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Biological and Economic Tradeoffs of Marine Protected Areas, Larval Aquaculture Systems, and Aquaculture Systems in the Bahamas

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ABSTRACT

The continued growth of the human population is causing an ever-increasing need for food. As one of the primary sources of food, ocean fisheries are being exploited at rates that are unsustainable. Since overfishing has become such an issue, there is a need for sustainable solutions to keep critical fish populations thriving, while still being able to provide for market demand. Three possible resolutions include aquaculture, larval aquaculture, and marine protected areas (MPAs). The biological and economic tradeoffs of each possibility were considered in the Bahamas, a set of islands in the Caribbean, which are experiencing a significant amount of fishery exploitation. It was concluded that although each option should be considered on a case-by-case basis, the implementation of MPAs would be the overall best solution for the Bahamas because several have already been implemented among the islands, and it would be a better tool than aquaculture to decrease overfishing and preserve marine habitats.

INTRODUCTION

With a world population of over seven billion individuals and still growing, there is a considerable amount of social, economic, and environmental problems humans face every day. One crucial issue is the lack of food security around the globe, especially in developing countries and low-income communities (Williams 1997). The growing demand for food caused land food production to become more limited, making the oceans an increasingly important source of food (Shumway et al. 2003). What was once considered a poor man's food due to low prices and easy access to the ocean (Williams 1997), fish is now desired all over the world, putting economic stress on islands and other marine communities via trade and export demands. Because of this and similar pressures on other food sources, there has recently been a movement toward incorporating sustainability practices into agriculture (Williams 1997).

The increased demand for fish has caused stocks of marine organisms, such as queen conch, Nassau grouper and spiny lobster in the Bahamas, to be overfished at rates that alter their population dynamics and disrupt ecosystem webs that involve these species. Overfishing has become such an issue, that "the United Nations has projected by 2030, there will be a 40 million ton seafood shortage" (Howard 2013). Not only will there be a seafood shortage, but numerous of the currently endangered fisheries may not exist by 2030, giving rise to extinction.

As people continue to understand the impacts humans are having on Earth's biological systems, there becomes a controversy on economic-based versus environmental-based actions. While some people need to sustain their livelihood, and only consider short-term economic benefits of fishing, others are more focused on the environmental and biological impacts that will become a serious cost in the long-term. As with most global issues, there are countless factors to consider when developing a plan of action, and there are various methods to either fix the problem or mitigate unfavorable outcomes. Several approaches to sustainable fisheries management have been considered, and they range on a spectrum from full farming to no farming. Three options include aquaculture, larval aquaculture, and marine protected areas (MPAs) respectively. All three have both biological and economic tradeoffs, and this will be analyzed in the following paragraphs.

SUSTAINABLE SOLUTIONS

Aquaculture

As fish stocks started to become over exploited, one response to maintain certain species for food was to farm fish. Some biological benefits of aquaculture include that it can help to minimize marine exploitation, which can result in a beneficial "[reduction in] stress on native fish stocks" (Howard 2013). Aquaculture can allow species of fish to be protected from natural environmental factors such as climate change, warming ocean waters, and ocean acidification by providing a suitable environment (Radulovich 2015). Some biological disadvantages include that ecologically valuable marine ecosystems have the potential to be degraded by inserting fish pens for aquaculture productions (Howard 2013). Additionally, if the farmed species is not in its native area, there is the potential of escape into the wild, which can cause detrimental effects to the biodiversity of the surrounding ecosystems (Radulovich 2015).

The implementation of aquaculture systems also has both positive and negative economic effects. The Bahamian Government is in favor of developing aquaculture operations, especially to provide opportunities for women and others in the Family Islands, and to improve trade through export (Idyll & Wildsmith 2015). Not only does aquaculture provide jobs and fish for food, but fish are also raised for the aquarium trade, pharmaceuticals, and biotechnology products (Queen Conch Fishery Management Plan 2016). These three products, especially pharmaceuticals, are in demand by consumers, and, therefore, benefit the economy. Unfortunately, not all species of fish are fit to be farmed, and as a result, mainly species with high market demand are the ones undergoing large productions (Radulovich 2015). These species of fish may not be an overexploited species, and this type of aquaculture will not benefit fisheries biologically. For some species of fish, the feed is largely dependent on fishmeal and oil to maintain the quality of meat, which is energetically and therefore economically expensive (Radulovich 2015).

Larval Aquaculture

Another method of sustainable fisheries management is larval aquaculture, which is when hatchery fish are released back into the wild. This method is a partial farming method because they are only raised through a certain life stage. One of the main biological goals of this is to restock marine populations, which can help to maintain or restore habitats and protect the population from dying off (Queen Conch Fishery Management Plan 2016). Reintroduction events also allow for the potential to have a larger survival rate of larvae than in wild populations (Heyman 1989). Although there may be an increased survival rate, it is easy for disease to spread among the larvae population, so vigilant lab practices must be taken to ensure the health of the population (Heyman 1989). Unfortunately, fisheries under stress cannot rely on reintroductions from aquaculture alone. For the native fish population to survive, it not only needs restocking efforts after larval aquaculture but also the implementation of fisheries management programs (Heyman 1989).

Economically, larval aquaculture systems allow for the restoration of fisheries that serve as a resource for the local economy (Heyman 1989). Small-scale hatcheries, which are appropriate for the Bahamas, are economical because of simple equipment and procedures and low operating costs (Heyman 1989), but this may not be able to counteract the amount of overfishing occurring. Whether done on a small or large scale, it is difficult to start a larval aquaculture production because it requires a large startup cost, and it is dependent on the local economy (Heyman 1989). Because a substantial amount of funding is spent on the cost of the initial infrastructure, little is left for research and development (Heyman 1989). Much research is needed before the public's money can be spent to restock populations (Idyll & Wildsmith 2015).

Marine Protected Areas

The last method of management discussed, MPAs, is a zero farming method. With this method, marine populations can regenerate on their own through policies surrounding these protected areas. Marine Protected Areas "help rebuild stocks, maintain biological productivity, and support sustainable marine fisheries" (Habitat and Communities 2016).

More specifically, they can have an effect on the number of species present, reproductive potential, and community structure within and nearby the reserve (Lester et al. 2009). Overall, they protect biodiversity and the habitat as a whole (Hilborn et al. 2004). Since MPAs can have differing levels of protection from activity within the area, a less strict level of protection may not have the same potential to maintain a sustainable habitat as no-take MPAs (Lester et al. 2009). Additionally, the implementation must be dealt with on a case-by-case basis because every potential fishery has differing objectives and differing biotic and abiotic factors to consider (Hilborn et al. 2004), such as location, water temperature, water currents, and species present. Because of this, it takes a significant amount of time and research to have any MPA implemented.

MPAs are economically beneficial because they can be used for education and research, which help managers better understand how to regulate the areas, and others in the surrounding community better understand the benefits (Habitat and Communities 2016). For example, MPAs don't necessarily prohibit all activity within their boundaries. Although people may not be able to take any organisms, they may still be able to swim, snorkel, scuba dive, and boat on the water (Hilborn et al. 2004). Sometimes, the benefits of MPAs can be misinterpreted, leading people to believe that they always produce yields. There is no guarantee that it will produce enough fish in the spillover regions to make up for the losses within MPA boundaries (Hilborn et al. 2004), and this is a prime reason for disagreement from local fishermen. Because fishing is such a large part of people's livelihood, and a large part of the economic sector due to trade and export, it is difficult to make decisions, such as where MPAs should be located (Halpern 2003).

DISCUSSION: BAHAMAS IN CONTEXT

Overharvesting of fisheries is happening all over the world, putting nearly one-third of the world's fisheries in danger (Overfishing: Worse than You Might Think 2016). Because no island or coastal marine habitat is alike, the Bahamas must evaluate the economic and ecological conditions of the country before attempting to solve the problem of overfishing. The Bahamian people must also be taken into account, because for much of the poorer population, fishing is their source of food and income. The most important fisheries, by landing in weight, include, spiny lobster, snapper, queen conch, Nassau grouper, and jacks, with Eleuthera being one of the primary landing sites among the islands (Fishery and Aquaculture Country Profiles 2009). Because fishing is such a large industry in the Bahamas with USD $83.4 million in fish exports in 2007, commercial fishing is entirely limited to Bahamian nationals and is regulated by the Fisheries Resources Regulations of 1986 (Fishery and Aquaculture Country Profiles 2009). These regulations include the open and closed seasons for important fish species, particular types of fishing methods for these species, size limits of fish that are allowed to be kept, and limits on landings as well.

Aquaculture in The Bahamas

Currently, "there are no communities based on or heavily depending on aquaculture" (Fishery and Aquaculture Country Profiles 2009). This is due to "constraints [such as] the frequency of hurricanes, limited freshwater supply, high surface evaporation and the absence of specific legislation for aquaculture" (Fishery and Aquaculture Country Profiles 2009). Even so, there have been many attempts at aquaculture in the Bahamas with about 30 licensed farms within the last 30 years, but only two have persisted from the late 1990s to present (Fishery and Aquaculture Country Profiles 2009). There are many factors as to why aquaculture has not been successful in the past, but that does not mean it cannot be successful in the future. The islands possess numerous qualities that are favorable for aquaculture such as warm, unpolluted waters, shallow banks, and a large export market (Idyll & Wildsmith 2015).

There is a case study of a successful queen conch aquaculture production in Providenciales, Turks and Caicos, which is an island just south of the Bahamas. The production started in 1984 and now has about 2 million conchs being raised and sold to international restaurants (Appeldoorn & Baker 2013). Since these two islands have extremely similar environmental conditions, the success of aquaculture production in the Bahamas is dependent on having the right economic conditions. These conditions may include having enough skilled and educated laborers with knowledge of aquaculture productions, enough food and materials produced locally for the aquaculture fish, appropriate shipping and communication logistics among islands to minimize poaching, and proper government infrastructure, all of which the Bahamas does not have (Idyll & Wildsmith 2015).

Marine Protected Areas in The Bahamas

Presently, there are four marine protected areas in the Bahamas among even more national parks (Figure 1). The Bahamas has worked with the Western Central Atlantic Fishery Commission (WECAFC) and the Caribbean Regional Fisheries Mechanism to combine technical expertise with fisheries management (Fishery and Aquaculture Country Profiles 2009). Even so, the government faces challenges with being able to constantly provide resources for data collection and research of fisheries, which results in a difficulty to develop and manage the fishing industry (Fishery and Aquaculture Country Profiles 2009). It is a long process to have an MPA approved and finally implemented, but since MPAs exist in the Bahamas, they are proven to be a viable option economically.

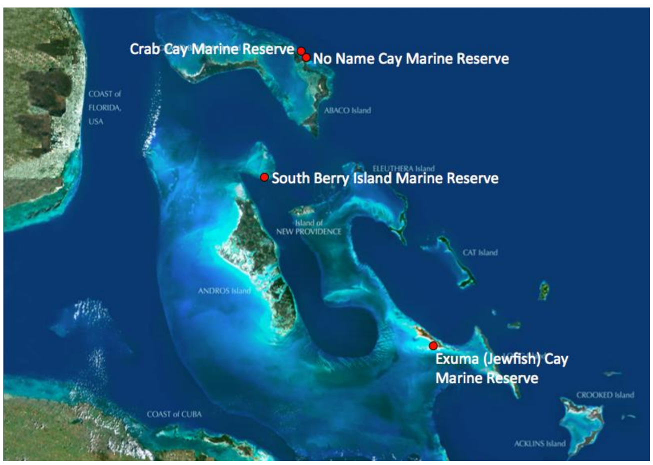

Figure 1. Locations of Marine Protected Areas in the Bahamas (World Yacht Group 2014).

CONCLUSIONS

Currently, aquaculture is in the very early stages in the Bahamas with an unknown potential of how successful it could be (Idyll & Wildsmith 2015). Although there are already some MPAs in place in the Bahamas, an extensive amount of research needs to be done for the government to warrant any additional MPAs necessary and beneficial. When considering these as options to improve ecological habitats and also provide food for locals and export, all may be difficult to meet demand.

Even so, something needs to be done to counter the effects of overfishing. It was hypothesized, that out of the above options, MPAs would be the optimal solution. Although it may take an extensive amount of research before the Bahamian government implements an MPA, they have greater benefits overall, both ecologically and economically. Valuable fisheries, some of which are endangered, will be protected from exploitation, and still have the ability to provide a catch to fisherman through the overspill regions. This method is the least invasive to the environment, allows fish to develop naturally, and will also prevent the species from dying off altogether, benefitting the fisherman in the long run. Since many marine species need to have a certain density of individuals of reproductive age for the population to reproduce, the implementation of MPAs would help to protect nurseries and breeding grounds from declining below that reproductive threshold, unlike aquaculture, which cannot guarantee the populations in the ocean. Although aquaculture has the potential to supply a significant amount of food for locals and export, there are only two small-scale operations in the Bahamas today, which do not provide substantially to the surrounding community. The economy is not in a place where it can afford the start-up costs associated with aquaculture productions. Furthermore, implementing an aquaculture production does not prevent fishermen from continuing to exploit the ocean waters, so this would not solve the issue of overfishing. Their complete access to fisheries would continue to endanger marine ecosystems. Additionally, aquaculture is better fit for particular species based on the characteristics of the fish, such as life history traits. Three of the highest valued and most exploited species of fish in the Bahamas, queen conch, Nassau grouper, and spiny lobster, are not as well fit for aquaculture as a widely used fish such as Tilapia, based on the amount of time it would take for them to reach maturity (Table 1). Because of this, aquaculture may not even be a viable option for the species in which it is necessary.

Overall, there was a limited amount of quantitative data available, which made it difficult to conclude which option would be best for the Bahamas. It can be argued that the different options may be better or worse in differing locations of the islands. It is also important to recognize that the economic and environmental sectors of society are often seen as conflicting entities, but they actually have the potential to work together in the long run. Currently, many countries are choosing short-term economic benefits to the detriment of the environment, but if the environment were preserved, it would sustain the economy over a longer period of time. Whichever method of sustainable fisheries management is used, action should be taken quickly in the Bahamas because critical fish stocks are being depleted at unsustainable rates, and if any populations die off, it will have lasting detrimental effects on the country's ecological and economic assets.

Table 1. Time until maturity of three important fish species to the Bahamas with potential for aquaculture and one common fish species currently used in aquaculture.

Fish	Time Until Maturity (months)
Queen Conch†	36 - 48
Nassau Grouper††	48 - 96
Spiny Lobster†††	24 - 36
Tilapia††††	2 - 3

†(Naro-Maciel & Brumbaugh 2007) ††(Ray & McCormick-Ray 2004) †††(Life History and Ecology of the Caribbean spiny lobster) ††††(Chapman 2015)

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