Pesca Limpia en El Salvador: Examining Management Measures for the Use of Artificial Reefs in the Bay of Jiquilisco

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June 15th, 2017

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Executive summary

The Bay of Jiquilisco in El Salvador is an important region of mangrove forests that serves as a habitat and nursery for many organisms, offers ecological services such as carbon sequestration and erosion control, and provides food and economic opportunity for nearby communities. In recognition of its importance the region has been designated both as a Ramsar site and as a UNESCO Biosphere Reserve. However, the use of explosives in fishing and other unsustainable practices threaten the bay, it's resources, and the people who depend on them.

For these reasons, some fishing cooperatives in this region are moving towards more sustainable fishing practices with what they've termed "Pesca Limpa". The Pesca Limpia method discourages the use of explosives and promotes the use of the hook and line method on artificial reefs to support the fishery. The purpose of this project is to explore the feasibility of sustainable artificial reef management in the context of the Bay of Jiquilisco. The social, legal, economic, environmental, and biological conditions of the Bay of Jiquilisco will be discussed to determine the best use of artificial reefs in this region.

Artificial reefs are a common management strategy used to attract fish, which can enhance the environment, promote fishery resources, increase the efficiency of fishing, and boost tourism. There are many factors that influence the effectiveness of a reef and how much life it attracts. If an artificial reef is placed in a barren area, has a complex structure with different sized holes and textures, and is made of concrete, it is more likely to attract a variety of fish. However, the use of artificial reefs may be harmful long-term if they are not used in a sustainable manner. Aggregating fishery resources in one area increases the possibility of overfishing, which would have negative effects on fishers, the community, and the environment.

Effective regulation and management measures can be applied to use the resource sustainably and avoid overfishing. Possible management measures include setting catch restrictions, prohibiting certain gear types, or protecting specific areas. Furthermore, effective management of artificial reefs involves setting objectives, implementing a monitoring system, and collaborating with stakeholders.

At the beginning of an artificial reef program, setting clear and measurable goals will allow the progression of the project to be evaluated. From there, continued monitoring of the reef, the resource, and the impacts on the community can assess the project's performance. Trends to monitor can include fish abundance, richness, biomass, and size, as well as the condition of the reef, fishery landings, fishing effort, and stakeholder opinions. The data collected from a monitoring program will support decisions on effective management strategies.

Collaboration between all stakeholder groups, including fishers, community members, scientists, the government, and local organizations is essential for a successful program. Involving stakeholders to identify issues, brainstorm solutions, aid in the decision-making

process, and participate in enforcement will diffuse conflict and promote compliance from each group.

Currently, limited community-based management of artificial reefs exists to monitor and enforce acceptable fishing practices. While there are national laws against blast fishing, non-selective gear types, and the catch of juveniles, there are no regulations specifically pertaining to the management and use of artificial reefs. The Salvadoran government fisheries agency, CENDEPESCA, is responsible for promoting the conservation and sustainable development of fisheries resources.

Over the past several years, the fishing cooperatives of La Vueltona, Acopilar, Remanzon, and Acocsile have been using artificial reefs to improve fishing in certain areas. This study interviewed thirty-seven members of four cooperatives to gain a better understanding of their Pesca Limpia practice and to hear their opinions on the method. During the interviews, all members expressed positive opinions of Pesca Limpia. Cooperative members were well-aware that sustainable fishing practices are better for the environment, better for the fishery, and produce a better quality fish. The interviews also highlighted areas that can be improved upon.

From this research and the interviews with fishing cooperatives, we have produced a list of recommendations to promote the sustainable development and management of the artisanal fishery in this region. The recommendations fall into the categories of education and training, collaboration, monitoring, research, policy and regulation, development, planning, and protection. The following paragraphs summarize those recommendations.

To train and educate, workshops should be held to reinforce the objectives of Pesca Limpia, reminding fishers of the gear types allowed near artificial reefs and discussing the reasons behind the restrictions that exist. Furthermore, a monitoring plan for artificial reefs should be implemented and cooperative members should be trained in monitoring and the collection of data. Monitoring should be periodic, and include fishing effort, fishery landings, and fish richness, abundance, biomass.

For proper planning of artificial reef programs, clear and measurable objectives should be created and prioritized. National regulations for the use of artificial reefs should be established to promote the use of selective gears and avoid overfishing. The carrying capacity of the Bay of Jiquilisco needs to be determined, which will inform future decisions about management and regulation for this region. Continued collaboration between all interest groups and stakeholders should be encouraged, with periodic meetings and workshops held.

The environmental restoration of the bay and surrounding areas should be promoted so that it is more productive as a resource. Fully protecting certain artificial reefs may enhance the fishery resource, and future deployment of reefs should consider this purpose. Finally, fishers should receive a higher price for using sustainable methods, which could provide an incentive for other fishers to do the same. Part of this goal should include developing a market for high quality fish.

Introduction

The Bay of Jiquilisco in the Usulután department of El Salvador is an estuarine region of mangrove forests, which performs important biological and economic functions for the community. It is the largest region of brackish water and saltwater forest in El Salvador and serves as a nursery and area of refuge for marine organisms (The Annotated Ramsar List). This diverse region includes estuaries, canals, islands, sand dunes, beaches, a freshwater lagoon, and mangroves and provides an important habitat and nesting site for many coastal birds and sea turtles (The Annotated Ramsar List). These species include the Eastern Pacific Hawksbill, *Eretmochelys imbricata*, along with the Olive Ridley (*Lepidochelys olivacea*), Green (*Chelonia mydas*), and Leatherback (*Dermochelys coriacea*). All four species are included in Appendix I of CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) and listed in Appendices I and II of CMS (the Convention on the Conservation of Migratory Species of Wild Animals). Hawksbills are listed as critically endangered on the IUCN Red List of Threatened Species and in 2005. El Salvador is home to 45% of all nesting observations of Eastern Pacific Hawksbill turtles. (Liles et al. 2015). The Bay of Jiquilisco also functions in stabilizing the soil and preventing erosion, which reduces the impact of natural disasters. Furthermore, the bay and its natural resources provide sustenance and income for communities living in the region, who partake in fishing, aquaculture, shellfish extraction, and salt production (The Annotated Ramsar List).

Fishing is an important activity in El Salvador, providing sustenance and work for not only fishers, but for their families and communities. There are approximately 27,000 artisanal fishers in El Salvador, with 5,000 living near the Bay of Jiquilisco (Lopez 2015). There are about 150,000 inhabitants living within the six municipalities surrounding the bay (Lopez 2015). In addition to fishing, economic opportunities exist in salt production, aquaculture, and on sugar and coconut plantations (Lopez 2015). It is estimated that 1.5 million kilograms are produced each year in the Usulután fishery (Guía técnica 1999). This level of production is higher than any of the other coastal regions of El Salvador (Guía técnica 1999). Of this catch, roughly 5% goes to local consumption, 65% is sold fresh at the local markets, and 30% is processed (Guía técnica 1999).

There are around 26 commercial species that are typically caught in the bay, including several species of snook, snapper, grouper, grunts, drums, mackerels, eels, sardines, jacks, roosterfish, spadefish, barracuda, and triggerfish (Phillips 1981; Lopez 2015). The Pacific goliath grouper (*Epinephelus quinquefasciatus*), a species related to the critically endangered Atlantic goliath grouper (*Epinephelus itajara*), also lives in these waters (Lopez 2015).

However, sometimes the direct impacts of fishing are detrimental to the very resource that the fishery relies on. Unsustainable fishing practices combined with pollution, habitat destruction,

overexploitation and a growing need for protein for increasing human populations can lead to the depletion of the natural resource.

The practice of blast fishing, where explosives are used to kill fish, is a destructive method that is still used by fishers in El Salvador. Approximately 90 fishers use this method in the Bay of Jiquilisco alone, building homemade bombs from sulphur, chlorate, and sugar (Liles et al. 2011). This method is non-selective, killing juveniles and adults of target and non-target species. After an explosion many of the animals then sink to the bottom, where only a few are collected by free-diving fishers. The endangered hawksbill turtle, which nests in the Bay of Jiquilisco, also fall victim. Blast fishing is one of the hawksbills biggest threats in El Salvador, where most of the nests in the eastern Pacific are located (Liles et al. 2011).

Not only does blast fishing damage the environment, but it also harms the fishing community. It is not uncommon for fishers to be injured by an explosion, often losing an eye or an entire limb when something goes wrong. Furthermore, the death of juveniles threatens the reproductive capability of the entire fishery resource. Still, fishers continue to practice blast fishing as an easy and thrilling method of catching fish.

Artificial reefs are used by many countries as a more sustainable option and a tool to promote environmental rehabilitation, enhance fishery resources, and to increase ease and efficiency of fishing (Bortone et al. 2011). An artificial reef can be created by placing an object in an area with bare substratum, which may attract fish and other organisms (Bortone et al. 2011). If the deployment of an artificial reef can make an area more productive, it could benefit the ecosystem, the fishers, and the community. While artificial reefs are common throughout the world, the application of artificial reefs in fisheries management is often lacking (Bortone et al. 2011). This may be due to the lack of good examples for managers to follow and the dearth of data supporting their use (Bortone et al. 2011). Without proper planning, monitoring, and management, artificial reefs can be overexploited and lead to negative outcomes.

Hundreds, if not thousands of artificial reefs are currently being used in El Salvador and the Bay of Jiquilisco. However, the region lacks regulation and effective management of the reefs. The purpose of this paper is to understand the social, legal, economic, environmental, and biological conditions of the Bay of Jiquilisco and to explore the feasibility of artificial reef management. We have created a list of recommendations specific to the fishing cooperatives in this area that aims to promote sustainable development and management.

Using Artificial Reefs


Figures 1 and 2. Artificial reefs in El Salvador (Lopez 2015). Photos by David Alfaro.

The Effects of an Artificial Reef

An artificial reef is a man-made object that is placed underwater, typically in a featureless area, to promote fishery resources, tourism, or increase fishing efficiency (Figures 1,2). The reef attracts different organisms by providing habitat, shelter, substrate for benthic organisms, and areas for recruitment (Pickering and Whitmarsh 1997). Reefs typically act as fish aggregating devices, as fish have the tendency to move towards areas with structure (Brickhill et al. 2005). For these reasons, the presence of artificial reefs frequently results in an increase in fish abundance (Brickhill et al. 2005). However, there is an ongoing debate as to whether artificial reefs just attract fish and aggregate them in an area, or whether they lead to an overall increase in biomass (Pickering and Whitmarsh 1997; Brickhill et al. 2005; Cresson et al. 2014). It is possible that if a species' population is limited by the availability of a refuge from predators, then the addition of an artificial reef could increase production in the area (Grossman et al. 1997). If artificial reefs do in fact increase the productivity of an area, they could be used as tools to sustain well-managed artisanal fisheries (Cresson et al. 2014).

There are many factors that can influence the degree of attraction or production on an artificial reef, including the characteristics of the surrounding habitat, the complexity of the structure, and the existence of management and monitoring in the area (Brickhill et al. 2005). To begin with, the structure of an artificial reef (Figure 3) and the material it is made of makes a difference in the type and number of organisms that it attracts (Pickering and Whitmarsh 1997). Concrete, for example, is the most common material used in artificial reefs, and is a more durable and stable material for this application than is plastic (Pickering and Whitmarsh 1997). If a lesser material is used, there is a risk that the artificial reef will be damaged by storms or

fishing gear (Pickering and Whitmarsh 1997). The size of the reef and the presence and complexity of cavities on the structure can affect the diversity and level of recruitment (Pickering and Whitmarsh 1997). Preferably, cavities should pass completely through the structure and their size should be varied, with smaller cavities to support recruitment and the survival of juvenile fish and larger cavities to support larger fish (Pickering and Whitmarsh 1997). The reef should be adapted to the size and needs of the target species (Bortone et al. 2011). While the presence of many smaller reefs can increase recruitment and fish density, larger reefs have been recommended for use with fisheries because of increased habitat area (Pickering and Whitmarsh 1997). As a rule of thumb, greater surface area and complexity of the reef will lead to a more diverse and abundant group of organisms (Chou 1997). The overall structure of the reef should support the main functions of a habitat, providing a nursery, breeding ground, and shelter (Bortone et al. 2011).

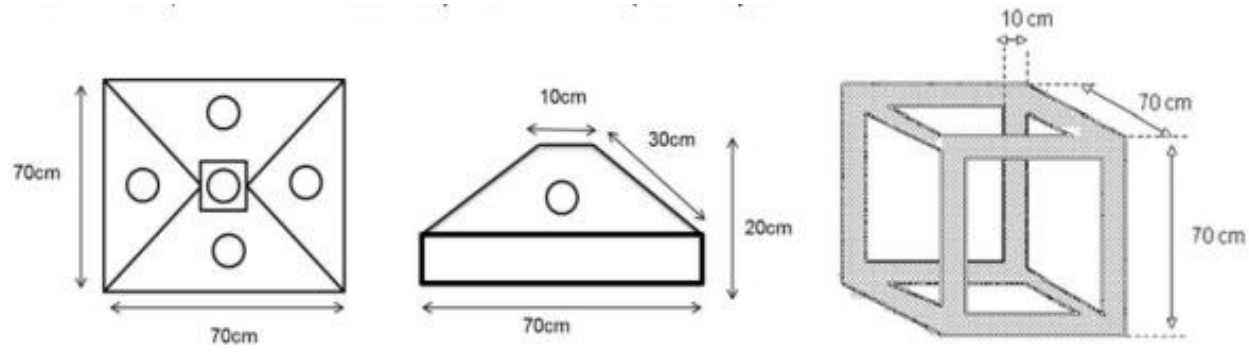


Figure 3. Types of artificial reefs that have been previously used in El Salvador (Lopez 2015). The two designs on the left-hand side of the figure are pyramid types, and the third design is a cube type.

With the presence of an artificial reef, there will likely be a local aggregation of fish and other organisms at the site. Fishers often take advantage of this localized abundance. Typically, the deployment of artificial reefs results in higher catch rates and a higher catch per unit effort. This allows for greater efficiency in fishing and benefits fishers in the short term (Bortone et al. 2011). Furthermore, artificial reefs may attract juvenile fish and promote their survival, which could help certain fisheries (Pickering and Whitmarsh 1997; Bortone et al. 2011). However, while there is ample evidence that catch rates at artificial reefs tend to be higher than other areas, there is not sufficient evidence as to whether the overall net benefits of artificial reefs are positive (Bortone et al. 2011). This is because an increase in fishing effort near reefs increases the probability that the local fish populations will be overexploited (Grossman et al 1997). This overexploitation of the reefs and the resources they provide could lead to negative long-term effects (Bortone et al. 2011).

Many commercial fisheries around the world are already operating at or above the maximum sustainable yield (Milon 1989). Yields per unit area tend to be higher on artificial reefs than elsewhere because these reefs are usually small and more concentrated than natural reefs (Chou 1997). Still, fishing yields from artificial reefs can vary greatly, depending on the fishing gear and methods used, the intensity, and the surrounding environment (Chou 1997).

With many factors involved, it can be uncertain how the deployment of artificial reefs will affect fishers. One artificial reef program in France was able to maintain artisanal fishing during its 25-year time frame, while at the same time fishing activities in the surrounding areas decreased (Charbonnel and Bachet 2010). On the other hand, a study in Malaysia found that artisanal fishers who fished near artificial reefs had a lower income than those who fished elsewhere (Islam et al. 2014). While the results suggest that these fishers are not benefiting from the use of artificial reefs, there are factors of social conflicts, overexploitation, less efficient fishing methods, and a lack of enforcement that may be affecting the fisher's income (Islam et al. 2014).

From a biological and economic standpoint, these issues present a paradox for artificial reef management. While the presence of an artificial reef often increases the number of fish in the area, it can lead to an overall decrease in local fish populations (Grossman et al. 1997). The reefs may be such a successful tool in aggregating fish that they impair the performance of the fishery if access is not controlled (Milon 1989). Thus, before installing new reefs or management measures, the positive effects should be weighed with the potential negative effects that fishing pressure has on an area. Efficient management strategies are critical; to prevent overexploitation of the reef and to achieve the benefits for fishers and other stakeholders.

Fisheries Management on an Artificial Reef

When resource managers are faced with issues of food security, overexploited fish stocks, damaged habitats, and other environmental and economic problems, a typical response may be to try to change the fishing pressure or increase the resources available (Bortone et al. 2011). Changing the amount of fishing pressure involves setting catch restrictions, prohibiting gear types, encouraging gear modifications, restricting fishing during certain seasons, or closing specific areas. The deployment of artificial reefs, along with other methods of enhancing a habitat, is one method that can increase the amount of resources available. Using both effective management and resource enhancing methods can have a positive effect on the fishery (Bortone et al. 2011).

To have a successful artificial reef program, it is important to set clear objectives, collaborate with stakeholders, and put a monitoring system in place from the beginning. Additionally, weighing the social, environmental, and economic costs and benefits of the program can help determine its feasibility (Milon 1989). While every artificial reef is different due to varying reef designs and the environmental, social, and cultural conditions of the site, it is nonetheless

essential to study the successes and failures of other reefs, in order to learn best practices and avoid mistakes.

Setting Clear Objectives

The objectives of management must be clear, in order to prioritize important steps and to reach your goals (Claudet and Pelletier 2004). Goals may be social, environmental, or economic. For example, goals may relate to increasing the number of fishing sites, improving tourism, decreasing the cost of fishing, or increasing the carrying capacity of an area (Sutton and Bushnell 2007). A clear goal should also be measurable, so that the success of the project can be evaluated.

In a review of thirty case studies on artificial reefs, Baine (2001) noted that the majority of the artificial reefs studied met at least some of their objectives. While this could be interpreted as a success, it is important to note the reasons why some artificial reefs didn't meet all their objectives. Many projects, including the reefs that were deemed unsuccessful, could have benefited from better planning, and improved management and monitoring plans (Baine 2001). Some of these studies cite thorough planning and management as areas that could be improved in the future (Baine 2001). For these reasons, only two of the thirty case studies met all of their objectives. These two successful case studies had two things in common: they set practical goals and had definable results to measure the success of the program (Baine 2001).

Collaboration with Stakeholders

For successful management of artificial reefs, all interest groups that will be impacted should be identified (Claudet and Pelletier 2004). Common interest groups may include recreational, artisanal and commercial fishers, government agencies, community members, businesses, environmental organizations, and the scientific community (Sutton and Bushnell). The support of interest groups is essential to a successful management program, especially in the initial phases (Bortone et al. 2011). Involving stakeholders who may be negatively affected provides an opportunity to address problems in the decision-making process, and could diffuse potential conflict. Long-term collaboration and cooperation can motivate fishers, for example, to embrace conservation rules and management measures (Bortone et al. 2011). Whenever possible, maintain open channels of communication and seek cooperation with all stakeholders involved in the resource. Stakeholder consultations and public awareness meetings are one way of promoting collaboration (Bortone et al. 2011).

Community involvement in the process can not only lead to greater cooperation with implementation, but stakeholders can identify issues and brainstorm solutions. Local knowledge can also be an asset in developing methods of management, especially when there is a lack of data (de Lara and Corral 2017). One community of artisanal fishers in the Canary Islands participated in workshops to identify problems that included overexploitation, poor self-

management, ineffective co-management strategies, and an increase in illegal fishing (de Lara and Corral 2017). Proposed solutions to these problems were to establish marine protected areas, place temporary closures of the fishery, limit catch, expand scientific monitoring, provide educational training for the community, and increase surveillance (de Lara and Corral 2017). Participants also suggested that a collective vision should be promoted throughout the community to avoid an outcome typical to the tragedy of the commons (de Lara and Corral 2017). The tragedy of the commons theory suggests that individual users will act in their own self-interest to deplete a shared resource when they don't have an incentive to conserve it. When participants were shown incentives and were involved in the decision-making process, they were more willing to work together towards solutions.

In another example of encouraging collaboration while also addressing management options, Turkey established a National Artificial Reef Program in 2008 (Bortone et al. 2011). The program brings together scientists and decision makers to select sites, prioritize goals, and discuss management options, while also encouraging discussion and participation from users (Bortone et al. 2011). The program has a set of objectives which include conserving biodiversity and promoting small-scale fisheries (Bortone et al. 2011). Management options that have been adopted through this collaboration include size restrictions, gear restrictions, no-take zones and seasonal closures.

Once there are defined objectives and collaboration exists between stakeholders, putting into place a monitoring plan can then assess if these objectives have been fulfilled (Claudet and Pelletier 2004).

Implementing a Monitoring Program

A good monitoring program includes periodic sampling of fish to track trends in fish richness, biomass, abundance and size (Bortone et al. 2011). Monitoring can be performed by any combination of fish surveys, still and video photography, tagging, or acoustics (Baine 2001). If done consistently and over a long-time scale, an assessment can be made about the reefs performance. If these indicators show signs that the resource is decreasing in size and quality, then more strict management measures can be put in place. A long-term monitoring system can support management measures to sustain or improve fishery resources and can lessen the risk of a fishery collapse (Baine 2001; Claudet and Pelletier 2004; Bortone et al. 2011).

One successful monitoring program of artificial reefs off of Rio de Janeiro studied changes in fishery resources over a decade (Bortone et al. 2011). From this continued monitoring, data was gained that was used to make informed management decisions. For example, studies found that fish assemblages on these reefs did not stabilize over the ten year time frame, which contrasts with the one to five year time frame other studies have found to be sufficient for stabilization (Bortone et al. 2011). This disparity can be attributed to multiple factors, including differences in reef colonization and changing environmental conditions (Bortone et al. 2011).

Another discovery of the monitoring program was that the reefs became the most productive for fishery exploitation during the sixth year after reef deployment due to increases in species richness, abundance, and fish size (Bortone et al. 2011). While the sixth year was the most productive overall, other years in the life of the reef resulted in higher abundances of different species, which varied depending on the year and conditions present (Bortone et al. 2011). Thus, fishers had the ability to maximize their profits by changing gear type to target the most abundance species at the time. Overall, results from the monitoring program found that the addition of artificial reefs improved the catches by local fishers (Bortone et al. 2011).

In addition to monitoring the status of the fishery resource, the social and economic conditions of the resource should be tracked. Social factors such as user attitudes, stakeholder opinions, the perception of crowding, and levels of conflict will have an influence on effective management, as will the economic factors of fishing effort and fishery landings (Sutton and Bushnell 2007). By monitoring the biological, environmental, social, and economic conditions of an artificial reef program over a long period of time, the decisions on effective management of the reef will be better informed.

Other Management Techniques

Effective management programs should address the specific management measures relating to the acceptable level of fishing effort, fishery landings, gear types, and fishing methods. One successful artificial reef program in France supported small-scale fisheries and selective gear types, which led to several benefits including a decrease in fishing pressure and increased fish reproduction (Charbonnel and Bachet 2010). Another benefit was that the presence of artificial reefs prevented the use of mechanical trawlers, which preserved the area from destruction (Charbonnel and Bachet 2010). By addressing the issues and needs of the particular area, this program was able to complete its objectives (Charbonnel and Bachet 2010).

Another common management method involves protecting an area to relieve the environment from fishing pressure and to restore fish populations (Bortone et al. 2011). If local fish populations have an area where they are protected from fishing, they have the potential to thrive and expand their population to unprotected areas when space becomes limiting (Alcala and Russ 1990). Additionally, it is more effective to have a long-term closure of a portion of the reef than to have temporary closures of the entire reef (Alcala and Russ 1990). Protective management can maintain high numbers of fish and high yields for fishers in areas near the protected area (Alcala and Russ 1990). Studies show the catch per unit effort for artisanal fishers on reefs is lower when the area does not have some form of protection or reserve status (Alcala and Russ 1990). Therefore, a management strategy could include designated areas of protection, to allow fish refuge from fishing and to sustain healthy fish populations. Artificial reefs are often used for this purpose, being deployed with protection from fishing to enhance the fishery resource (Bortone et al. 2011).

However, the deployment of artificial reefs is likely to have many social and economic impacts, which should be addressed beforehand. The success of artificial reefs will be judged by the benefits or drawbacks felt by individuals and stakeholder groups. Conflict can arise within or between interest groups, due to different priorities or because of crowding at the artificial reef site (Sutton and Bushnell 2007). Furthermore, demand for resources or opportunities at the site can be greater than the supply, which puts more strain on the resource and on interest groups. Methods of minimizing conflict can include selective access, gear and catch restrictions, and the spatial segregation of users (Sutton and Bushnell 2007).

Additional issues that should be addressed by management before artificial reefs are deployed include storm damage, cost effectiveness, proper site location, reef design, user conflict, fishery access, regulation of the fishing effort, and reef usage (Baine 2001).

There is no single defined approach that will be successful when it comes to effective management methods of fishery resources (Baine 2001). Each management system will ultimately be based on individual experiences in an area with unique historical, political, social, and economic factors (Baine 2001). If there is detailed planning, however, a management system can set achievable goals, involve stakeholders, implement a monitoring system, and decide upon management techniques that will be best suited for the area.

Fishing cooperatives in the Bay of Jiquilisco and Pesca Limpia

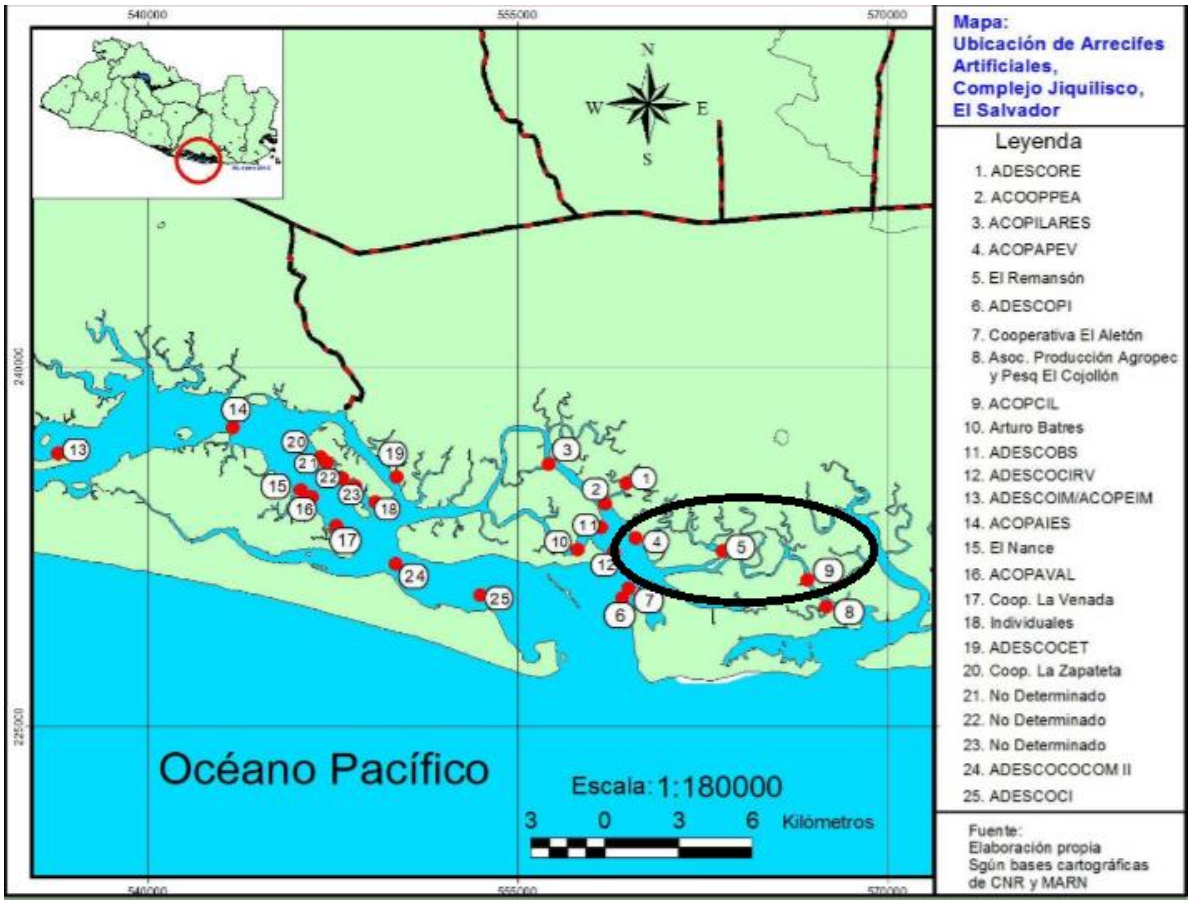


Figure 5. The location of 25 artificial reef systems that correspond to separate fishing cooperatives within the Bay of Jiquilisco (Lopez 2015). Encircled are three of the four fishing cooperatives practicing Pesca Limpia near Puerto Parada.

Roughly 25 fishing cooperatives (Figure 5) exist in the Bay of Jiquilisco (Lopez 2015). Many fishers in this area have practiced blast fishing. While blast fishing makes for an easy catch, it is extremely dangerous for fishers and destructive to the environment. Furthermore, the practice is illegal and a fisher caught with explosives could be thrown in jail or forced to pay a fine. For these reasons, many fishers in the Bay of Jiquilisco have opted to use other fishing methods instead.

This study focuses on fishing cooperatives in the Bay of Jiquilisco that use sustainable fishing methods. This includes four fishing cooperatives, based near the town of Puerto Parada. These fishing cooperatives are La Vueltona, Acopilar, Acocsile, and Remanzon (Figure 3). La Vueltona, which includes a fishing group called Acopapev, is the largest cooperative with 42 members.

Acopilar, Acocsile, and Remanzon are smaller cooperatives with 22, 22, and 18 members, respectively. Each cooperative has a Commercialization Committee, made up of women who buy the fish from the fishers. The women then sell the fish to intermediaries who take the product to the market. These women in the Commercialization Committees are included as members of the fishing cooperatives, with 3 to 10 women working in each cooperative.

These four fishing cooperatives currently practice what is known as Pesca Limpia. Pesca Limpia is a term meaning "clean fishing" which describes a more sustainable and safe method of fishing. The practice of blast fishing is discouraged by giving cooperatives other methods in which to fish. With Pesca Limpia, each cooperative is assigned a different section within the bay, where artificial reefs have been deployed to improve fishing. Fishing in these reef areas is only allowed using a hook and line method. This gives fishers the opportunity to catch fish using a method other than blast fishing, which is extremely dangerous for fishers and destructive to the environment. Similarly, nets are less selective and can lead to overfishing. For those reasons, nets are also not allowed to be used with Pesca Limpia.

Another benefit of Pesca Limpia is that it produces higher quality fish than when explosives or nets are used, which are more likely to bruise, crush, or blow apart the fish. However, these fishing cooperatives have struggled to receive a better price for their product. While a market exists for sustainably caught, high quality fish in the capital of El Salvador, storage and transportation of the product is costly and has not yet been feasible.

Over the past several years, the four fishing cooperatives that practice Pesca Limpia have been using artificial reefs to improve fishing in certain designated areas. Each cooperative uses a variety of materials to create the reef, depending on what is available to them at the time. According to the fishers, the most common structure used for artificial reefs is made of concrete and PVC pipe, which forms a cube roughly one meter wide (Figures 6, 7). Tree trunks are also commonly used for reef substrate (Figure 8). Often dead fallen trees are thrown into the water to create a reef, but it is possible that trees are also cut down for this purpose. With deforestation already an issue in the area, this practice should be discouraged. Estimates vary on how many reefs exist for each cooperative, but guesses range from 40 to 400. According to the head of one fishing cooperative, there are probably about 30 to 50 concrete reefs used by each cooperative, with an additional number of reefs created by tree trunks. However, many reefs were placed in the water 3 to 4 years ago, and their current condition is unknown.

The four cooperatives practicing Pesca Limpia manage and regulate themselves. There are no existing laws in El Salvador pertaining to the use of artificial reefs. The cooperatives have agreed upon their designated fishing areas, with each cooperative in charge of one area where artificial reefs have been placed. Each cooperative monitors their area to ensure that the correct fishing practices are in use, and only authorized fishers are utilizing the area. This is done by around-the-clock monitoring from a small hut in front of the fishing area. Using a system of rotations, fishers are assigned to keep watch inside the hut.

Figures 6 and 7. The deployment of artificial reefs in the Bay of Jiquilisco. This type of artificial reef is called “cubo,” meaning cube. These reefs were deployed with help from CENDEPESCA and USAID in 2015, and may be similar to the reefs used by the fishing cooperatives based near Puerto Parada. Photos by David Alfaro (Lopez 2015).

Figure 8. An artificial reef made of tree trunks, or “troncos” in the Bay of Jiquilisco. Photo by David Alfano (Lopez 2015).

Survey Implementation and Results

Implementation

Thirty-seven members of four different fishing cooperatives practicing Pesca Limpia in the Bay of Jiquilisco were interviewed near the town of Puerto Parada. Members of the cooperatives included fishers and women who work to commercialize the product. Out of the thirty-seven members interviewed, thirty were fishers and seven worked in commercialization. Ages ranged from 17 to 66 years, with the average age of fishers being 35 and the average age of the women being 27. Interviews were conducted two to three at a time, with two interviewers taking notes. Most of the questions gave qualitative results, with interviewees choosing from multiple choice answers. Interviewees often explained their answers in detail, providing more information. Women in charge of commercialization were asked fewer but similar questions compared to those asked to the fishers.

Interview questions included the types of fishing gear used, experience with blast fishing, level of bycatch, interaction with sea turtles, and opinion of Pesca Limpia. Interview questions can be found in Appendix A and B.

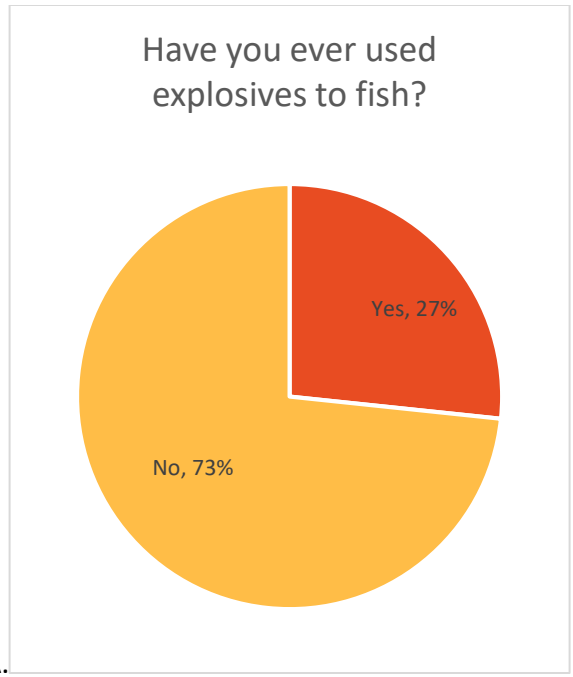
Results

Fishing methods

Every fisherman interviewed used a hook and line as a method for fishing. Five fishers (17%) said that this is the only method that they use to fish. More than half of interviewees (53% of the fishers) said that they use a large net to fish. Similarly, 57% of fishers interviewed used small nets, and 57% said that they used a longline. Only one mentioned using a harpoon. Fishing traps or explosives were not currently used by any of the fishers interviewed.

When asked if they had ever used explosives to catch fish, eight fishers (27%) responded that they had used that method before (Figure 9). They explained that blast fishing was an easy way of catching fish, which is why they had used the method in the past. One fisher described the thrill of using explosives as additional explanation for using them. Almost all of these fishers responded that previously they used this method “all the time”. The average age of the fishers who used to use explosives was 49, which is higher than the average age of all the fishers interviewed, at 35. When younger fishers were asked about blast fishing, many laughed and stated that it was too dangerous. It was noted by multiple fishers that only a few (two to four) fishers in the area still use blast fishing.

A.



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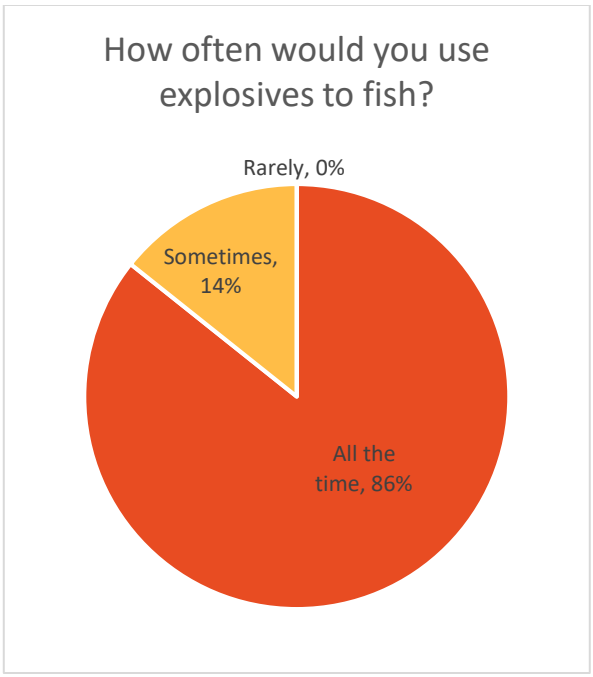
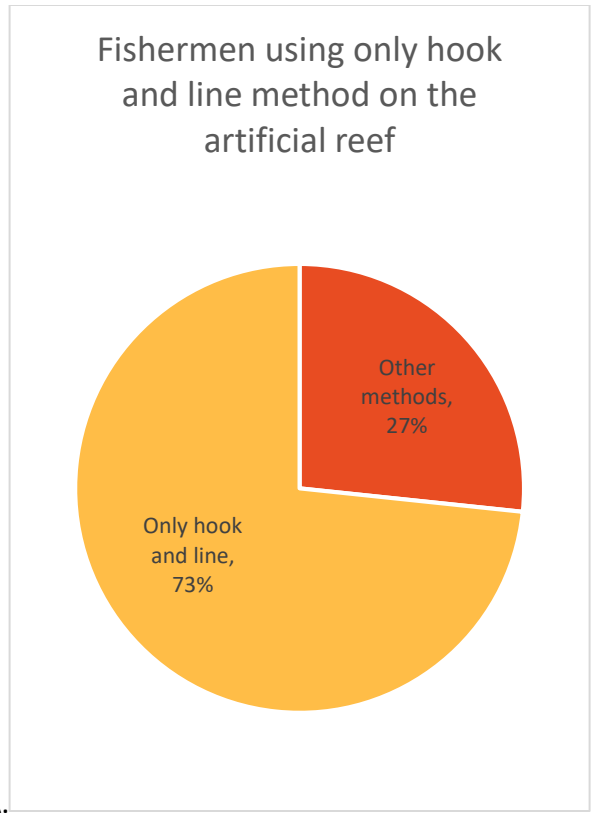


Figure 9. Responses of fishers to the questions "Have you ever used explosives to fish?" and if the response was affirmative, "How often would you use explosives to fish?" Question A had 30 respondents, while question B had 7 total respondents.

Artificial Reefs

Every fisher interviewed used the hook and line method while fishing around an artificial reef. Twenty-two fishers (73%) said that this was the only method that they used while on the reef (Figure 10). Eight fisher (27%) said that they also use a small net and a longline to fish at the reefs, and some said that they use both. The hook and line method is the only method that fishing cooperatives allow to be used on the artificial reefs.

A.



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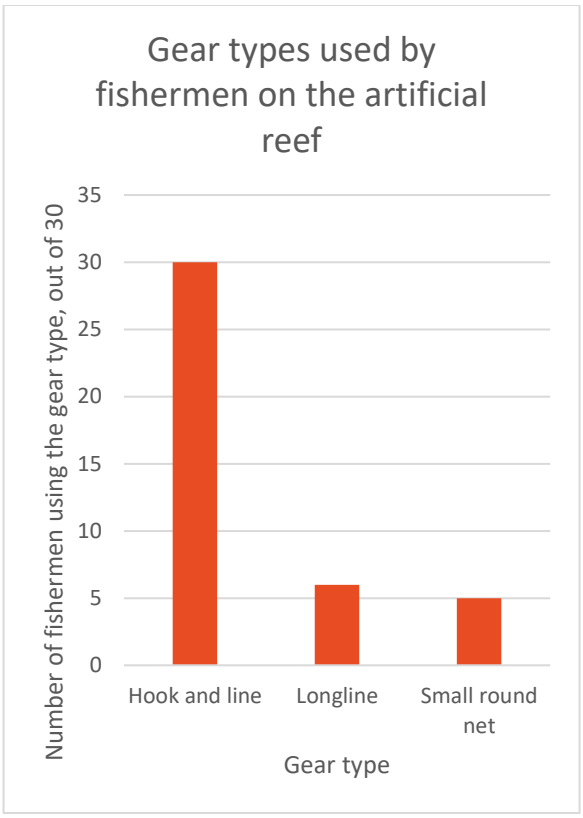


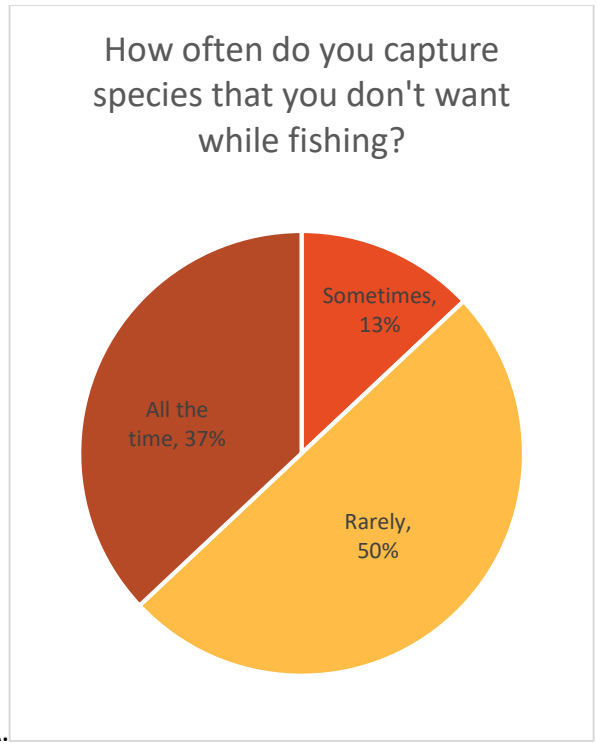
Figure 10. Gear types used by 30 fishers on artificial reefs. Chart A shows the number of fishers who use only hook and line methods. Chart B shows the number of fishers who use each gear type. Some fishers use more than one type.

Bycatch

Half of fishers interviewed said that they catch unwanted species "rarely" when fishing, while the other half said that they catch unwanted species "sometimes" to "all the time" (Figure 11). All fishers said that they catch unwanted fish species, such as pufferfish, crocodile fish, soapfish, scorpion fish, and eels. Thirteen fishers (43%) have caught turtles, specifically when they are using nets or longlines. Other organisms that the fishers have caught include birdsand sea snakes.

When these unwanted organisms are caught, every fisher said that they then release the organism back into the water alive. Three fishers (10%) said that depending on what fish species they have caught, they may eat it themselves. One fisher stated that he might try to sell unwanted fish species.

A.



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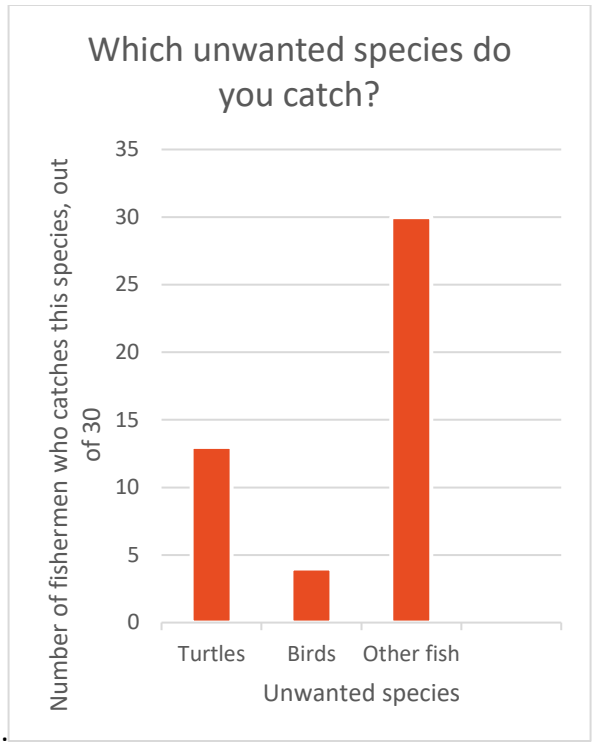
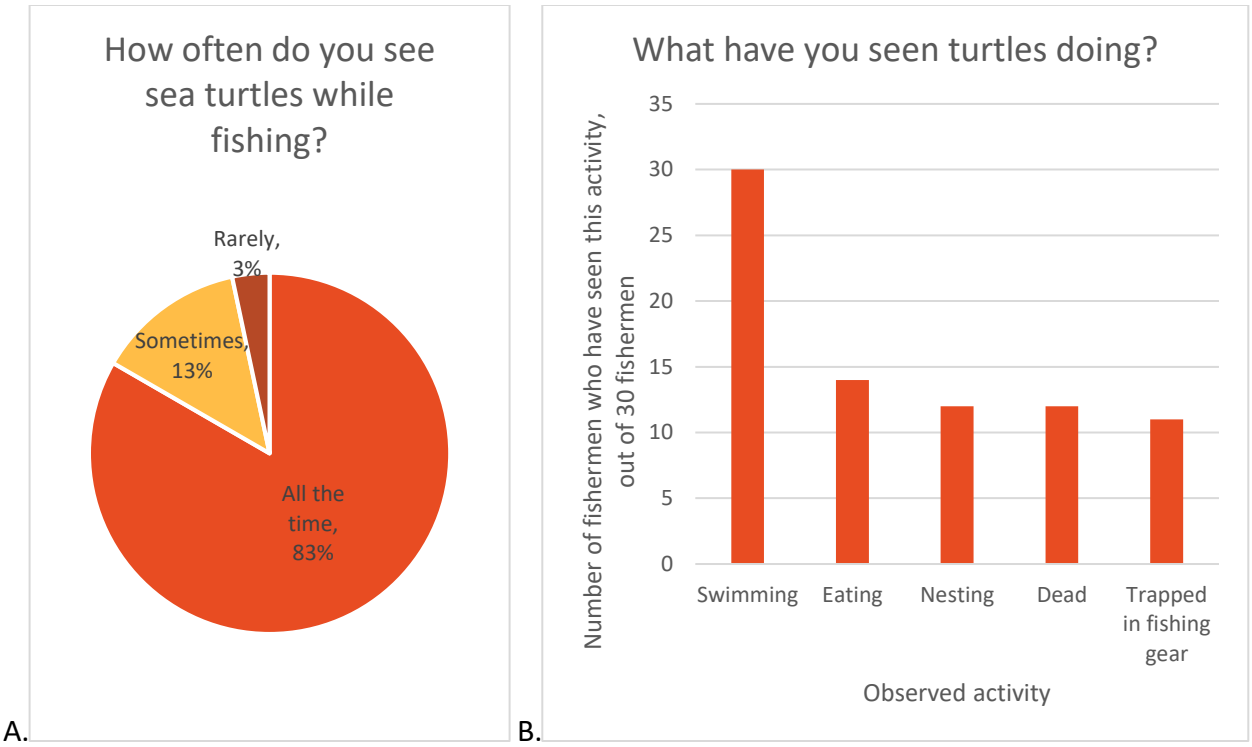


Figure 11. The responses of 30 fishers when asked about unwanted species that they catch. Chart A shows the percentage of fishers who catch unwanted species all the time, sometimes, and rarely. Chart B shows the number of fishers who have caught each type of unwanted species. Some fishers have caught more than one type of unwanted species, and are counted in multiple categories.

Interactions with Sea Turtles

The majority of the fishers (83%) stated that they observe sea turtles "all of the time" when they are fishing (Figure 12). Some specified that "all of the time" meant that they saw sea turtles every day of fishing and even multiple times a day. The species of sea turtle sighted included both hawksbill and olive ridley, with hawksbill being more common according to fishers.

All fishers observed turtles swimming, but only half observed them eating and even fewer (37%) observed them nesting. Twelve (40%) have observed dead sea turtles. Several mentioned that the turtles had died from the explosives used for blast fishing. Furthermore, eleven fishers (37%) observed sea turtles trapped in fishing gear, specifically in nets or longlines.



A. B.

Figure 12. Responses given by 30 fishers when asked about their observations of sea turtles. Chart A shows how often these fishers observe sea turtles while fishing. Chart B shows how many fishers have observed various activities. Some fishers observed multiple activities, and gave more than one response.

Opinions about Pesca Limpia

All 37 members of the fishing cooperatives interviewed had positive views of Pesca Limpia. Many stated that fishing with the hook and line method produced a high quality fish. Protecting juvenile fish was also important to many fishers, who recognized that those fish would grow to benefit them in the future. Fishers stated that there is a specificity with the hook and line method, because they can use certain sizes of hooks and bait to target adult fish. This specificity allows smaller fish to live and reproduce. Some also mentioned that this method of fishing doesn't disturb the rest of the environment, specifically the mangroves and shellfish, which many fishers rely on for additional income.

Many interviewees compared Pesca Limpia to blast fishing in order to describe the benefits of more sustainable fishing practices. They stated that using bombs to catch fish "kills everything", is very wasteful, and produces a lower quality fish to sell to the market. Many also said that explosives are too dangerous for them to use, because they could lose limbs or be caught by the police. In fact, three fishers had already been injured from using blast fishing in the past, resulting in two of them losing their right arm. Other fishers had been caught by the police for blast fishing, sometimes having to pay a large fine. For these reasons, the eight

fishers who admitted to having used explosives to fish in the past stated that they were now happier using the more sustainable and safer practices of Pesca Limpia.

When asked about problems that they currently face and what improvements could be made, cooperative members gave the following responses:

- There is no legal standing of the reefs; there should be a legal permitting system
- Maintenance of the reefs is needed
- The fishing cooperatives need better equipment, the equipment that they have is in bad condition and there is not enough
    - Boats, gear, and huts are needed for fishing
    - Scales and coolers are needed for commercialization
- The huts are too small; they are falling apart and need to be fixed
- More reefs are needed
- Their higher-quality product should earn them a better price
- More fishers should practice Pesca Limpia
- Some members of the cooperatives don't perform their duties, such as attending meetings and monitoring from inside the hut
- Floating devices are needed to identify the location of the reefs
- There is no patrol to catch the people who still fish using explosives
- There should be monitoring of the reefs
- More fishers need to be trained on maintenance and management of the site

Existing Policies and Management

Local Management

Roughly 25 fishing cooperatives exist in the Bay of Jiquilisco (Lopez 2015). Of those, four cooperatives use sustainable fishing practices, termed Pesca Limpia, on artificial reefs. Currently there are no laws in El Salvador pertaining to the use of artificial reefs. Therefore, these cooperatives use community-based management to monitor and enforce acceptable fishing practices. Members of the cooperatives monitor the area of the artificial reefs, to ensure that only those members are using the reef, and that fishers are using the accepted fishing practices. This monitoring is performed by community members and has no legal backing.

National Laws

Under the Ministry of Agriculture and Livestock, three governmental bodies assess, regulate and promote fisheries in El Salvador. The National Council for Fishing and Agriculture, CONAPESCA, promotes standards and projects for the sustainability and development of living aquatic resources. The Center for Fisheries Development, CENDEPESCA, is in charge of developing the fishing industry of El Salvador. The National Scientific Advisory Committee on Fisheries and Aquaculture, CCCNPESCA, advises and provides scientific and technical support to CENDEPESCA.

The General Law on Fisheries and Aquaculture Management and Promotion states that it's goal is to ensure the conservation and sustainable development of fisheries resources (Decreto No. 637). This law defines sustainable development as obtaining the maximum economic and social benefits of fishing, while ensuring the preservation and continued renewal of the resource (Decreto No. 637). The law also gives the following definitions for artisanal and subsistence fisheries:

> Artisanal/Small Scale Fishing – When fishing is done by manual labor in a boat no longer than ten meters in length.
>
> Subsistence Fisheries – When fishers use the fish caught for the direct purpose of feeding their nuclear family.

Furthermore, the extraction of fisheries resources is divided between two categories – commercial and non-commercial. Artisanal fishing falls into the "commercial" category, while subsistence fishing is non-commercial (Decreto No. 637).

Prohibited Fishing Methods and Gear

According to Article 28, trawling and non-selective fishing methods are prohibited in the aquatic reserve areas of El Salvador. This includes the mouth of the Lempa River and the Bay of Jiquilisco (Figure 4). These areas are protected up to one mile and a half on each side of the mouth, and up to three miles offshore (Decreto No. 637). However, this decree does not state which fishing methods are defined as non-selective.

According to Article 31 of the same decree, the use of explosives, poisons, or other destructive materials or methods are prohibited. Trunnions and gill nets are also prohibited from being used in the natural reefs. CENDEPESCA states that the General Law on Fishing Activities finds the use of explosives illegal because there is a high degree of damage and mortality of species (Guía técnica 1999). Furthermore, CENDEPESCA recognizes that some fishers place mangrove branches in the water to act as artificial reefs. These fishers are then able to come back later with explosives which cause great damage (Guía técnica 1999). However, there is no mention of the term "artificial reef" in the General Law on Fisheries and Agriculture Management and Promotion, and no laws exist to address it specifically.

If these destructive methods are used by artisanal fishers, they are considered minor infractions compared to use by industrial fishers. The minor infraction carries a lesser fine, which is based on the established monthly minimum wage (Decreto No. 637).

As for acceptable fishing gear, all types of bait, traps, longlines, and harpoons can be used. A small round net, called an atarraya, can also be used. When fishing with gill nets, the mesh size must be equal to or greater than 7.6 cm (Guía técnica 1999).

According to the Regulations for the Application of the General Law of Fishing Activities, the minimum size of catfish, corvina, mackerel, grouper, snapper, sea bass, and tuna that can be extracted and marketed is 18 centimeters (Guía técnica 1999). These species are often caught by fishermen in the Bay of Jiquilisco.

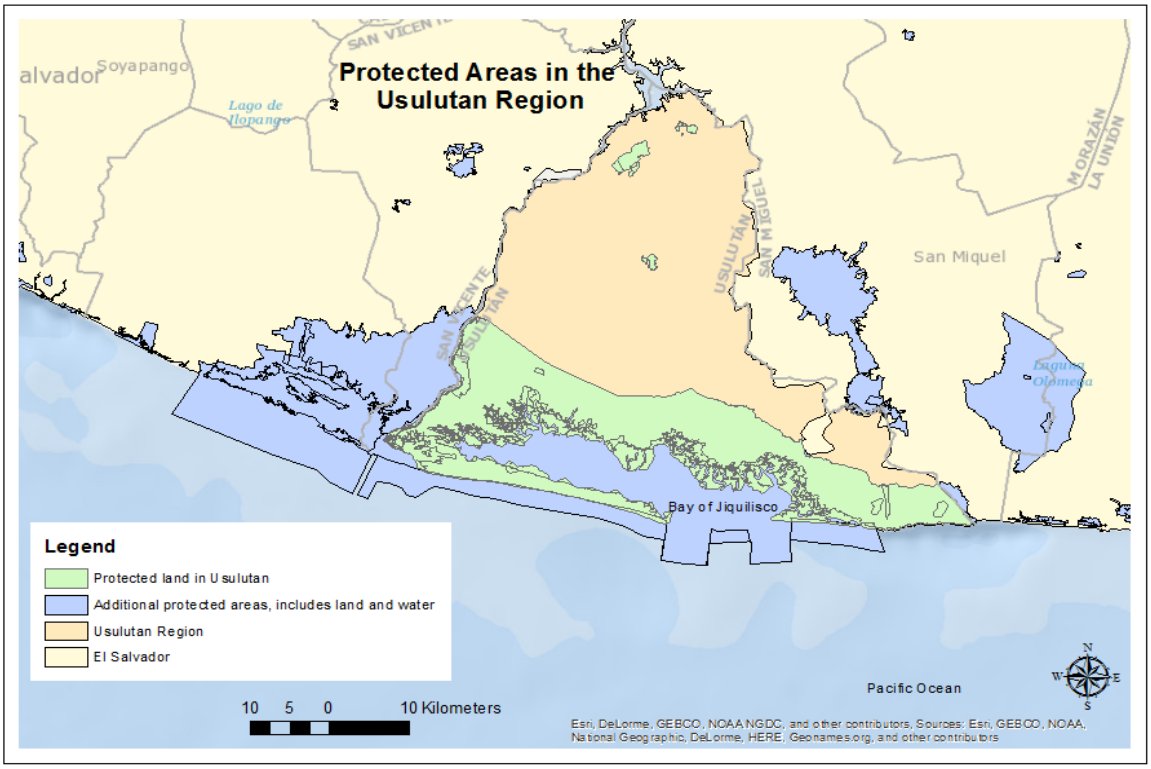


Figure 4. Protected areas in the Usulután Region of El Salavdor.

International Management

The Ramsar Convention

The Convention on Wetlands of International Importance especially as Waterfowl Habitat, also known as the Ramsar Convention, is an international treaty signed in 1971 (The Convention…1994). The Convention encourages all contracting parties, which includes El Salvador, to designate at least one wetland as a site of importance within their country, and to promote its conservation and wise use.

The Bay of Jiquilisco became a Ramsar site on October 31, 2005 (The Annotated Ramsar List). The location is 63,500 hectares and covers the entire bay, making it the largest out of the six current Ramsar sites in El Salvador (The Annotated Ramsar List). The Bay of Jiquilisco was selected as a Ramsar site because of its importance as a habitat and nesting site for many birds and sea turtles, its role in preventing erosion, and because it provides sustenance and livelihood for the communities in the region (The Annotated Ramsar List).

However, the Ramsar Convention does not have the legal strength to effectively protect areas. While it does promote conservation, it gives contracting parties the flexibility and discretion for national implementation, allowing for insufficient and ineffective management (Gardner and

Davidson 2011). In some instances, the Ramsar Convention has helped to develop additional environmental policies and to deter development near important wetlands, such as in Australia and in Bonaire (Gardner and Davidson 2011). Often additional benefits come from the status of having a Wetland of International Importance in the form of increased national protection and management of the Ramsar sites (Gardner and Davidson 2011).

UNESCO World Network of Biosphere Reserves

UNESCO, the United Nations Educational, Scientific, and Cultural Organization, manages a World Network of Biosphere Reserves as a part of its Man and the Biosphere Programme (Man and the Biosphere…c1971-2017). These biosphere reserves serve as 'Science for Sustainability support sites', where interdisciplinary methods can be tested to find solutions for the sustainable use of resources while conserving biodiversity (Man and the Biosphere…c1971-2017). Of the 669 current biosphere reserves worldwide, three are located in El Salvador. This includes the Xirihualtique-Jiquilisco Biosphere Reserve, which was declared a reserve in 2007 for its extensive mangrove forest (Man and the Biosphere…c1971-2017).

As a program that started as a tool for international cooperation in conservation, the reserve areas have evolved into learning laboratories to test the intersection of policy and practice as it pertains to sustainable development (Ishwaran et al. 2008). To maintain their goals of environmental, economic, and social sustainability, biosphere reserves undergo a periodic review every ten years (Man and the Biosphere…c1971-2017). Launched recently, the BiosphereSmart initiative aims to share ideas, best practices, knowledge, and experiences from biosphere reserves around the world on solutions for sustainability, climate change, and development (Man and the Biosphere…c1971-2017). On an interactive web-based platform, this knowledge can be shared and used by managers and scientists. Currently, the Xirihualtique-Jiquilisco Biosphere Reserve has not been selected to showcase its best practices (Man and the Biosphere…c1971-2017). Moving forward, the knowledge and experience generated from this initiative which documents the relationship between conservation, research, monitoring and management could influence policy and future projects (Ishwaran et al. 2008).

Analysis

The following analysis is the result of this research as it applies to the Bay of Jiquilisco in El Salvador.

Management

It has been shown that setting clear objectives, implementing a monitoring system, and collaborating with stakeholders is essential in effective management. These methods should be practiced by management bodies, if not done so already.

Management programs are not one-size-fits-all, and the specific needs of the communities in the Bay of Jiquilisco need to be addressed. Protection, a common management strategy, has been shown to increase fishery yields and could be a tool used in this region. In the Bay of Jiquilisco legal protection exists but is not enforced, so further action of regulation, enforcement, or community-based management should be taken. Protecting a subset of artificial reefs within the bay could provide a refuge from fishing and may help sustain the artisanal fishery. Deploying additional reefs for this purpose may be the most realistic approach in this area, as fishers and fishing cooperatives already maintain their specific fishing grounds around existing artificial reefs. Since the fishery resource is being utilized and it cannot all be set aside for protection, other management measures should be explored by managing bodies as well.

For management to run smoothly, collaboration between fishers, fishing cooperatives, local organizations, community members, scientists, and the government must exist. This is important for implementing management measures that avoid conflict and ensure compliance.

Additionally, a monitoring program is an important tool in fisheries management and could be implemented in this region. Scientists, fishers, or local organizations could collect this data on a regular basis. The degree of monitoring will depend on the availability of resources, with a simple system consisting of the number and type of different species observed at artificial reef sites and at control sites. If there is a lack of scientific data, then there is a greater risk of overexploitation because of uncertainty of the status of the resource.

For the same reason, the carrying capacity of the bay needs to be determined. If an area is overfished, even the best artificial reef design may not be colonized by target species. A monitoring program can help to determine if the Bay of Jiquilisco is currently being fished at a sustainable level. If it is not, a rebuilding plan should be considered.

Research is also required to determine the condition of the artificial reefs in the Bay of Jiquilisco. Estimates vary on how many reefs exist for each cooperative, but there are probably about 30 to 50 concrete reefs used by each fishing cooperative with an additional number of reefs created from tree trunks. However, many reefs were placed in the water 3 to 4 years ago,

and their current condition is unknown. Further studies are needed to determine a more precise estimate of the number and condition of artificial reefs present in the area. Using the results of a monitoring program and further research, management measures could be modified depending on the assessment.

Regulation

The legislative assembly of El Salvador has previously stated that it is necessary to formulate and apply new management techniques to use the nation's natural living resources sustainably and to optimize the benefits of fisheries resources (Decreto No. 637). Furthermore, CENDEPESCA's sustainable management objectives include promoting the optimal sustainable use of fishery resources to guarantee the resource for future generations, and promoting production alternatives to guarantee economic, social and environmental profitability (Guía técnica 1999). Artificial reefs are already in use in the Bay of Jiquilisco and elsewhere along the coast of El Salvador, but their use is not regulated by the government and thus the reefs might be currently utilized in an unsustainable manner. For these reasons, the use of artificial reefs in El Salvador should be addressed by national policy and management measures.

It is necessary to recognize that while the Bay of Jiquilisco is protected under certain national and international designations, it is a resource used by 5,000 artisanal fishers and affects at least 150,000 community members who live in the region (Lopez 2015). Therefore, the community's needs should be balanced with the protected status of the area.

Although the necessary manpower may not be available in this region to monitor and enforce regulations on fishing practices, regulations and management measures for the Bay of Jiquilisco should encourage best practices.

Pesca Limpia

The four fishing cooperatives practicing Pesca Limpia are actively moving towards more sustainable fishing practices, and the support of the government, scientists, and local organizations will be beneficial as they progress. Building upon the idea of Pesca Limpia, the creation of a common vision for the future of the artisanal fishery could encourage collaboration and compliance.

Blast fishing is already discouraged in communities near Puerto Parada because of legal, social, and economic factors, and it is likely similar in other communities in the Bay of Jiquilisco. Only a quarter of the fishers interviewed had ever used explosives to fish. These fishers who had used explosives in the past were older than the average age of the fishermen, suggesting that younger fishers are less likely to use explosives. Many fishers recognized issues of environmental degradation and the threat to juvenile fish that occur with blast fishing. Others recognized that blast fishing produces a lower quality of fish. For these reasons, all fishing cooperative members interviewed had a positive opinion of Pesca Limpia. These results show that fishers may be open to other sustainable fishing practices if they don't damage the

environment, the resource, or the quality of the fish. Future management measures to be implemented should be presented to fishers in this context so that fishers are more likely to comply.

The viewpoints of members of fishing cooperatives already practicing Pesca Limpia are clear, but it is unknown how other fishers view these sustainable fishing practices. Interviews with fishers in other fishing cooperatives and with fishers who actively practice blast fishing would be informative for future studies.

While the use of nets and longlines is not as destructive as explosives, they can be less selective and more prone to high levels of bycatch. Indeed, several fishers recalled seeing endangered hawksbill sea turtles caught in nets or longlines. Therefore, the use of these gear types should be discouraged. In fact, even though these fishing cooperatives only allow the use of hook and line near the artificial reef, nets and longlines are still being used by fishers. It is possible that some fishers use these gear types around the artificial reefs because they are unaware of this restriction. If this is the case, leaders of fishing cooperatives should remind members about the rules regarding different methods of fishing near the artificial reefs. Furthermore, workshops could be held to educate fishers on the reasons behind these rules, and increased monitoring and enforcement could help to deter these activities.

Recommendations

Pertaining to the use and management of artificial reefs by fishing cooperatives in the Bay of Jiquilisco, recommendations have been developed from the research presented in this paper and from interviews with stakeholders. Some recommendations were suggested by fishermen themselves, while other recommendations were developed because of their responses during interviews. Additionally, several recommendations were driven by research into successful management strategies. The recommendations fall into the categories of education and training, collaboration, monitoring, research, policy and regulation, development, planning, and protection. As a culmination of this research, the following recommendations are given.

To train and educate, workshops should be held to reinforce the objectives of Pesca Limpia. Many fishers are currently using nets and longlines, which are gear types that Pesca Limpia doesn't allow on the artificial reefs. Workshops should remind fishers that the hook and line method is the only method allowed near the reefs. These workshops should also create a forum to discuss the reasons behind the restrictions, including the benefits of using the hook and line method, the negative effects that certain fishing gear may have on the fishery resource and sea turtles, and the ecological importance of the Bay of Jiquilisco. Several members of these fishing cooperatives have expressed concern about the management and maintenance of the artificial reefs and the huts used to keep watch of the reefs. Thus, workshops could train fishers with skills and give suggestions for the proper maintenance of their fishing sites.

As an artificial reef program is developed, it is important to create clear and measurable objectives. By taking the time to plan properly, the program can be more driven towards its goals, which would make it more effective overall and allow it to be evaluated. Objectives of the program should be both short-term and long-term to ensure the program stays on track. Possible objectives could relate to the sustainability of the fishery resource, or to increased economic benefits for fishers.

If the deployment of more artificial reefs is an option, the objectives should be created before they are deployed. Other issues to address before deployment include the cost of the materials, maintenance of the reef, design and complexity of the reef structure, type of material used, spacing and placement of multiple reefs, and future monitoring of the reef. A cost-benefit analysis may be helpful before deploying more artificial reefs to determine if the expected benefits outweigh the costs.

For effective management and decision-making to occur, the artificial reefs and the fishery resource need to be monitored. A monitoring plan for artificial reefs should be implemented as soon as possible, ideally starting before the deployment of new artificial reefs. To collect meaningful data, monitoring should be periodic and occur as often as possible. There may be a lack of resources and manpower to fulfill this task, and so fishing cooperative members could be trained in monitoring and the collection of certain data. At the minimum, monitoring should

include fishing effort, fishery landings, and fish richness, abundance, biomass. The current condition of the artificial reefs should be documented as well. If done periodically, monitoring will allow assessment of the level of fishing impact, the needs of the fishery, the condition of the artificial reef structure, and the status of the objectives and management programs. Underwater cameras, scuba diving, tagging, and fish surveys are a few of the tools that could be used in monitoring. The data collected from monitoring will help to determine the carrying capacity of the Bay of Jiquilisco, which will inform future decisions about management and regulation for this region.

Similarly, for effective management to occur, it is important to understand the values that fishers hold. Informal interviews with fishers who currently practice blast fishing could give insight into how to best discourage this method. Interviews should be conducted in a non-threatening and non-accusatory manner to allow for meaningful conversation to take place. The survey questions used in this project could be modified for that purpose.

Currently, there are no national regulations for the use of artificial reefs in El Salvador. Artificial reefs are being used in this region regardless of the lack of management. Therefore, national regulations need to be established to avoid overexploitation of the reefs. Possible regulation may include targeting adult fish with specialized gear, restricting the catch of juveniles, promoting the use of selective gears, and protecting certain areas to allow the fishery to rebuild. For regulation to be effective, a legal permitting process for artificial reefs may also be needed.

To protect and enhance the fishery resource, there should be environmental restoration of the bay and the surrounding areas. A habitat that is free of pollution and has a healthy mangrove community will be more productive than a lesser habitat. This includes the protection of the species that live within the habitat, like the endangered hawksbill sea turtle. Discouraging the use of explosives, longlines, gillnets, or other non-selective gear will benefit these turtles, who are often killed by entanglement in fishing gear. Furthermore, the full protection of certain artificial reefs may allow a refuge for species and enhance the fishery resource. Future deployment of artificial reefs should consider this purpose.

Pesca Limpia is already promoting fishing methods that are more sustainable for the fishery resource. These methods should be further promoted in this region. To start, a market for high-quality fish caught with sustainable methods is needed. If fishers practicing Pesca Limpia can receive a higher price for fish caught in this way, it could incentivize other fishers to do the same. Improving the handling and storage methods for this high-quality fish could also allow higher prices to be obtained. Better equipment for fishing cooperatives, including refrigeration, scales, and transportation for the commercialization of the fish, is needed for proper handling and storage.

In all of these recommendations that have been discussed, it is vital to encourage continued collaboration between all interest groups and stakeholders. Periodic meetings and workshops

held should be open and accessible for all stakeholders, allowing them to be a part of the process. These groups may include fishers, members of fishing cooperatives, community members, government agencies, scientists, and non-governmental organizations. By meeting together to discuss issues and brainstorm solutions, members from each stakeholder group will be better informed and more willing to cooperate.

The following section summarizes the recommendations discussed here.

Education and training

- Hold workshops with fishing cooperatives to:
    - Reinforce the objectives of Pesca Limpia
    - Remind members of the types of fishing gear allowed near artificial reefs (only the hook and line method).
    - Remind members of the types of fishing gear allowed outside of artificial reefs.
    - Remind members of the minimum size requirement for fish caught (18 cm)
    - Educate members of the reasons for these restrictions.
        - The benefits of using the hook and line method, and the negative effects other fishing gear may have.
        - The benefits of leaving the juveniles to reproduce
        - The negative effects that certain fishing gear can have on sea turtles
        - The ecological importance of the Bay of Jiquilisco
    - Introduce restrictions on certain fish, i.e. goliath grouper, if present
    - Remind fishers about proper management and maintenance of their site, including the hut used to monitor fishing activity
- Train several members of each fishing cooperative in monitoring and collecting data

Collaboration

- Encourage continued collaboration between all interest groups and stakeholders.
    - These groups may consist of members of fishing cooperatives, government agencies, community members, scientists, and non-governmental organizations.
- Host workshops to allow stakeholders to be a part of the process
    - Encourage cooperation by brainstorming issues to come up with solutions together
- Ensure that meetings are open and accessible to all stakeholders

Monitoring

- Implement a monitoring plan

    - Monitoring should be periodic, starting before the deployment of reefs (if possible), and should occur every year
    - Monitoring should include:
        - Fish richness, abundance, and biomass
        - Fishing effort
        - Fishery landings (including species and size)
        - Substrate characteristics
    - Monitoring should assess the:
        - Level of impact from fishing
        - Status of management programs
        - Status of the objectives
        - Condition of the artificial reef structure
        - Needs of the fishery
- Document the current condition of the artificial reefs
    - Possible methods of documentation include underwater cameras or scuba divers
- Share monitoring information with stakeholders to keep them up to date in the decision-making process

Research

- Determine the carrying capacity of the bay
    - Data from a monitoring program can be used for this purpose
- Conduct informal interviews with fishers who currently practice blast fishing
    - Survey questions used in this project could be modified for this purpose
    - Interviews should be conducted in a non-threatening, non-accusatory manner

Policy and Regulations

- Develop national regulations for the use of artificial reefs
    - Target adult fish with specialized gear; restrict the catch of juveniles
    - Promote the use of selective gears
    - Avoid overfishing
- Provide a legal permitting process for artificial reefs
    - Restrict the number of permits given based on the carrying capacity of the bay
- Work with stakeholders and support both fishers and the sustainability of the resource

Development

- Promote Pesca Limpia
    - Develop a market for high quality fish that are caught using sustainable methods
    - Promote techniques for improved handling and storage of the catch to obtain higher prices
- Encourage members of fishing cooperatives to fulfill their responsibilities

    - Members should all contribute to monitoring and enforcement
    - Members should be encouraged to attend all meetings
- Provide better equipment for fishing cooperatives
    - Gear, boats, and huts for fishing
    - Refrigeration, scales, and transportation for commercialization
- Promote income-generating projects for local communities
- Develop alternative job sources for fishers

Planning

- Create clear and measurable objectives
    - Objectives should be short-term and long-term
    - Possible objectives could relate to the sustainability of fishery resources and increased economic benefits for fishers.
- Prioritize objectives
- Evaluate objectives periodically, as monitoring occurs and there is an increase in data
- If the deployment of more artificial reefs is an option, first address the issues of:
    - Cost
    - Maintenance
    - Design and reef complexity
        - Artificial reefs should have cavities of various sizes and textures, cost permitting
    - Spacing
    - Placement
        - Placement of new reefs should be in areas where the bottom is featureless, to maximize the attraction of fish
    - Material
        - Artificial reefs should continue to be made from concrete as that is the most durable material
    - Monitoring
- Conduct a cost-benefit analysis, to determine if the benefits outweigh the costs

Protection

- Fully protect certain reefs from fishing to enhance the fishery resource
    - May require the deployment of artificial reefs solely for this purpose
- Promote environmental restoration of the bay and surrounding areas. A habitat that is free of pollution and consists of healthy mangrove forests will be more productive than a lesser habitat.
- Strengthen protection for endangered species present, i.e. hawksbill turtles
    - Discourage the use of explosives, longlines, or gillnets

Conclusion

In this project we studied the use of artificial reefs, fishery management strategies, national policy and regulations, and the local practices and opinions of artisanal fishers. Communities will continue to use the natural resources in El Salvador, so sustainable use is essential to meet the needs of people and the environment now and in the future. It is unreasonable to suggest that the resources in the Bay of Jiquilisco should be completely protected or completely exploited. Management for sustainable use is about finding the balance between the two.

This paper has focused on management of artificial reefs in the Bay of Jiquilisco once the reefs have already been deployed. However, if additional artificial reefs will be deployed in the future, there are many other issues to address. An environmental impact assessment, a list of expected benefits, an evaluation of reef designs and placements, and a baseline monitoring study should all occur before justifying the deployment of artificial reefs (Baine 2001).

The Bay of Jiquilisco serves many functions and is important for biological, economic, and social reasons, as well as sustenance for fishers and their families. Thus, it is important to use its natural resources in a sustainable manner, which can benefit both the environment and the communities that rely on it. It has been shown here that management is essential in the sustainability of artificial reefs, with extensive consultation, monitoring, and stakeholder input as valuable parts of the process. Effective management strategies can make the difference between an overexploited reef and a healthy one. The use of artificial reefs have been shown to be beneficial with proper management, and so this project supports their continued use. The lack of effective management could lead to negative effects on the fishery, and thus recommendations have been given to promote education and training, monitoring, research, regulations, development, protection and planning of the reefs. The practice of Pesca Limpia by fishing cooperatives in the Bay of Jiquilisco is a good start towards the sustainable use of fishery resources, but there is more to be done. With these recommendations, the long-term goal is to create economic development, promote cooperation between stakeholders, increase the quality of life in the community, and increase productivity of fishery resources in the Bay of Jiquilisco.

Acknowledgements

This project was developed and completed with the help of Ana Luisa Ahern, Dr. Kathryn Mengerink, Dr. Martin Hall, and Jose “Chema” Maria Argueta.

I am also grateful for the cooperation and support of the many organizations that made this project possible:

Scripps Institution of Oceanography and the Center for Marine Biodiversity and Conservation, EcoViva, Associacion Mangle, La Coordinadora, ICMARES , and the fishing cooperatives practicing Pesca Limpia in the Bay of Jiquilisco: La Vueltona, Acopilar, Acocsile, and Remanzon.

It has been a great experience. Thank you!

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Appendix A

Survey Questions, Asked of Fishing Cooperative Members in the Bay of Jiquilisco

(Spanish)

Edad:
Fecha:
Cooperativa:
Arrecife artificial (si lo hubiere):
Lugar de pesca:

1. ¿Qué artes de pesca utilizas para pescar? (Encierre todas las respuestas apropiadas en un círculo)

   Anzuelo y Cordel — Redes agalleras – tipo y tamaño: _____
   Trampas o nasas — Arpón y careta — Atarraya
   Explosivos — Otros:_____

2. ¿Cuántos días por semana vas a pescar?

   1-2 días — 3-4 días — 5-6 días — Todos los días

3. ¿Cuántas horas diarias normalmente dedicas a pescar?

   1-3 horas — 4-6 horas — 7-9 horas — 10 o más horas

4. ¿Cuál es el número promedio de pescados capturados cada día que usted pesca?

   1-2 libras — 3-5 libras — 6-10 libras
   11-20 libras — 21 o más libras

5. ¿Has pescado usado explosivos?

   Sí — No

6. ¿Con qué frecuencia pesca con explosivos?

   Raramente — A menudo — Todo el tiempo
   Solía utilizar explosivos para pescar, pero ya no lo utilizo

7. ¿Tienes otra actividad económica alterna a la pesca? (En caso afirmativo, ¿cuál es la actividad?)

   Sí — No
   Actividad: _____

8. ¿Eres dueño de la embarcación?

Sí No

9. ¿Forma parte de una cooperativa de pesca?

Sí No

10. ¿Ha escuchado sobre Pesca Limpia?

Sí No

11. ¿Qué opina sobre Pesca Limpia?

Positiva Negativa Indiferente

12. Explique su respuesta a la pregunta anterior.

13. ¿Ha usado un arrecife artificial para la pesca?

Sí No

14. ¿Qué artes de pesca ha utilizado para pescar en un arrecife artificial? (Encierre todas las respuestas apropiadas en un círculo)

Anzuelo y Cordel Redes agalleras – tipo y tamaño: _____
Trampas o nasas Arpón y careta Atarraya
Explosivos Otros:_____

15. ¿Que tan frecuente usted captura fauna asociada en su faena de pesca?

Raramente A menudo Todo el tiempo

16. ¿Que tipo de fauna asociada captura? (Encierre todas las respuestas apropiadas en un círculo)

Otros peces Tortugas Aves
Otros: _____

17. ¿Que hace con la fauna asociada capturada en la faena de pesca?

Libera al agua* Carnada Consumo Comercializa
* viva o muerta?

18. ¿Con qué frecuencia ve tortugas marinas durante la pesca?

Raramente De vez en cuando Todo el tiempo

19. Cuando observa tortugas marinas en playa o estero, qué están haciendo las tortugas? (Encierre todas las respuestas apropiadas en un círculo)

Nadando Comiendo Están atrapadas en equipo de pesca
Muertas Anidando Otros: _____

Appendix B

Survey Questions, Asked of Fishing Cooperative Members in the Bay of Jiquilisco (English)

Age:
Date:
Cooperative:
Artificial reef (if you use it):
Fishing place:

1. What methods do you use to fish? (Circle all that apply)
   - Hook and line
   - Nets – type and size:_____
   - Traps
   - Harpoon
   - Small, round net
   - Explosives
   - Other: _____

2. How many days per week do you go out fishing?
   - 1-2 days
   - 3-4 days
   - 5-6 days
   - Everyday

3. How many hours each day do you typically spend fishing?
   - 1-3 Hours
   - 4-6 hours
   - 7-9 hours
   - 10 or more hours

4. What is the average amount of fish caught each day that you fish?
   - 1-2 pounds
   - 3-5 pounds
   - 6-10 pounds
   - 11-20 pounds
   - 21 or more pounds

5. Have you ever fished using explosives?
   - Yes
   - No

6. How often have you fished using explosives?
   - Rarely
   - Occasionally
   - All the time
   - I used to use explosives to fish, but I don't use it anymore

7. Do you have another job? (If yes, what job?)
   - Yes
   - No
   - Job: _____

8. Do you own a boat?
   - Yes
   - No

9. Are you part of a fishing cooperative?
   - Yes
   - No

10. Have you heard of Pesca Limpia?
    Yes No

11. What is your opinion of Pesca Limpia?
    Positive Negative Indifferent

12. Explain your answer to the previous question.

13. Have you ever used an artificial reef for fishing?
    Yes No

14. Which fishing methods have you used to fish on an artificial reef? (Circle all that apply)
    Hook and line Nets – type and size:_____
    Traps Harpoon Small, round net
    Explosives Other: _____

15. How often do you accidentally catch unwanted animals while fishing?
    Rarely Occasionally All the time

16. What kind of unwanted animals have you caught? (Circle all that apply)
    Other fish Turtles Birds
    Other:_____

17. What do you do with bycatch?
    Release it into the water* Use it as bait Eat it Sell it

    *Alive or dead?

18. How often do you see turtles when fishing?
    Rarely Occasionally All the time

19. When you see turtles in the water, what are the turtles doing?
    Swimming Eating Caught in a fishing gear
    Dead Nesting Other:_____