c}{p q K}\right)
\end{equation}

Biomass at MEY can now be obtained from:
\begin{align*}
(17) \quad X_{\text{MEY}} &= \text{PEC} = X(\text{E}) \\
&= \frac{q}{r} \quad (1 - \frac{q}{K}) \\
(17a) &= K \left(1 - \frac{qE_{\text{MEY}}}{r}\right) \\
&= K \left(1 - \frac{q}{r} \left(\frac{r}{2} (1 - \frac{c}{p q K})\right)\right) \\
(17b) &= \frac{K}{2} + \frac{c}{2 p q},
\end{align*}

while the harvest at MEY can be obtained by substituting the harvest and effort levels at MEY into equation (6):

\begin{align*}
(18) \quad H_{\text{MEY}} &= q E_{\text{MEY}} X_{\text{MEY}}
\end{align*}

Open access values are derived from the condition where \( \dot{x} = 0 \) and total revenues equal total costs.

\begin{align*}
\pi &= \text{STR} - \text{TC} = 0 \\
(19) \quad \text{STR} &= \text{TC} \\
(19a) \quad p h &= c e \\
&= p q e x = c e \\
&= p q x = c \\
(19b) \quad X_{\text{OA}} &= \frac{c}{p q}
\end{align*}

To determine effort at Open Access, the growth rate and harvest equations are set equal to each other:

\begin{align*}
&= r x \left(1 - \frac{x}{K}\right) = q e x \\
&= r \left(1 - \frac{x}{K}\right) = q e \\
(20) \quad e &= \frac{r(1 - \frac{x}{K})}{q}
\end{align*}
Equations (19b) and (20b) can now be used to derive the harvest level at open access:

\[ H_{OA} = q \ E_{OA} \ X_{OA} \]

\[ H_{OA} = q \ \frac{c}{p} \ q \ \frac{r}{q} \ (1 - \frac{c}{p \ q \ K}) \]
condos checked per year (Table 3.1). To determine effort for the remaining year, the assumption is made that harvest is related to effort \( e = \frac{h}{q \cdot x} \).

**Economic Data**

Data on annual spiny lobster landings and values were obtained from the Department of Marine Resources (Gittens, Personal Communication). [Landings and value data were missing for the years 2007-2009.] Data on costs, crew shares, and average ex-vessel price were determined from survey responses.

**Biological and Harvest Function Parameters**

Intrinsic growth rate \( r \) and carrying capacity \( K \) of the fishery were based on estimates obtained from a regression equation under the assumption that harvest equals growth as a function of biomass \( h=G(x) \). Equation (4) was adapted to:

\[
G(x) = h = r x - \frac{r}{K} x^2
\]

where in the regression equation \( y = \alpha x + \beta x^2 \), \( y = h \), landings data in lbs, \( x \) is the standing stock biomass, also in lbs. As detailed above, the resulting \( \alpha \) and \( \beta \) determined from the regression will represent \( r \) and \( r/K \), respectively. The harvest function was used to estimate the catchability coefficient \( q \). These biological parameters are described in Table 3.2).

**Economic Parameters**

To obtain a more specific representation for this fishery, total costs \( TC \), as defined in equations (3b) and (9), can be reinterpreted as the sum of variable costs and fixed costs:

\[
TC = v + f
\]
where \( v \) and \( f \) are the variable costs and fixed costs, respectively. Variable costs represent the costs incurred from fishing, and for this analysis, those are costs related to effort. These include the cost of fuel, food, ice, and bait, calculated per year. Estimates for these values were obtained from the interviews and surveys conducted with fishers in The Bahamas. A summary of these costs are provided in Table 3.3. The fixed costs are independent of fishing activity. These include values of the boats (the costs for repairing/replacing) and fishing equipment, such as spearfishing gear, compressors, and the total number of condos set per season. Estimates for these values are also based on information obtained from the interviews and surveys. A summary of these costs are provided in Table 3.4.

The price, \( P \), is based on the average ex-vessel price paid to fishers, based on their responses to the survey. This value is $10.35. Proportion of crew shares, \( a \), was also based on survey responses. The cost parameter (c) was estimated using the 2012 landings data and condo effort Economic parameter estimates are listed in Table 3.5. The bioeconomic model calculations can be found in Appendix C.

**Results**

The average Total Costs per year, at the vessel level, calculated from survey and interview responses was compared to the Total Revenue generated, fishery-wide, from the 2012 landings data (Table 3.6). These values were used to estimate the number of vessels necessary to scale the costs upwards in order for total costs (TC) to equal total revenues (TR). This quantity, 336, would be
necessary for the fishery to achieve the level of revenues reported in 2012 based on the total costs.

Fisheries management reference points were determined based on the bioeconomic model depicted above. The reference points include the conditions in 2012, as well as the calculated open access (OA), maximum sustainable yield (MSY), and maximum economic yield (MEY) conditions. A summary of these conditions for the Bahamas spiny lobster fishery, as well as the respective economic outcomes, is presented in Table 3.7. The 2012 data indicates the fishery is overfished due to excess effort and harvesting (Figure 3.1). While the 2012 stock levels are similar to those at MSY and OA, the biomass could be 1.5 times higher if the fishery was operated at MEY. Although operating at this level would result in a decrease in the harvest by about 44% of that landed in 2012, it would also allow for the associated effort and costs to be decreased by approximately half, while subsequently increasing the potential profits 9 times.

Landings, stock biomass, and estimated price per pound of spiny lobster harvested were compared over time (Figure 3.2). Harvest in The Bahamas has increased steadily since the 1950s, while the stock has experienced rapid declines through the 2000s. However, the biomass began to rebound in 2008 and continues to increase, even as the harvest levels have steadily risen during the same time period. On the other hand, the price of spiny lobster seemed to peak in the early 2000s. While there is an overall steady increasing trend in the price, every few years the price falls and is then followed by a spike of a couple dollars. Correlations between these factors (Table 3.8) indicate there is a strong,
positive relationship between harvest and price, Pearson’s r = .85, p<.001 (Figure 3.3), yet a strong inverse relationship between price and biomass, Pearson’s r = -.91, p<.001 (Figure 3.4). Additionally, there appears to be a quadratic relationship between harvest and biomass, Pearson’s r = -.91, p<.001 (Figure 3.5).

Discussion

The excess effort seen in the Bahamian spiny lobster fishery is most likely a consequence of the increased usage of condos. It is believed there are over a million condos placed throughout the Bahama Banks, and fisher responses from the surveys and interviews seem to confirm this is true. With the relative ease and low costs of building, setting, and/or locating condos, the levels of effort could also be due to more fishers entering the fishery due to the belief that condo fishing is a “sure thing”. Of the fishers surveyed who identified condos as their primary method of fishing for lobster (N=40; 62.5% of total fishers surveyed), 65% responded their reason for choosing condos was because condos yielded them more lobster per outing than the other methods (traps or fishing for lobster on the shoals/reefs). Additionally, 32.5% agreed that condo fishing was the most efficient method.

Even with excess effort, the stock biomass appears to be rising. The 2012 biomass is close to the level that would be seen should the fishery operate at either OA or MSY, reflecting the assessment that the stock is close to being fully exploited (Gittens and Braynen 2003). Despite this, the biomass has continued to increase, even as the landings have increased in recent years.
The steady increase in biomass can also possibly be attributed to the use of condos. There has been the belief that condos may be contributing to the stock as more are introduced each year. This has been reported anecdotally by fishers who claim they’ve seen larger numbers of spiny lobster since they’ve started fishing from condos (Personal Communications). Yet, it remains unclear whether the condos are in fact helping to boost the population, as opposed to simply amassing more individuals in locations where they are easier to find and catch. Additionally there is concern whether the continued utilization of condos will lead to long-term sustainable use or towards a decline of the stock (Eggleston *et al.* 1992; Briones-Fourzan *et al.* 2000; Lipcius and Eggleston 2000). Due to the lack of data on the impacts of condo usage on spiny lobster populations, further studies on their role, if any, on biomass production will need to be completed to have a full assessment of the fishery.

Although the price per pound of spiny lobster in The Bahamas has demonstrated a steady increasing trend, many fluctuations are present when a closer look is taken at the changes year by year. It is unclear whether these price drops are due to the global economy or due to shifts in the ex-vessel prices offered to the fishers locally. Anecdotal reports from the fishers indicate that in some years, when other fisheries have offered their lobster at lower prices, the price earned by the Bahamian fishers decreased as well (Personal communication). This may be an attempt by exporters to remain competitive while still earning a profit.
With 92% of the fishers surveyed indicating fishing is either their primary or secondary occupation, any drop in price has the potential to severely impact their livelihoods. When fishers worry about earning enough due to low ex-vessel prices, it may result in an increase in effort or more destructive practices such as harvesting undersized individuals or fishing out of season, behavior typically seen in open access situations. It may also lead to more conflicts, as fishers may decide to collect from more condos or more frequently than usual. Exporters can help alleviate some of these issues and worries if they consider setting a more consistent price and are subsequently willing to absorb some of the costs when prices do fall.

Although the number of vessels in the fishery in 2012, based on the total revenues and costs, was calculated to be around 336, the Department of Marine Resources (DMR) estimates the quantity to be 365 (Gittens, Personal Communication). The latter value represents the number of registered commercial fishing vessels 20 ft or greater operating in The Bahamas. As such, it is likely that not all 365 operate within the lobster fishery. Additionally, most of this fishery is believed to be composed of vessels under the size limit required to receive a permit (DMR 2014), indicating there may be a greater number harvesting spiny lobster than calculated in this study. There may also be as many as 9000 participants in the fishery (Gittens, Personal Communication).

It is difficult to calculate the exact number of vessels for several reasons. First, the requirement that only fishing vessels 20 ft or greater need to register with DMR only covers much of the large scale commercial fishers using
motherships as their primary vessel. However, as the survey responses indicate, most of the fishers operate smaller, dinghy-sized vessels, and as such, would not be responsible or registering. It also doesn’t account for the recreational sector of the fishery, which includes Bahamians harvesting for personal use and fishing occurring as part of the tourism industry. Second, since many of the fishers no longer utilize lobster traps, there is no need to obtain the associated trap licenses. Licensed traps would help to provide an approximation for the majority of the participants within the fishery, accounting for a large proportion of the fishers, with the exception of those small scale fishers who still choose to primarily dive the reefs and shoals for their catch. However, the licenses only indicate whether a fisher used traps, and do not record or account for the quantity of traps being placed. Third, the ability for fishers to either build condos cheaply or to fish from condos without building their own, opens the fishery to many new entrants. These new fishers won’t be captured as part of the overall effort in the fishery until a method to accurately track all the fishers involved and the structures being used is developed. The ability to quantify these items is imperative for ensuring sustainable levels within the fishery.

Despite the high levels of harvest, effort, and costs currently exhibited in the fishery, the bioeconomic analysis highlights some possible management opportunities. Operating the fishery at the maximum economic yield will present the most efficient and sustainable option. An MEY solution demonstrates the fishery has the potential to earn profits upwards of $18.5 million; this is almost 9 times the profits experienced in the fishery during 2012. Simultaneously, any
associated costs would be reduced by half. Additionally, biomass would increase 1.5 times and revenues decreased by 1/3. In order to achieve these profits, a 32.2% decrease in harvest would be necessary, accompanied by 55% decrease in effort. The large decreases in effort and harvest necessary to make the fishery more sustainable and profitable would be difficult considering the expansion in the fishery due to condo usage (as described above).

Many of the fishers believe they shouldn’t have to curb their condo use as they aren’t seeing a decrease in lobster population numbers (Personal Communications). When asked about the impact of condos on the environment and on the spiny lobster population, 73% and 69% of the fishers, respectively, answered that condos are having positive impacts on both, citing the population numbers are higher and that the condos provide additional shelter and protection for the individuals. This could be true, as indicated by the steadily increasing stock biomass seen in the population. However, as already mentioned, there have not been any studies done on condo impacts to confirm this as of yet. Because the fishers may not immediately see the benefit of slashing their harvest or limiting their condo quantities, they will need additional incentives to do so. Fishers would need to be ensured that any increased profits obtained by the fishery due to their direct actions will indeed reach them and not only benefit those at the top, such as the government, the exporters, or the buyers.

With the fishery already operating beyond open access, MSY would also be a viable solution, yielding double the profits seen in 2012. At this level, there would be a 17.5% decrease in effort versus the 55.5% drop at MEY. Similarly,
harvest would only show a 13.6% decrease at MSY, instead of the 32.2% decrease that would occur at MEY. Despite these smaller changes in harvest and effort, operating the fishery at MSY instead of MEY may be a more acceptable option for managing the fishery, particularly in the eyes of the fishers. More than half (58%) of the fishers surveyed expressed having no interest in reducing their effort levels, especially if that means reducing their number of condos. However, 88.3% agreed that local enforcement is not enough, but necessary for the fishery. And although they may show no interest in reducing the quantities of condos set, the fishers are willing to accept some additional condo use restrictions, ranging from a shortened season and licenses to limits on where the condos should be allowed (Figure 3.6; Figure 3.7).

Management Implications

The operation of the Bahamian spiny lobster fishery has surpassed MSY levels, indicating the necessity for undertaking measures towards maintaining the species and sustaining the benefits of the fishery long-term. The largest uncertainty currently plaguing the fishery is the increased use of condos. Their quantities continue to rise, as those fishers who construct condos set additional numbers each year, either in an attempt to offset the loss of catch due to the use of their condos by others or to replace the structures that have been stolen or displaced by storms. Having the ability to quantify the condos in play, coupled with a better system for tracking the number of fishers entering the fishery, would provide a more accurate measure of effort (and eventually better estimates of the
bioeconomic outcomes). Determining these numbers is essential for developing a complete assessment of the fishery.

The quantity of condos also presents some potential issues for the spiny lobster population. Because there have been few studies on the impacts of condo use (Bohnsack et al. 1994; Lozano-Alvarez et al. 1994; Stanley and Wilson 2000; Briones-Fourzán and Lozano-Alvarez 2001; Behringer and Butler 2006), the impacts of their implementation on the population and on the habitat have yet to be fully explored. Without this data, any stock assessments completed would fail to give a good picture of the current ecological standing of the population. Additionally, stock assessments of this population are not consistent. The first full assessment was recently completed in 2014 (Medley, Personal Communication). However, prior to this, there was no baseline data to compare against. If the fishery is to ensure sustainability, the stock assessments need to occur on a regular basis, allowing for the true status of the local stock to be determined.

Based on the bioeconomic model, the harvest and effort levels should be reduced. Regulating the fishery towards a maximum economic yield would provide a high amount of profits while also cutting costs by almost half. In order to achieve this, however, effort within the fishery would also need to be cut by half. Reductions in effort could be achieved through the implementation of quotas or via decreases in the total number of vessels/fishers operating within the fishery or in the quantities of condos. Decreases would require better estimates of the actual numbers prior to any management being put into place.
Landings data is obtained from the Marine Resource Landing Form collected by DMR and the Monthly Purchase Report collected by the processors (Gittens, Personal Communication; BMEA, Personal Communication). However, this data primarily represents the commercial fishers from the major fishing ports and does not account for the fishers on the smaller islands or whose catch goes unreported because it is sold informally to other residents, small restaurants, or tourists (Sullivan-Sealey 2011). Unreported harvests will undermine the ability to provide accurate predictions that can determine adequate management measures.

Additionally, a better understanding of how the condos are being used, more specifically, how many each fisher has and where they are located, as well as how many fishers are utilizing a specific condo is a necessity for successful management of the fishery. Based on the secretive nature of the fishers, due in large part to the attempts to prevent others from harvesting from condos they construct and set, the current number of condos has yet to be quantified and has only been estimated in the broadest sense.

The solution to the condo issue may come from the assignment of property rights to the fishers. Similar to many of the other spiny lobster fisheries throughout the Caribbean, the Bahamian fishery operates within a regulated open access scheme. This is more than likely due to its common property nature, and leads to the excess effort reflected in the data and the subsequent overexploitation within the fishery. Implementation of property rights based management, a technique used in fisheries worldwide, might provide incentives
for fishers to harvest more efficiently while also limiting effort to help maximize their profits. This method has been implemented in other Caribbean spiny lobster fisheries, such as the transferable trap certificate program in the Florida Keys (Milon et al. 1999; Larkin and Milon 2000) and territorial user rights for fishing (TURFS) in the Mexican Vigia Chico spiny lobster fishery (Cunningham 2013; Mendez-Medina et al. 2015). Under the trap program established in the Florida fishery, the total number of traps utilized was regulated by establishing a cap and each fisher owned transferrable certificates for every trap they used. A similar scenario for condos used within The Bahamas might be feasible. However, the total effort level (in regards to the number of condos) allowed within the fishery would need to be determined. As mentioned above, the Bahamian fishers have little interest in reducing their current condo numbers or having to retrieve displaced condos. As such, this may be a contentious solution.

With TURFS in Vigia Chico, individual fishing zones, known as campos, are allocated to the fishers who are part of the Cooperative. The fishers are allowed to place condos and harvest only within their assigned campo. This is another feasible option for Bahamian fishers, particularly those who still harvest lobster from habitats closer to the shore and just off their settlements. They refer to these locations as “traditional” fishing habitats, areas where their families have collected lobster for generations, and have a strong belief that fishers from other islands should not be able to harvest or place condos in these locations (Personal Communications). If they do, any of these condos are fair game. TURFS could provide these fishers with their own bounded areas protected from
others. Additionally, the community within the settlement can be responsible for assisting in the management of the TURFS. Since this does not necessarily solve the “Bahamians can fish Bahamian resources” problem, determining how to manage the condos outside of these TURFs will still be necessary.

Based on the above, management recommendations for the Bahamian spiny lobster fishery should include:

- Adjusting catch and effort levels closer to the MSY or MEY levels;
- Conducting regular stock assessments to determine the true status of the local population;
- Implementing additional input controls that will also allow for better estimates of effort. These may include:
  - licensing/permits for condos,
  - requiring all lobster fishers to register their vessels, regardless of size, or
  - requiring a personal fishing license;
- Researching the ecological impacts of condos on the habitat and the population, and correlating those impacts with the status of the stock;
- Considering property rights based management, such as TURFS or regulating condos as private property.
Table 3.1 Condo Effort. Average effort for 2012 based on responses from the surveys.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total condos set</td>
<td>196753</td>
</tr>
<tr>
<td>Avg quantity of condos currently set per boat</td>
<td>3392.3</td>
</tr>
<tr>
<td>Frequency condos checked per month</td>
<td>1.58</td>
</tr>
<tr>
<td>Frequency condos checked per year</td>
<td>18.9</td>
</tr>
<tr>
<td>Fishers Surveyed</td>
<td>66</td>
</tr>
<tr>
<td>Effort per month (# condos x freq checked per month x # fishers)</td>
<td>353749.044</td>
</tr>
<tr>
<td>Effort (# condos x freq checked per year x # fishers)</td>
<td>4231555.02</td>
</tr>
</tbody>
</table>

Table 3.2 Biological and Harvest Function Parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic Growth Rate</td>
<td>r or α</td>
<td>0.632847</td>
<td>Regression Estimate</td>
</tr>
<tr>
<td>Beta</td>
<td>β</td>
<td>1.60E-08</td>
<td>Regression Estimate</td>
</tr>
<tr>
<td>Carrying Capacity</td>
<td>K</td>
<td>3.96E+07</td>
<td>Calculated</td>
</tr>
<tr>
<td>Catchability Coefficient</td>
<td>q</td>
<td>9.07E-08</td>
<td>Calculated</td>
</tr>
</tbody>
</table>

Table 3.3 Average Variable Costs

<table>
<thead>
<tr>
<th>Average Costs per Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
</tr>
<tr>
<td>Food</td>
</tr>
<tr>
<td>Ice</td>
</tr>
</tbody>
</table>

| Total                  | $438.20    |
| Average variable costs/month | $13,146.00 |
| Average variable costs/year (at an individual boat level) | $105,168.00 |
### Table 3.4 Average Fixed Costs

<table>
<thead>
<tr>
<th></th>
<th>Average Costs per Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel value</td>
<td>$92,932.31</td>
</tr>
<tr>
<td>Equipment</td>
<td>$19,217.74</td>
</tr>
<tr>
<td>Spearfishing Gear</td>
<td>$4,158.00</td>
</tr>
<tr>
<td>Condos per season</td>
<td>$14,376.92</td>
</tr>
<tr>
<td>Compressors</td>
<td>$682.81</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$112,150.05</strong></td>
</tr>
</tbody>
</table>

### Table 3.5 Economic Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of crew share</td>
<td>A</td>
<td>0.111</td>
<td>Surveys</td>
</tr>
<tr>
<td>Ex-Vessel price</td>
<td>P</td>
<td>10.35</td>
<td>Surveys</td>
</tr>
<tr>
<td>Cost</td>
<td>C</td>
<td>17.23</td>
<td>Calculated</td>
</tr>
</tbody>
</table>

### Table 3.6 Summary Economics for 2012

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue</td>
<td>$72,919,000.00</td>
</tr>
<tr>
<td>Total Average Costs</td>
<td>$217,318.05</td>
</tr>
<tr>
<td>Profits</td>
<td>$72,701,681.95</td>
</tr>
</tbody>
</table>

### Table 3.7 Reference Points

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>H</th>
<th>Revenue</th>
<th>Costs</th>
<th>Profits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2012</strong></td>
<td>4231555</td>
<td>18882306</td>
<td>7244368</td>
<td>$74,979,209</td>
<td>$72,909,693</td>
</tr>
<tr>
<td><strong>MSY</strong></td>
<td>3489982</td>
<td>19776469</td>
<td>6257739</td>
<td>$64,767,603</td>
<td>$60,132,398</td>
</tr>
<tr>
<td><strong>OA</strong></td>
<td>3739749</td>
<td>18361132</td>
<td>6225689</td>
<td>$64,435,877</td>
<td>$64,435,877</td>
</tr>
<tr>
<td><strong>MEY</strong></td>
<td>1869875</td>
<td>28957035</td>
<td>4909215</td>
<td>$50,810,374</td>
<td>$32,217,938</td>
</tr>
</tbody>
</table>
Table 3.8 Correlation Table Comparing Harvest, Price, and Stock of Spiny Lobster in The Bahamas.

<table>
<thead>
<tr>
<th></th>
<th>Harvest (h)</th>
<th>Price (p)</th>
<th>Biomass (x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Harvest (h)</strong></td>
<td>Pearson Correlation</td>
<td>1</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td><strong>Price (p)</strong></td>
<td>Pearson Correlation</td>
<td>0.85</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td><strong>Biomass (x)</strong></td>
<td>Pearson Correlation</td>
<td>-0.91</td>
<td>-0.91</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>28</td>
<td>28</td>
</tr>
</tbody>
</table>
Figure 3.1 Sustainable Yield Curve. Bioeconomic reference points are compared against the sustainable total revenues (STR) and total costs (TC). \(E_{2012} = \text{Average Effort in 2012}; E_{\text{MSY}} = \text{Effort at Maximum Sustainable Yield}; E_{\text{OA}} = \text{Effort at Open Access}; E_{\text{MEY}} = \text{Effort at Maximum Economic Yield.}
Figure 3.2 Changes in Harvest, Stock, and Price of Spiny Lobster in The Bahamas Over Time
Table 3.8 Correlation Table

<table>
<thead>
<tr>
<th></th>
<th>Harvest (h)</th>
<th>Price (p)</th>
<th>Biomass (x)</th>
</tr>
</thead>
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<tr>
<td>Harvest (h)</td>
<td>Pearson Correlation</td>
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<td>Sig. (2-tailed)</td>
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<td>Sig. (2-tailed)</td>
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<td>Biomass (x)</td>
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<td>-0.91</td>
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<td>Sig. (2-tailed)</td>
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Figure 3.3 Harvest x Price Correlation

\[ y = 1E-06x + 3.5009 \]

\[ R^2 = 0.7235 \]
Figure 3.4 Price x Stock Correlation

\[ y = -4 \times 10^6 x + 6 \times 10^7 \]

\[ R^2 = 0.8356 \]

Figure 3.5 Harvest x Stock Correlation

\[ y = -2 \times 10^{-7} x^2 - 2.2235x + 4 \times 10^7 \]

\[ R^2 = 0.8414 \]
Figure 3.6 Condo Use Restrictions. 55% percent offishers surveyed (n=33) agreed restrictions are necessary for condos. Potential restrictions for utilizing condos within the Bahamian spiny lobster fishery proposed by fishers during interviews.

Figure 3.7 Condo Placement Restrictions. 64% of fishers interested in seeing condo restrictions (n=21) suggested there be limitations on where condos can be deployed.
Chapter 4: Exploring the Political Ecology of the Bahamian Spiny Lobster Fishery

Background

Many have a view of the world in which humans are separate and distinct from nature. The wild is often viewed as a “pristine exterior” (Whatmore 2002: 34) that occupies a special place outside human reach. This idea of people as separate from everything is an artificial and fictional concept (Williams 1976), especially as “environmental conditions are intrinsically part of human existence” (Santasombat 2003: 3) and vice-versa. Additionally, humans now play a dominant role in most ecosystem functions (Ellis 2013; Zalasiewicz 2010), prompting researchers from multiple fields to refer to this era as the “Anthropocene” (Monastersky 2015). Despite this, the tendency to differentiate humans from non-humans is very prevalent, especially while trying to resolve environmental issues or conflicts.

Political Ecology (PE) is one discipline that attempts to create a picture “where nature and society are undivided” (Robbins 2004: xvii). PE is an attempt to integrate natural and social science approaches to understanding human and ecological relationships by using holistic methods, and it contradicts the common assumption that studying nature must be the sole responsibility of natural scientists (Santasombat 2003). Instead, PE has been applied across numerous disciplines, including but not limited to geography, anthropology, biology, political science, and philosophy of science (Paulson et al. 2005). By considering multiple fields, PE presents a world view that explores how the notion of culture/power/history/nature (Biersack 2006) colors our perceptions of the
environment. This compound term highlights the interconnectedness of these four concepts and how they work together to influence how the environment is viewed. As such, PE seeks to examine how power relations impact human-environmental relations, including how social inequalities become a part of the environment and how the environment becomes part of systems of injustice. Both play a role in understanding why some have access to natural resources when others don’t.

Control over any resource translates to power. This power can be due to access and control of the resource, possession of environmental information, or even the practice of science as it is used to literally define resources. As such, resource management in any area will intrinsically reflect the cultural constructs, as well as the political and economic relationships and/or motivations of the community (Johnston 1994). Although much of the PE analysis on social relations and the dynamics of production and power focus primarily on the processes of change in land-based resources, the analysis can also be extended to marine resources, particularly fisheries.

In many communities, fishery resources represent an important source of food and income. And while most fisheries are currently in decline, income generated from fishery-related activities in developing countries tends to be higher than income from other resources (i.e. coffee, bananas, tea, tobacco, etc.) combined (FAO 2010). The resulting competition and market dynamics in fisheries serve to demonstrate how power relations can be created and institutionalized. Additionally, a full understanding of the inner workings of a
fishery must include the social and economic processes that support the creation of value across the industry (Campling et al. 2012). Social and cultural factors have now become as important as biological ones when attempting to create effective approaches to fisheries management (Moore 2012). Ostrom (1990) notes that the main subject of fisheries management is not fish, but instead the people involved in the existing social, political and economic institutions. It is the people and their interactions with the various systems in place, both natural and man-made, that ultimately determine how resources are utilized and what the best management strategies will be.

Although fish can be categorized as a renewable resource, they are exhaustible, and considered to be a common pool resource. In many areas, they are also fished under open access regimes. The combination of the two can (and often times does) lead to overexploitation, as it is often perceived that the main objective for fishers is not to protect and conserve the resource, but rather to preserve the available fish for one’s self. Yet, while there are many fishing communities where there is no ownership of the resources and fishers can fish when and where they want, in many others, fishers have established various systems of ownership rights. In some cases, these rights include control over a “fishing space” (McCay 1978; Lozano-Alvarez et al. 1991; Lozano-Alvarez 1995; Briones-Fourzan et al. 2000; Sosa-Codero 2003; Defeo and Castilla 2005; Ley-Cooper et al. 2012). In those areas where spaces are not formally owned, like in The Bahamas, fishers use various strategies, including information management (Forman 1967; Forman 1970; Anderson 1972; Lofgren 1972; Stuster 1978;
Acheson 1981) and *de facto* rights (Acheson 1975; Cordell and McKean 1987; Berkes 1986; Berkes 1989), to help create a sense of property rights.

Since lobster within The Bahamas is considered a common pool resource, all Bahamians have the right to use the resource. Yet, a common assumption is that every fisher has the incentive to maximize his catch, striving to capture any lobster in a given area before other fishers can do so. It follows then that in order to sustain the fishery, users must be excluded or limited in some way (Bish 1977). For commercial lobster fishers in The Bahamas, exclusion was mainly achieved through the requirement of licenses for traps. As the licenses and construction of traps both incurred a cost, they served to help limit entry into the fishery. However, when resources are depleted, fishers tend to over-invest in harvesting technology in an attempt to sustain their level of catch. This was achieved in The Bahamian lobster fishery through the transition to the usage of condos (fish aggregation devices commonly referred to as casitas throughout the rest of the Caribbean) as the primary fishing method, which currently have no regulations and incur relatively low costs to construct and deploy. Increased effort in this fishery has also been seen in the amount of boats, the sizes of boats, and a greater number of traps and condos in use. Collectively, these factors have helped to increase the number of fishers entering the fishery as well as contributed to increased levels of competition for an already limited resource, further complicating the development of adequate and sustainable management strategies.
Goals and Objectives

The goal of this chapter is to explore the political ecology of the Bahamian spiny lobster fishery, including the importance of various factors affecting fishing, consumption, and the perspectives on existing and potential policies and management strategies. It will present an examination of the increased usage of condos in the fishery, and implications on how the fishers define, perceive, and adhere to access and property rights within the fishery. This case is amenable to a political ecology analysis due to the heavy interdependence of ecology and human factors throughout the fishery. The pervasive use of condos in this fishery demonstrates the potential for humans to create additional habitats where there were none before. These human-induced changes to the ecosystem highlight the need for an interdisciplinary investigation of the fishery that takes into account the natural and anthropogenic impacts on the fishery. An analysis in this context will allow for an assessment of how the ecological, social, and economic factors come together to create and define the fishery, including the implications of this convergence on management. This will assist in the construction of a robust assessment of the fishery that will aid in the proposal of viable management strategies. Specific objectives of this chapter include:

1. Providing an overview of the PE of the fishery based on major themes;
2. Identifying common and differing perceptions about condo use and its impacts, the status of the resource/environment, rights, and management of the fishery;
3. Determining the factors influencing how condos are utilized and how rights are defined within the fishery.

**Significance**

In recent years, conservation and environmental issues have been at the forefront of many debates. The concepts of conservation, biodiversity, and sustainable development are all part of an increasingly globalized understanding of the various relationships people have to nature (Quiroga 2009). As these issues become more prominent in local, national, and international affairs, many are paying more attention to the underlying politics and to the defined power relations influencing the interactions between humans and their environments. With this in mind, political ecology gives more attention to the environmental knowledge and practices of local social groups (Gezon and Paulson 2005), instead of focusing on interpretations of environmental issues made by those perceived to be outsiders. As Paulson et al. (2005) note, political ecology focuses on framing research in such a way that it spans across different spaces, scales, and social groups while conceptualizing the politics in environmental studies.

When competition and overexploitation of resources occur within a community, the problems must be examined via the historical context of the resource’s utilization within the community, the political context of power relations, and the socio-cultural dimensions that help to characterize local contexts such as institutional arrangements or conflicts (Stonich 1993). Yet, this
fails to take into consideration the external factors that might play a role in how a community views and uses its resources.

The scales of many ecological processes, especially those related to the marine environment, are poorly understood, creating many interesting conservation and management challenges. This is because the spatial dynamics of species/ecosystems are often defined to fit only within human-delineated areas, whether for research or management purposes. These types of “scale mismatches” tend to occur when the spatial requirements for a species do not correspond with the administrative levels of management (Zimmerer and Bassett 2003; Crowder et al. 2006; Folke et al. 2007), as is typically seen in many fishery management strategies (Degnbol and McCay 2006; Berkes 2006; Johnson et al. 2012; Almany et al. 2013; Ourens et al. 2015). As these environmental processes interact with social ones, they lead to the creation of relationships that help to produce distinctive political ecologies; PE must then seek to incorporate a consideration of all these processes, including the appropriate scales that produce socio-spatial configurations of resource use (Zimmerer and Bassett 2003).

A PE framework helps to call attention to the fact that resource issues are often not created in isolation at the local level. All communities are influenced in some way by elements outside of their community and frequently beyond their control. Regional and global factors, such as relationships with exporters or the demand from and competition within global markets, can contribute additional dimensions to local processes. While these external factors may not always
have a direct impact on local practices, they certainly can create demands that local users will feel the need to respond to. This can be seen in the Bahamian lobster fishery, where fishers in the various settlements are affected not only by fishers from other islands and countries, but also by the buyers and exporters who choose the best lobster and set the prices, the scientists and resource managers who create and impose the regulations, the non-governmental organizations (NGOs) that promote conservation initiatives, and the public who creates market demand for quality and sustainable lobster tails.

With these factors in mind, an examination of the Bahamian lobster fishery must be considered in a much broader context, where demands on the local system are not only being created by internal factors, but are also being dictated by global ones as well. Instead of considering each part individually, it becomes important to make the assumption that all these parts are interrelated. It would be difficult to understand one factor independently of the others, just as it would be impossible to make changes in one without affecting the others. Attempting to create environmental changes, implement conservation strategies, or adjust policies and regulations can be difficult without considering the people involved, their historical and cultural practices, and how they relate to and utilize the natural resources in question. If the goals of management and sustainability are to be achieved, the interests, actions, and responsibilities of the actors at every scale must be recognized and incorporated into any analysis.
Political Ecology Framework

Political ecology rose from efforts to link social and physical sciences to address environmental issues. The field focuses on applying analyses of questions of access and social relations of production to aid in the understanding of environmental disturbances and degradation (Paulson et al. 2005). According to Vayda and Walters, PE was created in response to the disregard for the “political dimensions of human/environmental interactions” (1999: 168). PE evolved from what Atkinson (1991) referred to as “the ecological/environmental problematic” – essentially, that the current way of life is unsustainable and in order to save it and the environment, radical changes must be made. Research linking all these aspects first emerged in the 1970s and 1980s (Enzensberger 1974; Cockburn and Ridgeway 1979; Blaikie 1985; Turshen 1984; Thompson et al. 1986; Schmink and Wood 1987). An early concept apparent in these works was that resource use is organized through, and can also result from, social relations that tend to result in excessive pressures on the environment, marginalization of groups, and other issues of social justice (Paulson et al. 2005; Watts 1983). As the formation of PE stemmed from various fields and disciplines, such as ecological anthropology, cultural ecology, cultural geography, and political economy, researchers draw on, reinterpret, and bring together concepts from these fields to create what has come to be known collectively as “political ecology”.

The coining of the term “Political Ecology”, as it is used today, has been attributed to Wolf’s 1972 paper, “Ownership and Political Ecology” (Robbins
2004; Paulson et al. 2005; Walker 2005; Biersack 2006). In this paper Wolf states:

_The property connexion [sic] in complex societies is not merely an outcome of local or regional ecological processes, but a battleground of contending forces which utilize jural patterns to maintain or restructure the economic, social and political relations of society….The local rules of ownership and inheritance are thus not simply norms for the allocation of rights and obligations among a given population, but mechanisms which mediate between the pressures emanating from the larger society and the exigencies of the local ecosystem._ (Wolf 1972: 202)

This description provides some of the basic tenants that helped to form the identity of PE: relationships between social, economic, and political factors; interactions between society and the environment; assessing rights, ownership, and access; and the power relations that affect and are affected by these processes.

While there are many definitions, the most general is that PE examines the relationship between economics, politics, and nature, with the guiding objective of understanding their complex relationships through the analysis of forms of control and access over resources (Bloomer 2009; Newmann 2005; Robbins 2004; Watts 2000). Blaikie and Brookfield (1987: 17) give us the most often referenced definition, which states, PE “combines the concerns of ecology and a broadly defined political economy. Together this encompasses the constantly shifting dialectic between society and land-based resources, and also within classes and groups within society itself”. This definition identifies the key analytical approaches, highlighting the focus placed on those factors impacting power relations, and the linkages between local biological and social landscapes, as well as global processes. While many of the definitions tend to stress an
attention to political economy, others stress narratives of change and the importance of politics in ecological systems. Despite these differences, most PE operates under the same common assumption: ecological conditions and changes to the environment are products of political processes, and vice versa.

**Dominant Themes**

Because PE often encompasses a wide range of disciplines, it is not surprising the field touches on a variety of themes. These can be placed within the following overarching, interrelated categories: marginalization and degradation; access, power, and conflict; environmental identities, social relations and their impacts on the environment; and globalization.

**Marginalization and Degradation**

The degradation and marginalization theme focuses on the emergence of environmental changes due to the accumulation of resources or wealth and/or irrational resource use (Hecht 1985), often with increased attention on marginal communities, defined as “those on the fringes of social power” (Robbins 2004: 77). For many political ecologists, degradation is a result of marginalization, where people who are politically and socially disempowered are forced into ecologically vulnerable and economically dependent positions (Blaikie and Brookfield 1987), thus placing increasing demands on already limited resources. These marginal groups tend to increase their efforts on the resource, leading to overcapacity, yet returning lower yields and eventually leading to degradation (Robbins 2004; Blaikie and Brookfield 1987). The less they yield, the more effort is used, causing overexploitation and creating a cycle of not only environmental,
but social degradation. Many scholars believe that modern development efforts aimed at improving production by “local people” (Robbins 2004: 131) have contributed to this cycle, including decreased sustainability and decreased equity in resource distribution.

**Access and Conflict**

The theme of environmental access and conflict is based on the central assumption that social systems are structured around divisions of labor and power, which can determine how access and responsibility are distributed (Robbins 2004). Essentially, this theme helps to explain who has environmental access and why. This is especially apparent when increasing scarcity produced through resource enclosures or appropriations create conflicts between groups (Robbins 2004). The more diverse the groups and/or institutions, the more the emergence of conflicting interests in resource use and management becomes increasingly evident (Zimmerer and Bassett 2003). Furthermore, adjustments in conservation and resource development policies tend to “ecologize” these conflicts (Robbins 2004) by placing them in ecological terms and contexts, often raising questions about the suggested strategies, alternatives, and the hidden costs of conservation and/or remediation.

Historically, human societies have been marked by divisions of labor where different people are expected to do different jobs and allowed various amounts of control over resources, environmental or otherwise. Much of this is due to specific assumptions about class, race, and gender (Robbins 2004). Even the most well-intentioned initiatives have the potential to lead to conflict, as they
can be based on conjectures about the affected parties’ intentions, interests, and behaviors. Consequently, many of the arrangements create unfair distributions of burden and lack of access, often becoming additional sources of political tension. This politicizing of environmental problems also occurs when certain groups secure control of resources at the expense of others through the imposition of management strategies. Political ecology thus examines the questions and challenges that are raised when ecological change unjustifiably burdens some while benefiting others, especially when important individuals and groups, due to their marginality, are invisible to those making the decisions (Robbins 2004), thus tying back to the first theme of degradation and marginalization.

Environmental Identity and Social Movements

The fourth central theme, environmental identity and social movement, attempts to explain the causes of social upheaval due to changes in management regimes and the resulting impacts on the environment. According to Robbins (2004), changes in environmental conditions and management regimes have created opportunities for locals to represent themselves politically, often representing a new form of political action. This action is a result of the way the risks and hazards of conservation and development practices tend to be disproportionately distributed among those with less political and economic influence, thus forcing these communities to not only adapt, but actively respond to the perceived threats placed upon them.
These political and social movements highlight a unique approach to conservation cultivated through the cultural politics they inspire (Escobar 1998). This is the reverse mirror image of the first central theme of degradation and marginalization (Robbins 2004); the theme reflects that while resource exploitation can lead to the destruction of once fruitful resources, it can also simultaneously draw together otherwise disparate persons and/or communities into collective action. And although the historical descriptions of social action have been told from those in positions of power, these new types of social movements are built on the terms of those who have been disenfranchised. The political and social struggles displayed are often linked to basic livelihood issues; when the structure of a community’s livelihood is threatened, it motivates people into working together to take social action.

Agrawal (2005) investigates the role of environmental politics and its influence on the transformations in environmental relationships. He notes that changes in environmental beliefs and practices are due to shifts in governments, policies, and regulations, what he refers to as new technologies of government. These new technologies of government lead to the formation of new relationships, whether between states and localities, in how people interact around the environment, or in how people’s actions and thoughts change as a response. The linkages that exist within communities help to form their identities, but also help them to become potentially powerful forces, especially when they pull together to act collectively. It is this transformation from individual actors to empowered group that drives social movements and allows for these
communities to become political forces. These transformations make it difficult to implement new environmental strategies without considering the people involved, their historical and cultural practices, and their utilization of the resource, as well as how they will react to the new strategies. And when these factors are not considered, it can result in resistance, followed by social mobilization.

**Globalization**

Aspects of the fifth theme of PE, globalization, are woven through each of the previously identified themes. Globalization is the integration of the world economy and industrial capitalization into local economies. Smith (2005) describes this as the process by which capital minimizes the significance of local borders, opening the way for global markets and trade. As a dominant force in PE, globalization influences both society and ecology (Toly 2004); it “carries forward the alliance of modern science, technology, and markets in shaping society” (Byrne and Glover 2002: 7). Globalization also highlights the linkages that exist within environmental issues and the various actors involved, including the implications of the power relations that exist among those actors (Bryant and Bailey 1997). The framework of PE further helps to emphasize the flow of power that occurs through global linkages (Bloomer 2009). Globalization allows for social relations to take place on a worldwide scale, linking distant locations in such a way that events occurring in one area are influenced by other events occurring far away, and vice-versa. It further highlights the global connections formed when “extralocal political economic processes” contribute to local spaces,
but also when local spaces influence these processes as well (Gezon and Paulson 2005: 2).

Because of globalization, previously excluded parts of the world can make connections to the most powerful to gain access to additional markets (Ribot and Peluso 2003), with the hope that the playing fields will become more leveled and that they will achieve equal economic opportunity. However, it’s important to note that major benefits from a resource will depend less on who has the rights to it and more on who has access to markets (Ribot 1998; Ribot 2000). And although there are no boundaries for these global markets, much of the politics involved remain tied to the local communities. This places pressure on local communities to adjust and adhere to international standards, especially if they want to remain competitive.

A complete understanding of globalization must include understanding the structure of the global power relations arising from the economic, cultural, and political legacies of Western Imperialism (Hoogvelt 2001). The colonial period has some importance to the process of globalization, as in many regions, colonial powers were responsible for building and maintaining the infrastructure that helped to make poorer nations more modern and/or industrialized (Bayart 2011). However, it is important to note that under colonialism, globalization was forced onto most communities. In these postcolonial times, while this sentiment of “forced globalization” may not have changed for many localities, there are now many nations that initiate globalization on their own (Toly 2004), seeking to
integrate international and global economic and governance systems within what had been managed by local informal, traditional systems (Stern et al. 2002).

The Role of Political Ecology in Fisheries Management

In fisheries resource management, science is often used to help “mediate ambiguous property relations because it informs ‘management’ decisions” (Campling et al. 2012: 180). Part of the rationale behind this is that unlike scientific management, traditional management solutions are not usually based on biological information; by joining the two, regulations can attempt to accommodate the various human-nature relations, while also incorporating social issues (Berkes 1987). Beitl (2012) believes that a PE lens can be more appropriate for studying how policy shifts change the nature of property rights, the distributions of resources, and access to these resources. While most property relations found in fisheries are not legally determined, they are shaped by the interplay among historical, ecological, and social conditions (Sowerwine 2004). This makes a PE perspective relevant as a PE approach can assist in revealing the intricacies within the relationships that develop over the race for fishery resources.

Robbins (2004) believes that PE can improve its analytical fields by shifting from a focus on linear chains of explanation towards exploring the creation of networks and the complex and shifting connections that networks imply. Watts (1983) suggested human society should be conceptually treated like all other biological populations, which are centered in webs of ecosystem relationships. Through ongoing interactions, there is a constant making and
unmaking of socio-ecological networks (Rocheleau 2007), both on local and global scales. The world has always been networked (Massey 1994) and humans need to not only fully embrace this mindset, but also be aware of their positions within the network and the implications their positions may have on the way they view, act on, and/or contribute to the processes created as a result of these networks. By understanding how the themes of PE emerge from the examination of these interactions and their resulting networks, we can gain a broader prospective on how to use the linkages to develop conservation and management strategies that incorporate elements from social, economic, and ecological perspectives.

**Methods**

Survey and interview responses, as described in Chapter 1, were assessed against the four political ecology themes presented above. For each theme, the current state of the fishery, the demographics of the fishers, how the fishers utilize condos, and their perceptions about condos and the fishery, as well as the perceptions of other stakeholders within the fishery, were all taken into account.

**Linking Perceptions to the PE of The Bahamas**

*Marginalization and Degradation*

The smaller-scale fishers in The Bahamas, particularly those in the poorer settlements, like on the island of Andros, believe they are at a disadvantage when compared to other Bahamian lobster fishers who can afford more resources, such as thousands of condos or larger boats, or those fishers who
don't follow the rules. Fishers on Andros are unable to scale up their fishing operations to the levels demonstrated on the other islands. Additionally, they feel bound to continue within the fishing industry as additional economic opportunities outside of fishing are limited on the island. As more fishers continue to enter the fishery, even as the catches decrease (personal communication; Gittens, personal communication), these small-scale fishers tend to feel even more marginalized. The resulting increase in competition leads many of them to engage in behavior they wouldn't otherwise have engaged in before the rise of condo use.

One of the critical assumptions of fisheries management is that users don't see the costs, whether direct or indirect, they impose on others through their own utilization (Bish 1977). The costs of one individual's use may be so small that it is unnoticeable to him or her. Costs may also go unnoticed because they can accrue spatially and temporally. Yet, the accumulation of all these costs can lead to serious consequences. Despite this, when the costs are high and/or affect a large group, sometimes there is no incentive for individuals to alleviate their own costs (Baland et al. 2006). This is sometimes the case even when fishers realize their actions might have direct impact on the state of the fishery, as it may not be optimal, or rational, for them to attempt to conserve. Situations like those presented in The Bahamian spiny lobster fishery force fishers to face disharmonious incentives (Townsend and Wilson 1981), where they substitute other components to help increase their effort. In the case of this fishery, these components can include bigger boats, large quantities of condos, and in some
cases, poaching, whether from the condos of others or due to fishing outside the bounds of lobster season.

The development of competitive situations, such as the race to collect from condos before others have gotten a chance to, has the possibility to lead to specific types of behaviors outlined by Ostrom and Ostrom (1977). First, fishers may be moved to conceal or minimize information essential to harvesting. In the Bahamian fishery, fishers try to hide productive areas or attempt to conceal the locations where their condos are placed, sometimes setting the structures out prior to the start of lobster season so they have enough time to develop natural camouflage (Personal communication). Increased competition can also lead fishers to ignore the impacts caused by their own conduct. While a single user can change his/her own actions in order to account for social costs, this will not result in much unless all other users make similar changes as well, thus placing that individual at a great disadvantage in the face of continued competition.

Fishers may be enticed to continue their behavior, harvesting at increased levels to ensure they are not only outcompeting other fishers, but recouping any investments as well. In recent years, Bahamian fishers have continued to place condos on the banks in alarming quantities in an attempt to accomplish this (Gittens, personal communication; Personal communication). And those fishers who are not able to build condos or travel to areas with condos will take undersized or molting lobsters, even at the cost of decreased value, just to get their share (Personal communication), potentially resulting in further degradation of the fishery. When a North Andros fisher was asked why he would harvest
undersized lobster, he stated, “things are rough; you can’t pass an opportunity” (Personal communication).

This has the potential to become problematic when the level of effort exceeds the level necessary to maintain a sustainable fishery, especially when condo regulations are non-existent. Without adequate regulations in place, there is an incentive to ignore the ecological and social impacts of their personal behavior. While these behaviors may not be the modus operandi for all Bahamian fishers, the pursuit of self-interests while choosing to maximize short-term gains with disregard for the rapid rate of exploitation is becoming more apparent within the fishery and a cause for concern among fishers, fishery managers, and the local NGOs (Personal communication). The marginalization of certain fishers and the resulting degradation due to their actions creates the sense that the fishery may exhibit the characteristics of the tragedy of the commons model (Hardin 1968). While the inherent nature of the Bahamian lobster fishery is not open access, it is the perceived marginalization of the small-scale fishers (by fishers with more access to structural mechanisms or of Bahamian fishers by outsiders) that places the fishery in an “open access” light.

Access and Conflict

One issue that seems to be pervasive throughout the Bahamian spiny lobster fishery is the recognition of multiple and sometimes conflicting kinds of property rights. As a common pool resource, it is sometimes unclear to users as to whether the property rights regime is public or common property. Public property in The Bahamas takes the form of crown land, land held in trust for the
Bahamian people by the Queen of England as Head of the Commonwealth of Nations (Coalition to Protect Clifton Bay 2013; Smith 2007). This refers to land to be used by Bahamians or for the benefit of Bahamians. Crown land includes not only the dry land on the islands, but also the locations customarily utilized by local Bahamians for fishing (Smith 2007). However, these fishing areas could also be viewed as existing under common property regimes, as members of local Bahamian communities believe that they hold the rights to the fishery resources, especially those considered to be right in their own “backyards” (Personal communication).

Most of the management complications within The Bahamian spiny lobster fishery arise from the seemingly open access nature of the fishery. This stems from the belief by fishers from settlements like Spanish Wells and Long Island that they hold rights to fish anywhere within The Bahamas, because “the Great Bahama Bank and Little Bahama Bank belong to everyone” (Personal communication), especially as the habitats near their islands are not great for lobster fishing. Conversely, there is the belief within other settlements, such as on Andros, that they hold exclusive rights to the resources in their “traditional fishing areas”, those habitats located just within view of their communities. It is their sentiment that other fishers “should not put condos in areas where you can visibly see land, cause then you’re taking fishing grounds away from local fishermen” (Personal communication). While it is true that all Bahamian fishers possess the operational-level property rights of access to and withdrawal of fishery resources (Ostrom 2000), they do not hold collective-choice property
rights. Collective-choice rights allow the opportunity for resource users to help define future rights. These include the right to management, regulating the use of the resource and determining operational-level withdrawal rights; to exclusion, determining who will have access and withdrawal rights, and whether those rights can be transferred; and to alienation, the ability of the rights holder to sell or lease either of the previous two collective-choice rights, or to transfer those rights to other groups or individuals (Schlager and Ostrom 1992).

Bahamian fishers possess full operational-level rights in their ability to both access and withdraw the resources. When considering collective-choice rights, while there may be some local management due to de facto rights, the fishers possess no alienation rights and no right to exclude others from the resource, despite frequent attempts to do so. Without the rights to manage their resource, Bahamian fishers, particularly those from the smaller settlements with less resources to venture further out for fishing, do not have the power to determine how, when, and where fishing can occur near their settlements. And without the right of exclusion, they cannot restrict other fishers from utilizing habitats they deem to be “traditionally” theirs. This tends to result in conflicts as the fishers from settlements within Andros feel those fishers with more resources are infringing on “Androsian” fishing areas when they don’t have to, as they can use their resources to fish anywhere on the Bank without coming in so close to shore. It makes the fishers from Andros feel that the other fishers just want to take with no consideration for Androsian livelihoods, which in turn pushes them
to then seek out the numerous condos put down by those other fishers in order to compete.

One solution is to determine the best “bundle of property rights” that fishers can possess using the framework developed by Schlager and Ostrom (1992). Currently, under this framework, Bahamian fishers would be classified as authorized users based on their basic operational-level rights and their inability to directly participate in any of the decision making involved in determining those operational-level rules. However, providing fishers with rights, particularly to those waters within a certain distance of their settlements, the aforementioned “traditional habitats”, may alleviate some of the issues. As claimants, the fishers would possess the rights of an authorized user combined with the right of management, allowing them to devise harvesting rules for these areas. However, they would still lack the authority to limit access. Adding the rights of exclusion would remedy this and make the fishers proprietors, giving them legal rights to authorize who can access. With this particular bundle of rights, they can patrol their fishing areas and legally fend off intruders. Yet, as owners, fishers also gain the right of alienation.

Fishers who are part of the Vigia Chico cooperative in Ascension Bay, Quintana Roo are considered owners (Miller 1989). Using a TURF (territorial use rights for fishing) program, the bay has been divided into individual held capture areas from which spiny lobster can be harvested. These zones include a 25 m no-take buffer area between each and are assigned to fishers within the cooperative, where the fishers hold the rights of management, exclusion, and
alienation over their assigned areas, allowing them to either harvest that spot or to sell their rights to another fisher (Cunningham 2013; Mendez-Medina et al. 2015). While not explicitly a form of private property, the bundle of rights gained through the assignment of TURFs helps to distinguish the sites from other “common property”. The TURFs in Ascension Bay were an important establishment, as they provided the opportunity for self-sufficiency by the fishers, especially in light of the isolated location of the community. Implementing a similar program within The Bahamas could be an option, where effective management and enforcement is challenging given the spread of the islands. Additionally, tying the programs to traditional fishing grounds could give fishers a sense of having a level of control over habitats they have historically viewed as belonging to their community, while leaving other areas further out on the banks still open to all.

The rise of conflicts seen within The Bahamian spiny lobster fishery in recent years seems to stem from fishers’ attempts at exclusion based on their assumption of their “rights”. Yet, these assumptions are based on attempts at differentiating between access, the ability to benefit, and property rights, the right to benefit. Although these two concepts have been used interchangeably in the past, it has been argued that they are in fact different (Ribot and Peluso 2003), with “access” calling attention to the range of social relationships that can either enable or prevent people from benefiting from resources, by placing the focus on “the issues of who does (and who does not) get to use what, in what ways, and when” Neale (1998: 48). Access helps to emphasize the material, cultural,
economic, and political components that form bundles of power. These bundles shift and change over time, changing the nature of power and how access is determined, controlled and maintained (Ribot and Peluso 2003). With this definition, access can be seen as all the possible means by which a person is able to benefit or derive value from things, whether or not those means are socially acknowledged and whether or not those means impart property rights. On the other hand, “property” refers to having the right to an enforceable claim, one acknowledged and supported by law, custom, or convention (Ribot and Peluso 2003). In this sense, property is composed of the claiming of rights, as a means of access control, and the execution of duties, as a form or access maintenance to help sustain those rights (Hunt 1998). These claims of rights are socially sanctioned by either law or local custom. The key distinction between access and property rests with the difference between ability and rights (Ribot and Peluso 2003). For example, an individual might have the rights to benefit from a resource, but may be unable to do so because they don’t have access to capital or labor; they have the right to benefit, but without access, they lack the ability to benefit. Ability determines how people can control or maintain access.

Examining the fishery within this context, the Spanish Wells fishers can be viewed as possessing both the right and the ability to benefit from the spiny lobster resources present. They have the capital necessary to operate larger boats, to travel greater distances for longer periods of times, and to set higher quantities of condos – all contributing to their ability to sustain the large-scale fishing operations they have come to be known for. On the other hand, small-
scale fishers, like those from Andros and some settlements on Abaco, have the right that all Bahamians do to fish for spiny lobster. However, their access to these resources is limited because they can’t afford to make the investments that Spanish Wells, Long Island, and Grand Bahama fishers can. This severely limits their ability to increase their profits. The differences between access and property showcase a move from focusing solely on concepts of property rights to incorporating the role access plays in how property is viewed and utilized, as well as by identifying property within the greater context of political, social and economic relations and how property fits within the various institutional arrangements created.

The use of condos in the Bahamian spiny lobster fishery has contributed to some interesting interactions among users, especially in terms of both access (who has the ability to benefit from these condos) and property (who has the right to benefit from these condos), including how access and property are developed, assigned, or even assumed in light of the lack of rules/regulations and ownership. Currently, there is no law in The Bahamian parliament that defines crown land; it is a remnant of colonial law that was kept when The Bahamas gained their independence (comment from Bahamian Cabinet Member at the Small Island Sustainability Session of the Bahamas at 40 Conference, June 2013), and which the government uses to help benefit the state economically (most commonly for tourist development projects). Despite this, Bahamian fishers frequently reference “the crown” when they discuss their rights or access to fishery resources, especially in regards to lobster obtained from the utilization
of condos. This also leads to some additional debate, as there are some fishers who believe that the condo structure itself can be viewed as private property, similar in some ways to the traps, and so should any resource found under it. Yet, others maintain that due to the nature of condos, in regards to not being licensed, not being enclosed, or not having a bottom (which allows the lobster to remain on the seabed and not necessarily trapped), any private property claims are null and void. Basically, “once it’s on the ocean bed, it’s technically anyone’s” (Personal communication).

These disparate views on condos will become a major point of contention as DMR seeks to develop policies that will directly focus on condo usage, as they must consider how fishers’ perceptions, assumptions, and values about access and rights will align or conflict with any implemented regulations, thus creating implications for how new access or property regimes are theorized and enforced. As Beitl (2012) suggests, when designing and implementing conservation and management strategies for governing the commons, the importance lies in understanding the access and property systems, including the emerging relations produced by these systems, from all likely perspectives.

In regards to the quest for MSC certification, the Bahamian spiny lobster fishery will become poised to gain access to the benefits of being labeled as a “sustainable” fishery. Yet, the question remains as to who will gain that access, and serve as the beneficiary from any other additional profits brought on by the certification. Foley (2012) examines the MSC certification process of a shrimp fishery in the Province of Newfoundland and Labrador, and how acquiring the
certificate becomes a strategic move in terms of resource access. The paper argues that MSC certification allows those holding the certificates, “the fishery client”, to control access to the fishery resource and control the production relations. A fishery client can be an “individual, organization or group of organizations” who have “some influence over the management of the fishery, or the ability to be able to implement any conditions raised by the certification body” (MSC 2010).

Similar to the Newfoundland and Labrador shrimp fishery mentioned above, if the Bahamian spiny lobster fishery earns an MSC certificate, it will not go to the fishers, but rather to the group of exporters viewed as “the fishery client”, the BMEA. With the certification, the BMEA will hold more ability to exercise direct and indirect control over the fishery and how the relations created within the fishery, with regards to access and property rights, are affected. The BMEA already has a great impact on the fishery as they not only set the price of lobster, which is used by the buyers on the islands to purchase the product, but they also determine the optimal size of lobster harvested, showing a preference for tails that are 5-6 inches in length, the size that looks best on a typical dinner plate served at restaurants (Personal communication). Additionally, when the decision to attempt MSC certification was made, the BMEA, recognizing some of the unsustainable practices in the fishery, worked with DMR to institute the requirement that all catches were documented and to create a standardized catch certificate (BMEA, personal communication; Gittens, personal communication). The BMEA also instructed all buyers to refuse to purchase
undersized individuals (Former Buyer, personal communication; BMEA, personal communication). Due to this unofficial change in policy, the fishers, by their own accounts, became much more cognizant of confirming the sizes of harvested individuals before removing them from the water. Many of them stated it was no longer worth the effort to obtain undersized lobster if they weren't going to get paid for them (Personal communication). It has been anecdotally noted that since this edict was made by the BMEA, there has been a clear decrease in undersized numbers (Personal communication).

As progress continues towards the certification, the BMEA may have further influence over any additional regulations that may be necessary to deem the fishery sustainable. One such possibility is the need for traceability in the supply chain, with the ability to track the individual lobsters back to their harvesting source. This would include the boat the lobster was purchased from, and potentially the location where the lobster was caught. With all the secrecy surrounding the location and quantity of condos on the banks, it may be necessary to create regulations that can transfer more private property rights to condos and possibly also limit their numbers. While only a small percentage of the fishers interviewed had any interest in licensing their condos in a manner similar to what is currently done with traps, a nod of support from the BMEA on this issue may shift that percentage upwards, especially if there are clear benefits, financial or other, for adhering to such a policy.

The ability to control access, either to a valuable resource, or in this case, to utilizing a valuable eco-label to reach more viable markets, provides the owner
with a distinct advantage and influence over the relationships that are developed and/or changed as the decisions are made, especially considering this same owner might lack property rights. This further underscores the importance in being able to make the distinction between the right to benefit (property) vs. the ability to benefit (access), as it could be argued that one might have an advantage over the other. And while it is still unclear how certification affects power relations in the various fishing communities that have received MSC certificates, there is no doubt that a PE framework holds the key in gaining a better understanding of all the relationships at play.

When examining property, the main concern is to understand the claims that are made, especially those claims that lead to a definition of rights and the resulting conflicts stemming from those definitions. Conversely, an analysis of access helps to understand the different ways people can derive benefits from resources, while also exploring why some people or institutions benefit from resources, whether or not they possess rights to them. Placing access within a PE framework allows for creating a model of social change, where social differences and relations can emerge from the sharing and/or conflict over resource benefits (Ribot and Peluso 2003). New policies created by the Bahamian government in order to address these issues of access and conflict, especially those with a direct focus on condo use, need to not only consider the overall political ecology of the spiny lobster fishery, but also need to make a clear distinction between access and property.
Environmental Identity and Social Movements

The theme of environmental identity and social movements highlights how environmental issues, such as excessive resource exploitation, particularly when coupled social struggles, can drive communities to work together in order to create positive changes. In the face of limited fisheries enforcement throughout The Bahamas, fishers in many of the local settlements have come together to form *de facto* rights in an attempt to help preserve and sustain the fishery. Government centered management systems for fisheries are typically difficult to enforce and expensive, especially when fishers believe the managers don’t understand the resource or sympathize with their perspectives (Townsend 1995). Furthermore, compliance of regulations depends on the perceptions of how and why rules were created (Baland *et al.* 2006). Often times these issues with governmental institutional arrangements are combated with *de facto* property regimes created, enforced, and respected by local users.

Within The Bahamas, there is a common sentiment among the spiny lobster fishers that the decision-makers don’t truly understand the nature of lobster and the ecosystem, and that they simply don’t know what the fishers know form all their years of experience (Personal communication). Coupled with inadequate levels of enforcement, many of the islands and/or settlements have created their own institutional arrangements specific to the needs of their community. Many times, these arrangements take the form of enforcing patterns of behavior, rather than a focus on conservation (McGoodwin 1990), and include voluntary agreements between the fishers and the utilization of social pressure to
help enforce rules. For example, Andros fishers claim they don’t fish from
condos within their nearshore environments. Because it is a small community,
they often know who the condos belong to and who has taken from condos that
don’t belong to them. Fishers in these communities use social pressure in the
form of shunning to keep people from taking what is perceived to be their
property within their local environments. However, the same consideration is not
given to condos by fishers from outside the communities, especially if the Andros
fishers feel like their local waters are being invaded by outsiders. Spanish Wells
fishers mentioned creating a sense of private property for their condos by
creating symbols specific to their collective and using those symbols as a form of
identification to mark the condos as theirs. They believe the symbols should
serve as a warning the condos belong to someone and that they should be left
alone. Most of the other fishers attempt to create a sense of property rights by
using information management in the form of secrecy (where they place their
condos, the quantity, etc.) to help gain control over their resource.

Although there are currently no formal regulations in place for the use of
condos, self-regulating behavior is seen throughout the fishery, as there are
several unwritten rules that many fishers adhere to (Personal communication).
These include not removing someone else’s condos, not fishing from other
condos if you haven’t put out any of your own, and if harvesting from condos,
leaving some lobster behind or returning the structure to its correct position
(Personal communication). The cooperation that occurs among local users is
imperative to the success of these types of institutional arrangements and is
necessary for successful management of the fishery when strict external enforcement is absent. However, these arrangements may break down when outsiders, who are not subject to the local norms necessary for regulating behavior, begin to utilize local areas and create additional pressure on the fishery resources that locals perceive to be theirs (Berkes et al. 1991), such as fishing areas within a few miles of the settlements. Sometimes these outsiders come from other islands within The Bahamas. While these different communities might have similar institutional arrangements, the idea of others encroaching on what is believed to be inherently “ours” leads to conflicts and changes in behavior and conduct. These become exacerbated when it seems that the outsiders have a competitive advantage due to additional structural mechanisms of access, such as capital, technology, or larger markets. For example, fishers from Spanish Wells tend to have larger boats and higher numbers of condos and traps, as compared to some of the other small-scale fishers from other islands. As such, when Spanish Wells’ boats are seen near the traditional fishing grounds of other islands, the small-scale fishers feel that in order for them to stay competitive they must go against the agreed upon arrangements to take what they can while also attempting to hinder the others from getting the local community’s “share”. (Personal communication) Outsiders also include fishers from other countries, most commonly the Dominican Republic, who enter The Bahamas to take advantage of its highly productive waters. As they have no stake in any of the institutional arrangements in place, they also have no incentive to conserve the species or maintain a sustainable fishery. They ignore government instituted
regulations (Smith 2011), taking undersized lobsters and individuals bearing eggs, and have no understanding of, nor care for, local norms. In this case, local fishers feel that if the poachers are going to take everything anyway, then they, too, should disregard the rules to take what they can get (Personal communication).

There are also other situations where these informal voluntary agreements are challenged by those fishers who choose to follow a “holdout strategy” (Ostrom and Ostrom 1977), going against the local arrangements formed. If the majority of fishers follow these “rules”, this leaves an increased supply for those few who refuse to do the same. This leads some of the lobster fishers to choose to go against these agreements in an attempt to prevent others from harvesting more than them or harvesting anything at all (Personal communication). This highlights a major concern with voluntary agreements; when any user is able to terminate the agreements without consequence, then most users will be unwilling to enter into such agreements in the first place. Without adequate regulations in place, there is an incentive to ignore the social impacts of their personal behavior, despite attempts to self-regulate and create institutional arrangements for the betterment of the ecosystem and the fishery.

Managers of the Bahamian spiny lobster fishery should look toward enhancing rights-based management that empowers fishers to take on more ownership and greater responsibility, not only for decision making within the fishery, but also for the implementation and enforcement of the rules and regulations. These instances of self-regulatory behavior among the fishers help
form communal rights systems (Ostrom 1993; Berkes 1987). Additionally, managers of the fishery also need to ensure there is a balance between *de jure* and *de facto* property systems. When *de jure* systems fail to garner the support of locals, especially in those areas where self-organized collective-choice management occurs, *de facto* regimes can help to provide a legitimacy for self-imposed rules and regulations (Cordell 1972; McGuire and Langworth 1991). Moreover, many *de facto* arrangements have allowed fishers to reduce inefficient use by removing the incentive to overinvest in the fishery. Since regulation of these regimes is undertaken by local fishers who also benefit from the regime, the costs of monitoring and exclusion from the resource is internalized among the beneficiaries (Berkes 1989). As such, coupling *de facto* regimes with *de jure* ones can help to mitigate conflicts that might arise when either type is attempted alone, while also supporting fishers in implementing collective actions.

*Globalization*

In many cases, the demand for and value of resources are not defined locally, but instead by the global market; the Bahamian spiny lobster fishery is no exception to this. The prices lobster fishers earn per pound are set by exporters, who ultimately base this price on what they can fetch on the global market (BMEA, personal communication). In one such instance, the prices for spiny lobster harvested in West Africa were $5-6 per lb, much lower than the price sold by Bahamian exporters. As the Bahamian prices could not compete, this resulted in the exporters lowering the price at which they bought from buyers, who then subsequently lowered the price at which they bought from the local
fishers. (Former Buyer on Andros, personal communication) Situations like this cause local fishers, particularly those who choose to sell their catch to buyers/exporters, to be dependent on a system in which they have little say and even less power, often placing the fishers in marginalized positions, linking back to the theme of Marginalization and Degradation.

The quest for MSC certification for the Bahamian spiny lobster fishery can also be seen in this context, as earning the certification would provide access to US and European markets that will only recognize and purchase “sustainable” products from fisheries with the certification. Through the assessment process, the MSC has allowed certified fisheries to emerge from their traditional markets and enter into markets where there is less competition, a price premium on their labeled products, and potentially new consumers. This was seen in the Kyoto Danish Seine Fishery Federation, a small fishery that received immediate benefits from its MSC certification by being able to break away from markets dominated by larger fisheries and essentially dominating its own, new market as the products were now viewed to be “different” (Wakamatsu 2014; Loureiro and Hine 2002). This would be especially profitable for the Bahamian spiny lobster fishery, as The Bahamas would be one of 5 “certified sustainable” spiny lobster fisheries globally, and the second in the Caribbean (Figure 1.5), ensuring the broadest possible market for export, and potentially higher value for the product.

However, as was mentioned previously, if the MSC certificate is earned, it will not go to the fishers, but to BMEA, viewed as “the fishery client”. And with the certification comes additional control over the fishery. This has already been
seen with some of the changes instituted on certain aspects of the fishery when the fishery entered the certification process back in 2010. Although all Bahamian fishers will be impacted by any additional new rules and regulations put into place to obtain, and subsequently maintain, the certification, it remains to be seen how the market benefits will trickle down to the small-scale fishers and their communities, most of whom had never heard about the MSC or knew that the fishery was undergoing the certification process until these interviews (Personal communication). Contrast this with the Spanish Wells fishers, most of whom were not only aware of the MSC certification (Personal communication), but have also been very involved in the FIP process (Burrows, personal communication). Joseph Ierna, president of the Ocean Crest Alliance, believes the certification will bring increased profits, but cautions that in order for that to happen “the fishers need to be included in the process so they have buy-in, especially if the process of certification leads to changes in the regulations” (Personal communication). Excluding the fishers from this process will only result in increased marginalization, particularly amongst those small-scale fishers who already feel they are disadvantaged due to their local social and economic circumstances. Situations like this will only place them more at the mercy of global system that they already have little say in.

**Conclusion**

The tragedy of the commons model appears as though it could be utilized as an explanation for the declines seen throughout the Caribbean spiny lobster fisheries in the last decade. The model assumes that a resource is common
property and equally open to all users. Additionally, it assumes that all the users are selfish and focused on maximizing short-term benefits with disregard to the long-term effects on the resource and the community (Berkes 1987). While the self-fulfilling prophesy of the tragedy is in no one’s best interest, the underlying implication of the theory is that the tragedy is inevitable unless there is outside intervention, as it is believed users will not change their behavior on their own. However, the assumptions made by the “tragedy” model don’t necessarily account for all the historical, social, environmental, and political factors (many of the pieces relevant within a political ecology analysis), that might play a role in decisions made by local resource users. This is especially the case when Bahamian fishers feel their local stocks are threatened by outside forces, whether in the form of fishers from other settlements or islands, poachers from other countries, or decision makers, whether they be fisheries managers, NGOs, or exporters. These perceptions of threats lead the fishers to exhibit behaviors such as overharvesting, poaching, and ignoring fisheries regulations. This is pervasive when the access to resources seem to be unbalanced and certain fishers appear to have an advantage because of the island they hail from, their race, or their uneven access to resources.

When communities have users with different identities, cultures, histories, or relations to the resource, it can lead to the creation of an “us vs them” mentality. This can undermine the building of trust, which is necessary for developing, and ensuring that people are following management and conservation rules (Baland et al. 2006). The more differences that exist, the
more likely users will want to oppose imposed regulations, especially those they view as more beneficial to others outside of their group. This heterogeneity can also lead to spatial conflicts, due to competition between the different users, as well as when people attempt to “protect” the resource areas by excluding or restricting use (Bess and Rallapudi 2007). Resolving these conflicts would involve redefining rights in such a way that equal access is provided to all. However, while some fishers might support the revising of rights, it is very likely that many would resist because of the fear that a perceived “birthright” has been challenged. This would be especially true in communities, like the local settlements throughout The Bahamas, with long-held social, cultural, and historical relations to the resource.

There is no doubt that the institution of open access lies at the heart of the tragedy model and overexploitation in fisheries. While this is not necessarily the case for most fisheries, including the Bahamian spiny lobster fishery, the historical perception of the tragedy still lingers, largely due in part to contemporary conditions of worldwide fisheries decline. As such, the tragedy model continues to underscore how management decisions are made.

Historically, the obvious, most proposed solution involved instituting private property rights, with the hope that people develop the incentives to protect the resource rather than exhaust it (Hardin 1968); however, this solution presents many issues in a marine environment, especially when rights are not explicitly defined, rules are not enforced, and the fishers are not given concurrent responsibility for management. These issues also tend to intensify particularly
when the fishers believe managers don’t understand or sympathize with their perspectives (Townsend 1995), or, as revealed in the interviews, they don’t believe managers fully understand the ecology of the lobster, nor the interactions that occur between the fishers and the environment or even between the fishers themselves.

There is no guarantee that the implementation of only private property rights will lead to sustainable use (Bess and Harte 2000), especially when rights aren’t understood, regulations aren’t enforced, rules are ignored, and the people impacted have no say. In some cases government imposed rules take the place of local institutional arrangements originally devised to help limit resource use. When these *de facto* common property regimes enforced and respected by local users are converted to *de jure* property regimes that are not enforced well, they can revert back to *de facto* regimes, but this time, of an open access nature, leading to less effective and less efficient control of the resource than originally intended. When resources previously controlled by local users fall under government management, whether through nationalization, state control, or NGO intervention, it can sometimes lead to harmful effects (Ostrom 2000). This has been well documented in some fisheries (Cordell and McKean 1992; Cruz 1986; Dasgupta 1982; Higgs 1996; Panayotou 1982; Pinkerton 1989). For this to work, the property rights regime must incorporate an incentive structure that balances the rights of fishers to harvest the stocks, while encouraging their duty to help maintain the stocks’ productivity and to support the social structures that will allow this to happen (Sandberg 1996). This can be achieved by empowering the
fishers to help determine the markets and products, and define, as well as enforce, rules and regulations within their communities.

Understanding the role of property rights continues to be one of the greatest causes for concern in sustainably managing fisheries (Mace 1996). The creation of effective property rights systems is difficult, no matter what type of regime is place. Additionally, no one regime will work the same in all settings (Ostrom 2000), especially as the type of regime in place does not necessarily reflect the bundles of rights held by individuals or communities. Bundles of property rights, whether de facto/de jure or based on the type of property rights holder, can influence the actions of individuals and the incentives they face (Schlager and Ostrom 1992). For instance, users who hold alienation and exclusion rights to a fishery, have an incentive to commit to long-term investments, whereas, for those with only access and withdrawal rights, it would be in their best interest to take as much as they can in the short-term, as they don't know when those rights might change. The latter strategy is evident within the Bahamian spiny lobster fishery through the increased quantity of condos throughout the banks coupled with the rapid rise in conflicts amongst the spiny lobster fishers.

Comanagement agreements are one set of solutions that have grown out of claims that government management alone is insufficient to handle most fishery issues (Pinkerton 1989). Jentoft et al. (1998) define comanagement agreements as collaborative and participatory processes of decision making among representatives from government agencies, research institutions, and
Comanagement allows for the involved parties to work together to determine effective resolutions to resource conflicts. This works because the relationships between the actors in the fishery are altered in such a way that the pay-offs are greater when cooperation and long-term planning, rather than opposition, competition and/or short-sighted behaviors, occur (Axelrod 1984). Instituting property rights under these conditions can make them more effective in sustaining fishery stocks as the rights will reflect the joint interests of a community of users instead of individuals (Ostrom 1977; McCay and Acheson 1987). The shared decision making allows for the maximization of benefits for all involved. Proponents of this strategy believe it has the potential to help promote conservation and enhancement of fish stocks; reduce the need for excessive investments by fishermen due to the competitive strategy to outcompete; promote community economic development; make allocation of fishing opportunities more equitable; and to reduce conflict between the government and fishers, as well as conflict among fisher groups (Bess and Hart 2000; Pinkerton 1989). The most effective comanagement arrangements will involve shared management that makes the best balance of government and user control and input that varies with each fishery (Mace 1996).

The amalgamation of the various issues impacting the fishery can lead to devastating consequences for both the fishery and the spiny lobster population if not checked. In order to address many of the issues prevalent in the fishery, the historical, political, and socio-cultural dimensions of the community must be examined alongside the biological, ecological, and economical dimensions of the
fishery. As such, factors that are both internal and external to the local communities of Bahamian fishers must be considered when analyzing the state of the spiny lobster fishery and ways to maintain and successfully manage it. Utilizing a political ecology framework that will allow for an examination of each of these factors in relation to one other can aid in determining strategies that could be beneficial for all parties involved.

With the differing perceptions and interpretations occurring across the islands and settlements, coupled with the various objectives of the many stakeholders within the fishery, there is definitely a greater need for cooperation, both among the islands and between all the stakeholders. This chapter highlights that gaining a better understanding of how the fishers perceive the fishery and their role within it, will be imperative to those seeking to make effective changes to ensure its sustainability. To assist with this, the next chapter goes a step further to provide recommendations for the fishery based on the assessments made here and in the prior chapters.
Chapter 5: Policy Implications of an Interdisciplinary Approach to Guiding Spiny Lobster Fisheries Management

The Bahamian spiny lobster fishery provides a timely opportunity to examine cross-cutting human and ecological factors. The pervasive use of condos creates a unique ecological and property rights context, and the current quest to certify the fishery as sustainable generates many questions about equitable and efficient management. Thus this dissertation represents a first order attempt to integrate data on the ecological, social and political aspects of the fishery, and in this final chapter, to provide prescriptive policy and future research recommendations.

The coupling of biophysical modeling with bioeconomics and political ecology within the context of condo use provides a deeper understanding of the factors impacting the fishery. This integrated understanding of the fishery, including the lobster, its habitats, and the associated community and economy, that can serve to better inform management decisions. It can also provide a guide towards creating a fishery that is managed responsibly (Sissenwine and Mace 2003) by accounting for the changes being made to the environment through the use of the condos; assessing the benefits of the fishery and how they are distributed among the various stakeholders; and ultimately, determining the fishery’s sustainability.

The analyses described in this dissertation have uncovered the complexities that exist in trying to manage a dynamic fishery, where the species and habitats are constantly changing due to biology and human interaction, and
relations among the stakeholders are also shifting as a result. Chapter 1 provides an overview of the fishery and of the current factors at play, including the perceptions of fishers and other stakeholders. It highlights that spiny lobster landings and profits have increased steadily in the fishery over the past decade. Yet, the impacts of condo use on fisheries has remained largely unknown, due to the lack of studies conducted on their increased use and on their overall ecological impact. Much of the information known about condos and how they have been used since their implementation has been anecdotal and, to date, has not been quantified. Their continued use creates concerns about the ability to sustain the Bahamian spiny lobster population and the fishery it supports. This uncertainty is problematic with regard to the process of obtaining the MSC sustainability certification, which requires a stable population, ecologically sound fishing practices, and a level of traceability for each lobster collected that is not currently possible due to the manner in which condos are used.

Chapter 2 uses the data obtained from the surveys and interviews of Bahamian fishers to help develop a better sense of how they are using the habitats spatially, by considering their preferences for condo locations and coupling that information with an evaluation of the demographic connectivity. The chapter demonstrates the links that can be created between various methodologies, such as modeling and social science, as a strategy towards successful management. Based on the connectivity model, spiny lobster individuals from habitats in The Bahamas produce high percentages of successful larvae that tend to settle locally. This suggests the need for better
protection for those areas deemed to be optimal for self-recruitment, particularly against the high levels of harvest typically associated with condo use. Outputs from the model also suggest The Bahamas contains habitats that act as important sinks for both local and Caribbean-wide populations and serve as vital sites for maintaining the connections between the metapopulations across the Caribbean network. Securing these connections will only be possible if managers understand how the fishers are impacting the habitats locally through the placement of their condos, while also determining the levels of collaboration necessary across the Caribbean to keep the ecological network responsible for supporting the fishery intact.

In Chapter 3, a bioeconomic analysis, based on condo effort, was conducted. The analysis revealed excess effort in the fishery, likely a consequence of increased condo use, and that the fishery is operating beyond open access levels. Managing the fishery towards its maximum sustainable yield would double the profits, but require the effort to decrease by about 17.5%. Operating the fishery at its maximum economic yield would result in 9 times the profits currently achieved, but the harvests and efforts would need to be reduced by more than two-thirds and by half, respectively. Survey responses indicate that while fishers would like to see more regulations in regards to condo use, they are not necessarily interested in removing the condos already set. This may present some challenges to reducing the effort enough to achieve optimal yield goals, and further underscores the importance for gaining fisher perspectives before implementing policies. Although this analysis can provide a good first step for
making management decisions, the actual quantities of condos in use, an important parameter within the model, remains a large uncertainty. This is a present issue within the fishery that needs to be addressed before further policies are enacted.

Chapter 4 addresses the political ecology of the fishery, taking into account how the actions and perceptions of the fishers and other stakeholders help to shape the ecological, social, and economic factors impacting the fishery. For many of the fishers, participation in the spiny lobster fishery has been passed down through multiple generations. Most acknowledge that fishing is their primary source of income, and for some, particularly those from the poorer settlements and islands, their only source. Fishing from condos allows them to harvest more lobster sooner, improving the profits they can earn over the course of a season. However, by using condos, the fishers have a direct impact on the ecosystem by essentially creating spiny lobster habitat where there was none before. This modification of the landscape has resulted in changes in the fishery, particularly in how the fishers interact with each other, as seen in the rise of conflicts reported anecdotally by the fishers and the managers. The political ecology analysis suggests that much of this conflict is a consequence of the fishers attempting to differentiate between access (the ability to benefit) and property (the right to benefit), in regards to condo use. The lack of distinct property rights and regulations associated with condos leaves much up to interpretation for the fishers. Additionally, access to the fishery appears to be
unbalanced, with certain fishers having advantages based on their race, island, and/or wealth.

As the fishery is an important industry within The Bahamas, the question remains as to who truly benefits from its success and how. Many fishers believe these benefits are distributed unevenly. The black fishers believe that white fishers, particularly those from Spanish Wells, are given more “breaks”, allowing them to escape fines and other penalties; the white fishers have the same sentiment about the black fishers, citing close family ties between the fishers and enforcement officers. Additionally, wealthier fishers have the resources to fish the “best” areas, and often tend to encroach on the habitats traditionally fished by those with fewer resources. Furthermore, fishers also believe the prices they earn for their landings often don’t reflect the market value, with the buyers, processors, and exporters earning most of the profits. Due to perceived marginalization, some fishers are willing to harvest undersized or molting individuals in order to get their share, even at the potential degradation of the fishery. This creates a sense of the “tragedy of the commons” and potentially threatens attempts at sustainability.

Achieving MSC certification will create greater benefits by allowing the fishery to enter additional markets and develop a price premium for its “sustainable product”. Yet, it is uncertain how the new benefits from the certification will trickle down to the fishers. This is especially a concern since the certificate will be awarded to the Bahamas Marine Exporters Association, who will gain additional opportunities at controlling access (in terms of the ability to
benefit) to the fishery. It is also troubling that the interviews revealed many of the fishers were not aware of the certification process. As such, they remain outsiders in a process that has the potential to significantly impact their livelihoods, and lack the knowledge necessary to demand that distribution of benefits be fair and equal.

**Recommendations**

1. *Allow fishers to become more involved in the decision making processes.*

   Many fishers are dependent on the fishery, and have high stakes in the changes that are implemented. They also possess local ecological knowledge, particularly on the changes they have witnessed in the fishery since the implementation of condos. Including them in conversations about the MSC certification process would help create a sense of awareness for the impending changes to the fishery and the rationale for why these changes might be necessary. It would also allow the fishers to contribute to the determination of the best strategies for management, potentially increasing compliance for new policies in the face of limited enforcement.

2. *Acquire better estimates of effort.*

   The number of fishers and vessels operating within the fishery are uncertain. Similarly, the exact quantity of condos across the banks is largely unknown, with estimates ranging from a couple hundred thousand to a couple million. As long as these gaps in knowledge exist, determining the optimal strategies for maintaining the sustainability of the fishery will
be problematic because they will be based on many unknown factors. Strategies for obtaining a better understanding of effort might include requiring registration of all lobster fishing vessels (regardless of size), requiring lobster fishing licenses, or permitting condos through a mechanism similar to the one in place for lobster traps. Determining the number of condos may also be possible with high resolution satellite images of the Bahama Banks or the utilization of other observer systems.

3. **Manage the fishery towards MSY or MEY harvest and effort levels.**

The fishery is currently operating beyond open access levels. Scaling the harvest and effort levels down will result in higher profits for the fishery overall, while also protecting the stock. Managers must determine which level, MSY or MEY, is most practical given the current state of the fishery and willingness of the fishers to comply with the tougher regulations necessary to achieve those levels. The bioeconomic analysis would also need to be redone once effort estimates are improved.

4. **Assess the role of condos on larval recruitment.**

While adult lobsters are generally found on the reefs, larvae typically recruit to seagrass areas where their source of algal food can be found. Fishers tend to place their condos somewhere in between these two habitats where it is believed that juveniles on their way out to the reef find refuge. Because fishers typically “prime” their condos in seagrass areas a few months prior to setting them in a permanent spot (allowing the structures to become overgrown with seagrass and algae for camouflage
purposes), the condos may give off the same chemical cues that attract the larvae. If this is the case, it could result in some unintended consequences on larval recruitment.

5. **Incorporate Spatial Management with Local Considerations**

Responses from the surveys and interviews, coupled with the results of the connectivity analyses suggest that key spiny lobster habitats and fishing areas should be assessed individually. Once key areas have been identified, they should be examined on a case by case basis, with managers taking into account the possible management strategies, along with the varying degrees of connectivity, the popularity of the area with fishers, and proximity to traditional fishing habitats of the settlements. This type of assessment would allow for the selection of the most reasonable set of management strategies for a particular area, given that area’s unique ecological and social characteristics. However, this approach could potentially result in multiple strategies, which would require additional considerations for how to best manage and enforce policies across the Bahama Banks.

6. **Implement Marine Protected Areas with specific focus on spiny lobster protection.**

Domestic connectivity, or self-recruitment, is high within The Bahamas, suggesting spiny lobster harvested there are spawned there as well. Several of the areas identified as popular condo locations are also important nurseries for the local population, as they produce high
percentages of successful recruiters. Protecting these spawning sites would benefit the population and allow for other habitats within The Bahamas to receive larval subsidies from these areas.

7. **Create a network of protected sites that include important habitats from throughout the Caribbean that link to those in The Bahamas.**

Despite the high levels of self-recruitment, spiny lobster habitats in The Bahamas also have strong connections with others throughout the Caribbean, with some Bahamian sites acting as sinks that recruit individuals from elsewhere and others serving as important sites for maintaining connectivity throughout the entire metapopulations network. The creation of an MPA network at this scale would help to strengthen the population as whole, while also ensuring that the Bahamian population is supplemented by external subsidies. Additionally, it would further strengthen the international initiatives already underway and encourage the continued sharing of research and management strategies to protect the population as whole.

8. **Implement rights-based strategies that give fishers a sense of ownership.**

One of the largest issues within the fishery is a lack of property rights in regards to condo structures. Unlike traps, condos are not permitted and the “owners” are unidentified (unless they are present), making the claims that condos “belong to no one” valid, at least in the eyes of many of the fishes. Requiring permits for condos, as mentioned above, may help to rectify this. Another option is the implementation of TURFs. This
would be beneficial particularly for those fishers who tend to fish for lobster just offshore their settlements, either due to limited resources or a preference to continue diving the reefs. A TURF system would allow these fishers to have ownership of the nearshore habitats. With additional bundles of rights, fishers could possess rights of transferability, as well as exclusion, allowing them to prevent large-scale fishers from other islands from harvesting in these areas. It would also allow for the incorporation of community-based management strategies that give the fishers a greater responsibility for enforcement, while also creating a better balance between *de facto* and *de jure* regulations.

9. **Determine how best to legally classify condos.**

Condos are not considered traps; and while they are technically artificial reefs, they are not treated as such. Both traps and artificial reefs have specific regulations in place that detail how they can be used, where they can be placed, what materials can be used to construct them, how they are designed, and who owns them. The fishers expressed many conflicting views about condo ownership, particularly around who owns the condo verses who owns the lobsters found beneath them. The design of the condos also seems to complicate matters because the structures do not fully enclose or trap the lobsters, resulting in varying interpretations on what this may mean regarding who can harvest the individuals, and how to resolve conflicts over whose interpretation is correct. Clear policies are
needed to stem the rising conflicts, as well as manage the numbers of condos.

**Policy Implications**

Assessing the Bahamian spiny lobster fishery from an interdisciplinary perspective has highlighted the importance of examining the ecological and economic dimensions of the fishery alongside its historical, political, and social dimensions. An evaluation of each, including how they interact, is necessary for determining the best management strategies for the fishery that will lead to sustainability. For too long, these concepts and their related dynamics have been overlooked; utilizing an interdisciplinary framework seeks to rectify this.

This research showcases the many factors at play within the fishery, including the actions and attitudes of fishers and other stakeholders; the many possible options for regulations; and the environmental factors impacting the species and its habitats. Figure 5.1 provides a summary of these factors and how they overlap, with the aim of aiding in providing informed management decisions. Each factor must be considered before adequate management can be put into place. With such a variety of factors, however, there is also the potential for multiple permutations of management. Thus, the viable options within the fishery must be discerned, as well as the best ways forward for implementation.

For the case of the Bahamian Spiny Lobster fishery, managers must consider the health of the lobster stock; connectivity of the population; impacts from the condos; interactions between the fishers; perceptions of property rights,
management, and enforcement; implications of wealth, race, and other social factors; economic and political motivations; the local and global market; historical uses; fulfillment of sustainability goals, particularly related to gaining and maintaining the MSC certification; and more. With such a wide range of elements to keep in mind, providing recommendations for this fishery can become quite a complex task.

For example, take the Tongue of the Ocean (TOTO). Data from the surveys and interviews indicate this a popular location for fishing for lobster, particularly with condos. Fishers have also stated that this area has historically been a good source for lobster. The connectivity analysis indicated TOTO has high levels of self-recruitment, and although it is not well connected to other populations throughout the Caribbean, it has the potential to export high percentages of successful larval settlers to other habitats within The Bahamas. This highlights the area’s importance as a nursery for the Bahamian fishery. The bioeconomic analysis indicates that since the fishery is operating beyond Open Access levels, harvest and effort should be reduced to help manage the fishery towards its maximum sustainable or economic yield. With these conclusions in mind, two potential options for this fishery can be examined: 1) limit the numbers of condos placed in the area or 2) close it to fishing.

For option 1, the first priority would be to determine the quantity of condos and the number of fishers collecting from each condo. As mentioned above, this information would be difficult to ascertain due to the clandestine way the fishers deploy and utilize condos. Managers can search for the condos, but this would
require additional resources that may make this process inefficient and expensive. If they were to locate all the condos, they could estimate the number of lobster that can be collected from each over the course of the season and keep track of these numbers. However, in order to do so, the fishers who collect from each of the structures would need to be identified and also limited. While this may help with the traceability of the harvest (one of the requirements of the MSC certification), it would also result in the exclusion of the fishers who built and set those condos, or who have used the condos or area over time. Also, determining who gets excluded may be contentious. Fishers from Andros, Spanish Wells, and Long Island primarily utilize this area. Fishers from the latter two islands, especially those running large commercial operations, may argue that they have heavily invested in harvesting in this area and losing access is unfair, particularly if they have also constructed the majority of the condos found here and others can continue to collect from them. Issues like this might provide the opportunity to also incorporate the assignment of property rights to the condos, if the owners can be identified. Fishers from South Andros, may also argue that they should not be excluded as they live closest to the area and have regularly fished there. As they are small-scale fishers, losing access to a prime fishing area that they can travel to easily, or limiting how much they can harvest, may severely impact their ability to make a living. Similar arguments can also be made for option 2. Further considerations for this option must also include how to best enforce the closure of this popular area, when enforcement has been a primary issue within this fishery.
The options presented above do not address all the types of lobster fishing occurring here, like recreational or poaching, but do help illustrate how complicated the management process might be and why multiple methodologies must be included to help determine the best solution. While it shows there are many ways to incorporate recommendations, the decisions made about what and how to implement the changes must be based on the available science and tools. Because condo use need to be more fully explored, we cannot yet claim a full understanding of their impacts on the stock, and this means any assessments of the fishery continue to be provisional. The use of additional techniques, such as modeling and a political ecology analysis, can assist in filling some of the gaps in knowledge, such as how the condos are being used, where they are being placed, the costs associated with their use, and the types of interactions that occur among the fishers due to their use. As tools like connectivity modeling continue to improve and analyses like bioeconomics are strengthened with more accurate data, the decisions on what recommendations to focus on will become more informed.

The spatial aspects of condo usage also presents additional complications. Often, management responses are based on the spatial scales of ecological and/or biological processes, even when such an approach is not practical. And even when spatial considerations are explicitly incorporated, as was the case for the connectivity analysis here, the existence of wider scales (like those crossing political boundaries) may hinder the ability to fully execute any recommended policies to ensure optimal management. The nature of the
spiny lobster populations also adds another layer of complexity. When management plans are implemented for species that disperse, or are part of metapopulations, additional considerations need to be included, like the spawning and settlement locations, and assessed against the decisions and actions of the fishers. Effectively implementing management strategies also requires buy-in from the fishers and other stakeholders within the fishery. Advancing the design and implementation of new management strategies will require scientists and managers to work together alongside the fishers, buyers, processors, and exporters in long-term collaborative efforts that stress the importance of input from all parties. Additionally, understanding how local communities will benefit from intended management actions, and communicating those benefits, is key to obtaining support and ensuring compliance. Only through the incorporation of social and economic factors within the biological and ecological research of a fishery will it be possible to dictate which strategies are the most practical, while creating and maintaining adequate benefits for all users.
Figure 5.1 Factors within the fishery that might impact management decisions.

**ACTORS**
- Fishers
  - Commercial, small scale
  - Commercial, large scale
  - Recreational, Bahamian
  - Recreational, Americans
  - Poachers
- Buyers and Exporters
- Fisheries Managers and Officers
- NGOs
- Consumers

**REGULATIONS**
- Limits on
  - # of condos
  - # of vessels
- Licenses
  - Vessels
  - Fishing
- Lobster Quotas
- Adjust seasons
- TURFs
- Property Bundles
- Cooperative or Community Based Management

**ENVIRONMENT**
- Lobster stocks/population dynamics
- Connectivity
- Habitat/landscape characteristics
- Species life history

**Informed Management Decisions**
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APPENDIX A

LOBSTER CONDO USE SOCIOECONOMIC SURVEY INSTRUMENT
I. Background Information

A. General

1. How many people live in your household (not yourself)?

B. General - Indemnity

1. How many dependents in your household?

C. General - Financial

1. Do you have a computer at home? Yes/No
2. Do you have access to a computer and the Internet somewhere other than home? Yes/No
3. Do you have a smartphone or mobile phone? Yes/No
4. Do you have a smartphone or mobile phone and Internet access? Yes/No
5. Do you have a computer or internet access at work? Yes/No
6. Do you have a computer or internet access at school? Yes/No
7. Do you have a computer or internet access at the library? Yes/No
8. Do you have a computer or internet access other? Yes/No
9. If yes, please describe:

II. Demographics

A. General

Date of validation:

Who validated:

Date:

Location: Bahamas

Loter Condo Life Socioeconomic Survey Instrument
APPENDIX B

TOP 100 HABITATS FOR EACH CONNECTIVITY FACTOR, CARIBBEAN WIDE
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PEC=k(1-\(\frac{qe}{r}\))

STR=p\(^*\)SY(E)

TC=c\(\cdot\)e

\(\pi=STR-TC\)

Average Revenue of Effort = \(\frac{ARe=STR}{e}\)

Marginal Revenue of Effort = \(\frac{MRe=dSTR}{dE}=p\cdot qk(1-(2qe/...r))\)

Average Cost of Effort = \(\frac{ACe=TC}{e}=c\)

Marginal Cost of Effort = \(\frac{MCe=dTC}{dE}=c\)
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