Economic Viability and Sustainable Management of a Red Abalone Fishing Cooperative

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Abstract

Catch-share management systems that provide fishers with dedicated access to a marine resource have been demonstrated to remedy many shortcomings of open-access fisheries. An opportunity exists to test the use of such a system in California, where a moratorium on the commercial take of red abalone (*Haliotis rufescens*) has been in place since 1997. Evidence suggests that the population at San Miguel Island may now be capable of sustaining fishing effort, leading to the consideration of an experimental fishery at this location. In response, the California Abalone Association has developed a cooperative fishery plan, which, through a co-management agreement with fisheries managers, would provide members with dedicated access to a portion of the red abalone at SMI.

This study evaluated the long-term economic viability and potential for sustainable management of this proposed abalone fishing cooperative. Profits to the cooperative were analyzed by assessing operational costs and by calculating potential catch levels and market prices. We incorporated risk of cooperative closure due to population decline by constructing a matrix-based population model to simulate the growth of abalone under environmental uncertainty. This risk of fishery closure was incorporated with full ranges of possible cost and benefit values in order to calculate the net present value of the fishery, given uncertainty, over a 15-year time horizon. Our results show that even under worst-case scenarios the cooperative remains economically viable. As a further test, we determined that a minimum yearly catch of 3,260 abalone would be needed to maintain economic viability. Finally, case studies of other fisheries were analyzed to provide recommendations for a cooperative structure that would best promote sustainable management of the abalone resource. This work illustrates a method of analysis for the implementation of a cooperative fishery. In doing so, this study helps develop a tool for the management of wild red abalone, while demonstrating the structural characteristics and economic potential of a catch-share fishery management system.

Executive Summary

This project provides analyses and recommendations to support the economic viability and sustainable management of a proposed commercial abalone fishing cooperative at San Miguel Island (SMI), California. In 1997 a moratorium was placed on the commercial take of red abalone (*Haliotis rufescens*) in California. Evidence suggests that the population at SMI may now be capable of sustaining fishing effort, leading the California Fish and Game Commission to consider reopening a commercial fishery on an experimental basis at this location. In response, our client, the California Abalone Association (CAA), has developed a plan for a cooperative fishery that, through a co-management agreement with government managers, would provide members with dedicated access to a portion of the red abalone stock at SMI. Building from the CAA's initial plan, we conducted an economic viability analysis of this proposed fishing cooperative, taking into account uncertainty in both financial and ecological factors. In addition, we drew from cooperative fishery case studies found throughout the globe in order to provide the CAA with management recommendations for improving the economic, ecologic, and social well being of this cooperative fishery should it be opened.

Project Background

The common-pool nature of marine fisheries often leads to economic inefficiency and poor fisheries management (Hilborn et al. 2005, Pauly et al. 2005, Pauly et al. 2002). These symptoms are commonly implicated in the collapse of the California abalone stock that resulted in the fishery's closure in 1997 (Hilborn et al. 2005; Karpov et al. 2000). Since that time, evidence of a recovering stock at SMI (Butterworth et al. 2009; Prince & Valencia 2009) has led fishery managers to consider reopening the fishery on an experimental basis. Catch-share management systems, such as cooperatives, that provide fishers with dedicated access to a resource have been demonstrated to remedy the inefficiencies of open-access fishery factors (Costello et al. 2008). For this reason, a cooperative fishery structure is being considered as one potential management option for this experimental fishery. However, in order for this catch-share fishery to be implemented, some indication of the economic potential and capability for sustainable management is needed. In order to address this need, this project analyzes the economic viability of the proposed catch-share fishery, and provides recommendations for cooperative management practices intended to help ensure the long-term success of this fishery should it be opened.

Benefits, Costs, and Base-Case Analysis

We calculated values for potential benefits and costs to the cooperative. Benefits were quantified as profits resulting from the sale of red abalone. In order to calculate these benefits, we had to develop estimates for the market price of wild red abalone, as no such product is currently available in the United States. We used data from the farmed abalone market, as well as price estimates provided by seafood distributors and restaurants, in order to calculate possible market values for wild caught red abalone. This process resulted in a mean price of $23.03/lb.

We used the initial operating plan proposed by the CAA in conjunction with information provided by fishery enforcement agencies, scientists, case studies, and fisheries managers in order to determine possible expenses, loosely categorized into costs for labeling, fishing, data collection and monitoring, enforcement, taxes, marketing

and transport, and administrative needs. Interviews in conjunction with market and literature research were then used to determine values for each of the costs. Where possible, exact values of costs were determined. In instances of uncertainty, plausible ranges of costs (generally representing high, medium, and low scenarios) were developed. Potential harvest dependent costs (such as fishing expenses and landing taxes) were converted into a function of the total catch in a given year.

Having calculated these values, we conducted an initial analysis of economic viability under base-case scenarios, which represent two possible management options. One, in which the total allowable catch (TAC) is allocated 90% to the cooperative and 10% to the recreational sector (what we term BC90), and one in which the TAC is split 50%-50% between the two sectors (BC50). Using a TAC of 10,728 abalone, corresponding with annual harvests of 9,655 abalone for BC90 and 5,364 for BC50, we found both of these base cases to be economically viable in the first year of the fisheries operation. BC90 yields first year total profits of $506,703, while BC50 results in a value $176,587.

Population Modeling and Risk Assessment

Our base-case results provide initial evidence of the economic viability of the cooperative. However, in order to assess the long-term potential of this fishery, some measure of the abalone population dynamics at SMI are needed. The only available population model at the time of this study, however, is not usable for this study. As such, we developed a stage-structured matrix population model, based off of published studies and survey results, to simulate the dynamics of the abalone stock at SMI over time. Impacts of environmental uncertainty were incorporated using historic trends in environmental health at SMI, in a manner similar to Hobday & Tegner (2002) and Vilchis et al. (2005).

Using this matrix model, the abalone population at SMI was simulated over a 15 year time horizon under three harvest scenarios; no harvest (NH), constant harvest (CH), and adaptive harvest (AH). The NH model was run in order to test the validity of our modeled population, and without harvest our results show an annual rate of growth commensurate with that suggested by survey data conducted at SMI. Having performed this check, we used the CH and AH models to estimate the risk of fishery closure over time. We defined the fishery as being closed if the total population of reproductively mature abalone in any given year drops below the current levels believed to be present at SMI. Once such an event occurs, we rule the fishery as being permanently shut down. While this likely represents a stringent standard for fishery closure, given the politically contentious nature of this proposed fishery we believe this to be a reasonable approach. Using this rule, our model provided a probability of the cooperative remaining open in each year of a 15 year time horizon.

Economic Viability Analysis

We used this risk of fishery decline in conjunction with full ranges of potential benefits and costs in order to conduct a complete economic viability analysis of the cooperative over a 15 year time horizon. We used randomized combinations of possible costs and benefits in order to simulate the profitability of the fishery under a complete array of scenarios, from worst-case (lowest market value, highest operating costs) to best-case (highest market value, lowest operating costs). We ran this model under three scenarios, constant harvest with a 90%-10% split of the TAC between the cooperative and recreational fishers (CH90), constant harvest with a 50%-50% split of the TAC between the cooperative and the recreational fishers (CH50), and an adaptive harvest scenario (AH). Using this method, the net present value (NPV) of the fishery over a 15 year time horizon was calculated, with yearly profits scaled in proportion to a discount rate and our calculated risk of fishery closure.

Our results provide 95% confidence intervals for the NPV of our three scenarios over a 15 year period. The mean profits for the first year of the cooperative's operation were $334,843 (CH50), $724,491(CH90), and $715,420 (AH). To provide an illustrative example, for CH90 this result shows the potential for a single fisher to earn nearly $9,000 in profits per year of fishing. Over the long term, CH50 provides a substantially lower NPV than CH90 or AH. CH90 and AH do not provide statistically different NPVs. However, the AH scenario does contain the potential for much larger annual profits.

Finally, while the AH, CH90, and CH50 scenarios represent three possible divisions of the TAC, they do not represent all possible allocations of catch to the cooperative. In order to allow for the informed discussion of potential harvests for the cooperative, we calculated the minimum amount of catch that would be needed in order for the cooperative to remain economically viable. We determined that a minimum annual catch of 3,260 abalone is needed in order to ensure that the cooperative is able to offset its operational costs. Below this value, the economic viability of the fishery becomes compromised, and the ability of the fishery to support needs such as enforcement and data collection is diminished.

Recommendations for Cooperative Structure

The results of our economic analysis show that the cooperative is financially viable under a wide range of scenarios. However, profitability alone does not ensure the full success of this fishery. As expressed by the CAA, the goal of this cooperative is to develop a community-based management structure capable of both stewarding the abalone resource and providing social benefits. In support of this mission, we conducted a survey of global fishing cooperatives to develop recommendations for the structure of this proposed cooperative.

1. *Reduction of Membership*: Although a small group of fishermen is not necessary to achieve cooperative success, by reducing membership size the cooperative may be able to ease operations and increase efficiency. We modeled four options to reduce membership in order to estimate the potential of these different methods. Our results indicate that it is indeed possible to simulate the entry and exit of members to a cooperative, and suggest that a transferable share system with a cap on individual ownership may be the best option for reducing membership while retaining equity.
2. *Collaborative Research*: Fishers often have highly detailed information regarding the structure and health of the ecosystems in which they work. Effectively paired with scientific tools for fisheries analysis, this local knowledge often allows for improved management of marine resources. By collaborating with the scientific community, this cooperative could help move methods for abalone management away from broad-scale practices, and towards a fine-scale spatial management system. Doing so may reduce the impacts of fishing, improve the resiliency of the fishery, and potentially increase profits to the cooperative over time.

3. *Rotational Harvest*: The development of a rotational harvest system, in which fishing pressure is distributed throughout the area of the cooperative, can serve to alleviate localized overfishing and depletion.
4. *Internal Guidelines*: Clearly defined internal regulations can improve the efficiency of the fishery and allow for more open and organized operations. In addition, by establishing set penalties and rules for liability, the cooperative can help ensure compliance with both internal and external regulations.
5. *Coordinated Marketing*: By coordinating selling to prime portions of the year and focusing on quality over quantity of catch, the cooperative can substantially increase the value of their harvest with little to no additional fishing effort.
6. *Poaching*: Poaching is a severe problem for many abalone fisheries. Should a cooperative fishery be reopened, a number of mechanisms are available to reduce the risk of poaching. These include the use of tracing systems, self enforcement by the cooperative (as well as collaboration with government officials), and the use of spatial separation between the commercial and recreational sector. In addition, by creating a clearly defined brand of legally obtained wild abalone, the demand for poached animals may be reduced.
7. *Global Abalone Market*: The costs of marketing abalone globally would be excessive due to the distances and time required for transport. Prices on the global market are comparable with the local market values we calculated for wild abalone. Given these facts we recommend that the CAA focus their efforts on selling locally.

Conclusions

The results of our analysis indicate that a commercial abalone fishing cooperative at SMI is economically viable under a wide array of potential scenarios. However, this finding illustrates more than just the profitability of a business enterprise. The financial viability of this proposed cooperative demonstrates and creates a powerful reason for stewardship. By calculating the economic potential of this venture, we provide a tangible measure of the value to be gained in sustainably managing the stock at SMI. In addition, our economic viability analysis provides a concrete assessment of the ability of a cooperative fishery to financially support both enforcement and data collection efforts at SMI. Numerous other cooperative fisheries across the world have demonstrated the potential of dedicated-access incentives for fishers leading to improved science and management for the fishery as a whole. The positive result of our economic viability analysis demonstrates that this pattern could be a reality for the SMI red abalone fishery as well.

Our research shows that a cooperative abalone fishery at SMI can be economically, ecologically, and socially beneficial. As such, if an abalone fishery is to be opened at SMI, we recommend it be opened in the form of a cooperative. This method of catch-share management stands to provide the greatest benefit to both the resource and the community. Great care must be taken in the design and management of this catch-share fishery should it be opened. Properly implemented though, this cooperative presents an opportunity to demonstrate and develop a system for the sustainable use and community management of marine resources.

Acronym List

AAG – Abalone Advisory Group
AAUS – American Association of Underwater Scientists
AH – Adaptive Harvest
ARMP – Abalone Recovery and Management Plan
BC50 – Base Case with 50% commercial, 50% recreational TAC split
BC90 – Base Case with 90% commercial, 10% recreational TAC split
CAA – California Abalone Association
CDFG – California Department of Fish and Game
CFGG – California Fish and Game Commission
CH – Constant Harvest
CH50 – Constant Harvest with 50% commercial, 50% recreational TAC split
CH90 – Constant Harvest with 90% commercial, 10% recreational TAC split
CMLMA – California Marine Life Management Act
CPUE – Catch Per Unit Effort
EVA – Economic Viability Analysis
FCMA – Fisherman's Collective Marketing Act
ITQ – Individual Transferable Quota
LML – Legal Minimum Length
MOU – Memorandum of Understanding
MSC – Marine Stewardship Council
MSY – Maximum Sustainable Yield
NH – No Harvest
NPV – Net Present Value
RBL – Rogers-Bennett & Leaf model
SMI – San Miguel Island
TAC – Total Allowable Catch
TURFs – Territorial User Rights Fisheries
UCSB – University of California, Santa Barbara
UHA – Underwater Harvesters' Association
UNCLOS – United Nations' Convention on Law of the Sea
VADA – Victorian Abalone Divers Association
VML – Voluntary Minimum Length
WADA – Western Abalone Divers Association
WFS – Withering Foot Syndrome

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Research Objectives

The purpose of this thesis is to provide analysis and recommendations to support the economic viability and sustainable management of a proposed commercial abalone fishing cooperative at San Miguel Island (SMI), California (CA). The CA commercial abalone fishery has been shut down since 1997, as a result of stock declines stemming from a variety of factors. Our client, the California Abalone Association (CAA) represents a group of fishers from the former abalone industry. In response to the rebuilding of the red abalone stock at SMI, the California Department of Fish and Game (CDFG) is considering opening an experimental fishery on the southwestern corner of the Island. The CAA has put forward a proposal that this fishery take the form of a cooperative, made up of former members of the commercial abalone fishery.

Substantial anecdotal and academic information suggests that catch-share fisheries, such as cooperatives, provide a solution to shortcomings of open-access fishery that resulted in the closure of the California abalone industry. In order for a cooperative to be successful though, economic incentives and individually tailored management practices must be implemented. In order to address this need, this project

-Assessed revenue streams and operational costs facing the potential cooperative

-Considered the effect that environmental uncertainty and fishing pressure may have on the viability of the SMI abalone stock

-Utilized case studies from fishing cooperatives from around the world to develop and analyze specific recommendations for the internal operation of the cooperative

-Synthesized our results in order to create a comprehensive economic viability analysis of the proposed fishery, as well as provide a set of management practices designed to improve the long-term success and sustainability of the cooperative

The product of this analysis will both support the CAA, as well as benefit a broader base of stakeholders. By providing data on the potential structure and performance of this fishery, we provide currently missing information for use by fishery participants, managers, and interested stakeholders in considering the future of the abalone stock at SMI. Should the fishery be opened, our analysis provides a clear assessment of the financial benefits of this action. In addition, by calculating the long-term the economic performance of the fishery, we demonstrate a powerful incentive for stewardship of the resource by the members of cooperative. In doing so, our study hopes to support a fishery that will demonstrate a new and successful method for the management of California abalone, and provide a model for the sustainable management of marine resources.

Project Background

Management and State of Global Fisheries

The history of many global marine fisheries has been one of ever-increasing effort, resulting in shrinking stocks and growing economic costs (Hilborn et al. 2005; Pauly et al. 2005; Pauly et al. 2002). The common-pool nature of marine fisheries commonly creates misaligned economic incentives. While it is in the best interest of global fisheries to operate in a sustainable fashion, for individual people or nations, the natural course of action is to capture as much fish as possible before a rival fleet harvests the catch (Costello et al. 2008). This intense competition, symptomatic of open-access fisheries, results in the "race to fish", in which participants in the fishery continually increase fishing effort in order to maximize their catch, resulting in ecological damage and inefficient methods and levels of harvest (Costello et al. 2008, Deacon & Costello 2007; Hilborn et al. 2005).

Beginning largely with the signing of the United Nations' Convention on Law of the Sea (UNCLOS) in 1982, a number of management methods have been put in to practice across the globe in an effort to curb the overexploitation of oceanic fisheries. Typical fisheries management approaches focus on maximizing the catch of a single species, often through the use of a total allowable catch (TAC), guided by a calculation of maximum sustained yield (MSY) (Pikitch et al. 2004; Ludwig et al. 1993). This MSY principle is based on the practice of fishing the population down to the level that results in the greatest reproductive yield in the following year (Fujita et al. 1998). Given the poor data, enforcement, or management capabilities available to many fisheries though, in reality MSY-based management is often not sustainable or effective (Larkin 1977). While these MSY based efforts have functioned to slow fishing efforts some, the majority of global fisheries have continued to decline as stocks are chronically over harvested (Pauly et al. 2005).

The net result of commercial fishing has been a decline in global fisheries stock, damage to marine ecosystems, and increased fishing efforts yielding decreasing catch (Jackson et al. 2001; Pauly et al. 2002; Zeller & Pauly 2005; Worm et al. 2009). In their research, Myers & Worm (2003) found that modern commercial fishing practices resulted in an 80% decline of fish stocks within 15 years of industrialized exploitation. Subsequently, the total population of large predatory marine species has dropped by nearly 90% (Myers & Worm 2003). Over time, global fishing fleets have begun targeting increasingly lower trophic levels of organisms (Pauly et al. 1998). Whether this is indicative of fisheries moving down food webs due to over harvesting of top predators (fishing down food webs) or simply increased targeting of lower trophic level organisms (fishing through food webs) is a matter of debate (Essington et al. 2006; Pauly et al. 1998). Regardless, what is clear is that fishing fleets have continued to target new groups of organisms, further increasing the human impact on the marine environment. Numerous studies and reviews have documented the subsequent decline in global fish stocks and the impacts of this overfishing on the marine environment (Gewin 2004, Jackson et al. 2001, Pauly et al. 2002). Habitat has been destroyed, ecosystems restructured, non-target species lost, and stocks depleted (U.S. Commission on Ocean Policy 2004). This has left historic productive fishing grounds either over-exploited or abandoned (Myers & Worm 2003).

Chronic overfishing has resulted in fisheries experiencing a "pulsing" effect where catch diminishes and jobs are lost until new technology or a new stock revitalizes the industry, encouraging more fishermen to enter into the market. As stated by Ludwig et al. (1993), this pattern is kept alive through subsidies, therefore delaying the realization that open access management is often severely flawed. The extent of these subsidies has been estimated as $14-20 billion per year globally, often paid not by participants in the industry but rather in taxpayer dollars (Hilborn et al. 2005, World Bank 1998). The extent of these subsidies reflects the economic inefficiency of current global fisheries. These subsidies have kept fisheries industries growing, despite the fact that for many stocks, fishing effort is already at levels far higher than is economically efficient (Hilborn et al. 2005). This process has served to further amplify the pressures exerted on global marine fish stocks.

Examples of specific fisheries collapses stemming from this mismanagement include the Pacific salmon, the California sardine, and Peruvian anchoveta (Ludwig et al. 1993). There have been many alternative methods developed in an effort to better manage fish stocks. Marine protected areas (MPAs), ecosystem based management, adaptive management and the precautionary principle are all tools that have been utilized in fisheries management. However, in general none of these practices have been able to fully resolve the racing nature of open-access fisheries (Lubchenco et al. 2003; Hilborn et al. 2004).

The Case for a Cooperative Fishery

While examining global fisheries as a whole paints a bleak picture of the health of ocean fish stocks, recent studies such as those by (Worm et al. 2009) (Hilborn et al. 2005) and (Costello et al. 2008) have shown that by examining individual fisheries rather than the global industry, many instances of successful and sustainable fishing management can be found. Fisheries for species such as scallop, salmon, abalone, geoduck, and lobster in locations across the world have developed sustainable management practices (See Appendix 1 for an expansion on these examples). A common trait between these successful fisheries has been the use of designated fishing rights to alleviate the race for fish. This approach has been successfully used for centuries, particularly in island communities where families are granted exclusive fishing rights to fishing grounds in a practice customary marine tenure (Grafton et al. 2006; Johannes 2002). These catch-share systems have been shown to slow or even reverse the stock collapses endemic to open access fisheries (Costello et al. 2008). Therefore, while much attention has focused on the failures of fisheries management the situation should not be viewed as hopeless.

Rather than continuing to emphasize which elements of management do not work it is more important to understand key characteristics of management successes. There are commonalities shared between most forms of catch-share fisheries management. Central to this from of management is the principle that fishermen are guaranteed some percentage of the season's catch or effort, and are considered shareholders in the fishery. Under this design, secure dedicated access rights may further strengthen the security of their shares. Subsequently, catch-share systems have the potential to eliminate the race to fish and its associated detrimental impacts (Beddington et al. 2007). As has been shown in multiple cases, once fishermen believe they have long-term security over their resource they receive a powerful incentive to become stewards of the resource, knowing that in doing so the value of their stock will increase (Fujita & Bonzon 2005). This leads to greater economic efficiency, improved and safer fishing practices, and increased stewardship of the resource (Criddle & Macinko 2000). Although this basic structure is inherent to the design of a catch-share system, many different management methods exist for the actual creation and allocation of these dedicated access fisheries.

One such method of catch-share management utilizes spatial allocation to divide fishing grounds into units called territorial user rights fisheries (TURFs). Under TURF management, each fisherman or group of fishermen is granted exclusive access to a specified fishing area. Within an individual TURF, there are often harvest and gear restrictions to compliment spatial management and to prevent overharvesting. This is particularly important when fishing for mobile species that may travel in between adjacent TURFs (Holland 2004). The use of individual transferable quotas (ITQs) is another type of catch-share management. Under ITQ management, fishers are allocated a percentage of the season's catch and are guaranteed a harvest corresponding to this percentage (Fujita et al. 1998). The harvest associated with each share often fluctuates annually with changes in the TAC that are deemed necessary by fisheries scientists (Criddle & Macinko 2000). A third type of management utilizing catch-shares is the formation of a fishing cooperative. Cooperative management often represents a co-management agreement between fishermen and the government regarding operation of the fishery (Sen & Raakjaer Nielsen 1996). There are many ways that a cooperative can be designed, but generally, the government or management authority sets a form of catch limit for the season, and it becomes the responsibility of the cooperative to decide how to allocate the shares amongst its members. Cooperatives, using fishing profits, often self-fund the research, enforcement, and monitoring costs, reducing the burden placed on the government (Criddle & Macinko 2000). In doing so, cooperative fisheries often act as a means of community-level management of a resource, helping fishers move from "individual hunters to collective harvesters (J. Cooper pers. comm.). As a cooperative fishery is the management style being proposed by our client the CAA, it is this form of dedicated access that will be the focus of this study. In order to more clearly understand how a cooperative functions we will look at two case studies in detail.

Case Studies of Cooperative Fisheries Management

Case studies of the use of cooperatives in fishery management can be found throughout the world, in locations as diverse as North America, South America, Africa, Oceania, New Zealand, Australia, Europe and Asia (Townsend & Shotton 2008). More important to this study is the evidence of cooperative management of sedentary/sessile species such as abalone. Because the species of interest is inherent to the design of the cooperative, here we will focus on two fisheries with characteristics similar to that of the potential California red abalone fishery. Both the Challenger Scallop Enhancement Company of New Zealand (Challenger) and the Western Abalone Diver's Association (WADA) of New Zealand are dedicated access fisheries that, after experiencing stock declines, voluntarily began utilizing principles of cooperative fisheries management to improve the sustainability of their industry and prevent future fishery collapses.

Challenger reformatted their structure into that of a cooperative in 1994. They did so in order to begin collectively managing the scallop stock, rather than individually competing for common resource. Each quota holder in the fishery is considered a shareholder and cooperative decisions are made collaboratively with votes proportional to quota ownership. Challenger uses rotational harvest to manage individual "beds" of scallop. The fishing area of the cooperative is divided into zones, and throughout the season harvest is rotated throughout the zones, allowing depleting stocks to recover. In addition, each year a portion of the fishery is left completely closed to scallop fishing, allowing the population in these locations to recover. Challenger's changes and efforts have shown positive effects. Despite closures of specific zones, since the creation of Challenger average annual yields to the cooperative have increased over time. Subsequently the fishery has developed into a multi-million dollar business (Leal et al. 2008). In addition they have been able to develop high-resolution fishery data that was previously missing. By coordinating their efforts, members of the Challenger Scallop Enhancement Company have increased their profits and enhanced the long-term sustainability of the fishery (Mincher 2008).

Similar achievements have been made in Australia, by the WADA. Australia is the largest wild abalone producer in the world. Unlike many cases of collapse in abalone fisheries worldwide, Australia's abalone industry has taken careful steps to avoid the status quo of overexploitation and collapse (Prince et al. 1998). Despite these efforts though, in recent years abalone divers have reported losses in productive areas and government officials have reduced TACs regionally (Prince et al. 2008a). The WADA was historically managed through legal minimum lengths (LMLs) and TACs, but these measures have not prevented the over-harvest of micro-stocks. This is due to the localized nature of abalone populations. Given the low connectivity within sub-populations within a larger abalone fishery, some beds may remain stable others within the same region may collapse from overfishing or environmental factors (Prince et al. 1998). Subsequently the WADA found some of their micro-stocks were becoming depleted. They responded by voluntarily adopting a new harvest plan (Prince et al. 2008). The WADA began to use rapid visual assessment in conjunction with a decision tree rule to develop management plans for individual reefs based on their health (Prince et al. 2008). Once the reefs are evaluated voluntary minimum lengths (VMLs) and catch levels are assigned and harvest zones are designated to the members, based on a rotational harvest similar to that employed by Challenger. Initially members were suspicious of the cooperative structure, but their support was gained after they saw depleted micro-stocks rebound (Prince et al. 2008a). Since their voluntary formation the WADA has agreed to a memorandum of understanding (MOU) with the government which has resulted in 95% compliance with the organization's regulatory measures (Prince et al. 2008). Additionally they have increased their collaboration with scientists to broaden their understanding of a data poor fishery. In response to their success other abalone associations in Australia have followed suit.

There are many other examples of cooperatives being both economically and ecologically successful; however there are also case studies of cooperative management failures (Prince et al. 2008). This places emphasis on the importance of design and structure. The above case studies help to support the formation of a California abalone cooperative, but the operating structure, economics, and environmental characteristics of the fishery will ultimately determine its potential for success. Currently there are three primary options being considered by the California Department of Fish and Game for a red abalone fishery: no fishery, a transplant fishery, an evenly divided fishery between recreational and commercial components, or a experimental fishery centered around the formation of a cooperative. Numerous studies as well as our personal research of catch-share management have demonstrated the potential benefits achieved by cooperatives (Appendix 1). If a fishery does open at SMI, the cooperative structure has a greater potential to promote environmental and economic success relative to traditional fisheries management system, and stands to become a significant partner in the research and management of the abalone stock. Taken together, these points support the case for a cooperative at San Miguel Island should a fishery be put in place.

The California Abalone Industry

Having discussed the broader issues of fisheries management relevant to this study, we now turn our attention to the specific case of the California abalone fishery. The California abalone industry is a model example of the discussed failures of traditional fisheries management. The fishery was closed until 1942 and reopened during World War II in order to increase wartime food production (CDFG 2001). Regulations were implemented to control harvest and effort, such size limits and a seasonal TAC. Red abalone landings increased from 1942 until 1967, but by 1967, intense fishing pressure caused the population to decline, resulting in a gradual decrease in landings until 1982. In the years after 1982, landings numbers stabilized as fishing efforts for red abalone expanded to the new grounds of San Miguel, the northern-most of the Channel Islands. Even with this expansion in fishing grounds however, the statewide red abalone catch in 1996 was 87 tons, a mere 10% of the historical peak catch in the 1960s (Karpov et al. 2000). The poor state of the population led to a commercial moratorium on abalone in 1997. The collapse of the stock and subsequent closure of the fishery was a tragedy for fishermen, fisheries managers, and marine ecosystems all along the California coast.

The history of the California abalone fishery demonstrates that regulations were ineffective at managing the fishery and preventing the collapse of California abalone populations. The management structure and subsequent economic incentives in place at the time resulted in poor allocation of the resource and a lack of suitable data. The abalone fishery was managed as a multi-species fishery, consisting of red, pink, black, green, and white abalone, and landings for individual abalone species were not considered. This led to two principle problems. First, management used the total combined species landings as an indicator of stock health (CDFG 2001). Therefore, as red abalone started to decline, fishermen began to land pink abalone, and the overall catch remained relatively constant, masking the trends in individual species abundance (Karpov et al. 2000). Secondly, abalone population dynamics occur at very small scales, often on the order of 10-100 meters. Each species of abalone consists of many "micro-stocks," each of which reach sexual maturity at different stages and have different larval dispersal patterns. As a result, a statewide TAC that is set even for a single species of abalone is unreliable. Instead, management needs to be tailored to the biology and ecology of each of these individual "micro-stocks" (Prince 2003). In the period of the commercial fishery though, the abalone were managed instead through the use of large-scale management practices.

An additional factor contributing to the collapse of the California abalone fishery was that management efforts were based on an egg-per-recruit model, which assumes that successful recruitment occurs every year (Karpov et al. 1999). However, this assumption is inaccurate for abalone. Abalone require a minimum population density for successful spawning, and intense fishing pressure, coupled with unfavorable environmental conditions, can lead to population densities that are well below this minimum threshold (Prince et al. 1998; Prince et al. 2008). A five-year study of red abalone recruitment on Santa Rosa Island showed that significant successful recruitment occurred only once during a five-year study period (Tegner et al. 1989). This misunderstanding of the true nature of California abalone population dynamics resulted in a size limit and harvest restrictions per trip that could not ensure the sustainability of the stock. As abalone management lacked any protocols for dealing with additional stressors like diseases (such as withering foot syndrome (WFS)), pollution, or oscillations in temperature during El Niño years, this management structure placed the population in further danger of depletion. In addition, management efforts depended on catch per unit effort (CPUE) data as an indicator of stock health, assuming that greater catch per unit effort signifies higher fish abundance. CPUE relies on the assumption that stocks are mobile. Therefore CPUE is not an appropriate management tool for sessile species such as abalone. Improvements in technology such as GPS to locate fishing grounds increased efficiency, rendering CPUE data useless for monitoring stock trends (Karpov et al. 2000).

Finally, conservation efforts were undermined by the rising value of abalone in the market. As landings decreased, ex-vessel prices were increasing, and foreign demand was on the rise. As a result, political pressure to keep the fishery open was mounting (Karpov et al. 2000). Despite this increase in market value, the commercial landing tax was limited to a mere $0.03 per kilogram until the 1990s when an additional enhancement and restoration tax was instated, raising the total landing tax to $0.43 per kilogram. This tax revenue was used to restock abalone habitats with juveniles reared at aquaculture facilities, rather than for improving data collection and stock assessment methods. Juvenile restocking efforts had a success rate of less than 1%, resulting in the little positive effect coming from this expenditure (Karpov et al. 2000). These factors, combined with increased poaching and a relatively unmonitored recreational fishery, led to further decline in the stocks (CDFG 2005).

Factors such as inaccurate stock assessments, expanding market pressures, disease and overfishing resulted directly then in the closure of the California abalone industry, and are also indicative of the broader shortcomings of open access fisheries. Without having vested interest in the sustainability of the stock, fishers had little incentive to demand accurate stock data, precautionary management, or reductions in catch levels. While CPUE for the industry as a whole was declining, the high price commanded by abalone still led individual fishermen to enter the market so as to obtain some of the potential profits. Taxes were used towards restocking efforts rather than improving overall management practices, since there existed little incentive to invest capital in a management system in which fishermen had no actual stake.

Since the moratorium, many California abalone populations have displayed some evidence of recovery. Surveys assessments suggest that the abalone population at SMI may be sufficiently recovered and stable to support a small scale experimental fishery (Butterworth et al. 2009; Prince & Valencia 2009). In response, among a set of possible alternatives, the California Fish and Game Commission is currently considering opening an experimental commercial red abalone fishery at SMI.

The California Abalone Cooperative

Under the Abalone Recovery and Management Plan (ARMP), Alternative 8 allows the California Fish and Game Commission to consider a lift on the moratorium for abalone fisheries in specific locations that have partially recovered prior to achieving Recovery Criterion 3 (which requires that 3/4 of the recovery areas have achieved a specified density) as defined in the ARMP (CDFG 2005). Red abalone at SMI (Fig.1) qualify for Alternative 8 using a reduced density criterion that shows a viable abalone population with a broad size range exists at SMI. In addition, the red abalone at SMI, although patchy in population density, show evidence of recovery, further supporting its qualification for a local lifting of the moratorium under Alternative 8 (Butterworth et al. 2009; Prince & Valencia 2009). However, the California Fish and Game Commission will not consider opening the SMI red abalone fishery unless certain guidelines are followed that address concerns such as the Total Allowable Catch (TAC), allocation between the recreational and commercial fisheries, as well as regulatory and enforcement measures that ensure the ecological viability of the stock is retained (CDFG 2005). Given these needs the CAA developed a plan that is supported in the California Marine Life Management Act's (CMLMA) Restricted Access Policy (CFGC 1999). The Restricted Access Policy recommends using restricted access as a management tool to end the "race for fish" by matching the level of effort to the health of the resource, giving participants a stake in the long-term sustainability of the fishery, providing social and economic benefits over the life of the fishery, and shared enforcement/management between the participants and the Department of Fish and Game (CFGC 1999). In order for these benefits to occur a significant fleet size reduction is likely to be required. This can be achieved through the implementation of a community-based fishermen harvesting and marketing cooperative as defined by the guidelines of the Fishermen's Collective Marketing Act (FCMA).

The CAA has developed an operating structure for the California Abalone Cooperative. The mission of the plan states that "The California Abalone Cooperative places the health and habitat of the abalone resource above all other considerations and will co-manage an abalone fishery while recognizing the link between stewardship of the resource above all other considerations and will co-manage an abalone fishery while recognizing the link between stewardship of the resource and a successful cooperative (CAA 2009)." In pursuance of their mission statement the California Abalone Cooperative has set both economic and ecological goals deemed inherent to their success. Through their cooperative design they intend to enhance the abalone resource while still maintaining economic profits to their participants, reduce management and enforcement costs, and improve relations between the fishermen, authorities, and community. Especially essential to fulfillment of their goals, the California Abalone Cooperative intends to achieve comprehensive sustainable fishery management at a lower cost than under open-access by pooling their catches and profits, and efforts (CAA 2009). This process has been shown to be effective in other fishing cooperatives (Deacon & Costello 2008), though often the actual operational costs are seen to increase in cooperative fisheries (for examples see Makino & Matsuda 2005, Mincher 2008).

Upon examining the previous failures of the California abalone industry, and lessons learned at great expense in other fisheries, it becomes clear that a new method of fisheries management is needed if the abalone fishery is to be successfully reopened. The recent body of work demonstrating the efficacy of catch-share systems (Costello et al. 2008, Worm et al. 2009) in solving the historic shortcomings of open-access fisheries has led the CAA to propose a cooperative design as the management structure for their proposed commercial abalone fishery. The CAA hopes to create a management system tailored to the specific needs and challenges of the San Miguel Island (SMI) abalone fishery. If successfully implemented, the cooperative could potentially serve as an example of how a catch-share based fishing system might be implemented in place of traditional fisheries management in California. The cooperative could also help to address some of the factors responsible for the collapse of the fishery. For example, problems associated with inaccurate stock assessments and poaching could be alleviated by incentivizing fishermen to contribute to data collection and enforcement, as has been seen in numerous cooperatives worldwide (Appendix 1). The cooperative would have the potential to place an emphasis on data collection and record keeping in order to help maintain valid and useful stock assessments. These assessments would then be capable of analyzing the population of abalone at SMI down to the micro-stock (or "bed") level on SMI. Micro-stock assessments are vital when setting ecologically sustainable catch limits capable of adapting to changing stock sizes (Prince 2003). Poaching and black market trade of abalone are significant issues that may also be addressed by the CAA cooperative. Lax governmental oversight, improperly regulated markets, high profit margins, and ease of access have created conditions ideal for abalone poaching at both large and small scales (Raemaekers and Britz 2009; Daniels and Floren 1998). Prince (2003) argues that involving abalone fishermen in the data collection and management process is the key to overcoming these issues. By establishing a fishing cooperative in which the members have communal rights and access to the fish stock, a sense of stewardship can be created among fishers. This would help reduce over-exploitation and invoke self-regulation, thus enhancing the fishery's capability for success. With careful

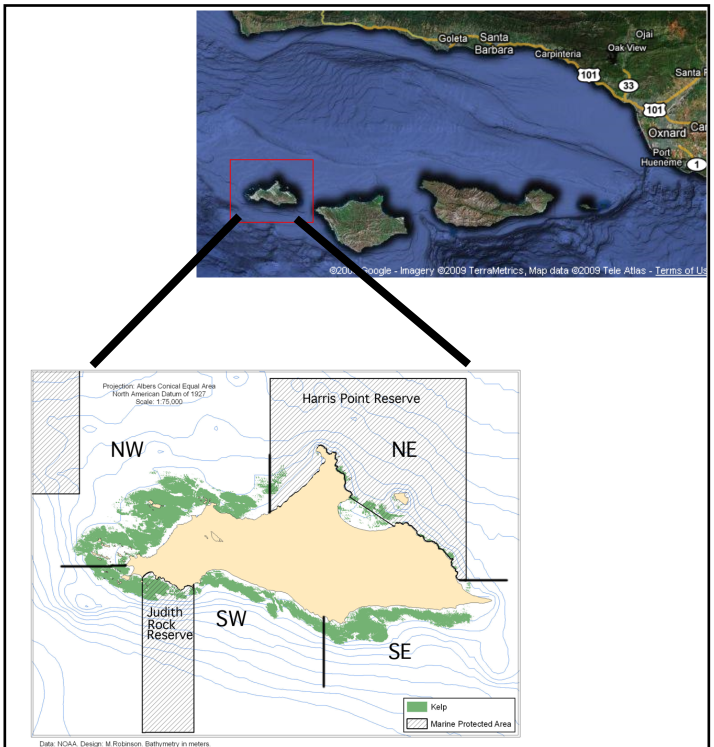


Figure 1. Map of San Miguel Island, the site of the proposed fishery

and informed decision making the abalone cooperative has the potential to address the issues responsible for the initial fishery collapse and to operate in a sustainable manner.

Project Objectives

The CAA has developed a strong initial framework for their cooperative. Extensive work has been conducted creating an operating structure that the fishers feel would best serve the interests of their members and the resource. However, additional knowledge is needed to support the success of this venture, should the cooperative be opened. The economic viability of the cooperative is a primary concern for its members. In addition, questions about stock status and management structure remain of great importance. This project serves to fill these knowledge gaps by providing comprehensive economic analyses and management recommendations for the CAA.

We approached this process first by analyzing the costs and benefits that will potentially be faced by the cooperative. While the CAA has developed a general idea of operating costs and revenue streams, they have not explicitly calculated these numbers. We examined the operating structure proposed by the CAA, and developed values or ranges for costs that we foresee being borne by the cooperative. Early evaluations of cooperative profits were based off of historical prices for abalone at the time of the fishery's closure. In order to refine this estimate, we researched abalone farms, seafood distributors, and likely client restaurants to develop a range of possible prices for wild caught abalone brought to market by the cooperative.

In attempting to analyze the long-term economic viability of the cooperative, some measure of the abalone stock size and stability is needed. Unfortunately, no model existed which was capable of providing data for the length of time required for this analysis. Therefore, using best available data we constructed a size structured population model of red abalone at SMI. By incorporating possible fluctuations in environmental health, we modeled the growth of the abalone population under a range of harvest scenarios. This analysis provided a measure of probability of the fishery remaining open over time, given the possibility of changes in the population dynamics of the abalone at SMI.

These potential revenues and risks were incorporated into a economic viability model, capable of assessing the profitability of the cooperative under a range of scenarios. We first provide an economic analysis of a base-case scenario, in which we include what we believe are likely costs and benefits to the cooperative. In order to fully assess the economic viability of the cooperative though, we developed a model simulating a wide range of possible costs and benefits, in order to create confidence intervals of financial outcomes for the cooperative. This model was run under three catch scenarios, a 90%-10% split of the TAC between the coop and the recreational component (referred to as CH90), a 50%-50% split (CH50) with the recreational component, and an adaptive harvesting (AH) strategy. This method provides a robust assessment of the economic viability of the cooperative given a suite of management scenarios and revenue uncertainty faced by the CAA.

We also we developed recommendations for the internal management of the fishery, should it be opened. Customization of design is critical to the success of a cooperative fishery. While numerous studies provide evidence of the benefits of catch-share management, little information exists laying out the characteristics and successful management practices of these fisheries. In order to address this lack of data, we conducted a survey of fishing cooperatives found around the globe, in order to assess causes for the successes and failures of these enterprises. These findings were then incorporated into recommendations for the structure of the CAA's cooperative design.

Our results indicate that the cooperative is economically viable under a broad range of likely scenarios. This comprehensive analysis of management options provides tangible evidence of the costs and benefits of choices facing both fishers and regulators. This will allow for greater clarity in the decision making process, and create a means for more informed debate.

Economic Viability Analysis

Our economic viability analysis is divided into two general sections: assessment of basic costs and benefits, and incorporation of uncertainty. Throughout these sections, we will discuss several possible quantities of catch that may be allocated to the cooperative. In our initial assessment, we outline the calculation and resulting values for the cooperative's costs and benefits. These include factors such as wild red abalone market price, as well as costs associated with fishing, data collection and monitoring, day-to-day operations, administrative activities, and support of enforcement. However, many of these values vary, either as a result of uncertainty, or as a function of some parameter such as the annual catch. Therefore, in order to provide a clear example of our methods we first present illustrative "base-case" scenarios, that represent initial economic viability assessments of likely collections of variables. These base cases will cover two potential allocation scenarios between the commercial and recreational sectors, a 90%-10% split of the TAC between the cooperative and the recreational sector (BC90) and a 50%-50% split (BC50).

For the second phase of our analysis, we incorporate uncertainty in both population dynamics and economic variables. Changes in the abalone stock at SMI were incorporated through the calculation of a risk of fishery decline, reflective of both environmental and harvest pressures. This risk of fishery closure was used to discount the future value of the fishery. Economic uncertainty was incorporated through the use of a Monte Carlo sensitivity analysis, which utilized full ranges of potential costs and revenues in order to model the profitability of the cooperative under a full array of possible values for three harvest scenarios, a 90-10% division of the TAC (CH90), a 50%-50% division (CH50), and an adaptive harvest system in which catch varies each year (AH). This method provides a robust calculation of the economic viability of this fishery over the 15 year span of this study.

Financial Variables

The following sections present the calculations and results for the financial variables of the cooperative. We first present a description of our revenue calculations, followed by our methods and resulting values for costs. The resulting costs and revenues for use in our analysis are presented in Table.3 .

Total Allowable Catch

The TAC used in this study was developed from the work and interpretations of Butterworth et al. (2009) and Prince & Valencia (2009). For the majority of our analyses, we will utilize a TAC of 10,728 abalone sized 203 mm and larger. This TAC is intended to represent an annual catch of 10% of the abalone of this size class believed to be present at the southwestern corner of SMI, or 1% of the total abalone population at SMI (Prince & Valencia 2009).

	90%-10%	50%-50%
Annual Catch	9,655	5,364

Table 1. Total annual catch (abalone over 203 mm in length) allocated to the cooperative under 90%-10% and 50%-50% divisions of the TAC

The actual proportions of this TAC that will be allocated to the cooperative in this study were based of options presented before the Abalone Advisory Group (AAG).

The two most likely allocations of the TAC are either a split of 90% to the cooperative and 10% to the recreational sector, or a 50%-50% split between the commercial and recreational fisheries. For the 90%-10% scenario then, the total catch allocated to the cooperative is 9,655 abalone. For the 50%-50% split, this value is 5,364. These results are summarized in Table.1, and will be utilized repeatedly in this study. In our Monte Carlo analysis, we will also model an adaptive harvest (AH) scenario, in which the catch allocated to the cooperative is dependent on the population size in a given year. This AH analysis will be described in detail in our section titled Monte Carlo Sensitivity Analysis (page.42).

Revenue

Determining Market Value and Demand for Wild Red Abalone

In order to calculate the total benefits to the cooperative, it was necessary to determine the market value for wild red abalone. This poses a challenge because there is currently no wild abalone market that exists in the United States. However, there are a number of abalone operations along the California coast that produce smaller farmed abalone. We used prices for this farmed product in order to provide an initial estimate of the market value of abalone. We contacted abalone farms and restaurants that serve farmed abalone. From these telephone interviews, we were able to obtain farmed prices from four abalone farms and ten restaurants. Farmed prices ranged from $11-24 per pound, with an average reported price of $17.35 per pound. Abalone farms also reported that demand is highest in the summer, due to tourism, as well as over the winter holidays.

In other fisheries though, it is seen that the wild product often sells for a higher price than the farmed product. As such, we expect the SMI wild abalone to be priced slightly higher than farmed abalone. In order to account for this price premium for SMI wild abalone, we conducted telephone interviews with 19 California-based seafood distribution companies and 33 high-end seafood restaurants across the United States that carry unique and sustainable seafood products. During these interviews, we used the following talking points to describe the SMI wild abalone product:

- Fresh, live, and in the shell
- Sustainably harvested
- Diameter of 8 inches or larger, average weight of 4 pounds
- Available year round, with a total harvest limited to 10,728 animals

By using this description in each of our interviews, we were able to standardize our responses and help ensure accurate estimates of wild abalone market prices.

Resulting Market Price of Wild Red Abalone and Total Annual Revenue

The results from our market research are shown in Fig.2. From our telephone interviews, we obtained price estimates for SMI wild red abalone from 20 contacts. Price estimates ranged from $16-$35 per pound, with a mean price estimate of $23.20 (See Fig.14 for frequency histogram of reported prices).

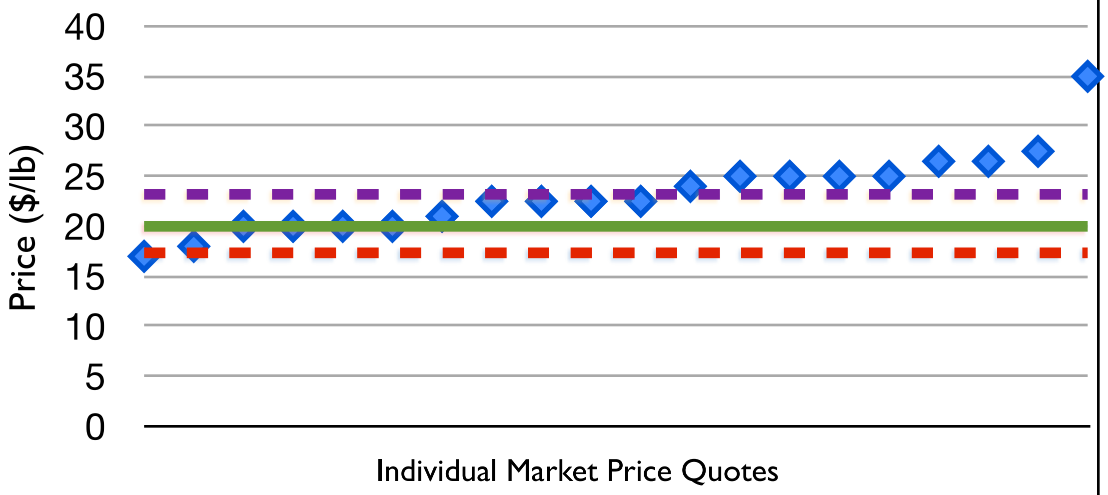


Figure 2. Summary of market research for price of wild abalone. The blue diamonds represent reported prices for wild red abalone. The purple dashed line represents the mean reported wild price, $23.20/lb. The red dashed line indicates the mean reported price for farmed red abalone. The solid green line shows the value used in BC90 and BC50, $20/lb

Analysis of Costs

In order to determine the economic viability of the cooperative, a thorough examination of the potential costs is required. Through our discussions with the CAA and our case studies of cooperatives across the globe, we were able to determine what types of costs the cooperative might incur. These are grouped into costs for fishing, enforcement, data collection and monitoring, harvest labeling, taxes, marketing and transport, and administrative needs. For each of these cost categories, we show the full range of possible costs and benefits resulting from our calculations in Table.3. To examine specific sets of these values, the parameters used in BC90 and BC50 are shown in Table.4 .

Units of Costs

The costs we present are of three general types; fixed annual costs, harvest related costs, and fishing trip dependent costs[1] . Fixed annual costs represent variables such as legal fees and salaries that may vary with uncertainty, but are assumed to be independent of any external variable once set. Harvest dependent costs are variables such as landing taxes and tags, that change as a function of the amount of abalone actually caught. Fishing trip dependent costs are variables such as fuel costs and boat maintenance, that are functions of the number of fishing trips taken each year. We define a fishing trip as one overnight roundtrip passage to SMI from Santa Barbara. This unit was decided on as it represents that amount of time required for one boat and its crew to fill their capacity of abalone.

[1] For an analysis of costs as either solely fixed or a function of harvest, see Appendix 2.

Fishing Costs

At this point, the CAA is unsure as to whether the cooperative will cover fuel costs for fishing trips to SMI, or leave this expense to be borne separately by the fishers that actually own the vessels. Furthermore, the cooperative does not intend to pay for maintenance and storage of boats, because owners use them for multiple purposes, such as in the urchin fishery. However, in order to determine if the cooperative can be economically viable for individual members, it is important to consider fishing costs, regardless of who incurs those costs.

As it is extremely difficult to obtain daily costs for all aspects of boat operations, we used annual boat costs in conjunction with relative proportions of fishing days spent on abalone in order to scale our fishing costs. Fishermen from the CAA reported that the average commercial urchin diver uses their boat for 100 days per year for urchin diving. We assume the same boat will be used for only 2 days per year for abalone diving. Therefore, a single boat that is used in both the abalone fishery and the urchin fishery will be used 102 days per year, resulting in abalone fishing accounting for 1/51st of the total estimated annual fishing costs. This calculation was used in order to standardize fishing costs per fishing trip (again, defined as one overnight roundtrip to SMI from Santa Barbara). The net result of our fishing trip cost analysis results in a value of $508 per fishing trip. The components of this total cost are outlined below

Number of Fishing Trips

The number of fishing trips required each year is a function of the cooperative's annual catch. In general, more trips are needed for more catch, and less for a reduced harvest. However, this relationship is somewhat complicated by the constraints of boat capacity, both for crew and abalone. Most boats that would operate in this cooperative can hold a maximum of 3 crew members and 260 abalone. In addition, the CAA intends that the cooperative require each member to personally catch their portion of the cooperative's catch, and that each members portion be equal. Following these stipulations, we determined ranges of total annual fishing trips required for the 90%-10% and 50%-50% TAC allocations. These values represent the number of fishing trips required for the cooperative's harvest to be caught, accounting for the need for every member to personally bring in their allocated catch[2].

Boat Insurance

The average cost of boat insurance is $2000 per year for $50,000 of coverage (Jim Marshall pers. comm.). This $2000 spread out over the 102 fishing days per year amounts to $40 per fishing trip. It should be noted that not all boat owners choose to insure their boats. As such, it is believed that this could be a high estimate.

Boat slip

While many boat owners choose to store their boat at home or in a storage unit out of the water, our economic viability model assumes that boats used for the abalone fishery will be stored in a boat slip at the harbor. The average cost of a boat slip is $400 per

[2]To see a mathematical method for calculating total annual fishing trips, see Appendix 2.

month or $4800 per year (Jim Marshall pers. comm.). This $4800 spread out over the 102 fishing days per year amounts to $94 per fishing trip.

Boat Maintenance
The average cost of boat maintenance for a typical urchin boat is $3000 per year (Jim Marshall pers. comm.). This $3000 spread out over the 102 fishing days per year amounts to $59 per fishing trip.

Fuel Costs
The CAA reported that an average trip to the potential harvest location on San Miguel Island costs $300 for fuel. For fuel costs we therefore use a value of $300 per fishing trip.

Dive Gear Maintenance
The average annual cost of diver gear maintenance for a commercial urchin diver was reported to be $500 per person (Jim Marshall pers. comm.). Spread out over the 102 days of diving per year, this amounts to $10 per person per fishing trip.

Enforcement Costs

Nancy Foley, the California Department of Fish and Game's Chief of Enforcement, reported that the cooperative will most likely be required to cover a portion of CDFG's enforcement costs (pers. comm.). One way the cooperative could meet this requirement is to partially fund a warden's position. CDFG provided a document containing all of the warden-associated costs, such as salaries and equipment expenses. This document was used to calculate potential enforcement costs to be paid by the cooperative.

The salary for a full-time warden including benefits amounts to $100,939 per year. In addition, there are operating and equipment expenses, such as training, uniforms, and travel. These expenses total $249,702 for the first year that a warden is employed and $166,249 each subsequent year. Because a warden will only be spending a portion of his or her time enforcing abalone regulations, these costs must be scaled to the length of the abalone season. Assuming a regular five-day work week, there are a total of 261 working days per year. We used this number to calculate the warden associated costs per work day.

In order to calculate our initial estimate of the possible enforcement costs to the cooperative, we considered a case in which the cooperative uses a total of 50 two-day boat trips to harvest their catch for the year. We then assumed that the fishery can be condensed into 2 days per month by sending 4-5 boats to SMI at one time, with two people each. This results in the fishery being open 24 days per year.

Setting up the abalone season in this structure is advantageous from a marketing standpoint. It will allow for the cooperative to sell live, fresh abalone year round, which has a higher market value than a frozen product. Therefore, no matter that total amount of annual catch, having the fishery open two days per month will allow the cooperative to minimize enforcement costs while maximizing market value. As such, we assumed that the abalone season, and the resulting number of days for which enforcement will be required, do not change as a function of annual harvest levels.

With a two-day per month abalone season, we determined the total cost for 3 wardens enforcing abalone regulations 24 days per year. The need for 3 wardens results from a stipulation requiring any CDFG patrol boat to be crewed by three wardens (S. Hastings pers. comm.). In addition to warden costs, there are also marine equipment costs, such as fuel and boat related costs. We scaled these costs for a fishery that is open only 24 days per year. Finally, we assumed that for every day that the fishery is open, there will be an equal number of days devoted to administrative tasks. We assumed that one warden could complete these required administrative duties in 24 days. These enforcement related costs and calculations are summarized in Table 2. Our results indicate a value of $99,210 for first year enforcement costs, and $63,779 for each subsequent year. The first year costs differ due to the need to purchase equipment in the first year of the fisheries funding of enforcement operations.

Costs	**Year 1**	**Year 2+**
Warden Annual Salary and Benefits	$100,939	$100,939
Warden Operating and Equipment Expenses	$148,763	$65,310
Total Warden Associated Costs per year	$249,702	$166,249
Total Number of Work Days per year	261	261
Warden Associated Costs per work day	$956.71	$636.97
Total Number of Abalone Season Days per year	24	24
Total Warden Cost for 24 Abalone Season Days per year	$22,961.10	$15,287.26
Total Number of Wardens Enforcing Abalone Regulations During the Abalone Season	3	3
Total Warden Costs for 3 Wardens during Abalone Season	$68,883.31	$45,861.79
Number of Warden Administrative Work Days	24	24
Total Cost for Administrative Work Days for 1 Warden	$22,961.10	$15,287.26
Annual marine equipment costs	$80,100.00	$28,600.00
Marine equipment costs per work day	$306.90	$109.58
Total Number of Days Marine Equipment is Used during Abalone Season	24	24
Total cost of marine equipment for 24 Abalone Season Days per year	$7,365.52	$2,629.89
TOTAL WARDEN ASSOCIATED COSTS PER YEAR	**$99,209.93**	**$63,778.94**

Table 2. Summary of potential enforcement costs

Data Collection and Monitoring

Independent Data Collection

In addition to providing the California Department of Fish and Game with fishery dependent data, the cooperative intends to contribute to fishery independent data collection. Fishery independent data consists of information collected in collaboration with scientists using visual surveys and other scientific techniques on days where cooperative members are not harvesting abalone (see Fig.3 for illustration). For each boat that participates, one skipper and one diver will require compensation. The CAA reported that the diver and the skipper will each be paid $800 per day. This level of compensation is approximately equal to what a fisherman would earn on a fishing day (Chris Voss pers. comm.). Additionally, the skipper will be reimbursed for all boat related costs. These costs of insurance, boat maintenance, boat slip, dive gear maintenance, and fuel are the same as the costs during a day of fishing. These costs added to the compensation gives a total cost of $2,005.88 for a single day of data collection. The CAA stated that 10 boats will participate, for a total cost of $20,058.80 per day of data collection.

Figure 3. Illustration of independent data collection activities

AAUS Diver Certification/Establishment of an Organizational Unit

The CAA has expressed interest in developing an American Association of Underwater Scientists (AAUS) organizational branch for the cooperative. This would allow for AAUS certified cooperative members to collaborate with CDFG and the University of California, Santa Barbara (UCSB) in research and monitoring efforts. This would allow for greater ease of research, as well as lend credibility to fishery independent data collected by the Cooperative. Because each cooperative boat participating in independent data collection will have two cooperative divers, we assume that 20 cooperative members will become AAUS certified. This requires each diver to undergo a diving physical by a licensed doctor at a cost of approximately $500. Additionally, each diver would need to have their SCUBA gear inspected and serviced at a dive shop, at a cost of approximately $200 per diver. There is also a $500 annual membership fee, paid for by the cooperative organizational branch. Thus, the total cooperative costs for developing an AAUS branch with 20 members is estimated to be $14,500 for the first year, and $500 for each subsequent year (Chris Rigaud, AAUS Membership Committee, pers. comm.). The CAA could however choose not to pursue this certification option, in which case no AAUS related costs exist.

Data Coordinator

The cooperative plans to employ a part-time data coordinator in order to manage the large amount of data that will be collected during fishing activities and during independent data collection. It is estimated that this person will work at a wage of $25 per hour.

Third Party Audit of Report

The CAA intends to have a third party conduct an audit of their annual report, which will provide an assessment of the CAA's efforts to effectively manage and protect the abalone stock at SMI. The Marine Stewardship Council (MSC) annual audits costs approximately $3,000-$5,000, where as the Friends of the Sea require $1,5000-$2,000 (Macfadyen & Huntington 2007). There is a chance that the cooperative may wish to become certified by MSC in the future, so we chose to use the MSC price of $5,000 per year in our economic viability model.

Adaptive Fishery Management Database

The CAA and researchers at UCSB have expressed an interest in the development of an adaptive decision key, that would combine basic fishery dependent data in conjunction with survey based information to develop management strategies capable of quickly reacting to changes in abalone population dynamics. Sarah Valencia, a PhD student at UCSB working in the field of abalone management, suggested that the best way to integrate a decision key into management of the fishery would be to develop a web-based data management system. This system would be accessible to both the CDFG and the CAA. An initial investment of $10,000 to $15,000 would be needed to hire a web consultant to integrate the modeling into a web-based code. However, once the website was up and running, a user-friendly interface could allow members of the CAA to apply their collected data to the decision tree and develop their own stock assessments.

Alternatively, a graduate student/ consultant could be hired to apply the decision tree to the fishery data. This would be a relatively time-consuming job since it would require extensive data input and a working knowledge of the decision tree. It was estimated this would be a full time job during the catch/ monitoring season (approx. 3 months), and that pay would be $30-$40 per hour (based on tuition and RA-ship fees) (S. Valencia pers. comm.) This totals $14,400 to develop this web based system (assuming $30/hour and 12 week period). Given that for the system to be implemented, extensive amounts of research and work would required, we do not include this cost in our standard analysis. However, it will be incorporated into the adaptive harvest scenario, representing the tool through which harvest levels are adjusted each year.

Harvest Labeling

Landing receipts

Landing receipts are required by the California Department of Fish and Game and serve as a record of the catch brought to harbor. Landing receipts must be filled out for each harvested abalone at the time of sale (California Fish and Game Code Section 8043). Information required includes weight of the abalone, name of the harvester, and other applicable information. The California Abalone Association estimated that buying the landing receipts for a harvest of 9,655 animals would cost approximately $1000 (Chris Voss pers. comm.). This amounts to $0.1036 per abalone harvested.

Trace Register

In order to prevent illegal catch and sales, the CAA has proposed to utilize the seafood traceability system called Trace Register. Trace Register is a third party system that will trace each individual abalone from the restaurant plate back to the fishing vessel and location of harvest, documenting each step in the supply chain. It will also provide the CAA with an online system where data is stored, including information on the length and weight of each harvested abalone (Trace Register 2008). Trace Register supplied the California Abalone Association with a quote of $3,000 per year for their services for all levels of harvest (Chris Voss pers. comm.).

Tags

The CAA has introduced the idea of tagging harvested abalone in order to distinguish between legal and illegal catch and also to aid enforcement efforts. At the beginning of the season, the cooperative will distribute to each member the number of tags corresponding to the member's allocated catch. The tags will be color coded for the year and will also contain a bar code that corresponds to the diver. As soon as an abalone is harvested, the diver will be required to affix a tag. Information regarding catch size and location will be entered into a data management system using the barcode as identification for each abalone. This system will help track the catch throughout the year and organize the data stream. Finally, if enforcement efforts find any abalone without a tag, penalties may be imposed.

The CAA, as well as CDFG, thoroughly researched the cost of a tamper proof security tag. Using quotes from numerous tag companies, the CAA estimates that tags will cost $1 per abalone (Chris Voss pers. comm.).

Taxes

Landing and Enhancement Tax

Tax rates used in the economic viability model are equal to the rates that existed when the statewide commercial abalone fishery closed in 1997. At that time, a landing tax of $0.0125 per pound and an enhancement tax of $0.195 per pound were in place.

Marketing and Transport

Delivery Costs

Initially, the CAA indicated that they were interested in delivering direct to restaurants and markets using a company such as FedEx, rather than using a seafood distributor. By delivering the product directly, the cooperative will incur both shipping costs and packaging costs. The cheapest packaging option involves placing the live abalone on a wet sponge inside a sealed plastic bag. The bag is then surrounded by gel ice packs and placed in a Styrofoam box. This insulated box in then packed in a cardboard box and shipped. The average price for this type of packaging is approximately $0.50 per pound of abalone (pers. comm. Giovanni's Fish Market). One issue with this is that there is risk of death during transit. Another more expensive option is to use an environmentally controlled container that can ensure the oxygen levels are optimal for keeping the abalone alive.

We calculated the shipping costs if FedEx is used for delivery and packaging is accomplished using the cheapest method. There are several assumptions that were used in calculating the shipping costs:

- The total harvest is 9,655 abalone per year weighting 4 pounds each.
- Each shipment contains 10 abalone for a total of 40 pounds per shipment.
- The price for wild abalone is $20/pound.
- Shipping zones and costs were determined using the prices listed in the FedEx 2009 Service Guide (fedex.com/ca_english/services/pdf/serviceguide_EN.pdf).
- 1/8 of the harvest will be shipped to New York, 1/8 will be shipped to Las Vegas, ¼ will be shipped to LA, and 3/8 will be shipped to other cities in California that are within 300 miles of Santa Barbara
- 1/8 of the harvest will be purchased by restaurants and markets in the Santa Barbara area and can be delivered in person. Therefore, FedEx services will not be required for this 1/8 and costs are assumed to be negligible.
- Packaging costs are assumed to be $0.50 per pound

Total FedEx services and packaging costs for an annual commercial harvest of 9,655 abalone will cost $96,103. This gives us an average shipping cost of $8.96 per abalone. Upon hearing these potential costs for direct delivery, the CAA decided to consider the use of distribution company to sell the product instead. There are several benefits of using a distributor. First, the distributor incurs these shipping and delivery costs, and second, the distributor is responsible for any product loss that occurs during transport. Therefore, we do not include delivery costs in our analysis.

Marketing Coordinator

In order to develop and strong relationship with the cooperative's distributor and maximize profits, the CAA would like to employ a part-time marketing coordinator. It is estimated that the marketing coordinator will work at a wage of $25 per hour.

Administrative Costs

Miscellaneous Administrative Costs

The CAA estimated that miscellaneous administrative costs would amount to $10,000 per year (Chris Voss pers. comm.).

Legal Costs

The CAA estimated that legal fees will amount to $5,000 per year (Chris Voss pers. comm.).

Accounting Costs

The CAA estimated that accounting costs will amount to $5,000 per year (Chris Voss pers. comm.).

Phone Costs

Phone costs were estimated as being $500 per year

Website Costs

The CAA needs assistance in developing a website for the cooperative. Ameravant, a Santa Barbara based website developing company, estimated that the cooperative website would cost approximately $1,500 to develop and $35 per month to maintain. Therefore, costs for year one are $1,920 and $420 for each subsequent year.

Results of Financial Variables Research

Full Range of Financial Variables

Using the methods described in our analysis of costs and revenues, we determined totals for the revenues and costs to the cooperative. However, several of these values contain uncertainty, either as a result of missing data or assumptions made in our calculations. Therefore the full range of potential costs and revenues to the cooperative are presented in Table.3. The uncertain variables included number of fishing days (and subsequent fishing costs), as well as costs for data collection, the data coordinator, AAUS certification, the marketing coordinator, and enforcement support. For these costs, the total range of values was selected to span from low to high cost estimates. In addition, revenue varies as a function of the selected price per pound, drawn from the frequency distribution shown in Fig.14 (this method will be described in detail in the "Monte Carlo Analysis" section, page 41). The values presented in Table.3 represent the parameters that will be used in all our subsequent analyses requiring constant levels of harvest[3], and are broken down into the CH90 and CH50 scenarios

[3] Separate values are used for the adaptive harvest scenario. The methods for this are outlined in Appendix 2 and on page 41

Base Cases

In order to clarify our results and provide an initial assessment of the economic viability of the cooperative, we pulled specific values from Table.3 to create our BC90 and BC50 scenarios. Values for this analysis were selected to represent what we believe are likely estimates for the cost and benefit parameters and are shown in Table.4.

Structure of BC90

The values used in BC90 are shown in Table.4. BC90 represents a constant yearly catch of 9,655 abalone. If the predicted commercial allocation of 9,655 abalone is equally divided amongst the 83 potential cooperative members, each individual member will have a harvest quota of 116 animals to be caught. Since each boat can hold and transport up to 260 live abalone, two cooperative members can travel to San Miguel on one boat and harvest their entire allocation of 116 abalone in the course of one trip. With 83 potential cooperative members and assuming two people per boat, 42 trips would be the minimum number of trips required for the cooperative to harvest the entire BC90 allocated catch. However, in the case that a few trips are unsuccessful in harvesting total individual allocation, a conservative total of 50 fishing trips was used in BC90. Given this total catch and number of fishing trips, harvest and fishing dependent costs were scaled appropriately. Uncertain costs related to hourly pay (data and marketing coordinators) were both set at 8 hours per week.

Revenues were calculated using a price of $20/lb. This value, lower than the mean price per pound calculated through our market research, was selected in order to reflect the use of a seafood distributor to sell the product, as well as the initial need for the cooperative to be competitive with the widely used farmed product. As the market adjusts to the availability of wild caught abalone, higher prices are possible and will be reflected in our complete analysis.

Structure of BC50

The values used in BC50 are shown in Table.4. BC50 represents an annual catch of 5,364 abalone. If the predicted commercial allocation of 5,364 abalone is equally divided amongst the 83 potential cooperative members, each individual member will have a harvest quota of 64 animals. Each member can still harvest this number in a single, overnight, two-day trip to SMI. However, in the BC50 scenario, each boat has the capacity to transport the entire harvest for three people. Therefore, three cooperative members can travel to San Miguel on one boat and harvest their entire allocation of 64 abalone each in the course of one trip. With 83 potential cooperative members, 28 is the minimum number of fishing trips required for the cooperative to harvest the entire 5,364 abalone. Again, it is likely that a few trips will be unsuccessful in harvesting the full individual allocation, so a conservative total of 33 overnight boat trips, is the value used in BC50. Harvest and fishing dependent costs were scaled to fit these parameters of the BC50 model. Uncertain costs related to hourly pay (data and marketing coordinators) were set to 8 hours per week. As in BC90, a market value of $20/lb was used for BC50.

		FULL RANGES OF COSTS AND BENEFITS with CONSTANT HARVEST											
		CH90						CH50					
		Low		Medium		High		Low		Medium		High	
		Year 1	Years 2-15	Year 1	Years 2-15	Year 1	Years 2-15	Year 1	Years 2-15	Year 1	Years 2-15	Year 1	Years 2-15
Revenue	Harvest	9,655	9,655	9,655	9,655	9,655	9,655	5,364	5,364	5,364	5,364	5,364	5,364
	Total Pounds	38,620	38,620	38,620	38,620	38,620	38,620	21,456	21,456	21,456	21,456	21,456	21,456
	Market Value ($/lb)	Based on Frequency Distribution (Fig.14)		Based on Frequency Distribution (Fig.14)		Based on Frequency Distribution (Fig.14)		Based on Frequency Distribution (Fig.14)		Based on Frequency Distribution (Fig.14)		Based on Frequency Distribution (Fig.14)	
Labeling	Landing Receipts	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$556	$556	$556	$556	$556	$556
	Trace Register	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000
	Tags	$9,655	$9,655	$9,655	$9,655	$9,655	$9,655	$5,364	$5,364	$5,364	$5,364	$5,364	$5,364
	Total	$13,655	$13,655	$13,655	$13,655	$13,655	$13,655	$8,920	$8,920	$8,920	$8,920	$8,920	$8,920
Fishing Costs	Number of round-trip boat trips per year	$42	$42	$50	$50	$58	$58	$28	$28	$33	$33	$38	$38
	Boat slip	$3,953	$3,953	$4,706	$4,706	$5,459	$5,459	$2,635	$2,635	$3,106	$3,106	$3,576	$3,576
	Boat insurance	$1,647	$1,647	$1,961	$1,961	$2,275	$2,275	$1,098	$1,098	$1,294	$1,294	$1,490	$1,490
	Boat maintenance	$2,471	$2,471	$2,941	$2,941	$3,412	$3,412	$1,647	$1,647	$1,941	$1,941	$2,235	$2,235
	Dive gear maintenance	$814	$814	$814	$814	$814	$814	$814	$814	$814	$814	$814	$814
	Fuel	$12,600	$12,600	$15,000	$15,000	$17,400	$17,400	$8,400	$8,400	$9,900	$9,900	$11,400	$11,400
	Total	$21,484	$21,484	$25,422	$25,422	$29,359	$29,359	$14,594	$14,594	$17,055	$17,055	$19,516	$19,516
Data and Monitoring	Independent Data Collection	$20,059	$20,059	$40,118	$40,118	$60,176	$60,176	$20,059	$20,059	$40,118	$40,118	$60,176	$60,176
	AAUS branch membership	$0	$0			$14,500	$500	$0	$0			$14,500	$500
	Data Coordinator	$0	$0	$10,400	$10,400	$20,800	$20,800	$0	$0	$10,400	$10,400	$20,800	$20,800
	Third Party Audit of Report	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
	Total	$25,059	$25,059	$55,518	$55,518	$100,476	$86,476	$25,059	$25,059	$55,518	$55,518	$100,476	$86,476
Enforcement	Warden costs for fishery open days	$0	$0			$68,883	$45,862	$0	$0			$68,883	$45,862
	Warden costs for administrative days	$0	$0			$22,961	$15,287	$0	$0			$22,961	$15,287
	Marine equipment costs for fishery open days	$0	$0			$7,366	$2,630	$0	$0			$7,366	$2,630
	Total	$0	$0	$50,000	$32,500	$99,210	$63,779	$0	$0			$99,210	$63,779
Taxes	Landing Tax	$483	$483	$483	$483	$483	$483	$268	$268	$268	$268	$268	$268
	Enhancement Tax	$7,531	$7,531	$7,531	$7,531	$7,531	$7,531	$4,184	$4,184	$4,184	$4,184	$4,184	$4,184
	Total	$8,014	$8,014	$8,014	$8,014	$8,014	$8,014	$4,452	$4,452	$4,452	$4,452	$4,452	$4,452
Marketing and Transport	Delivery Costs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Marketing Coordinator	$0	$0	$10,400	$10,400	$20,800	$20,800	$0	$0	$10,400	$10,400	$20,800	$20,800
	Total	$0	$0	$10,400	$10,400	$20,800	$20,800	$0	$0	$10,400	$10,400	$20,800	$20,800
Administrative Costs	Administrative	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
	Legal	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
	Accounting	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
	Website	$1,920	$420	$1,920	$420	$1,920	$420	$1,920	$420	$1,920	$420	$1,920	$420
	Phone	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500
	Total	$22,420	$20,920	$22,420	$20,920	$22,420	$20,920	$22,420	$20,920	$22,420	$20,920	$22,420	$20,920

Table 3. Full range of financial variables calculated from research, for CH90 and CH50 scenarios

		BASE CASE SCENARIOS			
		BC90		BC50	
		Year 1	Years 2-15	Year 1	Years 2-15
Revenue	Harvest	9,655	9,655	5,364	5,364
	Total Pounds	38,620	38,620	21,456	21,456
	Market Value ($/lb)	$20	$20	$20	$20
Labeling	Landing Receipts	$1,000	$1,000	$556	$555.55
	Trace Register	$3,000	$3,000	$3,000	$3,000
	Tags	$9,655	$9,655	$5,364	$5,364.00
	Total	$13,655	$13,655	$8,920	$8,919.55
Fishing Costs	Number of round-trip boat trips per year	$50	$50	$33	33
	Boat slip	$4,706	$4,706	$3,106	$3,105.88
	Boat insurance	$1,961	$1,961	$1,294	$1,294.12
	Boat maintenance	$2,941	$2,941	$1,941	$1,941.18
	Dive gear maintenance	$814	$814	$814	$813.73
	Fuel	$15,000	$15,000	$9,900	$9,900
	Total	$25,422	$25,422	$17,055	$17,055
Data and Monitoring	Independent Data Collection	$60,176	$60,176	$60,176	$60,176.47
	AAUS branch membership	$14,500	$500	$14,500	$500
	Data Coordinator	$10,400	$10,400	$10,400	$10,400
	Third Party Audit of Report	$5,000	$5,000	$5,000	$5,000
	Total	$90,076	$76,076	$90,076	$76,076
Enforcement Costs	Warden costs for fishery open days	$68,883	$45,862	$68,883	$45,861.79
	Warden costs for administrative days	$22,961	$15,287	$22,961	$15,287.26
	Marine equipment costs for fishery open days	$7,366	$2,630	$7,366	$2,629.89
	Total	$99,210	$63,779	$99,210	$63,778.94
Tax	Landing Tax	$483	$483	$268	$268.20
	Enhancement Tax	$7,531	$7,531	$4,184	$4,183.92
	Total	$8,014	$8,014	$4,452	$4,452.12
Marketing and Transport	Delivery Costs	$0	$0	$0	0
	Marketing Coordinator	$10,400	$10,400	$10,400	$10,400
	Total	$10,400	$10,400	$10,400	$10,400
Administrative Costs	Administrative	$10,000	$10,000	$10,000	$10,000
	Legal	$5,000	$5,000	$5,000	$5,000
	Accounting	$5,000	$5,000	$5,000	$5,000
	Website	$1,920	$420	$1,920	$420
	Phone	$500	$500	$500	$500
	Total	$22,420	$20,920	$22,420	$20,920

Table 4. Selected financial variables for base-case scenarios, BC90 and BC50

Results of Base-Case Analysis

Total cost of BC90 and BC50 in the first year of the cooperative's operation amounts to $269,196.59 and $252,532.97, respectively. The costs of BC90 are broken down into the various cost categories and are shown in Fig. 4.

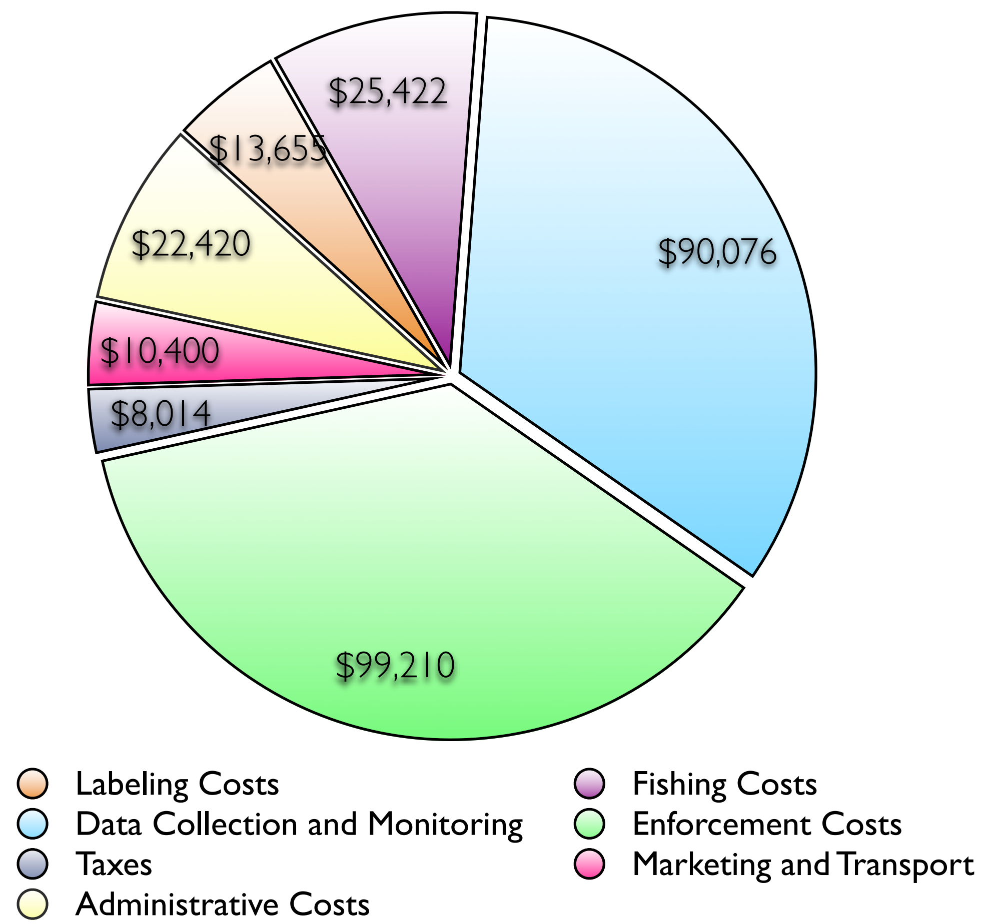


Figure 4. Summary of costs incurred by the cooperative in BC90 in the first year of the fishery's operation.

The total costs must then be weighed against the harvest revenues in order to determine if the cooperative is economically viable. Total benefits to the cooperative in year one for BC90 is $772,400, and benefits in BC50 are $429,120. Total benefits, costs, and profits are summarized in Fig.5.

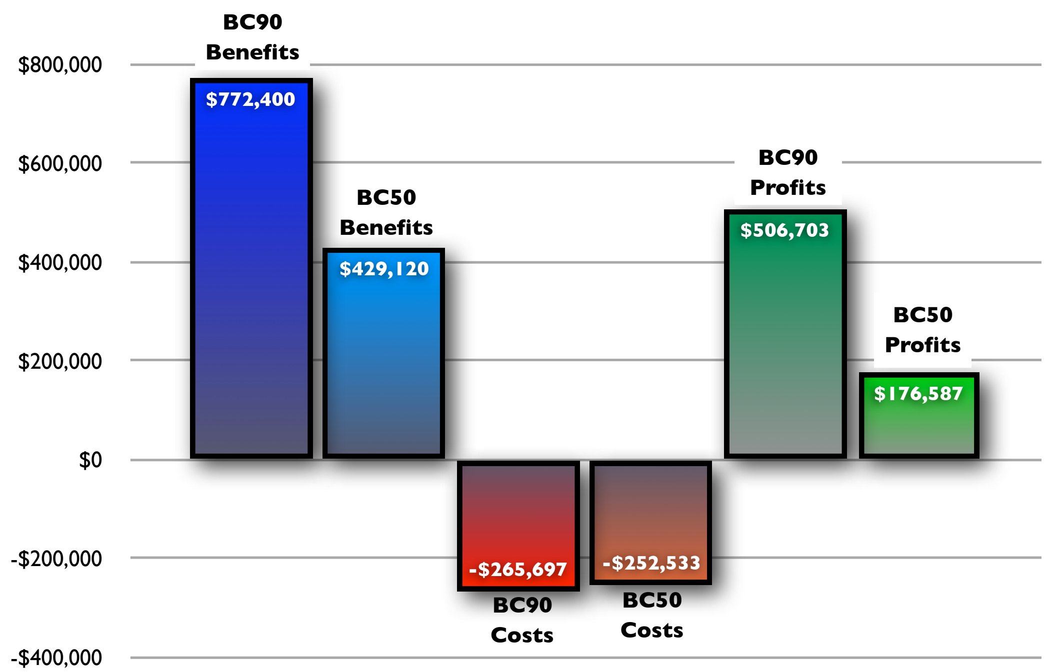


Figure 5. Summary of revenue, costs and profits for BC90 and BC50 in the first year of the cooperative's operation. Blue bars represents revenues, red bars costs. Green bars indicate net profits

As seen in Fig. 5, the costs are relatively similar in the BC90 and BC50 scenarios. However, the benefits are much greater in BC90 than BC50. As such, BC90 is a much more profitable scenario due to a more ample harvest. The total profits for year one of the cooperative's operation are $506,703 for BC90 and only $176,587 for BC50. These results indicate that the cooperative can be economically viable under the base case scenarios.

Incorporating Uncertainty

While the BC90 and BC50 cases provide a useful illustration of the potential economic viability of the cooperative, they represent only two possible sets of costs and benefits. In order to fully evaluate this question of economic viability, in the following sections we incorporated environmental and economic uncertainty.

Population model and risk of fishery decline

In order to properly assess the economic viability of a commercial abalone fishing cooperative at SMI, some measure of abalone stock levels and population stability is needed. Unfortunately, no model is currently available that is capable of projecting population trends for the length of time required for our economic analysis. In order to help fill this gap, we developed a stage-structured, non-spatially explicit, environmentally stochastic matrix population model to provide an estimate of the catch and subsequent profits available to the cooperative over time (Fig.6).

The patchy nature of abalone populations, difficulty in measuring recruitment, and uncertainty in the effects of environmental fluctuations all provide significant challenges to the modeling of this species (Prince et al. 1998; Prince & Valencia 2009; Rogers-Bennett & Leaf 2006; Vilchis et al. 2005). In addition, little quantitative data is available on the specific ecology of red abalone at SMI. What data is available was pooled in order to create our model. Growth rates, survival and fecundity were developed from published fieldwork (Rogers-Bennett & Leaf 2006) and lab-based (Vilchis et al. 2005) studies, as well as survey data collected from SMI. Temperature trends were gathered from a PISCO dataset located nearby the site of the proposed fishery. Initial population sizes were derived from the most recent visual survey data available. This method follows a similar approach as that utilized by (Hobday & Tegner 2002)

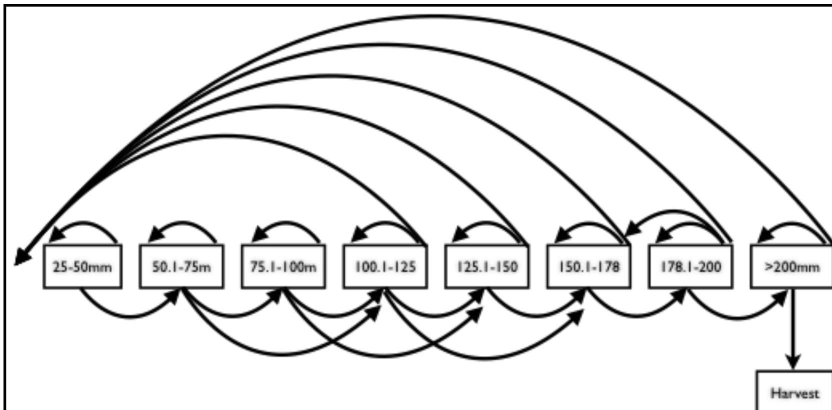


Figure 6. Basic structure of abalone population matrix model. Each box represents a size class, arrows show transitions during each year of the model

The resulting model was designed to address two specific questions; how many abalones will be present to be fished, and what is the risk of fishery closure as a result of population decline? In considering this risk of closure, we measured the probability of the occurrence of a threshold event. We defined this threshold event as a decrease in the total numbers of reproductively mature abalone (sized >=100.1) below the levels present at the opening of the fishery[4]. Assessing this threshold risk is valuable from a fisheries management perspective. Given the highly contentious nature of this potential fishery, and the great care that must be exercised if this particular population is to be harvested, it is a reasonable assumption that CDFG would choose to shut down the cooperative should population levels in the future become lower than what they are today. We also assume that should this threshold be crossed and the fishery be closed, the cooperative would not be reopened at a later date. In reality, the cooperative could voluntarily choose to reduce or eliminate fishing effort in any given year should they find it necessary to preserve the stock, subsequently reopening it upon signs of recovery. However, it is our consideration that should the cooperative be closed down by DFG, and not voluntarily as a preventative measure, it would be unlikely that the fishery would be reopened. In addition, by considering this particular threshold level, we avoid the need to consider the impact of possible Allee effects. Considering that the population appears to be breeding successfully as of its current population, we can assume that Allee effects are not currently impacting the stock at SMI. Since we consider the fishery closed once the population drops below this threshold, it is not necessary then for this model to explicitly model the Allee effect. This is because according to our rules the fishery would already be closed by the time the population reached low enough levels for this phenomenon to become a problem. We realize that this is a somewhat arbitrary threshold, but it represents a conservative approach that could easily be modified if more specific benchmarks for fishery health are developed in the future.

Matrix Structure

The following sections will outline the structure of our population model and our findings. Three different scenarios were evaluated, no harvest, a constant harvest, and adaptive harvest. Resulting population trends and risk of fishery closure are presented for each scenario.

While a variety of specific numbers were utilized in our calculations, the fundamental structure of our model was the same through all evaluated scenarios, and is presented as follows. A pre-reproduction transition matrix was utilized to model the growth of the abalone population over time. This matrix divided the population into 8 size classes, ranging from newly recruited abalone 25-50mm in diameter, up to abalones 200.1 mm in diameter and greater. Reproduction was assigned to begin at size 100.1 mm, and a single reproductive event was assumed to occur each year (See Fig.5 for sample illustration of the matrix structure).

The structure of the growth matrix was based off of Rogers-Bennett & Leaf (2006). However, the Rogers-Bennett & Leaf (RBL) model is likely not a completely accurate representation of the population at SMI. The RBL matrix was developed based off of a mark-recapture study of red abalone begun in 1971 in northern California (with an extension study performed in 1995 on juvenile abalone, also in northern California (Rogers-Bennett & Leaf 2006). Given this gap in both space and time between the data

[4] This assumes that the fishery is opened at a population reflective of the 2008 survey data. If the population grows from this level before the fishery is opened, then these results will only present a more conservative estimate

used to structure the RBL model and the current population at SMI, its ability to accurately model the population of interest for this paper is unclear.

Abalone population survey data from SMI provides a means for the construction of a more site-specific matrix. Survey data has shown an explosive growth of large individuals, with large individuals (sized 197mm and greater) increasing by 47.8% since the closure of the fishery in 1997 (Prince & Valencia 2009). This suggests that the survival of large adults at SMI is greater than the numbers reported by the RBL matrix, which when tested in a model against population data from SMI resulted in declines in numbers of large adults from current levels. In addition, the survey data appears to indicate that the total population has been growing at a compounding rate of approximately 10% each year, far quicker than the growth rates predicted under the RBL matrix (Prince & Valencia 2009). In order to account for these changes, for the SMI matrix survival and growth rates were modified in order to increase the numbers of large sized abalone**.** The results of this modified matrix show increased survival of adult abalone, and rates of growth comparable to the trends reported by survey data. These increases in survival are to be expected when considering the population at SMI, as the cold, nutrient rich water at the location of the proposed fishery make for highly ideal conditions for red abalone. The resulting growth matrix is shown in Table.5 .

Transition Size Class (mm)								
Size Class (mm)	25-50	50.1-75	75.1-100	100.1-125	125.1-150	150.1-178	178.1-200	>200.1
25-50	0.096			0.800	3.790	12.330	20.010	24.330
50.1-75	0.224	0.032						
75.1-100		0.256	0.125					
100.1-125		0.032	0.228	0.189				
125.1-150			0.027	0.300	0.188			
150.1-178				0.011	0.412	0.249	0.028	
178.1-200						0.581	0.270	0.012
>200.1							0.602	0.888

Table 5. Default structure of abalone population transition matrix

The initial population size was determined utilizing survey data for the SMI abalone population. For the largest, emergent size classes, selectivity of the visual survey was assumed to be near 1**.** As such, total numbers were extrapolated from the survey area to the total area of the fishery, and relative proportions used to determine the total numbers of abalone in each size class, down until the 75.1-100mm size class. For these largest size classes, the current estimate of 107,280 abalone sized 203mm and larger was used to develop the total population structure (Prince & Valencia 2009). Beginning at size classes 75.1-100mm and smaller, selectivity of the survey becomes relatively low, given the cryptic nature of these small abalone and the non-invasive survey techniques used, and as such simple proportional extrapolation from the survey data becomes impossible. For our purposes then, initial populations of cryptic sized abalone were determined through the stable age-distribution of our constructed matrix. The population matrix was allowed to run without environmental variability until a stable state was reached. Within this stable state, the relative proportions of cryptic to emergent abalone were calculated. These proportions were then used to determine the numbers of cryptic abalone present in the initial population, according the assumptions of the matrix used. Doing so provided a means of grounding the initial numbers of cryptic abalone, and prevented explosive growth from occurring in the first years of the model as the population structure adjusted itself to its stable state.

Environmental Variability

In order to account for the role of environmental variability in abalone populations, bottom water temperature (the water temperature most likely to be experienced by abalone) was determined to be a good indicator of environmental suitability for abalone (Hobday & Tegner (2002) employ a similar method). This is because water temperature provides a useful proxy for the variety of factors that impact the survival and reproduction of red abalone. As water temperatures increase, red abalone become increasingly prone to disease and mortality, and suffer reductions in their reproductive output. Conversely, as water temperatures decrease, reproduction and survival increase (Braid et al. 2005; Rogers-Bennett & Leaf 2006; Vilchis et al. 2005). In addition, water temperatures strongly affect the primary food source of abalone, kelp. As water temperatures increase, the nutritional value of kelp decreases (due to drops in nitrogen absorption by the kelp (Stewart et al. 2009; Vilchis et al. 2005). As temperatures decrease, the kelp available to the abalone becomes more nutritious. In total then, water temperatures significantly affect a large number of the variables that determine the health and growth of an abalone population, and as such provide a justifiable index of environmental health, from the perspective of an abalone. We elected to use yearly mean temperatures as an indicator of temperatures stressed, based on the results of Vilchis et al. (2005). In this lab-based study, abalone were subjected to either cool, ambient or warm temperatures for a period of 49 weeks.

Figure 7. Location of population and temperature data sets

Following the study, changes in mortality and reproductive potential were measured. Given the time scale Vilchis et al. (2005) determined as being of sufficient length for their study (approximately a year), we have decided to use yearly temperature stress as our measure of environmental health.

Bottom water temperature data was gathered from the PISCO TidBits database, measured at a location due east of the proposed fishery. While not exactly the same site, this dataset is the only consistent source of water temperatures available and is relatively near the fishery site (Fig.7). Available data spanned from 2003-2009, a period containing significant El Niño events (corresponding then with abnormally high water temperatures) (Vilchis et al. 2005). This dataset provides then a moderately robust picture of historical temperature trends at the study location, and as such a reasonable range for future temperature fluctuations.

In using this dataset in the construction of our model though, some adjustments were required. The PISCO dataset contains temperature readings collected 20 times each day. As such, it is of a much higher resolution than should be included in the annual time scale of our matrix model. A temperature recorded for 1/20th of a day cannot be considered representative of an average yearly temperature experienced by an abalone. However, simply using the yearly mean temperature also is not entirely accurate. Temperature variability also places stress on abalone (extreme spikes of warm water for example). Therefore, a year with a suitable mean temperature may still result in stress to abalone resulting from short periods of high temperature. In order to capture yearly trends in conjunction with frequency and magnitude of extreme temperature events, then we constructed a temperature dataset based off of yearly means and standard deviation (Fig.8).

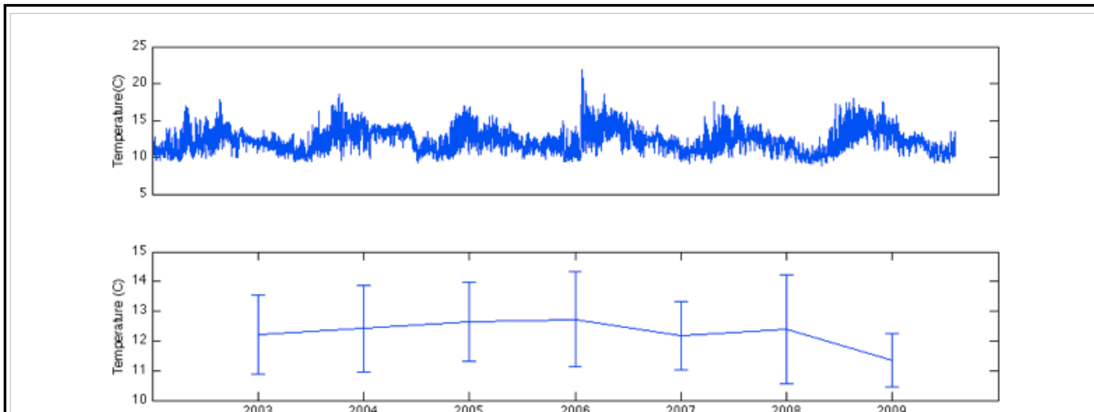


Figure 8. Temperature trends at SMI. The top graph shows total the total dataset. The bottom graph shows mean yearly temperatures ± one standard deviation

A mean temperature was calculated for each year of the dataset. A normal distribution of temperatures was then fit to each year, truncated at ± 1 standard deviation from the mean. For the model then, temperatures were drawn from this set of truncated normal distributions. This method incorporates the yearly trends in temperature, while accounting for the greater variability in some years than others. Truncation at ± 1 standard deviation prevents the inclusion of extreme (and unrealistic) values for yearly temperature that impact the resulting accuracy of the model.

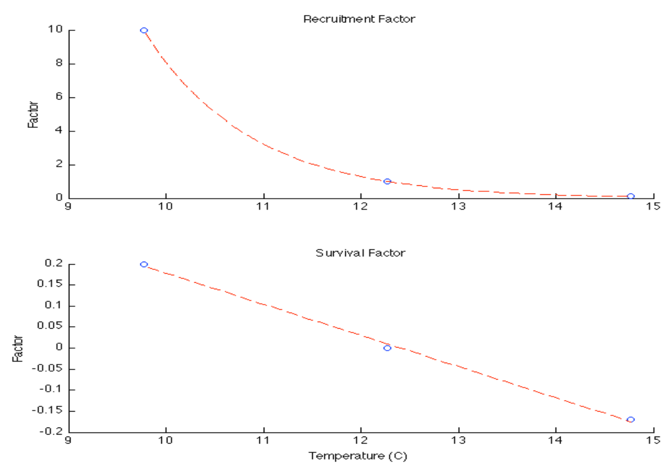


Figure 9. Functions for calculation of changes in survival and recruitment as functions of water temperature

The impact of water temperatures on the abalone population was determined through the use of calculated survival and recruitment factor curves. Through these curves, for any given temperature in any given year, the survival and recruitment rates in the growth matrix were accordingly adjusted. These curves are shown in Fig.9. The extreme bounds of the curves (best and worst case scenarios) were set according to the protocol developed by Vilchis et al. (2005), ± 2.5º C of the ambient temperature (set in this case as the mean of the total temperature dataset). The recruitment curve was derived from Rogers-Bennett & Leaf (2006). The survival function was developed from the lab result of Vilchis et al. (2005). This paper reported a 17% increase in mortality under the highest temperature stress conditions, which was used to scale our function. Within the model, recruitment and survival factors are incorporated as follows. For any given temperature experienced by the model, a subsequent survival and recruitment factor is calculated. The recruitment factor is then multiplied into the model, while the survival factor is added into the model (this method was used to maintain consistent relationships, and help prevent extreme values). Survival was capped at .99, preventing the spontaneous creation of abalone through survivals greater than 100%.

The total structure of the model then is as follows. The model was run for 7000 iterations over 16 time steps (corresponding to 15 years from year 0). Each iteration began at the same calculated initial population level of 5,542,029 abalone. For each year of each iteration, a random temperature was drawn from our developed temperature dataset. This temperature then altered the matrix in that given year, according to the survival and recruitment curves. Yearly temperatures were assumed to have no environmental autocorrelation. When called for by a particular scenario, harvest was modeled as the subtraction of the TAC from the largest size class (200.1mm and greater) each year. The probability of the fishery remaining open in a given year was then calculated.

The resulting population dynamics in sum then are described as

$$N_t = s_t N_{t-1} + r_t - H_t$$

where N is the total abalone population in year *t*, *s* (the net survival factor) and *r* (the net recruitment) are functions of temperature, and *H* is the annual level of harvest.

Harvest Scenarios

Our model was run under three separate scenarios: no harvest (NH), constant harvest (CH) and adaptive harvest (AH). The NH scenario was run in order to evaluate the viability of the population without harvest, and serves as a check of our results. Assuming that the population is growing at the rates reported by the survey data, then we would expect the matrix model would yield results consistent with these historic trends. The CH scenario was run to model the growth of the population under the fishing regime as it is currently proposed, being 10% of the total population of abalone sized 203mm and larger, equaling a take of 10,728 animals a year. For the CH model, we assumed that this level would remain constant over time. For the AH scenario, we considered a case in which a decision-tree style method is developed, allowing managers to assess yearly changes in population levels and set harvest accordingly. In this case, harvest in a given year was set as 10% of the largest size class of abalone present in the previous year.

Theta: Risk of Fishery Closure

The resulting population trends under environmental variability were then used to calculate the risk of fishery closure, a variable we term theta (ϴ). ϴ is defined as a threshold population level of reproductive sized abalone, below which CDFG would decide to close the fishery. We elected to set this threshold level equal to the total number of reproductively mature abalone believed to be present as of the most recent population survey, equal to 326,576 abalone. The risk of this "decline" event is calculated as

$$Decline_t = \sum_{t=0}^{T} \frac{Ic_t}{It_t}$$

where *Ic*= the number of iterations in year *t* that have gone under the threshold at least once and *It*= the total number of iterations

Under our model, if a population decline event occurs, the fishery is closed, regardless of future increases of the population. The risk of this event occurring then is ϴ, equal to

$$\Theta_t = 1 - Decline_t$$

In summary, Θ_t represents then the probability that the fishery will be open for a given length of time *t*.

Results of Population Risk Analysis

Fig.10-12 show the population trends over 15 years of the reproductive abalone population (size classes 100.5mm and larger) under the NH, CH, and AH scenarios. We report the growth in the reproductive population as this size group contains less variance than the smallest size classes. In addition, the reproductive population served as the basis for our calculation of ⊖, and as such is of particular relevance for the results of our study.

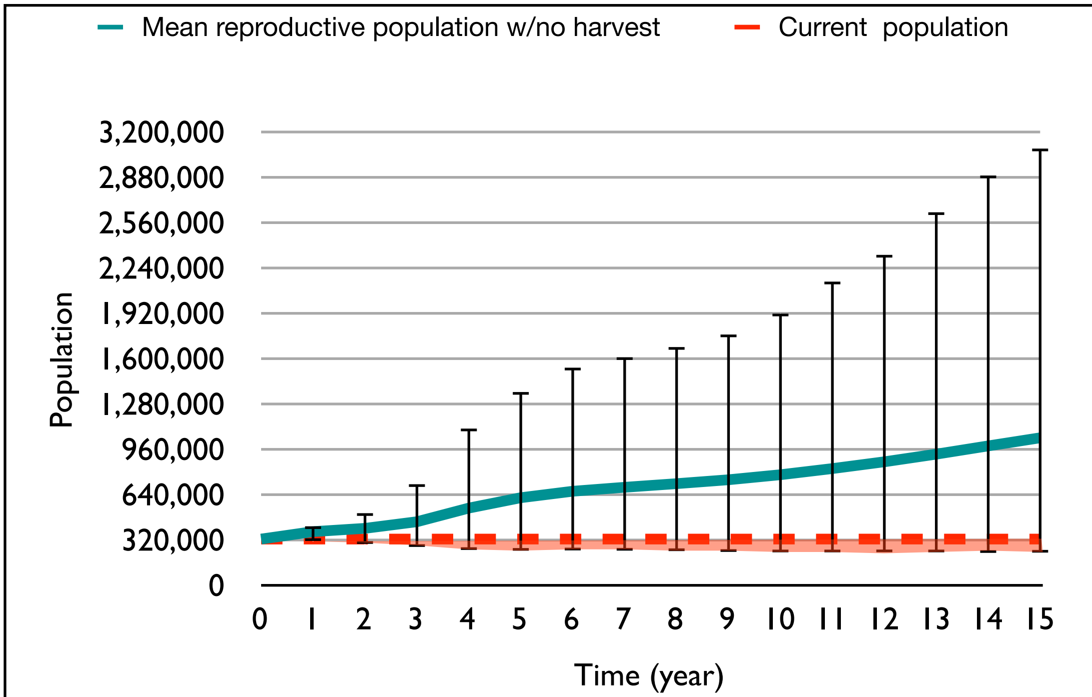


Figure 10. Growth of reproductive abalone under the NH scenario. The solid line shows the mean population growth, with 95% confidence intervals indicated by the black bars. The red dashed line and the shaded red area below it show the threshold population and events of fishery decline

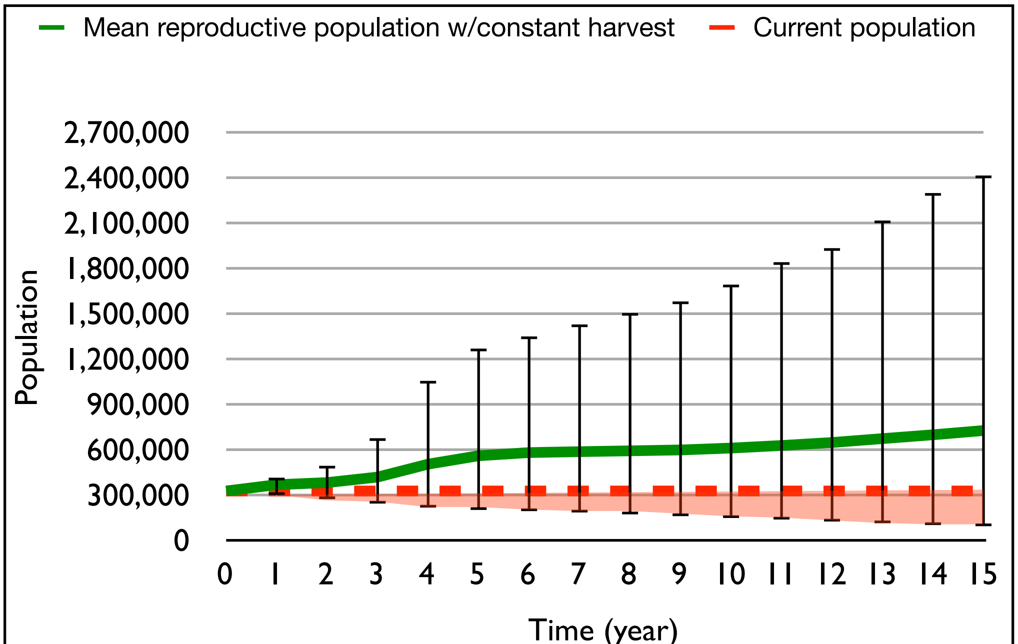


Figure 11. Growth of reproductive abalone under the CH scenario. The solid line represents the mean population growth, with the 95% confidence intervals indicated by the black bars. The red dashed line and the shaded red area below it show the threshold population and events of fishery decline

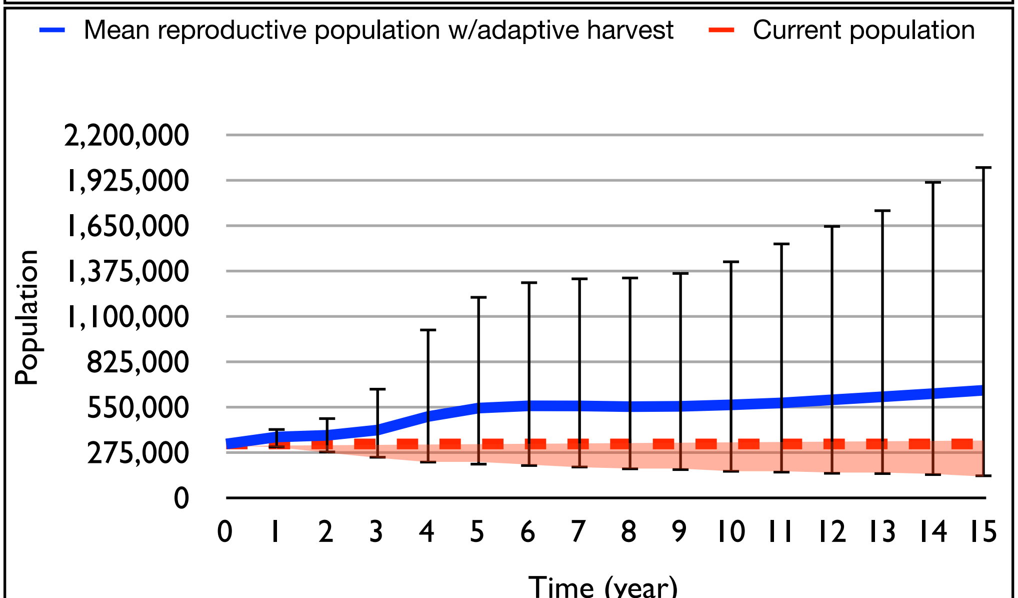


Figure 12. Growth of reproductive abalone under the AH scenario. The solid line represents the mean population growth, with the 95% confidence intervals indicated by the black bars. The red dashed line and the shaded red area below it show the threshold population and events of fishery decline

The NH scenario (Fig.10) shows that our model is consistent with both fisheries modeling theory (that under normal circumstances, a population should be capable of growth without harvest) and the evidence provided by the SMI survey data. The SMI survey data suggests an annual compounding growth rate of 10% for population at SMI. Our NH scenario results in an average annual growth rate of 6.7%, indicating a more conservative estimate of growth than the SMI data suggests.

In order to check the validity of our harvest model, a range of catch-values were tested, including extremely high values, up to 50% of the abalone sized 200mm and larger. If the population model is sound, there should theoretically be an unsustainable level of harvest at which the population crashes. Dramatically increasing the catch-rates in our model did results in the collapse of the population, indicating that the dynamics of our model function properly.

Fig.13 shows the trends in ϴ over time. Under no harvest, a background risk of fishery decline exists, reaching approximately .66 by year 15. This background risk occurs as a result of potential natural fluctuations in temperature, resulting in depletion of abalone, whether through recruitment failure or disease events for example. Under adaptive and constant harvest scenarios, theta decreases relative to the NH scenario. The exact extent of this decline relative to the NH scenario is shown in Fig.13.

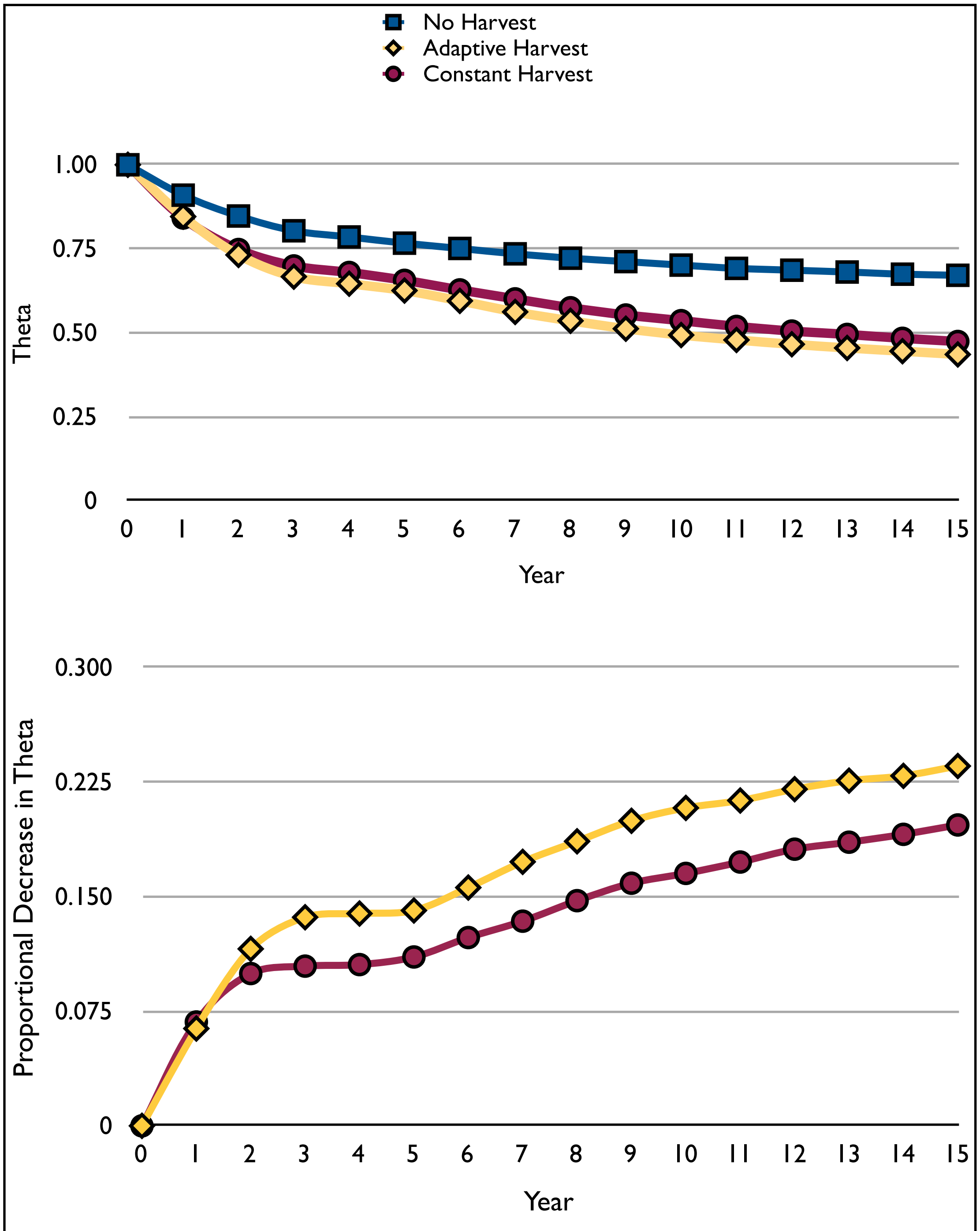


Figure 13. Trends in theta over time. Top graph shows theta for NH (□ series), AH (◇ series) and CH (o series) the 15 year model run. Bottom graph shows the decrease in theta for the AH and CH scenarios, relative to the NH scenario. A value of .075 for example indicates a .075 decrease in the probability of the fishery being open, relative to no harvest conditions

A number of considerations should be taken in interpreting our calculated risk of fishery decline. Our condition for fishery closure may be a conservative estimate of CDFG's requirements for the continuation of the cooperative's harvesting efforts. In addition, in interpreting our results the real meaning of a fishery-closure event must be clearly understood. Under our rules, the fishery is closed if the reproductive population falls below its current levels. However, the occurrence of such an event, as measured by Θ, is not fully indicative of the final fate of the simulated population. With harvest, many iterations within our analysis dipped below the current population, only to recover and continue growing at a later date, though some simulations did remain depleted or eventually crash. This ability of the population to rebound from a decline is not reflected in our model though, as the fishery is assumed to remain shut once a closure event occurs, a rule we feel is valid. The fact that a given value of theta only reflects the probability of crossing a threshold, and is not a measure of the likelihood of a complete stock collapse, must be taken into consideration then in considering the fishing impacts predicted by our model.

Considering its ability to adapt to population dynamics, it may seem counterintuitive that our AH scenario, in which harvest is altered to reflect the actual state of the stock at SMI, results in a greater risk of fishery decline than the CH model. This result is due to the fact that the AH scenario envisioned in our study represents a fairly blunt application of an adaptive scheme. Our AH model sets harvest at 10% of the legal population, regardless of additional factors such as population growth rate, environmental health, or recruitment success. As such, our model can set a very high harvest rate in a year of large population size, only to have the next year coincide with an especially bad year for abalone, resulting in a dip below the threshold population and subsequent closure of the fishery. If the fishery was allowed to continue, the harvest of that now lower population size would be appropriately scaled down, possibly resulting in recovery. Again though, this recovery is not accounted for in our model. In reality, an adaptive harvest scenario developed for red abalone at SMI should be built around a far more robust set of rules than simple population size. Taking into account a full picture of the state of the abalone population in a given year, in conjunction with spatially explicit modeling, may allow for an adaptive management strategy that reduces the risk of fishery decline.

In examining our results, those familiar with the history of this abalone fishery debate may ask why we simply do not employ the results of the Jiao model. The Jiao model was developed for the AAG in order to model the abalone population at SMI. However, the structure and results of this particular model render it of little use to our economic analysis. The Jiao model only provided one year of abalone population estimates at SMI, and for this year reported a collapse of the stock even in the absence of fishing. Numerous challenges have been made to these findings (Prince & Valencia 2009), but our reasons for not using this model are far more fundamental. The goal of our project was to assess the economic viability of a potential cooperative abalone fishery at SMI. If we take the results of the Jiao model as final, then our project would have been over before it began. Clearly, there can be no fishery if there is no sustainable level of catch possible, rendering an economic analysis of an impossible fishery useless. However, the results of the Jiao model have not been accepted as fact at this time, as reflected by the continued debate by the AAG of the opening of the fishery at SMI, as well as stated concerns as the validity of its results (Prince & Valencia 2009). Had the AAG decided the Jiao results were conclusive, then the debate would be over and the fishery would remain closed. Since the debate is continuing, the AAG must feel that the results of the Jiao model are not conclusive, and that the population at SMI may be capable of sustaining harvest, as the survey data suggests. As the Jiao model precludes the existence of a fishery then, we are unable to use it for our economic analysis, and as such had to construct a population model reflecting a population at SMI that is growing at a rate suggested by the SMI survey data.

Given these considerations, our results provide an estimate of the population dynamics both with and without harvest at SMI. In developing these results, many assumptions and simplifications had to be made. The most profound of these are likely to be the lack of spatial explicitness, and the assumption of yearly reproduction (though extreme fluctuations in the amount of recruitment occurring in a given year were included, on occasion reducing recruitment to essentially zero). In addition, we did not explicitly model the impacts of disaster events, such as severe WFS outbreaks, sea otter predation, or extreme temperature increases. Taking these caveats into consideration, our model still makes use of fundamentally sound and previously employed modeling practices (Hobday & Tegner 2002, Rogers-Bennett & Leaf 2006), using best available data on the abalone population at SMI. As research continues and data is collected on the abalone population as SMI, this increased knowledge could easily be incorporated in the general model framework constructed here, allowing for more refined results. The ideal goal should be the creation of a spatially explicit model, capable of using abalone population ecology in conjunction with oceanographic data to model the dynamics of the red abalone at SMI over space and time. Given the lack of a viable alternative for estimating the population dynamics at SMI though, our results provide a solid foundation through which to consider the role of environmental uncertainty in the economic viability of this cooperative fishery.

Monte Carlo Sensitivity Analysis

To fully assess the economic viability of the cooperative, its profitability must be evaluated in the context of both environmental and financial uncertainty. While the base-cases presented in Table.4 provide our best estimates of financial parameters, these are not the only possible values of costs and benefits that the cooperative might face. Through our research we developed a broad range of possible values for the variables shown in Table.3. In order to account for this wide array of potential costs and benefits, we ran our economic viability analysis using randomized combinations of these financial parameters, in conjunction with the probability of the fishery remaining open shown in Fig.13.

This process is known as a Monte Carlo sensitivity analysis. A Monte Carlo analysis uses randomized combinations of possible costs and benefits in order to simulate the profitability of the fishery under a complete array of scenarios, from worst-case (lowest market value, highest operating costs) to best-case (highest market value, lowest operating costs). Our Monte Carlo analysis was run under three scenarios; constant harvest with a 90%-10% split of the TAC between the cooperative and recreational fishers (CH90), constant harvest with a 50%-50% split of the TAC between the cooperative and the recreational fishers (CH50), and an adaptive harvest scenario (AH). These divisions of the TAC corresponds with annual harvests of 9,655 (CH90) and 5,364 (CH50) abalone. The annual harvest for the AH scenario envisions a management strategy based on an assessment protocol (such as those used in the abalone fisheries of Australia, see Prince et al. (2008)). For the AH model, managers are considered capable of accurately determining the population level

	Low		Medium		High	
Cost Category	**CH90**	**CH50**	**CH90**	**CH50**	**CH90**	**CH50**
Independent data collection	$20,059	$20,059	$40,118	$40,118	$60,176	$60,176
Data Coordinator	$0	$0	$10,400	$8,329	$20,800	$16,640
AAUS certification (year 1)	$0	$0	N/A	N/A	$14,500	$14,500
AAUS certification (year 2+)	$0	$0	N/A	N/A	$500	$500
Marketing Coordinator	$0	$0	$10,400	$10,400	$20,800	$20,800
Fishing Days (at $508.3 per day)	42	28	50	33	58	38
Enforcement Costs (4 categories)	Year 1: $0 ; $25,000 ; $50,000 : $75,000 ; $100,000					
	Year 2+: $0 ; $16,250 ; $32,500 : $48,750 ; $65,000					

Table 6. Summary of variable annual costs in Monte Carlo analysis for CH90 and CH50

in any given year, and setting the TAC accordingly. This shift in available catch under the AH scenario was included through the use of the mean population size derived from our population model. Fig.15 shows the cooperative's catch each year of the AH scenario. The AH scenario assumes a 90%-10% split between the cooperative and recreational fisheries. We assume this because the development of an adaptive harvesting methodology will likely require extensive research and data collection in collaboration with the fishery. It is unlikely that the fishery would be able to afford these actions if the TAC is split 50%-50% with the recreational component.

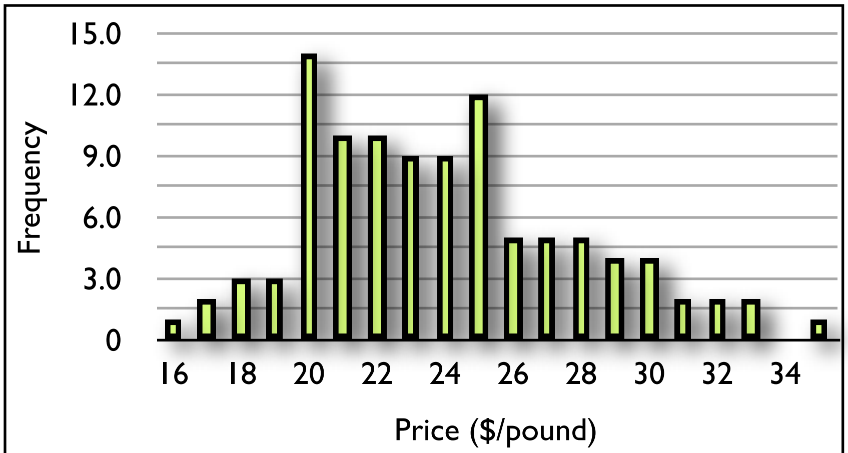


Figure 14. Frequency histogram of reported prices for wild caught red abalone

For the CH90, CH50, and AH scenarios, we calculated the cooperative's profitability using 7000 randomized combinations (iterations) of revenues and costs over a 15 year period. For each iteration, the combination of values selected were held constant over the length of the model. Revenues for each iteration were calculated as a function of the harvest and the market price of abalone. The range of abalone price values used in the Monte Carlo analysis is demonstrated in Fig.14, that shows the frequency of occurrence for each potential market abalone price, from $16/lb to $35/lb, developed from our market research. For each iteration, a random market price was selected from this distribution, providing a full range of potential revenues.The full range of costs used in the CH90 and CH50 scenarios are shown in Table 3. However, during the AH scenario, a number of values change each year as a function of the total catch. We therefore do not present these exact values in table form, but the method for calculating costs and revenue in the AH scenario is shown in Appendix 2.

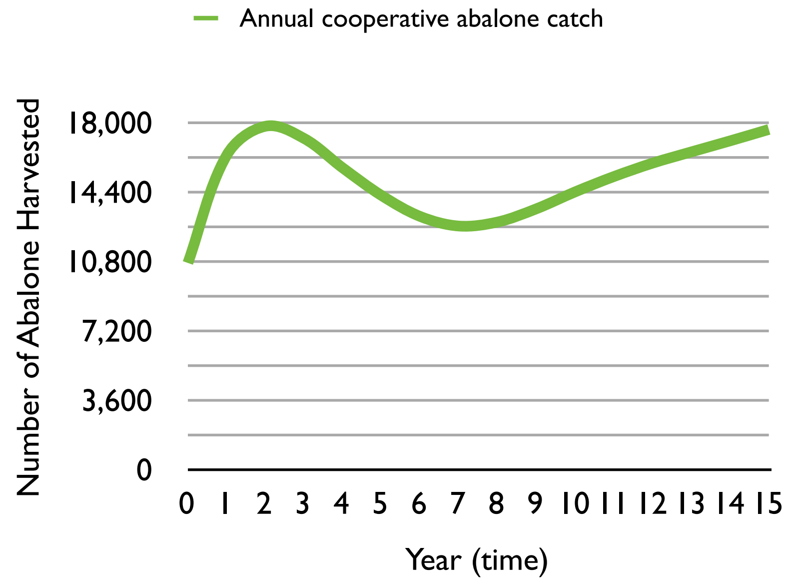


Figure 15. Number of abalone harvest each year under the AH scenario

Using these methods and the associated costs and benefits for the CH90, CH50, and A, the NPV of the fishery, for each given length of time *t* that the cooperative is in existence, was calculated as

$$NPV = \sum_{t=0}^{T} \frac{\Pi_t}{(1+r)^t} \times \Theta_t$$

where Π_t = profits in year *t*,

r = the discount rate, selected to be 0.05

and Θ_t = the probability of the fishery remaining open in year *t*

Expanded calculations for the NPV can be seen in Appendix 2. In addition to calculating the NPV of the cooperative for a given length of its existence, we also calculated the minimum level of catch (C_{min}) that would be necessary in order for the fishery to remain profitable in year 1 of its operation. We calculate this value due to the politically contentious nature of this proposed fishery. Should it be decided to open this experimental fishery, but at a lower level of catch, C_{min} represents the lowest possible level of harvest that could allocated to the cooperative in order for the fishery to remain profitable.

Results of Economic Viability Analysis

The results of our economic viability analysis are shown in Fig.15 and Fig.16. Our analysis indicates that under the CH90, CH50, and AH scenarios, the cooperative remains profitable even at the lowest range of values observed. The CH50 scenario provided the lowest benefits, nearing a NPV of 0 in year one. The CH90 and the AH scenarios did not result to be statistically different. However, the AH scenario does show the potential to provide higher revenues under extremely positive circumstances.

Fig.16 illustrates the potential benefits of this cooperative to individual members. Considering only year one from Fig.16, our results show that a single fisher can earn in the vicinity of $9,000 for each year of abalone fishing.

Fig.17 shows the results of our analysis of the minimum catch needed for the cooperative to remain viable. These results show that a TAC set above 3,260 abalone will most likely result in the cooperative being profitable. This value was calculated across the full range of possible costs and benefits we believe are likely to be faced by the cooperative. Below a TAC of 3,260 then, our analysis suggests that there is increasing risk of the fishery becoming unable to offset its operational costs.

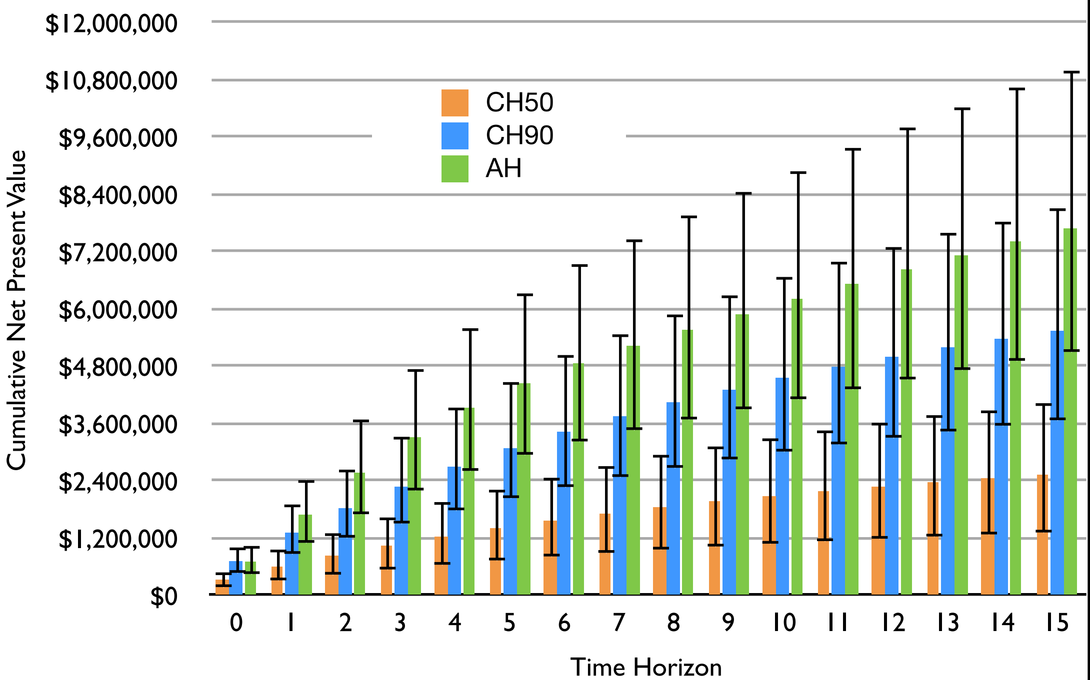


Figure 16. Cumulative net present value of the fishery of a 15 year time horizon. Black bars represent 95% confidence intervals

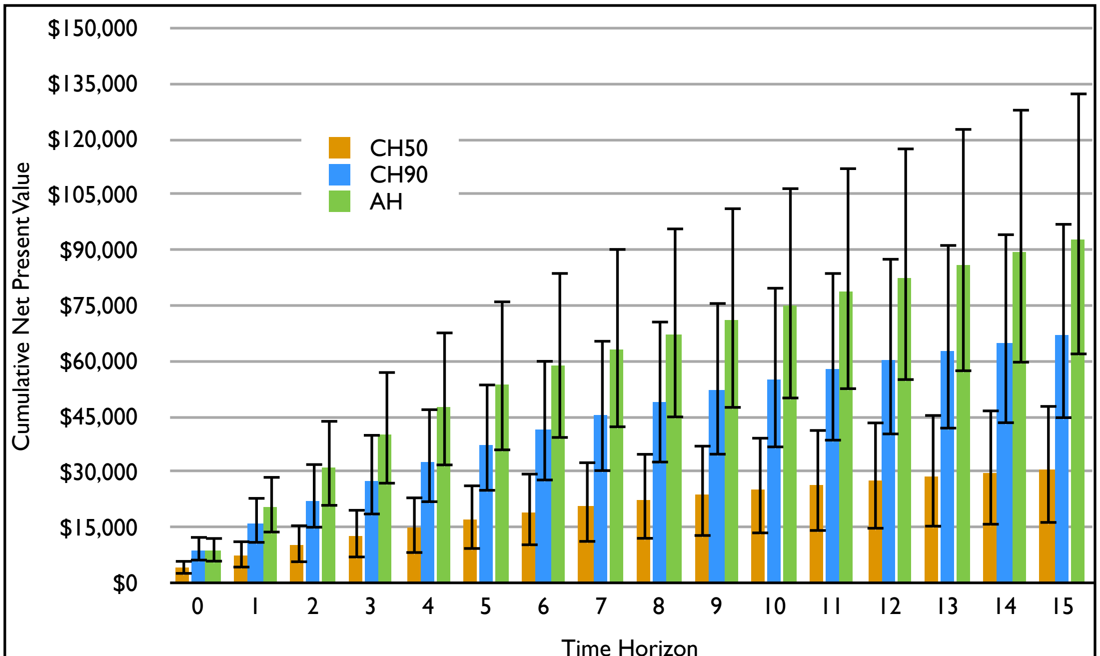


Figure 17. Cumulative net present value per individual cooperative member, assuming a total of 83 members

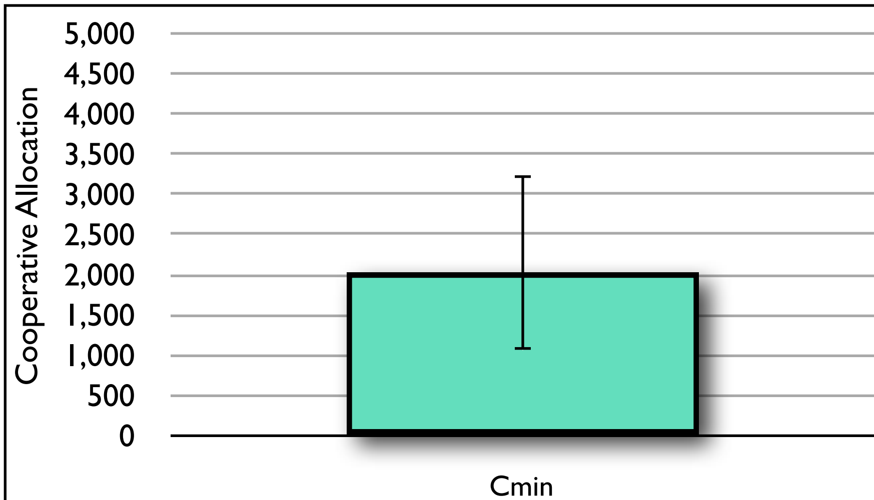


Figure 18. Minimum amount of annual harvest needed for the cooperative to remain profitable in year one of its operation. Black bars represent 95% confidence intervals. The top of the black bar represents the minimum amount of catch for which we calculate no significant risk of the fishery becoming un-economically viable

Synopsis of Economic Viability Analysis

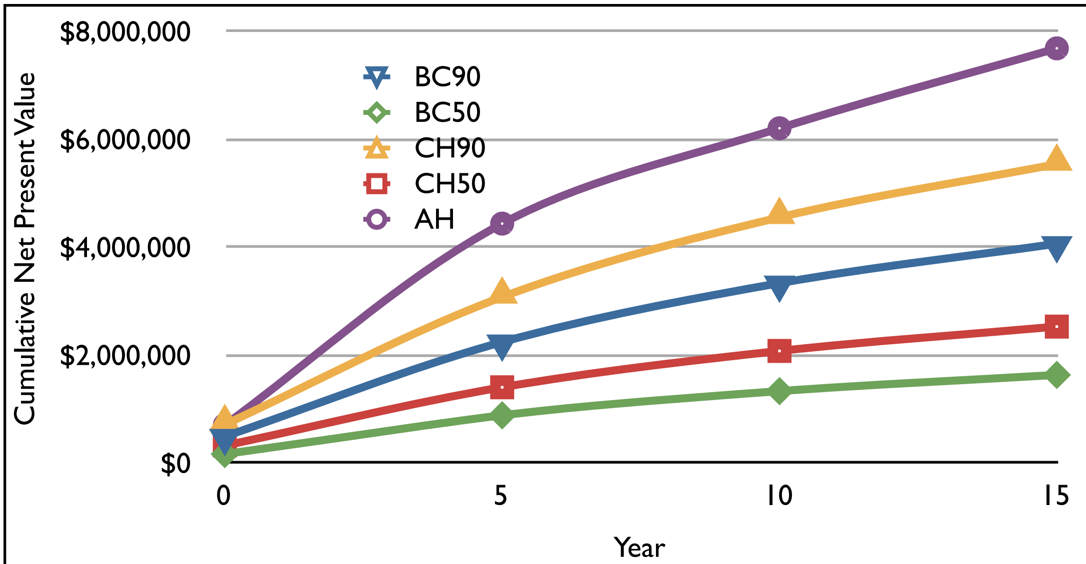


Figure 19. Mean NPV of our 5 scenarios

We evaluated the long-term economic viability and potential for sustainable management of this abalone cooperative by examining the costs and benefits over a fifteen-year period, assessing a spectrum of possible parameter values, and by incorporating uncertainty. The resulting mean NPVs over time are shown in Fig.19. Our initial base-case assessment evaluated two possible scenarios, BC90 and BC50. These represent a clear example of what we believe are likely values of costs and benefits to be faced by the cooperative. Our analyses of BC90 and BC50 both yield positive economic results for the first year of operations ($506,703 for BC90 and $176,587 for BC50), showing the the cooperative can be profitable under these conditions (Fig.20).

While BC90 and BC50 represent two possible realities, in order to fully evaluate the profitability of the cooperative economic viability was assessed in the context of both environmental and economic uncertainty. We incorporated risk of cooperative closure due to population decline by constructing a matrix-based population model to simulate the growth of abalone under environmental uncertainty and three harvest scenarios; CH50, CH90, and AH. The result of this analysis provided a measure of the risk of fishery being closed as a result of population declines over time. This risk of fishery closure was incorporated with possible revenue values into a Monte-Carlo sensitivity analysis model, in order to calculate the net present value of the fishery over a

	CUMULATIVE NET PRESENT VALUE			
	Year			
	0	5	10	15
BC90	$503,203.41	$2,252,515.80	$3,344,180.54	$4,075,429.08
BC50	$176,587.03	$894,824.49	$1,343,043.18	$1,643,281.20
CH90	$724,491.21	$3,088,462.99	$4,563,708.15	$5,551,896.96
CH50	$334,843.62	$1,414,247.34	$2,087,853.14	$2,539,066.08
AH	$715,420.10	$4,448,036.16	$6,215,439.39	$7,696,229.42

Table 7. Mean cumulative NPV for each of our scenarios

15-year time horizon under the three potential harvest strategies. Using 95% confidence intervals, we found that even under the worst case scenario the cooperative is still economically viable. These values correspond with mean profits in for the first year of the cooperative's existence of $334,843 (CH50), $724,491(CH90), and $715,420 (AH) (Table.7). To give an illustrative examples, if 83 members remain in the cooperative, under the CH90 scenario a single member can earn in $9,000 in profits for a year of fishing. Should alternative TACs beyond those envisioned by the CH90 and CH50 be considered, we also calculated the minimum catch needed in order to offset the operational costs of the cooperative, resulting in an annual minimum harvest of 3,260 abalone needed in order to ensure profitability (Fig.18). However, it should be noted that this number represents the bare minimum of catch needed to offset total operational costs. In summary, our results indicate that a commercial abalone fishing cooperative at SMI is a economically viable, fully incorporating financial and environmental uncertainty.

Recommendations for Cooperative Fishery Management

The results of our economic analysis show that the cooperative is financially viable under a wide range of scenarios. However, the success of this fishery cannot be judged purely by its profitability. As expressed by the CAA, the goal of this cooperative is to develop a community-based management structure capable of both stewarding the abalone resource and providing social benefits. The internal operating structure of the cooperative will play a significant role in the ability of the fishery in effectively filling this role. As such, our group has developed a set of recommendations for the management of the cooperative, based on a survey of the successes and failures of other catch-share fisheries around the globe.

Appendix 1 contains the results of our survey. Many published works have addressed the incentives created by catch-share management, the impacts of these cooperative systems on the economics and ecosystems of fisheries, and the technical principles that contribute to the success or failures of cooperatives. However, relatively few studies have looked at the internal mechanisms through which fishing cooperatives put the theoretical advantages of catch-share management to use. This survey was intended to fill that gap, by gathering information and developing a database of cooperative style fisheries from across the world. In doing so, we have collected as much information as possible as to how these individual cooperatives have actually gone about developing and managing their industry, and the subsequent effects that these actions have had on the economics and environment of local fisheries. While by no means exhaustive, in this document we have compiled those cases for which we were able to gather the most interesting and complete data, accompanied by relevant sources and when available contact information from experts on the cooperative in question.

Using this database, we have compiled a list of recommendations for the CAA, containing specific methods for implementation and sources for examples of other similar cooperative management experiences. While many of these suggestions are already being considered by the CAA, by providing concrete examples of other fisheries which employ these practices successfully we intend to provide the CAA with a strong case for the implementation of these strategies.

Options for Membership Reduction

The CAA has expressed a desire to explore tools for membership reduction. Based on the results of our research, we have developed and analyzed a number of methods for reducing the size of the cooperative. Specifically, the CAA wishes to reduce their membership size from 83 to about 35. Although a small group of fishermen is not necessary to achieve cooperative success it does have the potential to achieve positive benefits. Reducing membership size of the cooperative can lead to a more like-minded group of individuals, easing operations and simplifying decision making processes (J. Cooper pers. comm., G. Peacock pers. comm., Peacock & Eagles 2008). Furthermore, as membership is reduced the cooperative is left with those individuals who have the most desire and obtain the most benefit from being a member of the fishery. Due to this fleet reduction, costs decrease through gains in efficiency, subsequently increasing profits

(Deacon & Costello 2007). As a result of this relationship, from a purely economic perspective the most efficient fishery often has relatively few members with very different proportions of ownership. However, not all fisheries desire this consolidation to occur. While decreasing membership may increase efficiency, social problems may arise, such as inequities in access to the resource and restructuring of a traditional fishery system and way of life. Given a range of possible methods for membership reduction, in combination with requests made by the CAA, we have focused on four methods to achieve reduced membership. Although our results will not model the CAA membership exactly, our work demonstrates that it is possible to model membership reduction, and provides an indication of the most viable method.

Four Methods

The four methods we chose to recommend to the CAA for membership reduction are: transferable shares, transferable shares with a consolidation cap, a buy scheme, and a sealed bid mechanism. All of these schemes are dependent on the assumption that the fishermen have a range of opportunity costs, meaning some members are made better or worse off by their membership in the cooperative, depending on what they have to give up to fish their share of the harvest. For example, a former commercial abalone diver who has since become a lawyer working in London would gain far less benefit from being in the cooperative than a member who lives in Santa Barbara and is still an active fisher.

The four mechanisms that we modeled represent very different approaches to reducing membership. Transferable shares allow unlimited buying and selling of cooperative shares by the fishers. In this case, those members wishing to own more shares will buy allocations from those members wishing to own fewer shares. This may result in majority ownership in the hands of a few individuals. Through this process membership has the potential to be drastically reduced. Additionally, by concentrating fishing effort into a fewer number of hands, cooperative profits are maximized. Essentially transferable shares have the potential to find the economically efficient membership size, below which costs increase and above which excess fishing effort exists. However, if the cooperative wishes to maintain relatively equal ownership they may place a cap on consolidation. The cap limits the proportion of the fishery that an individual cooperative member may own. Subsequently, membership is not reduced as much and profits are not maximized. Changes in the level of the cap result in changes in the membership size and profits to the cooperative.

Should the CAA not wish to allow for trading of shares in the cooperative, the use of a buy scheme or sealed bid mechanism could be considered. These schemes may reduce membership without allowing individual members to own more or less shares in the fishery. In the case of the buy scheme, the CAA offers cooperative members a price for their shares. Those members who value their share less than the buy price will sell to the cooperative. After the sales take place the gained shares are reallocated evenly to the remaining members. This results in equal, but greater ownership for each member; essentially, the size of the pie remains the same, it is simply sliced into less pieces. Different buy prices will result in different reductions in membership and cooperative profits. The CAA would have to balance gains from membership reduction with costs of buying out fishers.

In the case of the sealed bid option, fishermen approach the CAA with a minimum price they would accept in exchange for their share. At this point the CAA can choose to deny or accept their bid. Depending on the number of bids the CAA accepts membership size and profits will change. Similar to the buy back scheme, after bids are accepted the shares are evenly distributed to the rest of the cooperative members.

In order to model these four options for membership reduction we have chosen parameter values that we believe are close to representing current CAA membership. However, these values are not precise and therefore we will not focus on the specific results of these four models, but rather the theory behind their answers and their general implications.

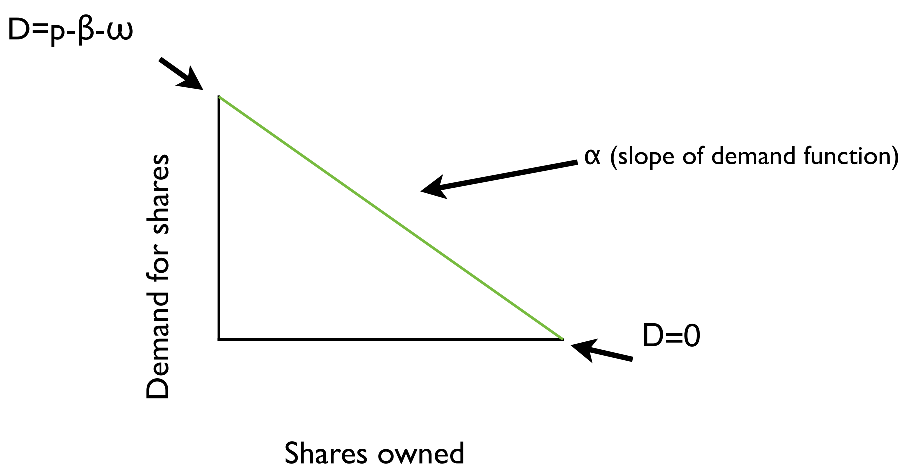
Modeling Membership of the CAA

To model membership we assigned demand functions to each individual member. The demand functions were based on profits that are reduced with each additional share owned. Our reasoning for this was due to an increasing opportunity cost.

Therefore, fishermen *i*'s demand for shares is modeled by:

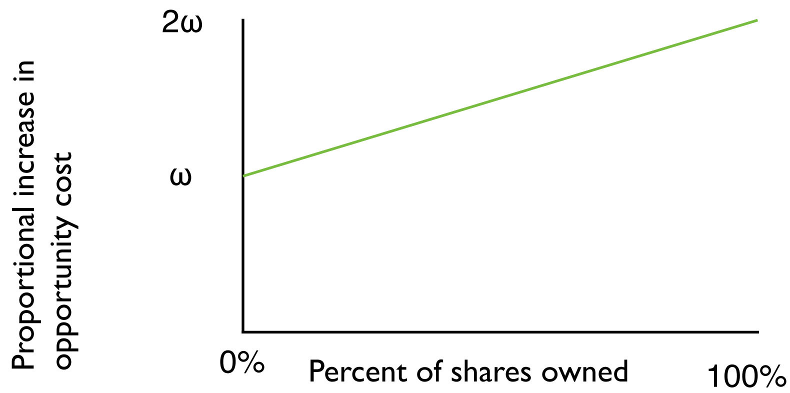
$$D = (p - \beta - \omega) - \alpha S$$

where p is the revenue from 130 abalone, β is the cost of fishing for two days (the amount of time it takes to harvest 1/83rd of the TAC) and ω is the opportunity cost



from two days of fishing. Finally, α is a measure of how much worse off one is made by each additional share owned, S. Together these result in a price D, or in essence the perceived value of each share. This can be visualized by the following figure.

Because we set α as a function of reduced value due to an increasing opportunity cost we estimated its value to be equal to ω/100 based on the assumption that an individual doubles their opportunity cost at S=100 as shown below.



In order to model membership using MATLAB we simplified the above function to:

$$D = a - bS$$

where $a = p - \beta - \omega$ and $b = \alpha$. Each member's inputs were based on a range of a and b values. This results in a range of member benefits as shown in Fig.20 .

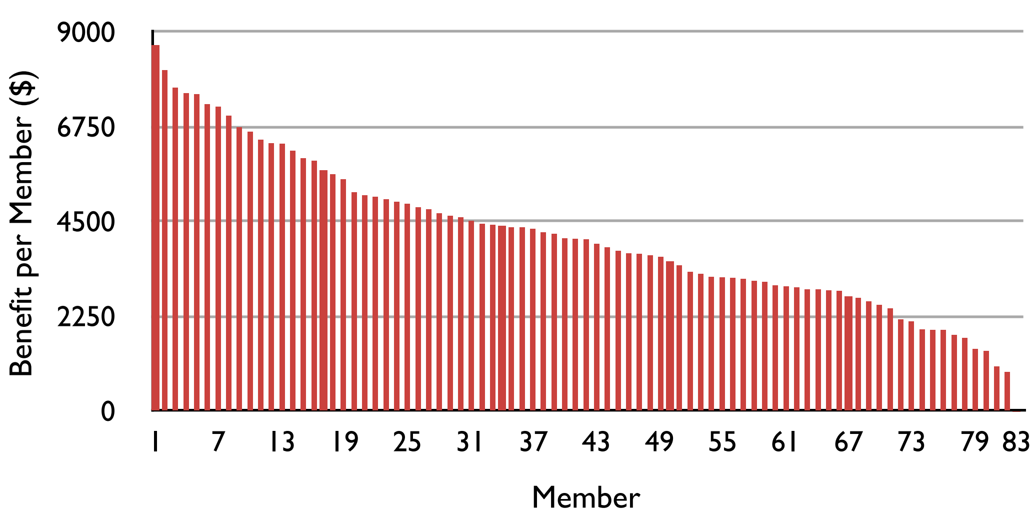


Figure 20. Distribution of member benefits

As shown by the above figure, the 83 members of the cooperative have varying benefits. These are for the most part due to their differences in opportunity costs. While one member may be happy to dedicate time to fishing another may have to make expensive sacrifices to do so. It is due to these differences that members are incentivized to buy or sell more shares as to accommodate their personal preferences.

Modeling the Effect of Membership Reduction on the CAA

Fig.21 shows the result of transferable shares and transferable shares with a cap on membership.

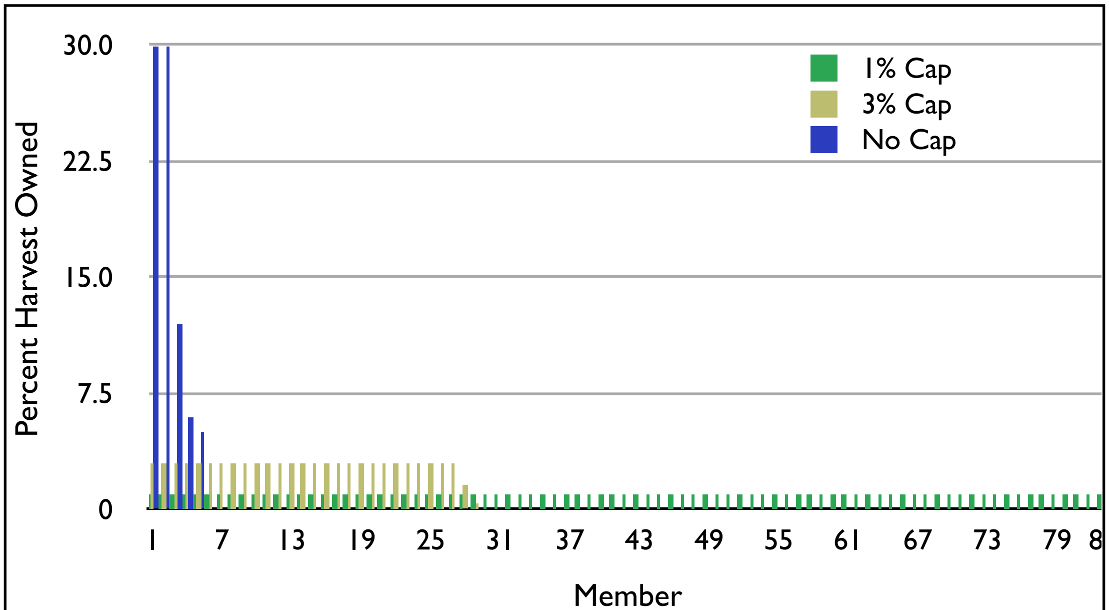


Figure 21. The effect of a consolidation cap on membership

The blue bars represent the envisioned default structure of the cooperative, in which each member is allocated an equal portion (1%) of the cooperative's harvest. The green bars represent the effect of a transferable share system without a consolidation cap on the membership. When fishers are allowed to trade shares in the fishery freely, membership is reduced to 10 members and ownership is concentrated among a few members, with member 1 owning 30% of the fishery. The yellow bars are the result of transferable shares with a 4% cap. As shown, membership is reduced to 30 members. Of those 16 members own 4% and the remaining own less. Under this limitation, excessive ownership of the fishery by a few members is prevented, but cooperative benefits are not maximized. As seen in Fig.22 , cooperative profits vary based on the cap used.

Placing a cap on consolidation decreases total cooperative benefit, as shown in the above figure. As the consolidation cap is increased the cooperative benefits also increase. Therefore if the CAA wishes to maximize their profits a large cap or no cap would be required. However, the consolidation cap scheme does demonstrate the potential to reduce membership size substantially while maintaining equity in fishery ownership.

The following figure demonstrates the effect of the buy price scheme. As shown, the actual buy price offered greatly affects the resulting benefits to the cooperative. The greater the buy price offered the greater membership is reduced. But in order to achieve this membership reduction the cooperative must spend large amounts of funds buying members out, therefore reducing total benefits.

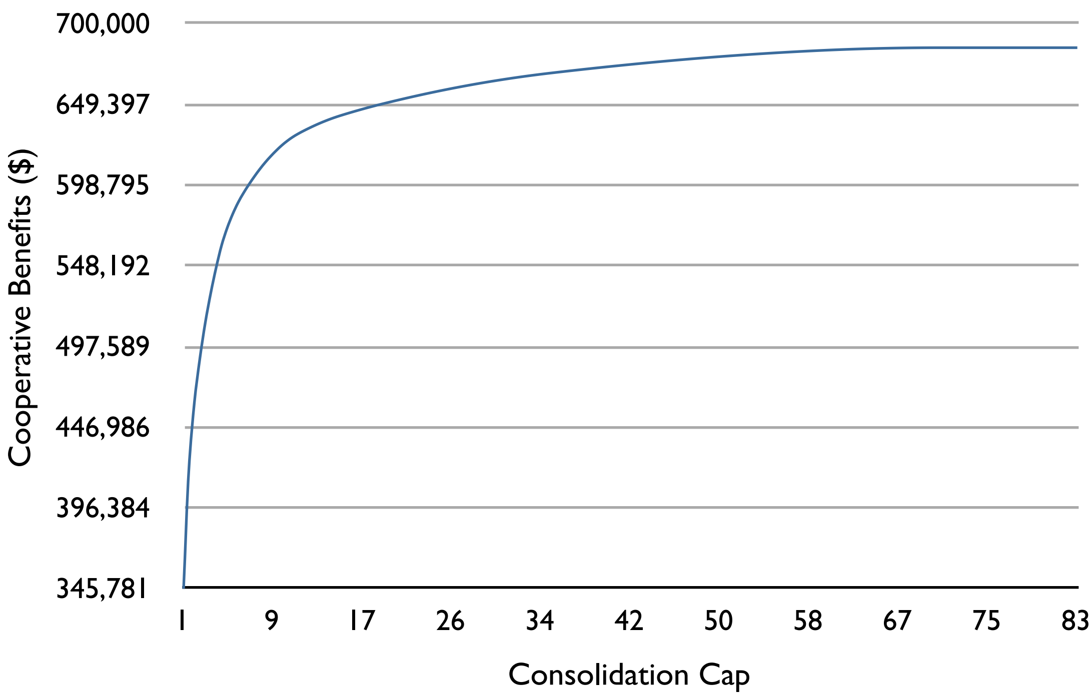


Figure 22. The effect of a consolidation cap on total benefits to the cooperative.

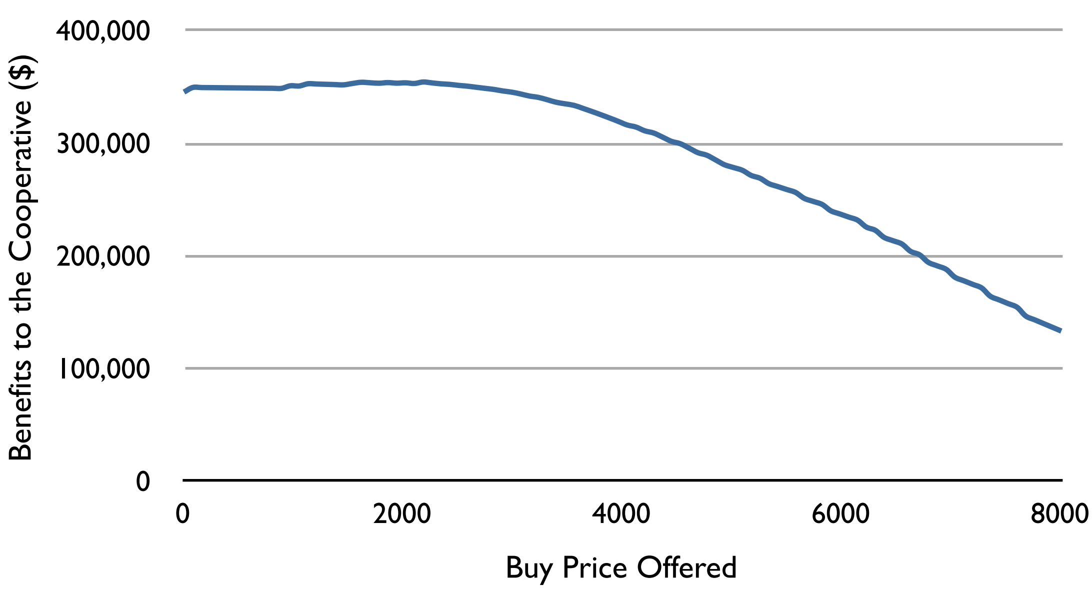


Figure 23. The effect of the buy price on benefits to the cooperative.

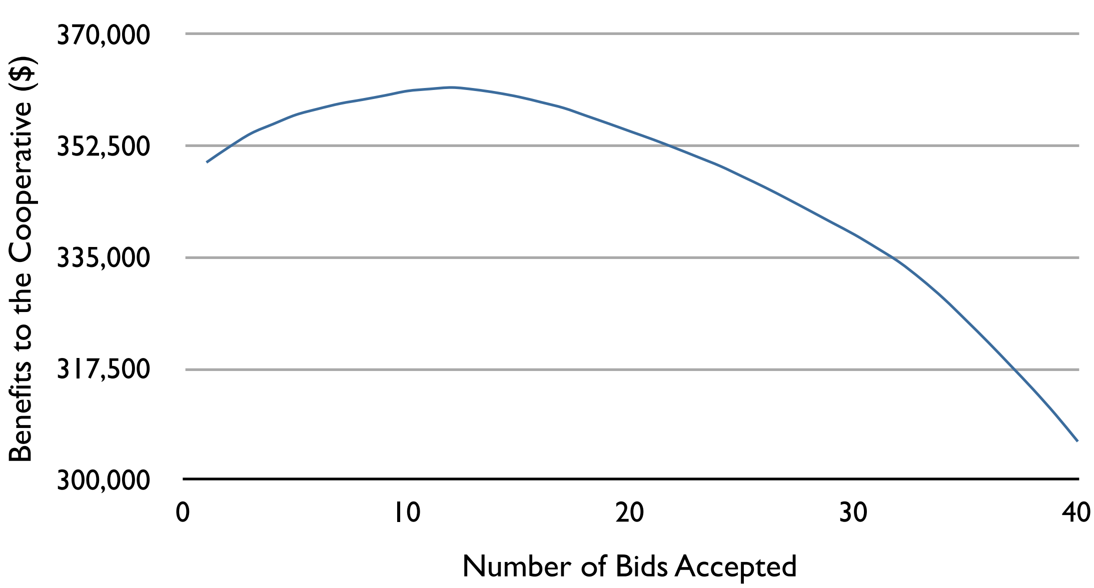


Figure 24. The effect of the number of bids accepted on benefits to the cooperative.

As shown, the buy price that maximizes benefits to the cooperative is approximately $2,000 (refer to Fig. 23). However, this price only reduces membership to 73 members and achieves lower cooperative benefits than those found through transferable shares. A similar result is found in the case of the sealed bid option. As shown in Fig. 24 the number of bids accepted alters membership and cooperative profits. By accepting approximately 13 bids, cooperative profits are maximized under this system. But, as was seen in the buy scheme model, the maximum benefits to the cooperative from a sealed bid mechanism is still less than that found in a transferable share system.

It is important to keep in mind that both the buy price and sealed-bid systems reduce membership while keeping member ownership the same for all remaining members. On the other hand, transferable shares result in a reduced membership, but results in discrepancies in cooperative ownership between members. This point may help to explain why benefits to the cooperative are reduced by the buy scheme and sealed bid option. When shares are equally allocated among members there are some members who would wish to own more shares and others who would wish to own less based on their individual opportunity costs. In the case of the sealed bid and buy scheme reductions, preferred ownership is not achieved, but when using transferable shares no individual will end up with more or less shares than their preferred amount. Subsequently, this interaction changes the cooperative benefits.

Conclusions from Reductions in Membership

Our results indicate that methods for reducing membership in the cooperative can be empirically modeled. Although our numbers are not currently reflective of the true opportunity costs and benefits of the CAA's members, our technique demonstrates the ability to model the effect of different reduction schemes on membership and cooperative benefits. Given the parameters that we used in our modeling, each of the four methods had significantly different effects on membership size and cooperative profits. Transferable shares with or without a cap have the greatest potential to reduce membership and increase benefits. Given the CAA's desire to maintain relative parity in each member's ownership of the cooperative, the transferable shares with a cap system may be more desirable, as it reduces membership without creating too many discrepancies in cooperative ownership among its members. Our results show that by placing a 3% cap on consolidation the CAA would reduce its membership to 29 members, but this comes with a reduction in overall benefits to the cooperative as well, compared to the unregulated transferable share scheme. Nonetheless, this method results in greater cooperative benefits than the sealed bid or buy scheme options. If the CAA is more concerned with retaining equity it could implement a buy scheme or sealed bid option. However, neither of these systems have the potential to greatly reduce membership or maximize benefits to the cooperative. Ultimately, the CAA must weigh the economic benefits and potential to significantly reduce membership size resulting from the transferable shares systems, with the ability to ensure equal ownership in the cooperative provided by the buy price and sealed bid options. Our results do indicate though that the transferable shares with a consolidation cap scheme may prove a reasonable solution for membership reduction.

Coordinated Marketing

For many of the cooperatives surveyed in Appendix 1, coordinated marketing served as the primary source of increased revenues stemming from the formation of a cooperative fishery. While developing a cooperative often results in fisheries taking on an increasing share of monitoring and enforcement costs, these costs are often offset by the ability of the fishery to fish and sell at the most profitable times of the year (Cancino et al. 2007; González et al. 2006; Kahn 2006; Makino & Matsuda 2005; Mincher 2008). While the CAA is already intending to pool catch, there is a significant difference from simply coordinating catch and truly developing a coordinated marketing system. We therefore strongly recommend that the CAA focus significant energy in the marketing and sales of their product.

By coordinating selling to prime portions of the year and focusing on quality over quantity of catch, a cooperative can substantially increase the value of their harvest with little to no additional fishing effort. The loco (*Concholepas concholepas*) fishing cooperatives of Chile provide a useful demonstration of this observation. Prior to the formation of cooperatives, loco fishermen simply caught as much as possible in the hope of selling all their catch at the beach. Following the establishment of the Chilean cooperative system, cooperatives began prearranging purchases with seafood buyers, allowing the fishers to catch only as much as actually demanded at a given time. In addition, doing so allowed the fishers to target the correct number of high-quality loco over large numbers of low-quality individuals. As a result, the Chilean cooperatives have been able sell their catch at a higher price for less effort (González et al. 2006).

The Underwater Harvesters' Association (UHA) of Canada shows a similar trend, experiencing increased total value of geoduck sales, despite a drop in annual catches (Kahn 2006). This is attributed to the cooperative's ability to spread fishing effort throughout the year, and in doing so supply only live, fresh geoduck (as opposed to canned product, the form in which geoduck was primarily sold prior to cooperative formation).

Both of these case studies are highly applicable to the proposed abalone cooperative, as both the loco fisheries and the UHA target high-quality shellfish. By following the examples of these similar fisheries, the CAA may be able to substantially increase the value of their catch. In addition, by tying fishing effort to demand, rather than catching excessive amounts of low-value catch, the CAA will be able to leave more abalone in the water until they are needed for harvest. This may give the animals more time in which to provide recruits to the fishery.

In addition to improving the economic efficiency of fishing operations, coordinated marketing can substantially improve the name recognition and subsequent competitive status of the cooperative. The cases of Crabco and the PauaMACS of New Zealand provide a useful example of this. The members of the PauaMACs work together to monitor and manage the stock, but their collective efforts stop beyond this point; individual quota holders in the fishery sell their catch independently (J. Cooper pers. comm.). Concurrently, contrary to the trend in many fisheries, the paua industry of New Zealand has experienced a decrease in the value of wild abalone compared to the farmed product. This is due to the fact that the farmed product is small enough to fit two whole pieces in a can, the predominant method of sale for paua. Wild paua of legal size to be caught is too large to fit in one can, resulting in decreased value. The

PauaMACs have found themselves unable to shift their sales towards a more high-end live market, since this demand is largely met by illegal catch (J. Cooper. pers comm.). As a counterexample, Crabco has utilized collective marketing to dramatically improve the standing of their fishery. This cooperative targets deep-sea crab, which historically was thought of as inferior to similar products from Australia and Asia. Through an aggressive marketing campaign branding their product as new and different, Crabco was able to turn this trend around and develop substantial international demand for their product, resulting in a substantial price premium. Their control of the market has grown strong enough to be able to blacklist potential clients caught attempting to buy illegal catch (T. Craig. pers. comm.).

Following the examples of these case-studies, a coordinated marketing system can also aid in the prevention of poaching for the CAA. A significant concern is that if a cooperative is opened at SMI, this will open a floodgate of poaching in the region. In order to combat this, a strong marketing effort of branding CAA caught abalone could both improve profits and reduce illegal catch. By working closely with restaurants and distributors, the CAA can craft a relationship through which it becomes common knowledge that the cooperative is the only source of legal and sustainable wild abalone. This knowledge will be especially important to the types of high-end, image conscious restaurants in which a product as expensive as abalone is likely be sold, consequently reducing their demand for illegally caught abalone.

Annual Diver Training- AAUS Certification

The CAA, has expressed interest in developing an organizational unit of the American Association of Underwater Scientists (AAUS) for the cooperative, in order to improve the ease of collaboration with organizations such as U.C. Santa Barbara and CDFG, and in order to lend increased credibility to data collected in surveys. Previous attempts at collaborative diving/ monitoring efforts between abalone fishermen, CDFG, and the University have been mired in logistical issues. The primary concern is that AAUS certified divers working under the guise of UCSB or the CDFG must dive from boats insured in excess of several hundred thousand dollars, and AAUS certified divers may only buddy with other AAUS certified divers. Thus, some certified divers were able to dive off of some boats but not others, and buddy with only other certified divers. Therefore establishment of an AAUS organizational unit by the cooperative will improve monitoring assessments of abalone stocks at SMI, by allowing fishers to collaborate more easily with government and university researchers.

It is important to note that during the membership application process the CAA must adequately distinguish their scientific research objectives from their commercial goals, and their scientific dives from their commercial dives. Generally, commercial entities are not granted AAUS organizational status, but since the CAA will also be doing important monitoring work, the case can be made that the cooperative members are scientists-in-training, with an ecologically important mission.

Rotational Harvest

In addition to providing a challenge for monitoring, the patchy structure of abalone populations can make them especially prone to localized overfishing and depletion (Prince et al. 1998). This can occur as easily accessible abalone beds (such as those especially close to port for example) are fished down while less easily accessed beds are left alone. Given the limited connectivity often existing between abalone patches in a fishery, this can present a serious threat to the stock, resulting in stunted beds and localized population loss (Prince 2003, Prince et al. 1998). As such, we advocate for the development of a rotational harvest system, in which fishing pressure is distributed throughout the fishing area of the cooperative.

Numerous other fisheries that target sessile organisms susceptible to localized depletion utilize rotational harvest systems (See Appendix 1). The Challenger Scallop Enhancement Company and the Underwater Harvester's Association (which targets geoduck) both utilize annual rotation plans, that leave portions of the fishery unfished each year. The location of these closed areas is rotated each year, with exceptions allowing beds not showing evidence of recovery to remain closed. The Paua Management Action Committee (PauaMAC) of Kaikoura, New Zealand, a cooperative fishery that targets paua (abalone), uses a rotation system within the year to ensure that the catch is distributed throughout the fishery (J. Cooper pers. comm.). The Kaikoura PauaMAC closes the beds closest to port to fishing for the early part of the season, preventing the easily accessible beds from being overexploited and instead spreading harvest throughout the cooperative's waters.

By using a rotational harvest strategy then, the CAA may be able to reduce the risk of localized abalone bed depletions. By reallocating fishing pressure over time, underpopulated beds may be able to more effectively recover and grow (Prince et al. 2008). As an extension of this system, harvesting could be moved away from beds engaged in spawning, helping to ensure that fishing pressure does not significantly impact recruitment.

Internal Guidelines

The cooperatives surveyed in Appendix 1 represent a very broad range of management practices, from highly corporatized enterprises to community-based fishing associations. A common ground between many of these fisheries was the use of clearly defined and obligatory internal regulations. Doing so can greatly increase the efficiency of the fishery, and allow for more open and organized fishing operations (E. Brazer pers. comm. ; J. Cooper Pers. Comm). Additionally, developing a well-defined voting structure can greatly influence the resulting operation of the fishery. Cooperatives such as Challenger utilize a more corporate style system (where more shares equals more votes), while organizations such as the New Zealand PauaMACs require majority consensus on most issues, creating a more evenly distributed balance of power within the fishery (but also resulting in "lively" debates (J. Cooper pers. comm.)). Given the CAA's desire to create a community-based fishing cooperative, the voting system of the PauaMACs outlined in detail in Appendix 1 may be a useful model from which to form a voting structure.

In order to ease compliance with cooperative (and CDFG) regulations, clearly defined and binding procedures for violations are extremely important. Creating impartial and non-arbitrary procedures for violations can increase confidence in the methods of the cooperative for both members and enforcement agencies. Having a clear understanding of penalties for specific violations can also serve as a powerful deterrent for illegal harvesting practices. The Sector Management System of New England provides a useful example for the CAA of internal enforcement regulations. The Sector system has outlined a clear schedule of fees for a variety of violations, including the potential for the revocation of fishing rights for sufficiently severe transgressions. Potential violations are brought to the attention of an infraction committee, which rules on the case without knowledge of the identity of the specific fisher involved, so that judgment can be made according to the facts of the case and not internal politics of the fishery. In addition, the Sector system utilizes joint and several liability. This system means that the cooperative as a whole can be held liable for the actions of an individual member. This stipulation was put in place by the members of the cooperative themselves, as a method of incentivizing compliance and internal enforcement of both cooperative and government regulations.

Considering the contentious nature of this proposed cooperative, it is extremely important that the CAA following the examples of these case studies and develop clear and binding regulations for their organization. By demonstrating a clear commitment to enforcing management regulations for the abalone stock at SMI, the cooperative can improve trust with enforcement agencies while creating a powerful deterrent for illegal fishing activities.

Poaching

Poaching is a profound problem for many abalone fisheries worldwide, particularly in South Africa, Australia, and Mexico. Nearly 3000 metric tons were harvested illegally from these four nations in 2002 and just over sixteen percent of the total world supply of abalone is estimated to be made up of illegal abalone catch (Gordon & Cook 2004). New Zealand and the historic commercial U.S. fishery also experience heavy poaching pressure (J. Cooper pers. comm. ; Karpov et al. 2000). Illegal fishing pressure not only jeopardizes the resource, but also drives down the market price of abalone (Gordon & Cook 2004). Poaching has increased the risk of collapse in abalone fisheries around the world and, along with global economic problems, has destabilized the global abalone market.

Economic difficulties have also translated to increased poaching and black market activity for a variety of wildlife, including abalone, in California (Fimrite 2009). Abalone poaching rings in northern California, where recreational abalone fishing is legal, have been an ongoing problem for enforcement and management officials. During a multi-day enforcement operation in Sonoma and Mendocino counties in California in May 2009 11 people were arrested for poaching 129 abalone and an additional 131 people were cited for various abalone fishing violations (Anderson 2009). It has been estimated that California wildlife officers catch only one to five percent of violators statewide (Fimrite 2009). Even at the high end of this enforcement rate, there are undoubtedly many cases of abalone poaching that go unseen in California's waters. The impacts of poaching can decrease stock recovery times or cause populations to further decline.

Should a cooperative fishery be put in place though, a number of mechanisms are available to reduce the risk of poaching. Other cooperative fisheries have used a combination of tracing systems, self and government enforcement, and clearly defined property lines to combat poaching. The CAA has already taken steps to differentiate their product from a poached product by offering to employ trace register and a tag system. By using trace register and tags, the cooperative can help identify the exact source of landed abalone, easing enforcement for government officials and allowing distributors and buyers to identify and solely purchase legally caught abalone.

As is the case with other cooperatives (for example see the New England Sector Management System, Appendix 1), a contract with cooperative members gives the president and the board members the authority to take action against any member that participates in illegal harvest. Within this contract it is also necessary for the punishment measures to be strong and clearly defined. Having clear penalties for illegal harvest will greatly increase compliance among members. Many cooperatives from our survey utilized a system through which if any one member is guilty of illegal harvest the entire cooperative can be held liable (see the Kerala, India Cooperatives, and New England Sector Management System, Appendix 1). Through this system, members are encouraged to self-monitor and report any illegal activities.

Beyond self-enforcement tools, measures to prevent poaching must also be taken by enforcement agents. The CAA has suggested that the cooperative fund an enforcement officer to oversee cooperative fishing days. This would serve as a strong deterrent of illegal catch, and allow wardens to know exactly when fishing operations will be taking place. Ultimately it is vital that poachers know that in addition to government officials, cooperative members will also be policing illegal catch. Since the presence of poachers jeopardizes the future and profitability of a cooperative, members are given a powerful incentive to prevent it. As such, if implemented a cooperative fishery will greatly increase the number of eyes on the water actively policing for illegal catch, as has been seen in fisheries from Central America to Japan to New Zealand and Australia. In addition, by creating a fishery of clearly defined cooperative members, the presence of any unidentified boats capturing abalone will be easily identifiable as operating illegally.

Another method that could be employed by the CAA is the use of clearly marked boundaries. The importance of spatial isolation and borders is also well documented in the cooperative fisheries of Chile (Appendix 1). Cooperatives in that system operating in relative isolation are reported to fare better than cooperatives sharing waters with numerous competing or non-connected groups (Orensanz et al. 2005). By installing buoys that clearly define harvest areas, both the cooperative and enforcement officers will be able to easily tell if an unauthorized vessel is illegally catching abalone. In addition, it will be beneficial to spatially separate the recreational and commercial sectors at SMI. This tactic is utilized in abalone and scallop fisheries in New Zealand to reduce conflict and increase accountability (J. Cooper pers. comm.; Mincher 2008). Separating the commercial and recreational components will increase accountability for both these parties. In addition, from the perspective of the cooperative as an experimental fishery, spatial isolation will allow for studies of the specific effects of the cooperative on the state of the abalone stock at SMI, without the potentially confounding impacts of a recreational fishing.

By using these methods, the cooperative has the potential to substantially reduce the risk of poaching. Doing so may also dramatically improve relations between the fishery and CDFG. Similar experiences have been reported in the scallop, abalone and deep-sea fisheries of New Zealand, as well as the abalone cooperatives of Australia (J. Cooper pers. comm.; Mincher 2008; Prince et al. 2008; Soboil & Craig 2008).

Collaborative Research

Many experts in the field of fisheries management have called for greater collaboration between those who study fisheries and the fishers who actively work in them (Johannes 2002; Ostrom et al. 1999; Parma et al. 2006; Prince 2003; Wilen et al. 2002). Fishers often have highly detailed information regarding the structure and health of the ecosystems in which they work, providing a wealth of knowledge that can be greatly beneficial to fisheries scientists and managers. In addition, the creation of catch-share systems creates a powerful incentive for fishers to develop a greater understanding for the ecology of their stocks. By aiding in the development of fine-scale fishery data, fishers can help create more accurate stock assessments and habitat monitoring (Prince 2003). This can in turn result in more effective management, by supporting the creation of harvest strategies targeted to maximizing the long term viability of a fishery (Soboil & Craig 2008; Mincher 2008; Prince et al. 2008; Yandle 2006). As such, numerous cooperatives have taken it upon themselves to increase the quantity and quality of data available, through independent research and collaboration with research institutions. The Challenger Scallop Enhancement Company, Underwater Harvesters Association, Victorian Abalone Divers Association (VADA), Crabco, and the Shiretoko Fishery Cooperative Association, all contain robust examples of these joint research ventures (see Appendix 1). It is likely that without these initiatives, much of the information now available on these fisheries would not exist.

The CAA finds itself in an ideal situation to pursue a similar course of action. Given the patchy nature of abalone populations, extremely high-resolution data is often needed to accurately study their dynamics (Prince et al. 2008). However, this type of information is difficult to collect and challenging to interpret, creating a natural environment for collaboration between the cooperative and the research community. The CAA has already taken substantial steps to aid in the collection of abalone population data at SMI. Should the fishery be opened, local knowledge that will be gained from diving at San Miguel must be put to effective use. In particular, developing bed-by-bed information will allow for individual plots within the fishery to be monitored and appropriately managed. The case study of VADA (See Appendix 1) provides a thorough description of a similar system, in which catch and size limits are imposed on individual beds within the abalone fishery, based off of population data derived from simple visual survey protocols. Using this system, VADA has been able to achieve substantial recovery at a number of once depleted reefs, while increasing catch levels at beds found to be stable (Prince et al. 2008). A similar method could be highly effective if employed by the CAA in conjunction with research institutions and CDFG.

Our ecological modeling efforts indicate that while fishing pressure does not present a high risk of collapsing the abalone stock at SMI, water temperature (and it's encompassed impacts) do have the capacity to significantly alter the population dynamics of the fishery. While laboratory studies (Braid et al. 2005, Vilchis et al. 2005) as well as field evidence (Rogers-Bennett & Leaf 2006) and modeling (Hobday & Tegner 2002) provide some quantitative information on the specific impacts to survival and fecundity that warm water events may have, no specific information is available for wild red abalone at SMI. Therefore, the CAA should monitor water temperatures at the fishery location, and be prepared to adjust harvest strategies according to the risk posed by warming waters. In addition, it would be beneficial for the cooperative to work with a research institution to quantify the effects of temperature on SMI red abalone. Doing so would allow for management to be appropriately adapted in response to potential temperature related stress. In addition, given the strong correlation between elevated water temperature and susceptibility to WFS (Braid et al. 2005, Vilchis et al. 2005), keeping careful track of temperature trends can provide the cooperative with a relatively simple warning system to the potential for a WFS outbreak. Obtaining a better understanding of the impacts of environmental variables, especially easily monitored conditions such as water temperature, will allow the cooperative to preemptively address threats to the fishery, reducing the potential for fishery related impacts to the abalone stock.

Conclusions

This project fills a critical knowledge gap in the consideration process for this proposed cooperative fishery. Our findings show that the cooperative system put forward by the CAA is capable of averting the specific factors that led to the collapse and closure of the commercial abalone fishery in California in 1997. Specifically, the cooperative stands to resolve threats from chronic over-harvesting, localized depletions, sparse enforcement, and lack of fishery specific data.

Our economic analysis shows that even under a worst-case scenario of low abalone market value and high operating costs, the fishery remains profitable. In addition, we provide a quantitative risk assessment of the effects of fishing pressure on the SMI red abalone population. Together these results show that the cooperative not only offers financial benefits, but does not pose excessive risk to the stock. However, we acknowledge that for this finding to remain true, extensive monitoring of the state of the stock must continue, to ensure that the assumptions of population growth made in this paper (based off of Butterworth et al. 2009, Prince & Valencia 2009, and the CDFG abalone survey data) remain true. In addition, events not specifically modeled in our study such as WFS outbreaks, sea otter predation, and water warming beyond the scale incorporated in our analysis all pose potential threats to the abalone stock. However our work provides a sound initial assessment of the population viability at SMI. Through expanded survey data, research on abalone ecology, and development of spatially explicit models, these results may be greatly refined, and made capable of predicting and adapting management to the full range of factors influencing the health of the SMI red abalone stock.

In addition to our quantitative results, the findings from our survey of global cooperative fisheries indicate that the CAA's proposal contains many similarities to currently active and successful cooperative fisheries. The spatially isolated nature of the SMI stock, presence of a committed and like-minded group of fishers, and use of collaborative research with university and government scientists, are characteristics shared by existing successful cooperative fisheries. Given these traits, the evidence collected in our survey of global cooperatives supports the argument that the CAA's proposed cooperative is a viable management option for SMI red abalone.

However, the results of our analysis show more than simply the profitability of a business venture. By calculating the economic potential of this cooperative fishery, we provide a tangible measure of the value to be gained by the CAA through sustainable management of abalone. In doing so, we demonstrate a clear incentive for the fishery to engage in rigorous self-enforcement and aid in the expansion of knowledge on the population ecology of the red abalone at SMI . This incentive for supporting research is especially important to the question of opening this experimental fishery. Several other options exist for the management of the abalone resource at SMI, but the common theme between them all is a call for more and better data. However, the cooperative fishery proposal, through its economic viability demonstrated by our study, is the only option that provides a real and quantifiable source of funding and manpower for the collection of this information on the SMI abalone stock. The development of an experimental fishery may then provide the most powerful form of support for gathering ecological knowledge for use in abalone conservation and management. Through the support of the cooperative, in collaboration with government and university scientists, the abalone fishery at SMI could be moved from a data-poor status, to a model of methods for spatially explicit fishery management. Numerous other cooperative fisheries across the world have demonstrated this pattern of dedicated-access incentives for fishers leading to improved science and management for the fishery as a whole. The positive result of our economic viability analysis demonstrates that this pattern could be a reality for the SMI red abalone fishery as well.

Through our examination of the CAA's proposed abalone cooperative, we determined that this system has the potential to be economically, ecologically, and socially beneficial. This fishery presents an opportunity for fishers, government officials, scientists, and community members to develop a collaborative, spatially managed, and catch-share based fishery in California. In doing so, this proposed cooperative stands to support economic efficiency, sustainable fishing, collaboration in management, and the perseverance of a traditional livelihood. While great care must be taken in the design and management of the cooperative, the CAA's proposal presents an opportunity to begin a new form of fisheries management in California, and in doing so demonstrate a system for the sustainable use and community management of marine resources.

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Appendix 1: A Global Review of the Structure and Impacts of Cooperative Fisheries

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Introduction

Many published works have addressed the incentives created by catch-share management, the impacts of these cooperative systems on the economics and ecosystems of fisheries, and the technical principles that contribute to the success or failures of cooperatives. However, relatively few studies have looked at the internal mechanisms through which fishing cooperatives put the theoretical advantages of catch-share management to use. This survey is intended to fill that gap, by gathering information and developing a database of cooperative style fisheries from across the world. In doing so, we have collected as much information as possible as to how these individual cooperatives have actually gone about developing and managing their industry, and the subsequent effects that these actions have had on the economics and environment of local fisheries. While by no means exhaustive, in this document we have compiled those cases for which we were able to gather the most interesting and complete data, accompanied by relevant sources and when available contact information from experts on the cooperative in question. Our goal is that this survey be of use both to researchers and practitioners of fisheries management. By providing synopses and sources for a wide range of fishing cooperatives, academics studying principles of catch share management will be able to use this document as a source for case studies, data or anecdotal evidence supporting theoretical results. We also intend for this document to serve as a guide for those interested or actively participating in the establishment of fishing cooperatives, allowing them to examine the experiences, actions and impacts of other organizations. By considering cooperatives both great and small across the world, this document serves to fill a current gap in the descriptive literature of fisheries management.

The history of global marine fisheries has been one of ever-increasing effort, resulting in shrinking stocks and growing economic costs (Hilborn et al. 2005, Pauly et al. 2005, Pauly et al. 2002). This can be attributed largely to the open access nature of many commercial fisheries, which incentivizes individuals to capture as much fish as quickly as possible before the harvest is brought in by a competitor, in a process often referred to as the race to fish (Costello et al. 2008). Many of these common-pool fisheries depend on top-down restrictions to regulate fisheries, such as gear restrictions, limited entry, shortened seasons and the setting of a total allowable catch (TACC) for a given species (Lugwig et al. 1993). Although theoretically sound in some instances, these management techniques have failed to prevent the decline of stocks due to data-poor stock assessments, inadequate enforcement, and lack of incentives for sustainable management (Pauly et al. 2005). Myers and Worm (2003) demonstrated this pattern by showing that commercial fishing practices have resulted in an 80% decline of fish stocks within 15 years of their industrialized exploitation. This has led to depletion of many stocks and targeting of new, lower trophic level species as well as habitat destruction and economic collapse (Essington et al. 2006, Pauly et al. 1998, U.S. Commission on Ocean Policy 2004).

Among these bleak conclusions however, some cause for optimism exists. Recent studies such as those by Hilborn et al. (2005), Costello et al. (2008) and Worm et al. (2009) have shown that by examining individual fisheries rather than the global industry as a whole, many instances of viable and sustainable fishing management can be found. A common trait between these successful fisheries has been the use of dedicated fishing rights, often referred to as catch-share management, to alleviate the race to fish. Small island communities have used this principle for centuries, but its success is increasingly being demonstrated in commercial fisheries (Costello et al. 2008, Johannes 1981).

Cooperative fisheries serve as one method for making use of dedicated access rights by, as one fisherman put it, "turning individual harvesters into collective farmers" (Cooper 2009). Through group structures, cooperatives are able to pool their resources and knowledge in order to maximize the efficiency and value of their industry. This ability to add value results largely from the ability of these organizations to take on self-management rather than top-down government regulation. As groups rather than individuals, cooperatives are able to take on expensive responsibilities such as monitoring and enforcement, environmental research, stock enhancement, and marketing. In addition, as the operators (and funders) of these activities, cooperatives have a strong incentive to ensure that all actions are performed in the most effective and efficient manner possible. As such, cooperatives can serve as a bottom-up alternative in places where traditional top-down management practices such as pure ITQs or limited-entry fisheries may be impractical. This is highlighted in the cases of New Zealand discussed in this survey, where cooperative management allowed for improved fisheries performance than had occurred under the pure ITQ system already in place. Under the appropriate circumstances, cooperative fisheries provide an opportunity and incentive for sustainable fisheries management, resulting in socioeconomic benefits and ecological stewardship.

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North America

Sector Management of New England Groundfish

Populations of groundfish, such as cod, along the coast of the New England have declined dramatically under common-pool fisheries management. The National Marine Fisheries Service (NMFS) has primarily attempted to reduce this decline through top-down government restrictions, such as limiting days-at-sea, establishing daily catch limits, and reducing the total allowable commercial catch (TACC) These practices have served to reduce the economic efficiency of each fishing trip, as fishermen must race to catch fish on their allotted days, while simultaneously being forced to throw back and waste any catch in excess of their daily limits (Leal 2008). Small boat (primarily 40-50 feet in length), fixed gear (such as hooks and gillnets) fishermen suffered the most as a result of these top-down restrictions, being unable to compete with large trawling operations in the limited amount of fishing effort now available to them (Brazer 2009, Leal 2008). In order to preserve their industry, groups of these small boat fishermen represented by the Cape Cod Commercial Hook Fishermen's Association developed a system they termed sector management (Leal et al. 2008). Through this system, sector members are granted special access rights and a fixed portion of the cod TACC, which they are able to allocate as they see fit. In exchange, they must perform extensive environmental monitoring as well as comply with benchmarks set by the Northeast NMFS.

Industry Structure

Sector management was legally enabled by Amendment 13 of the New England Marine Fisheries Council (NEMFC) in 2004, which allows for the formation of community based fishing sectors. While the individual management plans established by these sectors may vary, several general principles have been developed to allow for the success of these cooperative organizations. Established sectors are granted a yearly TACC in proportion to the historical catch of their members. In this way, while participation in the sector program is voluntary, the more members that join, the higher the TACC available to the sector becomes (subject to established yearly caps). While being voluntary to join, once entered into sectors agree to a legally binding contract between NMFS and within their organization, which carry an agreed upon list of rights and responsibilities. Once a sector is approved, NMFS provides the cooperative with a yearly TACC, proportional to the historical catch of its members. Individual sectors are then free to determine how to allocate this TACC; for example, some have elected to divide the TACC equally among members and allow for internal trading, while others have established a monthly quota available to all members (Brazer 2009).

In addition to guaranteeing a portion of the catch, the sector management system contains four general regulations designed to incentivize cooperative management. Unlike the open-access part of the groundfish fishery, members of established sectors are not subjected to a daily catch limit. This allows sector members to make the most out of their days at sea, allowing them to make fewer trips for the same amount of fish. In addition, by eliminating daily catch limits fishermen were no longer forced to throw back and waste legally sized cod caught in excess of the daily limit (Brazer 2009). Both the Sector and common-pool fleets are also permitted to trade days at sea among themselves, with some restrictions. In the near future though, sector fishermen will become exempt from days-at sea regulations for groundfish, which will be simultaneously tightened for the open-access fleet (Brazer 2009). While not granted exclusive access to their sectors, cooperative members can be allowed access to regions of the fishery closed off to the open-access fleet, providing them with uncontested access to select, ideal fishing grounds at times. Lastly, as an important provision, under the sector management system agreement if the total quota for cod is reduced as a result of the open-access fleet, the quota for the sectors will not be reduced. This ensures that cooperative members will not be penalized for the actions of others, and provides a further incentive to join these community organizations.

In exchange for these rights, sectors must perform extensive environmental monitoring, including a NEPA level assessment, of the target stock and the impact of their fishery on the local ecosystem. The sector must also monitor their cooperative for compliance, and submit catch and infractions data to NMFS and the NEMFC. The group is required to prepare an annual operations plan and agreement (OPA) which serves as the legally binding contract for the internal operations of the sector. As an additional measure, members of sector organizations may be held accountable to the OPA through joint and separate liability. Industry members report that this has helped with compliance within organizations, as the mistakes of one may become the responsibility of many (Brazer 2009).

Management Tools

The sector management system in and of itself is only a mechanism by which communities of fishermen can be granted cooperative-like access to the groundfish resource. It remains up to the individual sectors to develop their own methods for managing their resource. As such, the sector system may serve as an interesting case study in the efficacy of different management tools in operating a sustainable fishery.

The Georges Bank Cod Hook Sector (GBCH Sector) was the first sector to be approved under Amendment 14, and provides some of the richest data on the structure of these sector systems. The GBCH sector is run by a board of directors, which in turn appoint a manager in charge of the daily operation of the sector. Membership is open to any member of the community, and the sector systems are actively trying to incorporate more fishermen into their cooperative from the open-access sector (Brazer 2009). As part of their OPA, the GBCH Sector appoints an infraction committee, charged with developing a strict schedule of fees laying out the exact extent of penalties that will be incurred by sector members that violate cooperative rules, with the issue of a mandatory "stop fishing" order existing as an option should the violation be severe enough. As an added enforcement measure, the manager may bring an enforcement investigation against a member believed to have violated the sector agreement. Under these circumstances, the manager brings their case to the board, which reviews the case without knowledge of the identity of the suspected person or vessel, allowing for some aspect of impartiality.

Catch monitoring is an important part of the GBCH's plan for the development of their cooperative. As part of this system, they have put a variety of safeguards in place. Each vessel must report to the manager when they intend to leave to fish, unless their vessel is equipped with electronic software linking them to a system called skytracker, which acts as a monitoring agent of boat activity. As an additional cost-saving effort, the GBCH is experimenting with a company called Archipelago that utilizes on-board cameras in place of a live observer. Upon returning to the dock, each boat has 48 hours to turn in their vessel logs and the sales slips of any fish caught to the manager. As a final safeguard, the manager makes spot-checks with dealers authorized to receive fish caught by the sector to ensure that the number of fish sold is in agreement the number reported caught (George Bank Cod Fixed Gear Sector 2008).

As a further effort to prevent overharvesting of the stock (and the TACC), the GBCH has developed a trigger system for the allocation of the year's catch. Under this system, each year the board decides an amount (no more than 5%) of annual TACC to be set aside in a "reserve". The remainder of the TACC is allocated per the management plan of the sector. Once this remaining catch is exhausted though, the reserve catch is opened, but carefully allocated by the GBCH committee (Brazer 2009). This serves to slow down fishing when the TACC is being approached, providing a method of ensuring that the yearly catch limit is not exceeded. However, to date the sector has never caught enough fish to result in the use of the reserve, so the functioning of the system is as yet unknown (Brazer 2009).

The sectors profiled in this section operate in a somewhat unique hybrid environment; they do not have exclusive access to their fishery, and do not even operate in conjunction with other ITQ owners. Instead, they share their fishery with a fleet of open access vessels. In response, the sector cooperatives developed several safeguards to ensure that cooperative members commit themselves to the organization, and do not leave to exploit the open-access fishery as well. Upon signing on as a full member of the GBCH Sector, fishers must commit to the cooperative for three years. They also must agree not to sell their share in the Sector to anyone who does not agree to comply with the OPA of the Sector. Any non-member who agrees to these provisions and enters the Sector is allowed to continue fishing for the rest of the year, and then must become a full member the following year to continue operating in the cooperative. In order to ensure that established members have the option to benefit from their cooperative actions, the Sector also has a "first refusal" provision in their OPA. Under this system, if any current sector member seeks to sell their permit, the Sector shall have the option to purchase the permit at the same price and under the same conditions as were offered to a non-sector member.

Faced with the hybrid system encountered in the New England groundfish industry, NMFS and the NEMFC have brought a number of mechanisms into play to encourage membership in the sector system. NMFS has ratcheted down the days at sea allowed to the open access sector each year, and are in the process of instituting a rule through which any fishing trip that leaves the dock will count as a full vessel day, even if the ship is forced to turn back immediately by foul weather or some other such reason. Combined with decreased daily catch limits and an increasing share of the TACC being allocated to the sector system, it is becoming increasingly un-economically viable for open-access fishermen to operate (Brazer 2009).

Performance

Unlike the high grossing, corporate style cooperative fisheries of New Zealand, the sector management system represents a much more community-scale level of management. Economically, the greatest success of the sector management system has been the continued ability of small, fixed gear fishermen to remain in the industry. Under the new cooperative system, communities of fishermen have been able to preserve their way of life and increase profit margins to a point that they may sustain themselves (Brazer 2009, Georges Bank Cod Fixed Sector 2009). In addition, by having a guaranteed share of the TACC, sector members have been able to project their catch for the year, allowing for more accurate budgeting. Sector members now also have the ability to spread their catch throughout the year, providing a steady stream of income rather than the spurts of fishing income necessitated under the open-access race for fish (Georges Bank Cod Fixed Sector 2009). Lastly, members of the sector system with high levels of historical catch received a high increase in value for their permits, which now reflected not simply a right to fish, but a right to a guaranteed portion of the TACC (Brazer 2009).

While the sector management system may be too small at this time to significantly impact the state of New England groundfish stocks, the actions of these cooperatives represent an important positive step in preserving these fish and the habitat they depend on. The fixed-gear systems utilized by the sectors cause less damage to marine bottom habitats than the large trawling operations of the open-access fishery (Georges Bank Cod Fixed Sector 2009). By being allocated a guaranteed portion of the TACC, as well as greater flexibility in the days at sea, the sector system should result in reduced levels of bycatch as well, since fishermen are able to focus on efficient rather than expedient methods of fishing (George Bank Cod Fixed Gear Sector 2009). The sector's exemption from the daily catch limit provisions prevents wasteful fishing practices, in which fishermen are required to throw back legally sized cod caught so as to not exceed the daily maximums. As government regulations make the open-access sector increasingly unprofitable, the resulting influx of fishermen to the sector system could serve to amplify the ability of the sector fishing regulations to improve the state of New England groundfish stocks.

Discussion

Perhaps the largest uncertainty facing the sector management system is how these cooperatives will respond to the growth of the program. Currently, groups such as the GBCH sector have only been able to capture a small portion of the TACC allocated to them (Brazer 2009). So, fishermen in the sector have been able to catch as much as they are able without having to compete with their fellow cooperative members. With the fishery slated to grow in numbers and size of jurisdiction in the coming years, it remains to be seen how the cooperative's structure will fare once the TACC is actually capable of being exhausted. It seems possible that sectors that divide their catch into aggregate monthly quotas may experience a miniature race to fish once the demand for fish by the fishermen exceeds the supply of TACC. Should this scenario arise, it may be necessary for the sectors to introduce some measure of profit sharing or effort pooling.

From a community perspective, the development of the sector management system represents a significant shift in traditional fishermen/government relations in New England. Fishermen in this region have long had a highly adversarial relationship with fisheries regulations, viewing them as obstacles that they must overcome in order to survive. The sector system has served as an example that under the appropriate circumstances, fishermen can in fact benefit from working with the government and within the system (Brazer 2009). The active role that NMFS has taken in promoting the development of the sector systems also indicated the powerful role that government may have in co-managing and developing cooperative fisheries management.

As the sector program continues to grow, it should provide highly informative case studies in fisheries management, as different communities develop their own solutions to similar problems of management. As time goes by, it may be possible to evaluate different the strategies developed by individual sectors to examine what has proved effective and what has not.

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Community Management of Canadian Crabs[5]

For many of the small villages scattered across the eastern coast of Nova Scotia, the only significant source of income is fishing. Collapses in the cod and other groundfish fisheries in the 1980s and 1990s drove increasing numbers of these fishermen into the crab fishery, leading established crab fishermen and the government to realize that some method of control was needed to prevent destructively high levels of effort from entering the fishery. Already utilizing an individual quota system, the Canadian government was forced to develop a system that could account for the needs of local fishing communities while not opening the crab fishery to overexploitation. The resulting program utilized a system of revenue and biomass thresholds to allow increased access to the fishery, providing communities access to crab fishing while limiting effort (Peacock & Feagle 2008).

As snow crab biomass increased along with the value of the fishery during the 1990's, established license holders in the industry began making substantial sums of money (Peacock 2009). These events also led other members of local fishing communities to demand for a restructuring of the system, asserting that it was unfair for access and profits from the crab fishery to be withheld from them when the fishery showed signs of being able to sustain increased levels of effort (Peacock & Eagles 2008). The resulting temporary access program instituted by the Canadian DFO operated in a relatively simple manner; once a the crab population was deemed to be capable of sustaining a TACC above an established minimum threshold (or if a threshold level of revenue was made by the established license holders), the excess catch would be allocated

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[5] The bulk of this section was adapted from Peacock & Eagles 2008

to a group of temporary license holders. Under this system, these temporary license holders would be granted a share of the excess quota, to be fished primarily in currently under-utilized regions of the fishery. These temporary license holders were issued by local associations, who divided the total temporary catch allocated to a specific region (broken up into Crab Fishing Areas or CFAs) among the eligible members of the community. However, if the TACC dropped down below threshold levels, these temporary groups would be the first to have their catch rights removed or reduced.

The apparent shortcoming in this system was the lack of governance structure of the temporary associations, and the absence of clear rights to the resource. The associations were charged with simply maximizing profits to their fishermen; they were not required to develop any stewardship guidelines for their resource. They also did not provide a financial incentive to look to the future, as the continued existence of their fishery was more dependent on the DFOs established TACC levels rather than the efforts of the associations. The result of this situation was augmented social conflict, as temporary fishermen sought increased access to the resource, but had no incentive to ensure that this increased effort was commensurate with the state of the fishery.

In 2005, the DFO sought to resolve these challenges through the development of a system termed "CORE companies." Under the CORE structure, rather than issuing temporary licenses dependent on the state of the stock, the DFO instead now evenly divided the catch allocated to the former temporary license holders between the eligible fishermen within the CFA[6]. However, these new licenses were not fishable when used independently. In order to actually be allocated quota in the crab fishery, a certain number (depending on the specific location and type of community in question) of fishermen must consolidate themselves into a CORE company. Once established, these CORE companies are then allocated a percentage share of the TACC (initially equaling only up 1/3rd of the quota allocated to an established permanent license). These CORE companies operate in a cooperative fashion. A maximum of three vessels are allowed to fish for an individual company, and these designated vessels are charged with catching the quota allocated to the entire company. The company decides how fishing operations will take place, and how profits from the catch will be divided among the company members. This system has several built-in improvements over its predecessor, the temporary license allocation program. Primarily, through the CORE companies new entrants to the fishery now have an interest in the long-term status of the stock, reflected in the value of their shares in the CORE companies. The CORE system stipulates that trading be allowed between established CORE companies, therefore companies that wish to expand their fishing efforts may buy quota from companies that do not wish to be as active in the industry. In this way, the new fishermen were granted a permanent and valuable stake in the fishery, rather than relying on the year's TACC for profits. Secondly, requiring the formation of CORE companies in order to gain access to the fishery incentivized the formation of cooperatives by like-minded individuals (Peacock 2009). By requiring fishermen to self-organize, groups were formed that

[6] It is important to note that two separate systems are at work here. The established license holders operate under their own individual quotas. The CORE system represents the DFO's efforts to increase access to the fishery beyond these established owners without simply allowing a race to fish to occur

contained individuals with similar goals. This represented an improvement over a purely geographically based system of associations developed under the temporary access system (Peacock 2009).

The CORE system represents a potential solution to some of the societal challenges created by property-rights based fisheries. By providing permanent rights to the fishery to greater numbers of people, the benefits of the crab fishery were made available to fishing communities at large, rather than being concentrated in the hands of established license holders. However, by requiring the formation of cooperatives, the DFO was able to minimize the amount of direct fishing effort that might otherwise result from the expansion of access to the fishery. This served to balance the needs of larger, corporate style fishing organization, such as the original license holders, with those of small communities who came to depend on the crabs as a source of revenue. As an example of the potential benefits of these systems, anecdotal evidence exists that up to 70% of the profits generated by CORE companies are reinvested in the local community (Peacock 2009).

Fishermen were at first extremely apprehensive about this management system. Established license holders felt it would put too great a strain on the fishery, while the temporary license holders worried that the system was too complicated. However, the initial success of the program has improved the general opinion of the system, and increased participation in the CORE companies (Peacock & Eagle 2009). Still, the development of this system has coincided with a large upswing in the population of snow crabs. Should the resource begin to decline, it remains to be seen how the new CORE system may respond to the need for reductions in effort.

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The Underwater Harvesters' Association[7]

The Underwater Harvesters' Association (UHA) is a non-profit organization that fishes and co-manages (with the Canadian Department of Fisheries and Oceans [DFO]) the geoduck fishery of British Columbia. The organization was formed a result of the overexploitation of the fishery during the 1970s and 1980s (James 2008). During this period, interest in the geoduck fishery increased dramatically as demand and prices for the shellfish began to rise (Mitchell 1998). In an attempt to prevent overfishing, the DFO began a moratorium on the issuance of new licenses, which culminated in the capping of the industry to 55 licenses in 1981. In addition, during this period an industry wide TACC was put in place for geoduck. Despite these efforts, the fishery continued to be heavily exploited, with annual TACCs often being exceeded by up to 80% (Mitchell 1998). In a final effort to control the fishery, the DFO began progressively shortening the seasons, resulting in a racing scenario, and preventing geoduck fishermen from capitalizing on the year long (and high-value) live market in Asia (Mitchell 1998). Realizing the inefficiencies that this situation was creating, the UHA lobbied for the implementation for an individual vessel quota (IVQ) system, which the DFO agreed to in 1989 (James 2008).

Since that time, the UHA has gradually assumed an increasing role in the management of the fishery; taking an active role in stock assessment, catch monitoring, quality assurance (for a form of paralytic shellfish poisoning sometimes found in geoduck), general marketing, and industry lobbying (James 2008). However, unlike many cooperative organizations the UHA is purely a non-profit industry group; while it provides agreed upon services, it does not necessarily decide on the management of the fishery (James 2009). As a result, value in the fishery is generated by ownership of license and quota, not membership in the UHA. In addition, while the UHA engages in some general market advocacy, they do not engage in any centralized marketing or sales of geoduck caught by individual members of the UHA.

Membership in the UHA is completely voluntary, and requires the payment of membership dues, which amount to far more than the license fees charged by the DFO (Jones & Bixby 2003). Membership is now completely unanimous among geoduck license holders, despite the initial resistance of the few high-volume fishermen at the inception of the IVQ system. Non-license holders are also permitted to enter the UHA as associate members (James 2008). Associate members take part in industry discussions, but are not provided voting rights in the industry (James 2009).

In order to control the spatial concentration of effort in the geoduck fishery, the UHA divides the fishery into three zones. Fishermen's licenses are then assigned to a specific region based on their historic fishing locations. While license holders are permitted to apply for a change in location, they may only fish one area in a given year; this could serve to prevent overfishing in particular areas of the fishery (James 2008). As a further precaution, the UHA implements a rotational system, such that only 1/3rd of

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[7] James 2008 provides an excellent summary of the history, management, and economic impacts of the geoduck fishery in British Columbia. As such, this section will attempt to highlight the most relevant points from this article; please see James 2008 for an expanded description of the fishery

the fishery is actively fished in any given year, allowing other portions of the stock to recover (Kahn 2006). Quota in the fishery can be traded, but no one vessel may hold more than 5 licenses, though practically one vessel could only fish up to 4 licenses (James 2009). However, there is no limit to the number of vessels, and hence licenses that one owner could in theory control (James 2009). In addition, quota cannot be divided and sold as separate licenses, serving to prevent the expansion of the fleet targeting the fishery (James & Bixby 2003).

Since the implementation of the IVQ system, the UHA has developed and supported an extensive program of scientific monitoring of the geoduck stock. This research has been motivated by a desire to see the TACC set at a mark (preferably higher) reflective of the geoduck population and the level of catch that it can sustain. Without the additional data collected by the UHA, industry members fear that information would be extremely scarce on the true nature of the stock and the DFO would as a result set the TACC at a low precautionary level (James 2008). In order to prevent this, the UHA has funded and carried out bed-by-bed surveys of the fishery, intended to develop high-resolution data (as of 2008 approximately 35% of the beds had been surveyed). If survey data on a particular bed is unavailable, the UHA may utilize anecdotal information from fishermen familiar with the area (James 2008).This bed-by-bed data is then extrapolated to the fishery as a whole to in order to determine the yearly TACC, as well as establish maximum quotas for individual beds (James 2008, Trenor & Danner 2008). In order to reflect the varying degrees of stock knowledge available for different geoduck beds, bed-by-bed TACCs are set at more conservative levels where only fishery-dependent or anecdotal evidence is available (James 2009). This program has provided sufficiently high-resolution data to allow the DFO to fluctuate the annual TACC up and down with current fine scale estimates of population size (Trenor & Danner 2008). As a further effort of preserving geoduck stock levels, the UHA has undertaken a stock enhancement program, through the reseeding of geoduck. Recent estimates place the survival rate of the reseeded geoduck at 20-80% (James 2008). Geoduck intended for harvest are grown in a nursery run by the UHA, not taken from the wild (James 2009).

In order to ensure that the industry achieves the maximum benefit possible from its management efforts, the UHA utilizes a number of monitoring and catch verification techniques. They have contracted an independent 3rd party to verify the extent of fishing effort. Dockside landings are crossed checked with volumes delivered to distributors, and extra monitoring efforts are put in place in the more remote northern regions of the fishery (James & Bixby 2003, Kahn 2006). Minor quota overages by a vessel can be offset by being sold to fishermen who have not yet exceeded their quota. Excessive quota overages are sold and the profits are returned to the UHA for use in management efforts (James 2008).

The UHA funds the majority of these actions by utilizing a clause in the geoduck license agreement, which states that fishermen must log their catch in a specific format. An affiliate of the UHA is the exclusive supplier of the logbook required for this format, and members must pay the annual UHA membership fee in order to purchase the book (James & Bixby 2003).

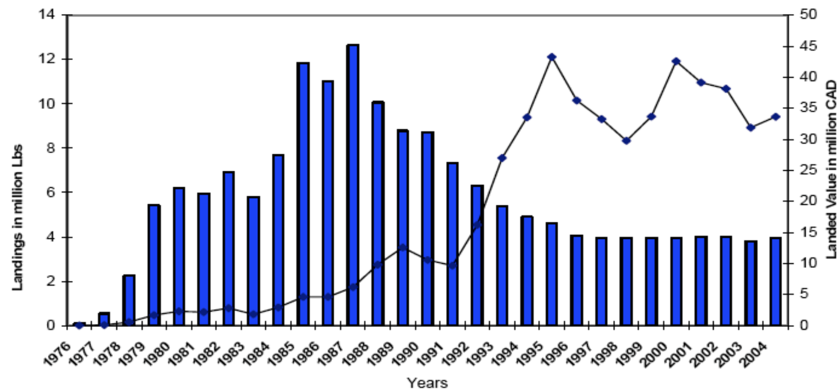

Figure 1 Trends in annual catch and landed value of Geoduck in Canada (Kahn 2006)

Performance

The implementation of the IVQ system and the formation of the UHA have resulted in a dramatic increase in the value of the British Columbian geoduck fishery, as illustrated by Fig.1. This data demonstrates that while catch levels have dropped, total value of geoduck sold has increased. This is largely due to the ability of the fishery to continually supply the high value live geoduck market, now that the race to fish has been dissolved by the creation of the IVQ system (James 2008, Kahn 2006). In addition to being able to sell a higher value product, members of the UHA were also able to reduce individual fishing costs, as they were able to concentrate on efficient fishing, rather than overcapitalizing for the race to fish under the pre-IVQ conditions (James & Bixby 2003). These savings in fishing effort have been largely offset however by large increases in management costs; individual UHA fees have increased by over 700% since 1989, reflecting the cost of the management efforts now undertaken by the industry (James & Bixby 2003). Despite this vast increase in management costs though, industry members report that the profitability of the geoduck fishery has improved dramatically since the inception of the IVQ system (James 2008, James & Bixby 2003).

The impact of the IVQ structure and the UHA's actions on the geoduck population and the local ecosystem is less clear. Under the current management system, TACCs have almost never been exceeded, and overages that occurred have been on the order of 1%, compared to an average catch of 30% over the TACC prior to the IVQ system (James 2008, James & Bixby 2003). Fishery-independent data provided by bed-by-bed stock assessments has provided a far more precise estimate of the extent of the geoduck stock, as well as allowed for localized rather than regional management. Despite the improved data available on the state of the stock, the DFO still sets the TACC at between 1.2-1.8 % of the current estimated biomass, in order to account for the low levels of natural mortality (James 2008). In addition, this TACC has been modified, both up and down, in order to acknowledge the current understanding of the state of the stock; this reflects the fact that scientific information is capable of guiding harvesting decisions in this industry (Trenor & Danner 2008). However, while trends have been identified showing an increase in the virgin biomass of geoduck, the accuracy of this data is uncertain (Orensanz et al. 2004). Still, while the ability of the IVQ system to improve geoduck population sizes is uncertain, it is highly unlikely that the population is being overfished (Trenor & Danner 2008). In evaluating the sustainability of the geoduck stock though, Oresanz et al. (2004) advocate caution; the long life-span and low natural mortality rates, combined with sparse data on the ecology of the fishery may mask slow declines in the stock, whether through natural or anthropogenic means. While bed-by-bed data may provide higher resolution on population numbers, dispersal and recruitment patterns are still poorly understood, and the effect that fishing might have on connected meta-populations is not currently well incorporated into the management of the species**.** In order to resolve these uncertainties, Orensanz et al (2004) recommend the development of an adaptive management strategy utilizing a continual loop of feedback and response over the more traditional method of setting TACCs in response to raw population data.

High-grading is a potential environmental concern to the geoduck fishery, as fishermen may seek to maximize their profits by filling their quota with only high value organisms and throwing inferior (in this case darker meat) organisms back (James & Bixby 2003). In order to prevent this, the UHA members have agreed to sell their catch to distributors at a flat, prearranged price (James & Bixby 2003).

Discussion

Mitchell (1998) and James (2008) summarize a number of factors that have contributed to the success experienced by the UHA, including the sedentary, long lived and highly valuable nature of geoduck, the small spatial area of the fishery, the relative youth and historical small size of the industry, the influence of local community leaders, and a clear example of the failures of the earlier racing fishery. In considering the variables leading to the positive impacts of the UHA and the IVQ system, two potential shortcomings must also be examined. The first lies in the fact that license holder rights to the fishery are not guaranteed. Under current regulations, the Canadian DFO may add or decrease access to the fishery, in the form of licenses or fishing grounds, as they see fit. As such, quota owners are uncertain they will be able to recoup the cost of investments made for the future of the geoduck fishery, and are unable to utilize their licenses in collateral to obtain loans or financing (Kahn 2006). This also serves to depress the value of quotas below their potential value (James 2008).

Secondly, while the fishermen of the UHA have undoubtedly experienced an economic upswing in response to their management efforts, there is concern that the benefits obtained from the common-pool geoduck resource is being concentrated in the hands of a few people, rather than benefiting the community as a whole (Kahn 2006, Mitchell 1998). Some argue that more shares in the fishery should be made available to the public and to the First Nations of Canada (Mitchell 1998).

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Mexico

The 'tragedy of the commons' has been the demise of many of the world's fisheries and Mexico is no exception. As has been the case of fisheries throughout Asia and Africa, the once community-based management efforts found along Mexico's coastal waters were replaced by top-down government control (Young 2001). This has led to environmental degradation and a loss of socioeconomic wellbeing. Although federal law has allowed for the privatization of resource rights to Pescadores libres (free fishers) and cooperativistas (cooperatives) this has not always prevented misuse of the resource (Young 2001). To avoid the over promotion of cooperatives as a "save all" for fisheries managers it is necessary to evaluate cases in which cooperatives have failed alongside those which have succeeded.

"Tragedy" in Laguna San Ignacio and Bahia Magdalena

Baja California Sur incorporates 23% of Mexico's coastline and is dominated by small-scale fishers using seven-meter skiffs equipped with nets and diving equipment (Young 2001). The area's waters are important environments for abalone, lobster, shark, finfish, scallop, and clam. Laguna San Ignacio consists of 502 permanent inhabitants who live scattered around the lagoon; isolated from the nearest town. Bahia Magdalena is 200 km south with 2,391 occupants living throughout the fishing villages. In both cases, access to marine resources was allocated to cooperatives and individual fishermen. Cooperative members were legally required to work collectively, pay dues, and assist authorities in monitoring and enforcement (Taylor 2001). Free fishers were considered to be solely subsistence and were therefore not regulated. This led to conflict between the cooperatives and free fishers. Furthermore, cooperatives were required to sell to a state-operated marketing firm; diminishing their ability to increase profits. In addition to user conflicts and a lack of marketing influence there was also a lack of enforcement efforts from the governing agencies. Combined, these measures led to illegal fishing, encroachment by outsiders, and corruption.

By allocating fishing rights to two overlapping bodies, the government created a de facto open access fishery (Taylor 2001). The free fishers took advantage of the strict processing regulations applied to the cooperatives by catching a greater than subsistence amount and selling it on the black market (Taylor 2001). The cooperatives were dissociated from profits through selling to a state-operated firm with a fixed price, giving them no incentive to protect the resource. In addition, government officials, lacking funds to properly enforce the fishery, were bribed to allow poaching. It is evident there were already elements at play against the stock and the cooperatives, but the real tragedy came through two unique avenues.

During the 1970s four cooperatives were established in Laguna San Ignacio for the harvest of clams. These four groups had to harvest an inferior product because the best grounds and species were already taken by other groups (Taylor 2001). They had neither the funds nor the political prowess to purchase new equipment or keep up on maintenance. When the government opened a scallop fishery in Laguna San Ignacio immigrant permisionarios flooded the resource and poached the clams, furthering the cooperatives' hardships (Taylor 2001).

Bahia Magdalena is home to the largest and most important government owned processing plant (Taylor 2001). When the plant opened, government officials encouraged immigration to Bahia Magdalena by advertising free housing to those working at the plant. The cooperatives in Bahia Magdalena were dependent on the cannery and shrimp fisheries. When the plant's parent company issued a massive layoff, workers from the plant joined the shrimp fishery. Because the cooperative members were not accustomed to defending their fishing rights the new fishermen severely depleted the resource (Taylor 2001). This event lead to changes in policies that redistributed cooperative concessions, privatized enterprises, and liberalized trade. However, these changes have not necessarily been for the good.

The changes in policy led to an increase in conflict between users, more destructive fishing activities, and decreased government intervention (Taylor 2001). Fortunately it has led to an avenue in which communities can contest policies that infringe on their rights. In the case of Laguna San Ignacio, NGOs have stepped in to help provide social capital. Their efforts established a biosphere reserve and prevented construction of a proposed salt works.

These two case studies provide evidence to the notion that the establishment of cooperatives alone cannot ensure an economically and ecologically sustainable livelihood. This finding is reinforced by the cooperative failures in the unproductive abalone fishery in Baja California (Prince et al. 1993). Regardless of these failures, the red lobster fishery of Baja California has been a success thus far.

FEDECOOP (Scientific Certification System, Inc. 2004)

In 2004 Scientific Certification System, Inc. evaluated the red lobster fishery of Baja California, Mexico to determine if it qualifies under MSC (Marine Stewardship Council) standards. The assessment specifically reviewed a conglomerate of nine fishing cooperatives, known as the Federacion Regional de Sociedades Cooperatives (FEDECOOP), and their management of a single stock of red lobster (*Panulirus interuptus*) from Isla Cedros to Punta Abreojos. Due to a complicated language barrier and multiple failed attempts to make contact with FEDECOOP fishermen, the majority of the analysis of FEDECOOP is based off the MSC assessment in 2004 and their annual recertification reports.

Of the twenty-six cooperatives in the Pacifico Norte Region, 80% of the lobster harvest is taken by ten cooperatives, nine of which make up FEDECOOP (Chaffee 2003). FEDECOOP itself consists of approximately 1,300 members, deploying an average of 13,000 traps from 230 skiffs (Vega et al. 2000). Table.1 provides the names of all nine cooperatives as well as their membership and equipment details. These values vary from year to year, but in the past have remained relatively stable. Members of FEDECOOP use 5-7 meter long boats propelled by 40-65 horsepower outboard motors to get to their designated fishing sites where they place plastic sheathed wire mesh baited with fish or mollusks in order to catch legal sized lobster (Scientific Certification System, Inc. 2004). The live lobsters are held in tanks on-board the boats and then transported to reception centers where the majority of them are sold alive, mostly to Asia (Scientific Certification System, Inc. 2004).

There is no specific management plan for Baja lobster, but the cooperative management is based on federal law that exclusively allocated fishing rights in 1936-1938 (Vega et al. 1997). These concessions are good for twenty years. FEDECOOP, in collaboration with federal agents, have added additional regulations that include a closed season, minimum legal size, prohibition of the harvest of egg-bearing females, and regulations on gear in specific zones (Scientific Certification Systems, Inc. 2004). Formation of these regulations will be discussed in more detail in the following paragraphs.

As previously discussed, the formation of fishery cooperatives does not necessarily ensure a sustainable product. But in the case of the red lobster fishery managed by FEDECOOP, catch has been fairly profitable and sustainable. Lobster catch is highest during the first two months after the season opens between 0.37-0.55 kg per trap per night (Vega et al. 1996). This value varies in each cooperative based on their harvest territories and environmental variability. The CPUE in 1999/2000 was 0.57, 0.78 for 2000/2001, 0.687 for 2005/2005, and the highest in 2006/2007 at 0.83 (Scientific Certification Systems, Inc. 2007). A study by Vega et al. (2000) determined that the stock is above the optimum level, but they still advised against catch over 1,239 tons per year due to environmental and stock uncertainty. The particular organizational structure and harvest strategy of FEDECOOP is unique and worth additional discussion.

FEDECOOP members are able to avoid the tragedy taking place in the two communities discussed above because, although there are other fishing activities in the area, these to do not effect or interact with the red lobster fishery (Scientific Certification Systems, Inc. 2004). FEDECOOP access rights are reserved within specified geographic areas, designated by buoys of specific color, and the fishery is managed by two types of documents: the NOM (general management rules) and the DOF (Diario Oficial de la Federacion). The NOM rules are generated primarily by government agencies, whereas the DOF are formulated by the cooperatives. Workshops and meetings take place every year between fishermen, scientists, and federal agents to discuss and update regulations. These meetings now take place multiple times throughout the year in order to increase collaboration (Scientific Certification Systems, Inc. 2007). Not only does FEDECOOP set their own regulations they also physically and financially assist with the enforcement of these regulations (Scientific Certification Systems, Inc. 2004). Within the cooperatives there are executive and management committees to manage internal conflict as well as trained biologists or technicians that collect information relevant to the science and management of the resource (Scientific Certification Systems, Inc. 2004). These measures inspired the cooperatives to introduce escape gaps in their traps to reduce bycatch, a voluntary agreement that was legally agreed upon in 2007 (Scientific Certifications, Inc. 2004). Such management efforts have led to environmental success, but not without significant costs. Each cooperative member makes payments to the welfare of the cooperative, adding up to $100,000, that goes to compliance (the salary of one enforcement officer) and other management activities such as research, none of which is subsidized by the government (Scientific Certification Systems, Inc. 2004). It would, however, appear that these efforts are warranted.

FEDECOOP has very strict regulations against illegal fishing, including the potential removal of the member found to be in non-compliance (Scientific Certification Systems, Inc. 2004). In addition, their research efforts have led them to restrict their catches below the suggested annual harvest (Scientific Certification Systems, Inc. 2005). Nonetheless, the commercial size of their catch has continued to decrease whereas CPUE is increasing, while membership numbers are less than they were in previous years (Scientific Certifications Systems, Inc. 2007).

Additional regulations are up for review by FEDECOOP and the government that include changing the trap design (such as escape caps, biodegradable materials, minimum mesh size), a limit to engine size of 150 hp, a requirement of logbooks on each vessel, and the recommendation to give the subcommittee more authority from the government institution (Scientific Certification Systems, Inc. 2007). Through these measures and the others already in place FEDECOOP managed Baja California red lobster fishery received MSC certification in 2004 and passed their annual reviews in 2005, 2006, and 2007. Not only does MSC consider the fishery to be a success, but so do members of the cooperative, scientists, and government agents. They all agree the success is the result of "excellent operations of the cooperatives and their ability to work cooperatively with state and federal agencies" (Scientific Certification Systems, Inc. 2004).

Table 1					
Cooperatives in operation (2002) in the central zone in Baja California					
NAME OF THE COOPERATIVE	**Number of Members**	**Number Of boats Authorized**	**Number Boats Worked**	**Traps Authorized**	**Traps Worked**
PESCADORES NACIONALES DE ABULON	167	22	19	1,480	1,480
BUZOS Y PESCADORES	86	24	18	1,440	1,170
LA PURISIMA	96	36	30	2,500	1,950
BAHIA TORTUGAS	87	22	21	1,320	1,260
EMANCIPACION	77	33	29	1,760	1,595
CALIFORNIA DE SAN IGNACIO	195	20	16	1,040	960
LEYES DE REFORMA	185	18	18	1,045	900
PROGRESO	210	40	28	2,600	1,960
PUNTA ABREOJOS	191	45	41	2,700	2,665
Total	1294	260	228	15885	13940

Fig.2 Composition of FEDECOOP (Scientific Certification, Inc (2004))

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South America

Management and Exploitation Areas of Benthic Resources (MEAs) in Chile

Chile is one of the most productive fishing nations in the world. Along with the large offshore commercial sector, small-scale artisanal fisheries also play a significant role in Chilean fisheries (see Bernal et al. 1999 or Castilla et al. 1998 for detailed definition of "artisanal fisheries) (Bernal et al. 1999). In response to chronic overfishing of easily exploitable and highly valuable species such as loco by the artisanal sector, the Chilean government developed an innovative system of co-management (Castilla & Fernandez 1998). Though identified by a number of different acronyms, this paper will follow Cancino et al. (2007) and refer to these co-management regions as "Management and Exploitation Areas of Benthic Resources" (MEAs). Under the MEA system, in exchange for performing extensive environmental assessments and submitting and following a management plan, a community of fishermen (termed *caletas*) may be granted exclusive access to an MEA, creating a territorial user rights fishery (TURF) and providing caletas with incentives for sustainable management (Cancino et al 2007).

The Chilean MEA system operates in the manner of a TURF; however unlike many TURF utilizing societies across the world, the Chilean MEAs are not a traditional part of the local fishing culture along most of the Chilean coast (San Martin et al. In Press). As such, the Chilean government has developed, essentially from scratch, a number of regulatory mechanisms in order to support the success of these spatially managed artisanal fishing communities. In order to make these coastal fisheries viable and competitive, Chile has designated the waters up to five nautical miles from the coast as "priority access" for artisanal fisheries. In practice, this "priority access" protects the existence of these small-scale fisheries, as industrial operations are only allowed to fish within the five-mile zone if they do not significantly conflict with artisanal operations (Bernal et al. 1999). Within the artisanal zone, the *de facto* state of the fisheries is an open-access system (regulated through fishery specific mechanisms such as licensing and total allowable catches). However, through the mechanisms of the MEA system, the Chilean government has sought to incentivize fishermen to move away from the open access race and instead embrace a community based co-management system (San Martin et al. In Press).

In order to be granted an MEA, a group of fishermen must submit a proposal for the boundaries of their TURF. In the northern and central portions of the central coast, these boundaries generally adhere to the natural borders of a fishing community and its adjacent fishing grounds (often defined by a bay or other geographic feature) (San Martin et al. In Press). In order to ensure that MEA owners are personally vested in the success of their fishing area, only fishermen registered in the geographic region in which the MEA is to exist may apply for an MEA (San Martin et al. In Press). Once a community has organized itself to apply for an MEA, it must conduct a thorough environmental assessment of the region, including mapping of the region and assessments of species population abundances. In addition, they must develop and submit a two-year management plan to the Chilean government (Orensanz et al. 2005, San Martin et al. In Press). This two year plan must estimate yearly catch targets, lay out survey methods for mandatory annual environmental assessments, and detail compliance benchmarks for the MEA. Once granted, an MEA is established for a 4 year period, after which renewal is dependent on completion of the agreed upon performance benchmarks (Orensanz et al. 2005).

While this general process of MEA formation is well established, the Chilean government does not have strict guidelines for the specific management plans themselves. Instead, management plans are approved on a case-by-case basis, with the specific details varying between individual caletas (San Martin et al. In Press). Internal governing structures of the MEAs, such as profit and effort distribution, rules for entry and exit, and penalties also differ greatly, though unfortunately little specific data is available on this critical component of a fishery's management (Cancino et al. 2007, San Martin et al. In Press). To give an example, while nearly all MEAs collect a fee to pay for environmental assessments and other managerial needs, their methods of dividing catch and profits differ drastically. Some MEAs simply take their allocated TAC and divide it evenly among their members. Others take a more hands-on approach and actively manage when and where their members fish while pooling resulting profits. In order to avoid free-loading, these organizations may utilize a rotation system to ensure that all members of the MEA contribute to the fishing effort, as well as a piece-rate payment system where payment depends on the quantity of catch brought in during a given fishermen's allocated period of effort (Cancino et al. 2007). An additional innovative approach which has been observed in Chilean MEAs is to allocate the TAC between members and allow them to fish as they see fit, but pay them for the quality, not quantity, of their catch, and in doing so encouraging more selective fishing practices (Cancino et al. 2007).

Economically, the MEA system has seen mixed, though often positive, effects. While the system has reduced management costs to the government, the price for much of the environmental assessment, enforcement and other needs of the fishery must now be borne by the caletas (though the Chilean government heavily subsidizes the consulting process required for environmental assessments) (San Martin et al. In Press; González et al. 2006; Castilla & Defeo 2001). However, a study by Schumann (2007) found that 60% of interviewed Chilean MEA members found their TURFs to have positively impacted the profitability of their fishery. In addition the continually growing number of MEAs being applied for in Chile is evidence that the economic benefits often outweigh the new management costs**.** The majority of these economic benefits have come through the increased control of the market afforded by the MEA system. Under open-access conditions, fishermen simply caught what they could and sold their catch on the beach. By having exclusive access in MEA, caletas can now leave their catch alive and in the water until market conditions are favorable for them (Gonzalez et al. 2006). As a result, caletas now often pre-negotiate orders with fish buyers, allowing them to catch only as much as needed, and providing the ability to focus on catching high quality organisms. Some MEAs have taken these market efforts to a further level, and pooled their catch with other local caletas as a unified marketing and sales organization, allowing them greater leverage over prices (Cancino et al. 2007). The popularity of these marketing efforts is shown by the fact that approximately 34% of current MEAs have developed official marketing committees, and many report that marketing classes are the most useful types of fisheries seminars for their caletas (Departamento de Pesca Artesanal 2005).

The MEA system has provided environmental benefits in a number of instances as well, both towards targeted species and local ecosystems as a whole (San Martin et al. In Press; Cancino et al. 2007; Gelcich et al 2006; Castilla et al 1998). A study by Castilla & Defeo (2001) showed that in certain surveyed areas, mean size and CPUE of targeted organisms (specifically loco, sea-urchin and keyhole limpets) were far higher within the boundaries of MEAs than in comparable open-access fishing grounds. A paper by San Martin et al. (In Press) shows a similarly increasing trend in CPUE within a MEA managed region of Chile's central coast. This is not to say that the MEA system represents a panacea for fisheries governance; while some MEAs have flourished, others have been able to attain the level of organization and community involvement needed for the operation of a successful TURF (Castilla et al. 1998). Besides these fishery specific benefits though, ecosystem improvements have been reported as well, as many caletas have taken steps to improve the overall health of the marine communities within their borders. Some caletas have voluntarily closed off highly productive areas of their MEA to fishing in an effort to protect their stocks (Castilla et al. 1998). As further evidence of ecosystem level management, some caletas have voluntarily reduced their take of species preyed upon by favored catch such as loco, as well as taken steps to improve the health of the kelp habitats on which many Chilean shellfish species depend (Cancino et al 2007). As a reflection of these efforts, Gelcich et al. (2008) demonstrated that beyond simply boosting the status of targeted species, MEAs contained higher overall species richness and habitat complexity than comparable open-access areas. Lastly, some caletas have seen in their MEAs opportunities beyond fishing, and instead created an ecotourism industry by promoting scuba diving in protected areas of the MEAs (Cancino et al, 2007).

Despite these numerous environmental and economic successes, the Chilean MEA system still faces many challenges. While many well-studied caletas have flourished under the MEA system, others have not fared as well. The high costs of MEA management are only affordable and tolerable to members if they are relatively certain that their investment will be recouped. As a result, many MEAs that target highly variable stocks, such as those strongly affected by El Niño events, have failed as, faced with uncertainty in future catch, fishermen choose to catch what they can when they can, rather than invest in expensive and potentially unfruitful ecosystem management (Gonzalez et al. 2006). Gelcich et al. (2007) provides a fascinating study of the factors affecting this willingness to accept risk within individual loco-fishing caletas (in this case, risk aversion was categorized by the willingness of a group to harvest all of their loco TACC for immediate certain benefits or to leave a portion of their TACC in the uncertain hope of improved returns on a later date). The authors found that MEAs that relied on loco for a large part of their income were more risk-accepting than those who depended less on shellfish resources for survival (MEAs that primarily harvest finfish for example). A possible explanation for this trend is that loco-dependent fishermen are more familiar with the local ecosystem, and as such have a higher faith that actions that they take will be able to improve the fishery, and hence their profits over time (Gelcich et al. 2007). The authors also found that risk preferences varied greatly in response to the size, value, and performance over time of the fishery, as well as societal needs of the caleta. The high variety of responses found by this study indicates that the ability of MEAs to serve as effective tools for sustainable fisheries is highly dependent of the context and community in which they occur.

Fig.3 Map of Chilean Fishing Districts

Geography has also proved an important variable in the success of individual MEAs. The north and central regions of the Chilean coastline have shown generally positive results from TURF management. MEAs have proven far less successful in southern Chile, and simply looking a map of the country provides a powerful explanation for this. The northern and central regions of the coastline are relatively geographically simple, allowing for easily defined boundaries around which TURFs can be based. The south of the country though presents a much more poorly defined coastline. In addition, while in the north villages tend to be located on the coast, the majority of the fishing population in the south lives in cities farther from the coast. The net result of these factors is that the organization of TURFs around caletas is far less a "natural" state of affairs in the southern portion of the country, and as such the system has not proved as effective there (Orensanz et al. 2005, San Martin et al. In Press). This is not to say that the MEA system operates perfectly, in a societal sense, in the north. While TURFs may be a more easily formed entity there, in some regions numerous social groups stake a claim in the same fishery; some of these may become disenfranchised if one particular group is able to gain exclusive access through the formation of a MEA. In addition, the complex process of MEA approval has created a long line of potential MEAs waiting in the red-tape of the system, slowing the development of new MEAs and dulling the impact of completed reports, as government agencies are swamped by reams of documents (Orensanz et al. 2005, San Martin et al. In Press,). Environmentally, while management within the MEAs has been shown to be successful, external forces are causing problems. Many caletas bolster their catch by harvesting large amounts of (often illegal) organisms in the open-access areas bordering their MEAs. In fact, recent estimates show illegal catch to make up over 50% of the total harvest of loco (Gonzalez et al. 2006). In addition, some MEAs suffer from what has been termed a "tragedy of the larval commons" (Orensanz et al. 2005). The Chilean system operates by developing individual management plans with each caleta. While beneficial for localized fisheries, this creates problems with widely dispersed organisms, in that there is little to no management coordination between biologically interconnected MEAs. Lastly, the environmental assessment process which is a cornerstone of the MEA program is heavily dependent on the advice of professional consultants, which are in turn often reliant on government subsidies (Gonzalez et al 2006). Should the government become unable to support these consultants, it seems possible that the environmental monitoring aspects of MEAs could suffer greatly.

The Chilean MEA system is a highly complex entity, comprised of a wide variety of geographic regions, fisheries and peoples. On the whole, while containing numerous shortcomings, the system has had many successes and proved a clear improvement over the prior forms of management that it replaced. In addition, the extreme heterogeneity in management types and ecosystems which the MEA system encompasses could allow it to become an ideal laboratory for the study of the formation of successful cooperatives.

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When Cooperatives Collide: Impacts of the Chilean MEA Program on an Existing system of Community Management

The authors of Gelcich et al. (2006) have written an impressive number of papers examining the effects of the Chilean MEA system. While the cooperatives brought about through this initiative have had many successes, in this instance the authors chose to investigate to effect of the MEA system in a community that had a pre-established system of community management. They found that the implementation of MEAs in this particular group of fishermen resulted in the deterioration of the existing system and a loss of the ecosystem and social benefits that were a part of the existing fishing society.

The community examined in this case was called Puertecillo, and consisted of several groups of people that harvested a species of bull kelp called "cochayuyo" through a generally informal union system developed by the industry. The established system essentially divided the kelp beds into a series of small TURFs assigned by lottery. Under this informal (from a governmental standpoint) system, each year union members were assigned a lot through the lottery, with lots being marked out not by their size but by their productivity. Once assigned a lot (termed a parcela), a union member could manage it as they saw fit, or trade it to another member of the community if they could not or did not want to harvest their plot.

A number of social and environmental practices came into being as a result of this system. Parcela owners could harvest their kelp in whatever manner they were able; those capable enough did the job on their own, others brought in family members, some asked for help from the community, those who were unable to work their parcela at all simply sold it off. Help could be paid for by the promise of returning the favor at a later date, or through food, drink or money. In this way, the proceeds of individual parcelas dispersed throughout the community.

This system also led to the development of environmental management practices. The union utilized a voluntary closed season, which was timed to allow the kelp to recover during its slow growth phase of the year. As part of this program, fishermen would target other species of kelp during the closed summer months, which in effect mimicked the effect of natural disturbances on the local ecosystem. The effects of this practice may have served to improve the resiliency of the ecosystem. Lastly, the voluntary TURF system contained a built in method for creating closed areas. Under the parcela lottery system, widows are able to be receive lots, but they do not actively harvest them. As a result, lots owned by widows often go untouched, creating a network of protected areas which local fishermen feel improves the health of their area and provides them with a benchmark for the state of the kelp. In order to keep track of the effects of harvest practices on the kelp, each year the union collects information on the amount of kelp harvested in each parcela, allowing them to track their resource and redraw the parcelas if it appears that some have an unfair advantage over other in terms of productivity.

It is important to note that this entire system operates solely through community level enforcement; the parcela system has no legal grounding to the Chilean government. As a result, the implementation of the MEA program in this region has caused conflict with the pre-established system of kelp management. The MEA program was instigated here in order to gain access to the potentially lucrative loco fishery, which can only legally be harvested within establishes MEAs (San Martin et al. In Press). In creating a MEA, the system has essentially moved from one of many independent TURFs operated by parcela owners, into a single large TURF operated by the community as a whole. This has created a set of societal externalities. Under the old system, a clear set of agreed on practices governed the distribution of wealth from the kelp harvest. Working for individual parcela owners in exchange for goods or services seemed like a fair way of compensating individual people for their particular skills or abilities. Under the new MEA system, it became unclear to the people as to how benefits would be divided to different members of the community, if they could no longer strike agreements with individual parcela owners. This led to increased conflict in the community.

Environmentally, the MEA system also inadvertently served to deteriorate the system by which the kelp union had managed their local ecosystem. The MEA system requires management decisions to be based off of scientific advice collected by an approved consultant. As a result, rather than being able to rely on extensive local knowledge, under the MEA the union had to pay for an external consultant to inform the community about their own ecosystem. Monitoring requirements of the MEA system also resulted in the breakdown of the traditional timing of harvest to mimic the natural growth and disturbance patterns of the kelp.

The net result of the MEA system in this particular instance appears to have been to increase conflict within the community, dissolve long-held and locally developed ecological management techniques, and increased costs of management to the community, all without providing the increase in profits intended to result from the MEA system. Given the success of the MEA system, in many instances, this example illustrates the need for caution in assuming cooperative structure can provide automatic improvement to a fishery. While the MEAs provided many benefits when replacing an essentially open-access system, they in fact may have deteriorated fisheries management when installed in place of existing, socially acceptable norms and practices.

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The Failure of the José Olaya Fishing Cooperative in Peru

Sabella (1980) describes the experience of the small village of San Pablo in Peru with the governments attempt at cooperative fisheries development. These efforts came about during the 1970s; the Peruvian government decided to embark on an ambitious program to develop fishing cooperatives for the artisanal fishing fleet, in the hope of increasing domestic food production and providing benefits such as boat motors and increased job security to rural populations. Despite these good intentions, the cooperative program failed in this instance; the author argues that it did so due to a lack of connection with the societal system already in place in this fishing community.

The village of San Pablo consisted of a small number of fishermen who primarily caught fish for personal consumption, selling any excess at the market. Fishing was mainly a family business, with boat owners employing sons first, followed by the next closest male relations and filled out as needed with close friends in the community. Help was recruited for other activities such as boat repair in the same manner. These family fishing units formed the basis of the fishing industry in the village, providing the means for accountability and cooperation.

With the inception of the cooperative program, the Peruvian government planned an ambitious set of goals, including the provision of boat motors, access to loans, assistance with the technical setup of the organization, and educational centers for fisheries operation. The fishermen of San Pablo were extremely enthusiastic about this program at first, believing it would deliver them boat motors in a matter of weeks. However, many of the local community viewed this cooperative program as a means for achieving personal economic independence, not as a tool for developing a community business.

In order to become part of the cooperative, members were required to begin paying dues immediately. However, for the first few months of the program, fishermen paid these dues only to watch the process slog through the paperwork of the system; no progress was seen in the disbursement of loans or motors. Little was done either during this time to establish the foundations of the cooperative. While three elected members attended meetings intended to guide them through the development of a fishing cooperative, a technical advisor, who was an appointee of the Fishing Ministry with no previous experience in fishing or fisheries, ran these meetings. After many months, a contract was reached with a Japanese company to supply outboard motors for the local artisanal fleets boats, but the contract was never delivered on and it was later found that the paperwork for the importation of the motors had never cleared the first level of bureaucratic red tape.

The fishermen quickly began to tire of paying dues without seeing tangible benefits and began to drop out of the cooperative program. This exodus was expedited by the lack of understanding on the part of the village as to the purpose or functioning of cooperative action. Rumors began to circulate that instead of being paid directly for their fish, cooperative members would receive a ticket for their catch, redeemable for money once the government had sold their fish. This system was unacceptable to the local fishermen, who often needed to use the previous days sales to pay for the next day of fishing. More fundamentally, fishermen did not understand how a cooperative was supposed to function. The idea that boats would be owned by the group, rather than individually, and that profits would be distributed among the members, did not sit well with the villages existing social structure. To exemplify the concerns felt by many budding cooperatives worldwide, in response to the proposition of collective action, one local fisherman stated, "How could you deal with loafers or drunkards who might share equally without putting out sufficient effort?" In the end, the cooperative effort in San Pablo dissipated in the space of several months.

While the government inefficiencies present in the system provide a large reason for this failure, it is instructive to consider the more fundamental reasons behind the inability of cooperative development to function in this setting. As Sabella (1980) discusses, the governmental cooperative initiative represented a fundamental change from the existing system of family fishing already in place in the village of San Pablo. This is not to say though that a cooperative could never be formed out of a kinship based fishing society. Artisanal fishing operated in a similar manner in Chile, and yet the government developed MEA system has been a great success there. The problem appears to lie in the incentive structure. In the Peruvian experiment with cooperative development, the government attempted to create a cooperative structure where none existed before. In the Chilean MEA program, the government provided an incentive for cooperative formation (exclusive access to a resource) and left it up to the communities to organize themselves into a group if they so wished. This provided an incentive for communities to act cooperatively, and allowed them to see a direct benefit from group action. The primary incentive for fishermen in the Peruvian case was access to capital and motors. The cooperative process in Peru appears to have been more of an administrative hurdle to the fishermen, rather than a process through which the community members felt they could begin to earn more and control their resource. While an isolated example, the inability of the José Olaya cooperative to develop represents the challenges of attempting to instill cooperatives in a top-down manner, rather than providing incentives for a bottom-up movement within the fishing community.

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Australia

According to Foster and Howard (2003), Australia was the first country in the world to "develop a comprehensive national plan to protect and manage the oceans." It is no surprise then that many of their fisheries have maintained sustainable stocks and still support 20,000 people employed by the industry. As is the case in many developed countries, Australia traditionally uses a top-down approach to fisheries management. However, the rigidity of this approach has loosened with the implementation of ITQs in the Tasmanian commercial rock lobster fishery (Bradshaw 2004), the northern prawn fishery (Jarrett 1999), the Western Australia rock lobster fishery (Caputi et al. 1997), New South Wales fisheries (Young 1995), the blue fin tuna fishery (Kearney 1996), and the Western Australia abalone fishery (Prince et al. 1998). Fishery cooperatives have also been used as a tool to manage Australia's waters with varying degrees of success. In personal conversation with Jeremy Prince he explained that remote fisheries often formed cooperatives as a tool to develop the infrastructure needed to land, process, transport, and sell catches. He further clarifies that these cooperatives had very little involvement in the management of the resource. Furthermore, when other buyers entered the market the cooperatives would fall apart which lead to an inability to retain profit. The available literature suggests that this scenario was the norm in Australia's cooperative fisheries history, but there have been some exceptions in the prawn and abalone fisheries.

Industry Initiative to Promote Stock Sustainability

The Exmouth Gulf and Shark Bay prawn fisheries of Western Australia are two of the most profitable and well-managed fisheries in the country (Kangas et al. 2008). Because prawns are short lived, the fishery is managed by input controls, which are arrived at via a cooperative agreement between the industry and managers. Although there is no specific body which is formally recognized as a fishery cooperative there has been the development of homogeneous bodies with one company owning 15 out of the 16 licenses in Exmouth Gulf and eight out of the twenty-seven in Shark Bay (Kangas et al. 2008). A majority ownership by relatively few companies signifies a large commitment by the industry to the resource. Subsequently the industry has taken the initiative to properly manage their stock. Two buy back schemes have taken place since 1984. Both were initiated, and in one case financed, by the industry, as a mechanism to reduce fleet size (Kangas et al. 2008). They have also suggested a movement to quad gear, the implementation of moon closures and other temporal/spatial closures, and financed surveys to establish prawn size and abundance data (Kangas et al. 2008). Compliance and enforcement has also been addressed by the industry. For example, the MG Kailis Group, owning 15 permits, installed a "smartcatch system" on their boats that downloads boat activity directly to their company database, making illegal fishing difficult. Similar results have taken place in the Northern Prawn Fishery.

The Northern Prawn Fishery (NPF) is known as one of the best-managed fisheries in the world, arguably due to the industry's involvement in the management process and well-defined property rights (Jarrett 1999). A Northern Prawn Advisory Committee was set-up after the non-regulated period prior to 1974. The Committee placed a freeze on new entrants into the fishery, which essentially gave exclusive commercial access to those fishermen already established (Jarrett 1999). By making the quotas transferable in 1984 the industry was given further control over the fishery. Similar to the case of the Western Australia prawn fishery, industry took initiative by issuing a buy back scheme to reduce the fleet to a sustainable number. The industry also pays, in full, the fishery's management-costs (Jarrett 1999). Again, although there is not an official arrangement between the fishermen, they have worked together cooperatively to promote the economic and ecological health of the fishery. A more direct case of fisheries cooperative management can be found in Australia's abalone fishery.

Keeping Abalone Alive in a World of Failures

Globally, annual abalone production has declined from 29,000 t in 1969 to 10,000 t today (Prince). Australia remains the largest producer, contributing 5,000 t per annum (Prince). In China and Japan abalone is considered a delicacy and therefore the price is set in Asia (Prince et al. 1998). Historically, abalone has been managed by the government through the use of Legal Minimum Lengths (LMLs), licenses, and a TACC. Initially the licenses were non-transferable, but allowed divers to retire by nominating a replacement diver for their license (Prince et al. 1998). However, there is evidence to suggest that in the case of some fisheries a regulatory management framework does not necessarily ensure the health of the stock. As Prince et al. (1998) explain in their work, sedentary stocks, such as abalone may face isolated collapses where "nuggets" (individual populations) can be severely depleted without an overall decline in the stock. Therefore other measures must be taken to avoid the "tragedy of the commons."

In Tasmania, for example, the industry lobbied the government for an overall TACC reduction of 40% after realizing their stock was depleted (Prince et al. 1998). This effort was made despite agency interference. The zone 2 abalone divers of southwestern Australia initiated additional action. The divers voluntarily agreed to participate in "concept fishing". Within their zone, the fishermen collectively agreed to: 1. Coordinate their efforts to ensure an aggregation of abalone was only harvested once a year, 2. Share their daily catches, 3. Avoid harvesting populations not yet recovered, 4. Use self-determined minimum size limits above the legal size, and 5. Remove a fair balance of age structures from an aggregation (Prince et al. 1998). Known as the Augusta concept plan, the voluntary arrangement in zone 2 promoted a sustainable abalone stock. But, because these measures were taken voluntarily, there was no guarantee against one individual reversing the efforts of the group. Jeremy Prince suggested that a movement towards a TURF system would help combat this issue.

Based on the abalone management systems used by the British Columbian Abalone Harvesters Association, Prince suggests that within each zone the fishermen should arrange themselves into homogeneous entities that discourage free riding. In order to distribute the TACC equally it would be necessary to grid the coastline. Then each stakeholder would assign a value to each square and the TACC would be divided within each square, which would then be divided among the owners. One should allow for the trading of sites to promote an arrangement accepted by the majority of the fishermen. Although the success of this management plan was already evident in other abalone fisheries in Canada, New Zealand, and Japan, it wasn't until very recently that it took hold in Australia.

The use of Rapid Visual Assessment (RVA), a decision rule tree, and a harvest plan have drastically changed the way Australian abalone is managed. The initial implementation of this approach took place in the Victorian Western Zone by the Western Abalone Diver's Association (WADA) that targets blacklip abalone. In this zone membership consists of quota owners who dive, divers who lease quotas from owners, and quota owners who do not dive (Prince et al. 2008). Licenses are transferable through a two for one exchange or a one for one with a $A10,000 transfer fee (Sanders & Beinssen 1996). This has maintained relatively low membership making collective action possible. Recently it was proposed that the relative maturity of abalone can be gauged by the shape and appearance of their shell (RVA). Therefore it is possible to assess an entire stock through 5-10 days of interviews (Prince et al. 2008). Another approach that was suggested is an assessment based on several days of workshops guided by a decision tree. The industry and managers are then able to determine the relative status of the stock (each reef given a different code) and act accordingly. The WADA was the first cooperative to use these measures to determine the size of their stocks. Once their reefs were analyzed they set VMLs (voluntary minimum lengths) and voluntary catch caps (VCCs) for each code. They agreed to monitor the catch and stop fishing once the VCC was reached. Initially the fishermen were hesitant to fully embrace these measures, but their doubt was quickly relieved after one reef, The Crags, began to rebound. Now the WADA's management scheme is fully intact and consists of two workshops a year implemented by a MOU with the Victorian government. It is estimate that there is 95% compliance. Given the success WADA has had with their new management system, other abalone associations have followed suit.

The Victorian Abalone Diver's Association (VADA) used the decision tree to assess their reefs in 2004. They have structured their management system slightly different than that of WADA in order to fit their environment (Prince et al. 2008). In recognition of WADA and VADA's initiatives, the federal government has granted four years of funding for their workshops and the expansion of reef management to the other three zones. Although there is visual evidence to suggest this regime has lead to a healthier, more balanced stock, a recent infection has prevented statistical scientific evidence proving is the case. There is potential to use a similar TURF management system for other fisheries in Australia that possess similar characteristics.

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New Zealand

The New Zealand Paua Management Action Committees

Industry Structure

The New Zealand paua fishery is managed through the Quota Management System (QMS), which divides the country into a series of Quota Management Areas (QMAs), each with their own Total Allowable Commercial Catch (TACC). TACC is allocated through quota, that provides quota holders with an Annual Catch Entitlement (ACE) which represents that actual amount they or their representative may fish (For a thorough summary of fisheries management policy in New Zealand, see Harte (2008)). However, in an effort to improve upon the management of the paua industry, members of the fishery have created a voluntary system of paua Management Action Committees (PauaMACs) for each of the QMAs, which are in turn, are represented by the Paua Industry Council (PIC). These PauaMACs consist of cooperative organizations comprised not only of quota owners in the fishery, but also associated members of the industry, such as divers, ACE holders, licensed fish receivers, and scientists. As a group, these PauaMACs attempt to develop their region's ability to self-manage, through efforts such as voluntary catch reductions, expanded environmental monitoring, and reseeding, all in order to "add value" to their fishery (Paua Industry Council Ltd. 2009). Each PauaMAC may then elect one representative to sit on the board of the PIC, which acts to promote the sustainable management of paua on a national level, while providing support to the regional activities of each PauaMAC.

In order to more accurately represent real involvement in the fishery, the PauaMACs utilize a three-tiered voting system, with class one representing actual quota owners, class two being divers and other such peoples, and class three containing interested parties. Matters regarding the budget are only voted on by class one members. Matters concerning the TACC and stock management can be voted on by all members, though class one members retain extra rights, while other general decisions are open to all voting members on an equal basis. In addition, to maintain parity in the fishery the first round of voting works through a 75/75 voting rule. Any action requires 75% of the quota ownership by volume to agree and, to protect minority interests, 75% of the total number of voters to agree. While this may seem as a potential source of conflict, given that clearly some members of the PauaMAC are far more heavily involved than others, members of the industry feel very positive about the process, stating that it ensures a lively and thorough discussion of any idea up for voting (Cooper 2009). Agreements reached through this process are entirely voluntary, and no formalized penalties for non-compliance have been established, though there is talk of developing a set of formal sanctions.

The management efforts that the PauaMACs undertake are funded through a mandatory tax system, proportional to the amount of quota owned by a member. PIC efforts are in turn largely funded by contributions of the constituent PauaMACs, in proportion to each of their TACCs. The PauaMACs and the PIC do not engage directly in pooling of profit, catch or harvest effort. Rather, through their actions they seek to improve the overall state of the fishery, and in doing so adding value to their individual quota shares.

Management Actions

Through this cooperative organization structure, the PauaMACs and the PIC have taken many steps to improve the management of their fishery, and in doing so move from being "individual harvesters to collective farmers" (Cooper 2009). A case from the Kaikoura region of New Zealand serves as an illustration of this phenomenon. This area consists of a highly spread out coastline, serviced by one major port at Kaikoura. The natural result of this setup was that the local paua fishermen collected most of their TACC from the easily accessible areas directly near port, causing localized depletions even though they were observing the regional TACC. In order to alleviate this problem, the local PauaMAC decided to voluntarily close the regions closet to port for the first two months of the season, forcing effort to be more evenly distributed between the region's stock. The members of the Kaikoura PauaMAC reached this simple, yet potentially contentious, decision with 100% agreement in the space of 15 minutes (Cooper 2009).

Cases such as this are but one of many examples of management tools that the PauaMACs have undertaken under this cooperative style system. Members of the PIC believe that paua catch restrictions imposed by the New Zealand government are too lenient, and as such have created self-imposed tighter controls on catch. As an example, the New Zealand government established a minimum legal harvest size of 125 mm for paua. However, size is a very poor indicator of age in paua; in the south of NZ paua are only just reaching maturity at 125 mm, while in the north of NZ they may never even reach this size. In order to resolve this issue, PIC members took it upon themselves to develop alternative, larger minimum size limits for particular harvest areas, based on their estimates of the size of reproductively mature individuals in those regions. Despite being completely voluntary, spot checks by the PauaMACs at distributors found that nearly all paua being brought to market were in compliance with these self imposed size restrictions. Anecdotal observations by members of the fishery have shown increased numbers of juveniles in regions where the minimum size limit has been raised. MACs have also implemented voluntary catch reductions within their zones, sometimes amounting to a 30% decrease from the TACC (Cooper 2009).

The cooperative system employed by the New Zealand PIC has also provided an incentive to improve environmental monitoring of the stock. Under the current system, stock assessments and other monitoring needs are almost entirely funded by the industry and performed by the government. Industry members fear though that this system is costing much and providing little, citing concerns that the resulting data is simply too broad to be accurate or useful. In order to resolve this, the PIC intends to take on an increasing share of monitoring duties itself, through which they hope to reduce costs while improving data quality. The government program bases its results on scattered diver surveys, and as a result paints a very broad picture of the paua stock. The PIC plans to utilize their divers to provide much more high resolution data, through the use of custom designed data loggers capable of providing microstock level information on stock status and CPUE throughout the fishery.

As a further effort to actively manage their fishery, most PauaMACs have adopted a paua-reseeding program. They believe that properly implemented, the reseeding program should allow them to effectively replace their harvest, improving the stability of the stock and allowing for increased levels of catch (Cooper 2009). The belief of the importance of this step is such within the PIC that members are currently putting $500 (NZ) per ton of quota owned to go towards reseeding, and will soon vote on increasing that amount to $1000 (NZ). In an attempt to ensure that reseeding efforts do not detract from natural recruitment, seed stock is only taken from areas that are already being replanted. Currently the PIC estimates that 15% of their reseeded stock will survive to reach the minimum legal size limit of 125 mm, though they hope to reach 20% in the near future (Cooper & Hill 2006).

While the PIC has utilized the cooperative nature of their organization to improve the management and monitoring of their resources, they are also proposing options for reducing the societal externalities that may result from catch share systems; namely the concentration of fisheries benefits in the hands of a few rather than the community as a whole. To resolve this problem, the PIC hopes to develop a diver permitting system that would extend ownership benefits from quota owners down to on-the-water members of the industry. Currently, divers operate under week-by-week catch contracts, which essentially means that the benefits that they the see from the fishery come from immediate sales of paua. As an alternative to this state, the PIC is negotiating to develop a long-term contracting and licensing system for divers, creating a system where the value of a diver permit reflects the perceived long-term worth of the fishery. In this way a diver could now see more direct benefits from the sustainable management of their fishery, as well as utilize their permits as collateral for bank loans (Cooper 2009). As an added incentive for divers to comply with fishery management decisions, the PIC hopes to tie the use of breathing apparatus such as hookah to diver license holding. Hookah diving is a far safer method of paua harvest than the free diving techniques utilized now; by allowing only divers licensed by the PIC to utilize hookah, a powerful incentive to comply with license requirements is created. As a final measure, the PIC wants to develop a system where diver licenses are issued by local PauaMACs only, preventing consolidation of the industry in the hands of a few large firms. The Chatham Islands, located approximately 800 km off the coast of NZ, provide a strong example of the need for this localized control on the industry. Under the current system, it would be possible for a large company from the NZ mainland to buy up quota in the Islands, and bring out its own fleet of divers to harvest the paua there, essentially driving local divers out of business. Under the proposed PIC licensing system, paua diving within a QMA would be licensed by the local PauaMAC only, allowing them to ensure that local divers are given fair access to the resource (Cooper 2009).

Performance[8]

Clear data is unavailable on the specific economic impacts of the cooperative nature of the PIC and PauaMACs. However, the willingness of PIC members to undertake expensive and challenging management efforts, such as microstock level fishery monitoring and reseeding, reflects a belief that such actions improve their livelihoods. In addition, membership in PauaMACs and the PIC as nearly at 100% of commercial paua fishermen, and the number of fishermen remaining outside the cooperative is continually declining, indicating that fishermen feel an incentive to be within the PIC/PauaMAC system, despite the high costs of management efforts.

The general economic impacts of paua management in NZ can be seen however through trends in the asset value of paua. Asset value is a useful indicator of the state of the fishery, as it is based on the value of paua quota, which is in turn reflective of the state, both short-term and future, of the fishery. For NZ as a whole, since 1996 the asset value of paua has increased from 143 million NZ dollars to 390 million in 2007 (Statistics New Zealand 2009). On a regional basis, all QMAs with the exception of the Northland/Auckland region experienced an increase in the asset values of paua (Statistics New Zealand 2008).

The impacts on the environment of this system also remain unclear. TACCs have been adhered to nearly every year across every QMA for the past 10 years, indicating the strength of the system in enforcing regulations (Ministry of Fisheries 2008). However, the TACC for paua across New Zealand has decreased by 16% from 1996-2007 (Statistics New Zealand 2009). Three paua QMAs have had 40% cuts in their TACC necessitated by the state of the stock (Cooper 2009). While numerous possible explanations exist as to why paua populations may decline, industry members attribute the drop in these three zones to two matters: First, the 125 mm minimum catch size mandated by the NZ government, which is of insufficient size to ensure that organisms in those regions attain reproductive maturity. Second, the level of illegal take, which as of the mid 2000's was estimated by the Ministry of Fisheries to be equivalent to the amount harvested under the TACC, approximately 1000 tons per year (Cooper 2009). Possibly as a result of these factors, despite the PauaMACs continuing efforts as of the 2006-07 fisheries surveys, only one of the paua QMAs has experienced an increase in their TACC in the last 10 years (Ministry of Fisheries 2008).

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[8] For more specific region by region data on economic and catch trends in the New Zealand Paua industry, see the New Zealand Fisheries Infosite at http://fs.fish.govt.nz

Adherence to fisheries regulations has been extremely high within this cooperative structure. There have only been minor infringements by the commercial industry within the last 5 years, and the last three major busts of illegal paua catch to be made in New Zealand found no connection to the commercial paua industry. Industry members report that as a result, their relationship with law enforcement has improved dramatically, creating a collaborative environment in which both groups seek to reduce illegal catch. As part of this improved relationship, there have been recent cases where fines imposed by the courts have been reparative, meaning that the majority of the fine is forwarded to the PauaMACs to go towards reseeding back into the area that the poachers were caught in. This has further incentivized industry members to help monitor for illegal catch.

Challenges

In an effort to reduce conflict with the recreational sector, the PauaMACs have often voluntarily designated certain areas for recreational use only. Still, illegal and unreported catch remains a significant problem to the industry. Government estimates place black-market catches as being equal to the TACC. In addition to the clear environmental risk posed by this, it creates a marketing problem for the industry as well. Despite the innovative efforts that the PIC has taken to manage the paua stock, little has been done on the marketing side of the business. Instead, most of the cooperatives involvement stops "at the beach". The lack of a concerted marketing effort may be preventing the cooperatives from fully utilizing the benefits of their management efforts. Illegally caught animals make up a large portion of the paua consumed locally in New Zealand, glutting the market and resulting in the PauaMACs exporting nearly all of their catch to Asia (Cooper 2009). This creates a problem for New Zealand paua, as wild caught paua of legal size are in fact larger than is ideal for the Asian market. Most paua shipped to Asia is canned, with the standard practice being two whole pieces of abalone per can. However, the wild caught NZ paua is so large that only one and a half pieces will fit in a can, serving to drive down the value of the wild caught product.

Discussion

While the QMS system has had many successes in New Zealand fisheries, the decision of members of the paua industry to organize itself in this cooperative manner has greatly added to the management of this industry. The QMS system operates in a very large-scale manner, not ideal for the management of species that consist of numerous microstocks, such as paua. By electing to take on management efforts for themselves, the PauaMACs and the PIC have been able to develop much more high-resolution data, allowing for site-specific management decisions such as localized size limits, area closures and reseeding. These costly endeavors would likely not have been accomplished through the actions of individual quota owners. In addition, this form of collective action and investment in the future of the fishery has created a strong incentive for self-monitoring, as reflected by the lack of enforcement actions taken against PauaMACs, as well as the absence of specified internal penalties for non-compliance of PIC members with their agreed upon measures.

While the economic and environmental impacts of these cooperative management efforts are not directly available, the high membership rates, despite the associated costs and management activities, suggest that fishermen must feel that becoming a part of the PauaMACs is worthwhile effort. In addition, the continually growing asset value of the fishery, both nationally and regionally, may reflect the positive impacts of this cooperative management on the state of the fishery.

However, that stocks have declined dramatically in many of the QMAs reflect the continued challenges facing the paua fishery. While members of the PIC have taken voluntary measures in an effort to restore depleted populations, they are not the only harvesters of the resource. Recreational fishermen catch large numbers of abalone, and while they may follow the regulations entirely, as previously stated the 125mm size limit imposed by the government regulations may be too small to allow for recruitment to occur. While the PauaMACs have taken efforts to spatially separate themselves from the recreational sector, fishing of immature individuals by recreational fishermen may still be detrimental to the fishery as a whole. Combined with illegal catch, a significant portion of paua harvest may be occurring outside of the jurisdiction of the PauaMACs. Should stocks continue to decline, it is foreseeable that members of the PauaMACs may be less inclined to follow their management practices if illegal and recreational catch are able to snap up any benefits created by the cooperative. Under these circumstances the voluntary nature of agreements made by the industry may prove detrimental to the stability of the PIC and its constituents.

An organized marketing effort on the part of the PIC could serve to both to reduce the extent of illegal paua catch, and improve the economic performance of the fishery. Developing a system of coordinated catch and sales, combined with aggressive promotion of the value of sustainably harvested locally caught paua, might allow the industry to command a higher price for their goods on the market, rather then being sold almost entirely as canned goods in Asia. Given the highly sophisticated efforts currently being undertaken by the PIC to improve the stock of their fishery, the potential for the success of a cooperative marketing effort seems high.

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The Challenger Scallop Enhancement Company

The Challenger Scallop Enhancement Company (Challenger) was among the first organizations in New Zealand (NZ) to utilize the Quota Management System (QMS) as a basis for the development of a cooperative style fishery (Yandle 2006). Beginning in 1994, Challenger has taken on a continually increasing role in the governance of the southern scallop fishery, resulting in a robust co-management approach to management with the New Zealand Ministry of Fisheries (MFish) of a significant fishery estimated to be worth over $10 million per year (Leal 2008).

Industry Structure

Challenger operates along the northern edge of the South Island of NZ, in the Golden Bay, Tasman Bay and Marlborough Sounds. Commercial scallop fishing has long been a presence in this area. Following the history of many coastal fisheries worldwide, fishing effort increased dramatically in the later part of the 1900s, culminating in the collapse and closure of the scallop fishery in 1981 (Mincher 2008, Yandle 2006). In the wake of this even, the NZ government began a reseeding program, which along with the commercial closure led to the reopening of the fishery in 1983. In 1992, the southern scallop fishery was introduced to the QMS, providing the new quota holders in the fishery with an incentive to improve its management. This year also provided the impetus for the official formation of Challenger, with the passage of a mandatory tax on the industry passed by the NZ government. Quota owners in the industry felt that if they were going to be taxed for the management of the scallop fishery, then they should at least take an active role in ensuring the money was spent so as to maximize the benefit to the fishery. As such, they formed Challenger and began working with MFish for the development of a co-management model for the southern scallop fishery (Mincher 2008)[9].

The current structure of Challenger follows a corporate style model. Shares in Challenger are available only to southern scallop quota holders, with each member of the company receiving one share, regardless of the amount of quota owned. Voting rights however are assigned in proportion to the amount of quota controlled by a shareholder, and seats on the board of directors are also allocated in proportion to the number of votes held by a shareholder. Each year, the board meets to develop a business plan and set the annual levy (tax). Decisions on these matters are passed by a simple majority vote. Challenger also develops an annual management plan (AMP) that is developed through a far more involved process. Challenger develops a draft management plan based upon the

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[9] For a detailed history of Challenger, see Mincher 2008

results of stock assessments and other available environmental data. The draft management plan is then presented to MFish and the other interested stakeholders in the industry, including all commercial industry members as well as scientists, environmental groups, recreational fishermen, Maori groups, and the general public, for comment and review. The results of this process are then returned to the Board of Directors, which submit the AMP to a final round of review before approving the plan. Originally, MFish required that they also approve the AMP, but they have since dropped this stipulation. MFish does however have agreed upon fishery benchmarks, through which the government can assess the performance of Challenger (Mincher 2008). The AMP dictates fisheries management decisions such as catch restrictions, spatial and temporal closures and recreational allocation. This AMP serves as the basis for civil contracts that Challenger enters into with industry members such as boat owners, processors and scientific consultants (Arbuckel 2000, Yandle 2006). These civil contracts contain clearly defined penalties for non-compliance with agreed upon measures.

The day-to-day operations of Challenger are carried out by a team of several full time staff, with the support of many part-time workers that they employ throughout the year. While not directly under their management, Challenger works in close conjunction with contracted boat owners and seafood processors, as well as parties hired for scientific consultation (Arbuckle 2000).

Management Tools

Challenger is unique among NZ fisheries in that it is not actively managed under the TACC system of the QMS. Scientific studies requested by Challenger demonstrated that a system in which fishing effort was rotated throughout the region, allowing portions of the stock to recover periodically, would in this instance produce a more stable fishery than management based on a TACC or other biomass controlled management practice (Arbuckle 2000, Mincher 2008). The default setup of this rotational system is described in Mincher (2008), though the system may be amended each year as dictated by the needs of the fishery. For example, rotation has been stalled in certain areas that have experienced severe stock declines (Mincher 2008).

In order to allow for this rotational system, rather than eliminate the TACC system, MFish has simply elected to set the TACC far above the actual expected catch, providing Challenger with the discretion to fish as they see fit, so long as they continue to meet MFish's expectations. The result of this though is that individual quota holders now hold more ACE than exists in the areas open to fishing in that year. This could in theory result in a miniature race for fish at the start of each year, as each cooperative member attempts to catch as much scallop as possible in the most accessible and cheapest fishing grounds, before the targeted region becomes so depleted that fishing becomes prohibitively expensive (Mincher 2008). In order to prevent this scenario, Challenger has entered into a "shelving" agreement with its members. Under this agreement, Challenger places a limit to the total amount of catch allowed in a given region set slightly below the amount they believe the fishery can sustain. They remainder of the ACE is then shelved until later in the season. As the year progresses and this agreed upon limit is reached, fishing effort becomes increasingly costly and as a result many boats leave for more profitable sectors. Once this occurs, Challenger releases the "shelved" ACE for use by those still fishing for scallop in the area (Mincher 2008).

As part of their efforts to sustain the scallop fishery, Challenger utilizes an extensive reseeding and enhancement program, which grows and replants spat to replenish portions of the fishery. Vulnerable areas are targeted for reseeding, and no spat are taken from portions of the fishery suffering a significant decline in numbers (Mincher 2008).

The fine-scale management that Challenger requires to sustain its fishery necessitates a great deal of scientific information. Challenger has responded to this need by taking responsibility for all research and monitoring duties for the fishery, in a partnership between themselves and contracted scientific advisors. Rather than relying on government efforts, Challenger decided that their funds could be better spent by contracting research activities through the private sector. As such, each year they enter into civil contracts with scientific consultants to perform stock and environmental assessments of the fishery. Challenger collects all required data itself, partly through use of their own private research vessel, and the passes the data along to the scientific parties, who analyze the information for review by MFish. In addition to this data, Challenger collects their own, more detailed fishery data in order to develop their AMP.

Funding for the enhancement, research and monitoring activities of the industry are provided through a commodity tax system put in place by the NZ government, as well as through fees to members. Under this system, a tax is charged to processors of the scallop, based on a percentage of the total landed value. This percentage is decided by Challenger based on their estimated budget needs for the year. This system does however require government sanction of a tax, which may not be plausible for fisheries in other parts of the world.

Performance

As one of the longest running case studies of cooperative fisheries management in New Zealand, researchers have been able to examine the specific economic benefits of the Challenger model. A study by Akroyd et al. (1999) found that the implicit discount rate of the Challenger fishery approximated that of the real interest rate. This was contrasted to a non-cooperatively managed scallop fishery in which the implicit discount rate was found to diverge widely from the actual discount rate (Arbuckle 2000). This trend can perhaps be attributed to the increased security that members of Challenger feel with regards to the ability of their long-term management actions to be reflected in the value of their quota shares. It should however be noted however that the accuracy of these interest rate calculations is not certain (Mincher 2008).

In addition to experiencing potential improvements of economic indicators, through their management actions Challenger has been able to significantly increase their average annual landings of scallop over the levels experienced under the open and limited access periods of the fisheries history (Mincher 2008). This has occurred despite the introduction of regional and temporal fishery closures and strictly defined catch limits.

As a final indicator of the positive impacts of the Challenger model on the economics of the southern scallop fishery, while studies have demonstrated that costs to the industry of management actions such as stock assessments, monitoring and enforcement and reseeding have remained relatively constant, the value and quality of the information and actions resulting from these expenditures have in many cases increased (Arbuckle 2007, Harte 2007, Leal 2008).

Challenger has seen mixed results with regards to the state of the southern scallop stock. Leading up to 2000, Arbuckle (2000) reported that stock levels and recruitment to the fishery increased following the implementation of Challenger's fishery management practices in 1996. However, scallop stocks experienced a sharp decline in 2002, and in many locations continued to be depressed despite Challenger closing depleted areas to commercial fishing (Mincher 2008). Recent fishery data suggests that parts of the fishery may be recovering somewhat, though too little data is available to establish a clear trend (Ministry of Fisheries 2009, Mincher 2008). In the face of lower catch levels and profits though, Challenger has maintained their commitment towards reseeding, sustainable harvest rates and halting fishing in threatened areas (Mincher 2008).

Discussion

In addition to allowing for economic rationalization and increased environmental stewardship, perhaps the most significant success of Challenger has been the relationships the company has developed with the stakeholders in the southern scallop fishery (Arbuckle 2000, Yandle 2007). Through the course of the cooperatives formation, Challenger has developed an extremely positive relationship with MFish, in which each entity utilizes their relative strengths the help in the management of the fishery (Yandle 2007). In addition, by involving all interested parties in the development of their management plans, Challenger has created a highly transparent process that is able to incorporate the concerns of widely disparate factions. As a result, Challenger has been able to reach agreements with other commercial and recreational fisheries that operate in the area of the southern scallop stock, which have served to reduce spatial conflict and improve protection of the local habitat (Leal 2008, Mincher 2008). While Challenger has exclusive access to the southern scallop fishery encased by the bays, other fisheries also operate in this area, targeting species such as oysters and a variety of finfish (Mincher 2009). Due to the NZ ITQ system, these fisheries were not engaged individually in a race for fish. However, without coordination the actions of these fisheries were adversely impacting the operations of others within the region, especially between the oyster and scallop industries. The oyster and the scallop fisheries operated in separate seasons; without communication, oyster fishermen would often dredge over areas reseeded or left dormant by the scallop fishermen in the pervious season, generally by accident (though sometimes on purpose, in the case of a few irate oyster fishermen) (Mincher 2009). Conversely, scallop enhancement projects were capable of damaging oyster yields, as newly seeded scallops can drive oysters down into the mud where they cannot survive.

In order to resolve this "straddling stocks" dilemma, Challenger helped the oyster quota owners to develop the Challenger Dredge Oyster Fishery Management Company (COMC), helping shift the fishermen form individual quota owners to a collective fishing organization similar to the already successful Challenger scallop model. Facilitating the organization of the oyster fishermen into a cooperative organization allowed for the scallop and oyster industries to coordinate their efforts so as not to negatively impact each other's fisheries. The two fisheries now conduct annual surveys develop yearly fishing rules together (Mincher 2009).

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Crabco

Crabco Ltd. (Crabco) is a corporation that fishes for deep-sea crabs in New Zealand, namely king crab, red crab and giant spider crab. Crabco was formed in response to the introduction of deep-sea crabs to the New Zealand Quota Management System (QMS) in 2006. As there was no deep-sea crab fishery of any significant scale prior to this date, Crabco was free to develop the model for their corporation without the complication of an established, open-access fishing infrastructure. They did so by asking the simple question "If we were the sole owners of this fishery, how would we manage it?" (Craig 2009). Through this line of reasoning Crabco was able to develop an operating structure that encompasses all aspects of the New Zealand deep-sea crab fishery, and in doing so utilize market forces to promote the sustainable management of their resource.

Industry Structure

Crabco operates through a corporate structure, in which shareholders act to maximize returns on their investment in the company. Under this system, rather then each crab quota owner undertaking research, harvesting, marketing and selling operations individually, they instead simply invest their Annual Catch Entitlement (ACE) in Crabco, which coordinates all of these efforts for them. Any quota owner of deep-sea crab in New Zealand is eligible to become a member of Crabco. In electing to join the company, each quota owner receives one share, regardless of the amount of quota held, in Crabco. Upon joining the company, they agree to invest their ACE with Crabco. Crabco then utilizes this ACE to harvest, process, market and sell crab, the profits from which are returned to the initial investors in proportion to the total amount of ACE they invested. Rather than taking on all these activities themselves though, Crabco contracts them out to whichever company they believe will do the best and most cost effective work. The operating structure of Crabco is well summarized in Fig.4 presented in Soboil & Craig (2008).

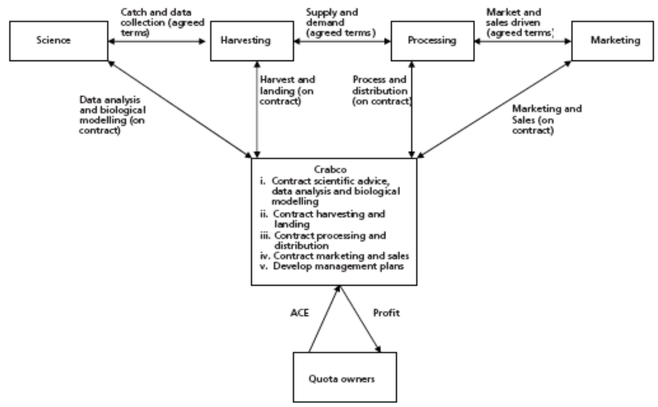

Fig.4 Operating Structure of Crabco (Soboil & Craig 2008)

Crabco has developed several management tools designed to ensure the success of this venture. At its inception, every initial member of Crabco agreed to a two-year program in which all profits gained through the sale of crab would be utilized reinvested in study and development of the fishery in order to better understand the crab stock (Soboil & Craig 2008). This could be seen as a mechanism both provide increased knowledge (and hence TACC), and to ensure that all stakeholders had capital invested in the long-term sustainability of the industry, discouraging free riders. Once a member of Crabco, each quota owner receives one share in the company regardless of the amount of quota owned. However, in following their corporate structure, voting rights within Crabco are assigned in proportion to the value of the ACE shareholders invested in the company in the previous year. In this way, the more you invest the fishery, the more control you gain in Crabco's operations. This voting control is especially important, as the amount of votes controlled dictates the number of people a quota holder is allowed to elect to the Crabco Board of Directors. Representation on the Board of Directors is very important to shareholders, as the Board decides on the annual distribution of Crabco's budget. In order to ensure the compliance of Crabco members and contractors with management decisions, Crabco enters into civil contracts with its members regarding the rules and responsibilities of members, with clearly defined penalties for non-compliance (Craig 2009).

Shares and quota are tied together under this model; while shares may be traded they cannot be transferred to a non-quota holder. This could serve to ensure that shareholders in the company are active and invested members of the industry. Should a member decide to sell their share in the company, current Crabco members must be given the option to buy said quota at the same price as would be fetched on the open market (Soboil & Craig 2008). In this way, those who have invested in the fishery have the option to increase their shares in the company before new members are able to.

Performance

The highly structured industry resulting from the "single owner" philosophy of Crabco has produced very positive results to date. Despite being completely voluntary, fully 100% of the deep-sea crab quota owners are fully invested shareholders in Crabco (Craig 2009). This is an extremely important result, as it effectively provides Crabco with exclusive access to the resource. The reasoning for this unanimous membership is clear to understand. To date Crabco has invested approximately 1 million NZ dollars in the setup of their fishery operations, including detailed mapping of the locations and estimated numbers of crab populations, and the development of a management plan designed to provide continual feedback on the state of the deep-sea crabs (Craig 2009). Without the presence of a cooperative organization, quota owners would have had to develop and finance their knowledge of the fishery independently, each paying large amounts of money for redundant data. Acting through Crabco, the quota owners were able to divide the costs of fishery setup between each other, reducing individual costs and improving the resulting management plan.

In addition to saving up-front costs, Crabco has had highly beneficial effects on the value of the fishery. In acting as a single-owner, Crabco has involved itself in every aspect of the crab fishing process. A vital component of this has been aggressive marketing practices. Upon the inception of the fishery, deep-sea crab from New Zealand was seen as an inferior product. In response, Crabco developed a marketing campaign branding their crab as a new and superior product, different than any other on the market. The result was a dramatic upswing in demand, which Crabco has utilized effectively by controlling the flow of crab to the market. In doing so, they have been able to command significant price premiums**,** gaining increased profits from their work without having to fish any more. As an incentive for their marketing contractors, Crabco has negotiated a percentage payment system in which more valuable the crab fishery becomes, the more the marketers receive.

Through its efforts, Crabco has also developed a management system designed to increase the TACC and hence the crab available for members to catch and sell. Their method for doing so is by increasing knowledge, and as a result moving the deep-sea crab industry from a data poor fishery with an appropriately cautious TACC to a data rich fishery with a TACC reflecting the robustness of the deep-sea crab populations.

Although the short-term sale of TACC provides a clear economic incentive, the real motivator of Crabco and its constituents is the value of their quota (Craig 2009). While the sale of crab provides immediate profit, the value of quota reflects the current profitability of the fishery and the long-term potential of the industry. As such, by developing a sustainable fishery, Crabco shareholders see the value of their permits increase. This has been demonstrated in that within 10 months of the inception of Crabco, an industry member sold a portion of their quota for a 75% increase in its original value (Soboil & Craig 2008).

The ability of Crabco shareholders to truly realize the economic benefits of a well-managed fishery has resulted in the industry taking several positive steps to protect the health of their crab populations. This is especially so given the relatively little amount that is known about deep-sea crab ecology. Given this paucity of knowledge, government regulators set a precautious TACC when the fishery was opened. In order for the TACC to reflect the true capacity of the fishery, the true capacity had to be determined. This provided Crabco with the incentive to undertake extensive scientific research as part of the development of their fishery. In doing so, they have gone above and beyond the level of scientific study required by government regulations, both improving knowledge of the management needs of the fishery and increasing the potential revenues for the cooperative.

This desire to study and sustainably harvest deep-sea crabs has led Crabco to also put in place innovative measures on the water. As part of their agreements, contracted harvesting boats have agreed to share catch and other collected data with scientists working with the fishery, providing a flow of data which may have been unavailable or at the very least underutilized without the cooperative Crabco model. The cooperative fishing practices of the corporation also serve to reduce fishing pressure on deep-sea crab ecosystems. Rather than each individual quota owner sending boats out into the water, Crabco concentrates and reduces fishing effort by contracting to the most efficient boats. As an added measure, Crabco members have agreed to utilize only crab pots in their industry, rather than bottom trawls or other means of fishing harmful to the benthic environment (Soboil & Craig 2008)

Discussion

Crabco represents the perhaps the far end of the cooperative spectrum in level of organization and managerial control. By taking an active role in all aspects of their fishery, from monitoring to sales, they have been able to effectively realize their mission of managing, as would a "single owner". This economic rationalization, and the added value it provides to the shareholder's quota, provides a strong incentive for sustainable management. It is important to note though the special circumstances that have facilitated Crabco's success. As no significant commercial fishery existed prior to its inception, Crabco was able to essentially write the rules of the game, without the challenges of an established fishing community to bring on board. In addition, as most fishing for deep-water crabs occurs at over 900 meters of depth, making it nearly impossible for small scale recreational or black-market take to occur (Soboil & Craig 2008). This serves to further cement Crabco's status as the sole "owner" of the crab fishery, but is not the type of setting in which most fisheries find themselves.

The Crabco model also may bring societal externalities into play. Shares in Crabco are held almost entirely by 4 major players; this combined with the cooperatives efforts to coordinate fishing, processing and marketing efforts may further serve to concentrate the benefits of the fishery, large as they may be, in an increasingly small number of hands. While it is far beyond the scope of this survey to wade into the issue of social equity in fisheries, it is an important matter to consider.

In considering Crabco's ability to serve as a model for the development of other fishing cooperatives, it should be considered that the comprehensive, corporate style fishery required extensive amounts of capital to put in place. Many smaller fishing operations may not have the financial ability to undertake extensive environmental monitoring and forgo initial profits for the long-term value of their permits. In addition, the powerful incentive provided to Crabco shareholders in the form of their quota permits may only be possible in other scenarios where there is a clearly designated and guaranteed right to a portion of a fishery, as exists within the New Zealand QMS. Given these concerns though, it is clear that Crabco has been able to gain significant benefits through taking control of their fishery in a cooperative manner. While their situation may be fairly unique, the model employed by this corporation could be a highly useful guide for the formation of other similar cooperatives.

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The South Pacific

Traditional Fisheries Management Systems of South East Asia, India, and Oceania

There are over 51 million fishers in the world and of these over 99 percent are found in small-scale operations (Berkes et al. 2001). Throughout the majority of fishing communities in South East Asia, India, and the small Pacific Islands of Oceania, fisheries, as well as other natural resources, are managed by systems of tenure and access rights that closely reflect the social organization of these communities (Ruddle 1988). In many cases, access to a specified area or territory is granted to a user group within the community, who then adopts organizational rules and regulations that are either upheld within the group, by a local authority, or, more recently, by State and Federal agents

(Ruddle 1998). A local authority may be a community leader, a religious leader, a member of the user group, or a specialist from a third party (Ruddle 1988). Although these arrangements are not always official and often times go unwritten (Kurien 2003), the fishing communities of this region of the world have been shown to work together to protect their resources from internal and external factors and promote the wellbeing of the group (Thomson & Berkes 2006). Despite changes in government organization, modern technology, immigration, and the influx of western fisheries management schemes, many of these communities continue to take a custodial attitude towards their resources and their methods are widely advocated throughout the scientific community (Ruddle 1988, Ruddle 1998). Evidence of the success of these systems is supported by the Pacific Island Region and Oceania, which has the highest concentration of still-functioning community-based fisheries regimes based on access and tenure (Johannes 2002). Given the long-lived resiliency of traditional fisheries management in South East Asia, India, and parts of Oceania, it is necessary to evaluate, in detail, how these cooperatives and associations function and which aspects of their management promote ecological and economical sustainability and in what cases do these organizations fail. The following paragraphs will provide an in-depth evaluation of two fisheries: the Kerala State, India, and a Sri Lankan estuary as well as a comparative summary of two cooperatives in the Philippines. Additional examples from this region will be used to further support these case studies.

The Cooperative Management of the Cochin Estuary in Kerala State, India

Ten percent of India's coastline resides along 600 km of Kerala State (Kurien & Paul 2000). The most productive waters in India are found here, as are the largest concentration of marine fishermen, numbering 170,000 in all (Kurien & Paul 2000). Although there are cooperative arrangements between the fishermen and the state government throughout this region, we will focus on one area within the Cochin Estuary known as the Cherai Poyil. This brackish water covers 210 hectors and is located within the Kerala State peninsula (Thomson 2006). The fisheries of Cherai Poyil have undergone many changes in government over the last 100 years. Their management system, known as kappu, originally regulated through community arrangements, was assigned to the government, only to be reallocated to the fishing communities in the end.

Prior to the 1950's, the fisheries department of the Travancore-Cochin State retained ownership of fishing rights (Thomson 2006). These rights were leased out to various parties until 1955 when the fishermen demanded the government to return to fishing rights to local fishermen organizations (Thomson 2006). The government seeded to their demands and rights were granted to three local societies that formed a joint management scheme between the local Panchayath (government body organized by the community elders (Kurien 2003)) and the community (Thomson 2006). Fishing cooperatives developed regulations to ensure sustainable use of the fishery resources, however, they did not have the resources to manage it themselves and therefore had to return primary ownership to the local government, Panchayath (Thomson 2006). In this case, the Panchayath leased fishing rights primarily to two Sanghams (fishery cooperatives); the Kerala Swatantra Malysa Thozhilali Federation (Kerala Independent Fisherworkers Federation) and Akhila Kerala Swatantra Malysa Thozhilali (Kurien 1991). The lease rates were dependent on the type of gear used and therefore, the type of fish caught and subsequent revenues earned (Thomson 2006). The individual leases are non-transferable and a percentage of the profits are returned to fishermen welfare fund through a simple profit share system (Thomson 2006). Under the current management system the fisheries receive financial support from the government as well as regulatory control through the Panchayath (Thomson 2006). The Panchayath also serves to intervene in the case of user group conflict and issues of compliance by employing 12 full time workers who act as enforcement staff (Thomson 2006). The cooperatives also work to protect their resources by reporting illegal entry and non-compliance (Thomson 2006). Subsequently fish catch has increased since 1970 as have a multitude of social and economical benefits (Kurien & Paul 2000).

Benefits are granted to those individuals who participate in the fishery cooperatives. These include a secure livelihood, a higher than average per capita income, a healthy resource, and the funds to promote future conservation, as was the case in the implementation of an artificial reef system (Kurien 1991; Thomson 2006). It is evident that the partnership that exists between the Panchayath and the fishery cooperatives is mutually beneficial in yielding income for both parties as well as a sense of ownership and tenure for the communities (Thomson 2006). Regardless of these benefits there are still ills that jeopardize this advantageous arrangement. Kerala State is under pressure to "open up the commons" and increase entry into their fisheries (Thomson 2006). Furthermore, externalities such as pollution and the development of private property are increasing coastally. This emphasizes the point that, although a traditional cooperative arrangement may be most appropriate for managing these fisheries, it is not immune to damaging effects.

Management of the Negombo Estuary of Sri Lanka

The stake-seine fishery of the Negombo Estuary in Sri Lanka has been operational for hundreds of years (Amarasinghe et al. 1997). The estuary consists of several islands close to the sea mouth with the northern part segmented into a number of channels (Amarasinghe et al. 1997). Gillnets are placed across the channels in order to catch shell and finfish species as they move in and out of the estuary (Amarasinghe et al. 1997). Although this fishery has always been managed through a sharing arrangement based on territorial user rights, various government incentives have solidified this system (Atapattu 1987).

Four rural fisheries societies (RFS) make up the Negombo Estuary stake-seine fishery. Within the RFS all fishermen are Roman Catholic, and being such, organization and operation is well established through the church (Amarasinghe et al. 1997). In 1958 these societies were granted exclusive fishing rights by the Negombo Fishing Regulation (Amarasinghe et al. 1997). In 1979 the government introduced a 90% subsidy scheme that would provide fiberglass out rigger canoes and new gillnets to local fishermen (Amarasinghe & De Silva 1999). However, this subsidy was granted only to those individuals who belonged to a cooperative within the RFS, therefore encouraging increased membership within the fishery organizations in return for new gear (Amarasinghe & De Silva 1999). With an increase in membership fisheries officials were able to implement fishery regulations applying to the cooperatives that ultimately lead to an increase in fish production within the estuary (Amarasinghe & De Silva 1999).

Currently there are approximately 100 members in each RFS who function under a very unique and complicated operating mechanism.

A general meeting takes place on three consecutive days in March (Amarasinghe et al. 1997). At this meeting each RFS appoints an auctioneer who is in charge of assigning fishing sites. Within 22 sites any where between 65-68 stake-seine nets can be fixed (Amarasinghe et al. 1997). Using a lottery system the auctioneers assign numbers from 1-n (n being the number of members) to each RFS member (Amarasinghe et al. 1997). Those members who draw the lowest numbers are able to bid for the most productive sites. Competition is benign, therefore fishermen are able to make well informed decisions about their bids because members openly share information regarding what sites are performing better than others (Amarasinghe et al. 1997, Kurien 2003). Those members with the lowest lottery numbers often choose to opt out of the bidding because they will not likely secure a productive site. Fortunately the sites are shared and rotated between members and the lottery draw is repeated throughout the year to guarantee a fair distribution of the resource (Amarasinghe et al. 1997). The profits from the resources for each member of the four RFS are distributed: 90% to the fisher, 3% to the auctioneer, 3% to the welfare fund at the RFS, and 4% to a welfare fund at the church (Amarasinghe et al. 1997). Although the cooperatives establish their own rules and regulations (such as a fine of Rs. 100 for every 0.5 m of net beyond the allowed width) the MoFARD employs additional field staff to monitor the fisheries, resolve conflicts, and provide subsidies (Amarasinghe & De Silva 1999). The effectiveness of this arrangement was tested in 1990 when the government terminated state patronage and the subsidy scheme, which immediately lead to a weaker monitoring system and ultimately a drop in fish yields. The policy was therefore reinstated in 1994 after strong protest from the fishermen (Amarasinghe & De Silva 1999). Overall this system has shown to be both economically and socially beneficial to the fishermen of the Negombo Estuary.

When the average income of cooperative members is compared to that from other industries it is found that cooperative members make more than the average citizen whether or not they receive supplemental income from other work (Amarasinghe et al. 1997). What is even more interesting is that the average yearly income of cooperative members, when compared to unorganized fishermen, is approximately Rs. 11,287 compared to Rs. 4,435 (1 E – 113 Rs) (Amarasinghe & De Silva 1999). Although one would expect such an economic difference to encourage excessive membership, many community members still choose to not join. Because those reservoirs managed by the cooperatives are not overwhelmed by high entry they have been able to maintain higher CPUE values than those in other reservoirs (Amarasinghe & De Silva 1999). To further promote conservation of the resource the cooperatives have chosen to increase gill net sizes to avoid catching juvenile shrimp, and for their efforts have been granted fishing rights in those reservoirs banned to non-organized fishermen (Amarasinghe & De Silva 1999). It is believed that a combination of a high average income, a long time horizon, the collective action of the members, and the rational utilization of the resource has cemented a high willingness of heads of households to actively participate to promote the wellbeing of the group (Amarasinghe & De Silva 1999, Kurien 2003). A similar result has been found in the case of the brush park fishery of the Negombo Estuary which is also organized into cooperatives, assigned with the objective to dissuade newcomers and develop strict mangrove conservation plans (Amarasinghe et al. 2002).

Although these fisheries are still under threat by outside forces, it is believed that the resilience of the cooperatives and their advisory arrangement with government officials are capable of maintaining a sustainable livelihood in Sri Lanka.

A Comparative Study of Two Fishing Cooperatives in Batangas Providence, Philippines (Lejano & Ocampo-Salvador 2006)

As the Philippine government decentralized their control over the country's natural resources, international aid agencies stepped in to provide support and encourage the establishment of community-based resource management (CBRM) systems (Lejano & Ocampo-Salvador 2006). Although many of these communities were already managing their resources through traditional forms of regulation, they remained susceptible to resource depletion through modern commercial fishing operations, pollution, and immigration. Subsequently two communities, Calatagan and Mabini-Tingloy, established CBRM. These two communities are close in proximity but do have some important differences. Calatagan is situated besides the open ocean and is therefore a fish-centered community with additional income supplemented by the sugar cane industry. Unlike other communities throughout the Philippines, Calatagan has relatively low tourism (Lejano & Oceampo-Salvador 2006). On the other hand, Mabini and Tingloy, two adjacent towns in the interior of Balayan Bay, have a mix of industries to support community members as well as a high level of tourism that further supports the local economy. However, because both of these communities are relatively dependent on the health of their marine resources they organized cooperatives to combat the declining fish catch. While both cooperatives arose out of similar conditions and incentives, the slight differences in their organizational structure have had very different results.

The cooperative established in Calatagan is known as SAMMACA and that in Mabini-Tingloy, MATINGCADC (Lejano & Ocampo-Salvador 2006). They both received assistance from NGOs, SAMMACA from a Manila based group CERD, and MATINGCADC from the WWF. SAMMACA and MATINGCADC have similar management strategies that include enforcing bans on illegal fishing, establishing marine reserves, rehabilitating the marine environment, educating members about sustainable fishing, and limiting entry to outsiders without officially allocating fishing rights to members of the cooperatives (Lejano & Ocampo-Salvador 2006). On their face the two cooperatives appear relatively similar, but a closer look reveals a far more complex and bureaucratic program in Calatagan (Lejano & Ocampo-Salvador 2006).

SAMMACA membership is primarily limited exclusively to fishermen whereas MATINGCADC is made up of a wide societal mix, including women. Furthermore, while SAMMACA's structure is more complex, it is also more informal in its arrangements, which are based on societal ties. MATINGCADC takes a more rational approach in which organization, monitoring, and enforcement are handled similar to western fisheries (Lejano & Ocampo-Salvador 2006). This has lead to differing priorities within each cooperative. MATINGCADC places its focus on monitoring and rule enforcement, but SAMMACA prioritizes internal and external relationships of the organization. A final, noteworthy difference is in the way in which the two cooperatives profit share. MATINGCADC uses a typical fee system to support the organization where as SAMMACA simply uses fishing site exchange to guarantee equality amongst its members.

Both cooperatives have succeeded in renewing the health of their marine ecosystems. In the case of MATINGCADC there has been a more immediate increase in catch, which is not as obvious for SAMMACA. Lejano & Ocampo-Salvador (2006) offer insight into this result stating that SAMMACA's seemingly obsession with relationships and informal arrangements promotes long-term sustainability whereas the straightforward organization of MATINGCADC leads to short term success. This statement is supported by the evidence that SAMMACA is growing in membership and MATINGCADC is merely maintaining. This example provides substantiation of the importance of the details within a cooperative operating plan.

Additional Examples Supporting Community-Based Resource Management

As previously stated, community-based cooperative arrangements common throughout the majority of fisheries within this region. Cooperative participation is also found in Capiz, central Philippines, where there are 10 fishing cooperatives, joined by common socioeconomic and demographic characteristics, that are granted exclusive fishing rights by the government (Baticados 2004). The members have agreed to have closed seasons, place a ban on dynamite and cyanide fishing, and regulate the harvest of fragile species (Baticados 2004). They have even used the public radio to publicize their advocacy against harmful and illegal fishing methods (Baticados 2004). The government is also actively involved in the conservation of the resources and has assigned coast guards to threatened areas and provided financial aid as well as training and seminars (Baticados 2004). However, despite their efforts their catch has decline from 11,350 t in 1990 to 8,188 t in 1998, due to pond effluents and industrial waste and encroachment by other commercial fishing activities (Baticados 2004). Despite this cooperative member's average monthly gross of P 5,317 (US 1 – P 50) is still well above the poverty threshold (Baticados 2004). In many cases management regimes similar to this have been in place historically, but there is also evidence that they are used to overturn systems that have failed.

In San Salvador Island, Philippines, the average CPUE for finfish species shrunk from 20 kg in the 1960s to 1-3 kg in 1988 (Katon et al. 1999) and in the Bohol Province the fishery became overfished within the last twenty years (Martin-Smith et al. 2004). These results were due to an influx of migrants using destructive fishing gears and the international market for aquarium fish (Katon et al. 1999). In both cases, the government and NGOs have taken steps to reverse the damage. Residents of San Salvador Island were encouraged, through the use of education campaigns, to take collective action to establish a marine sanctuary that was backed by the municipal government (Katon et al. 1999). The result was a dramatic increase in coral health and species richness (Katon et al. 1999). In the case of the Bohol Province, MPAs, tenure systems, and minimum size limits were implemented and enforced by the fishermen to promote long-term success (Martin-Smith et al. 2004). They also collaborated with NGOs to control the Chinese medicine market and the aquarium trade, thereby further reducing negative externalities (Martin-Smith 2004).

This region of the world is also rich in examples of community based fisheries creating "private MPAs" (PMPAs) in order to protect the state of their resource and potentially enhance their fisheries. In Samoa, the passage of a bill that restored some traditional marine tenure rights back to local communities resulted in the development of numerous voluntary marine protected areas run by the fishing groups. By 2002, of the 64 fishing villages that had developed their own marine resource management plans, 52 contained community-operated marine protected areas (Johannes 2002). While little empirical data exists on the impacts of these closures, high levels of community support and involvement suggest that local fishermen must feel positively about the effects of these PMPAs on their livelihoods (Johannes 2002). A study by Aswani and Hamilton (2007) illustrates an example of voluntary fishery closures in the Solomon Islands. Populations of bumphead parrotfish had declined dramatically in this region, as the fish is a local delicacy. Consultation with local fishermen found that juvenile bumpheads lived exclusively within the inner lagoon, while adults favor the outer reef and were most susceptible to fishing at night. Through this knowledge, two private MPAs were created, both designated as no-take areas and geared specifically towards the preservation of these parrotfish. Their location was chosen to protect juveniles and breeding females of the species, along with providing nocturnal protection. These efforts stand to have a significant positive impact on the overall health of the local coral reefs. Bumphead parrotfish are keystone species, which provide vital reef habitats to other species through bioerosion of corals.

Discussions with experts in traditional forms of management in the Philippines also reported the existence of private MPAs, as well as profit (or some form of benefit) pooling among competing user groups. In Bolinao (Philippines), tensions arose as different factions of the local fishing community sought to utilize the reef for a variety of purposes (Talaue-McManus 2009). Poor management and overcapitalization led to the serial depletion of the resource (McManus et al. 1992). In particular, conflict arose between groups vying to use the reef as space for fish corrals and others seeking to actively fish. In an effort to preserve the local coastal community, researchers and community leaders began efforts to bring local stakeholders to develop a coastal development planning (CDP) board, intended to coordinate the management of reef and coastal resource in Bolinao (Talaue-McManus 2009). While no formal cooperative fishing structure was developed through this process, the CDP allowed for numerous community groups to come together to share information and find solutions to common problems facing Bolinao. A preliminary result of this process, which occurred around the year 2000, was the development of a zoning system for the reef and the establishment of several PMPAs in some of the most productive fishing grounds on the reef (Talaue-McManus 2009). Marine reserves have also been used to protect community-managed resources on Santiago Island, where again some of the formerly most profitable fishing grounds were closed to preserve the reef ecosystem (McManus 2009). In another example of marine tenure, many resorts and dive operations in the Philippines have created MPAs in order to preserve adjacent reefs and hence their income (Tupper 2009)

Conclusions

The Indo-Pacific remains unique in both the rich history of spatial fisheries management, as well as the large numbers of community-managed fisheries now in existence. Despite the high presence of cooperative style management of marine resources in Oceana, little attention has been paid to this region in the fisheries economics literature. This may be due to the large geographic span of the region and the difficulty in obtaining concrete data on the region, especially as compared to the well-studied cooperative fisheries of North America or New Zealand for example. While there is a large and growing body of work on customary marine tenure (CMT), much of it consists of descriptive accounts of specific TURFs, with little analysis of their functionality or effects. Few studies at all have attempted to look at broader patterns with the region (see Cinner 2005 for an example). For these reasons, cooperative management in the Indo–Pacific could prove an interesting source of anecdotal evidence or empirical data for fisheries economics studies; few other works have looked at the region in this light, and the large body of descriptive work could be a useful starting-point for research. In addition, as in the case of Chile, the large numbers of community-developed organizations could allow for comparative studies examining how different communities have responded to similar challenges, and to what effect.

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Africa

Fisheries Management Structure Under Leadership Uncertainty

Unlike many small-scale fisheries that have historically used community-based management efforts to preserve their stock, African fisheries have typically been based on common property and open access. Unsurprisingly this system has lead to ever increasing fishing effort and a subsequent decline in catch and profits (Bulayi 2001). This failure has lead to the promotion and implementation of community-based cooperative fisheries management, the allocation of individual quotas (IQs), and in some cases the explicit delineation of exploitation rights. Similar to many of the coastal fisheries in Asia, distributing individual rights to fishers is not feasible in all cases due to the large number of fishers working out of an array of landing points and often without the conditional support of the government (Viswanathan 1999). Although the majority of the case studies discussed throughout this article are based on marine fisheries this description of African fisheries will include examples from Lake Victoria, due to its economic and ecological significance to multiple countries. Unfortunately there are very few studies of cooperative fishing schemes in Africa; primarily due to the fact there this is only a recent movement throughout its coastal countries. Despite the lack of overwhelming evidence of its success, the few cases in which community-based cooperative membership (also known as joint management, collaborative membership, and community-based membership (Brown 1998)), and other innovative approaches have lead to economic and ecological health, have lead to the general conclusion that these management methods have a promising future.

Using Cooperatives to Manage Inshore Fisheries

In 2001 Bulayi reviewed the fisheries regime in Lake Victoria, Tanzania in order to evaluate elements of its management plan to determine if and how the use of cooperatives could better manage the resource. Tanzania is a coastal state with a population of 32 million people. Lake Victoria is the second largest freshwater lake in the world and provides an important commercial shrimp fishery and is home to over 250 fish species. Its importance to Tanzania is made evident by the 200,000 metric tons of fish harvested annually, with 90% of the harvest made by artisanal fishermen.

Historically fisheries management in Tanzania was an integral part of the culture and traditions of the local communities. This system was replaced in 1888-1960 by a centralized management system that is controlled through a licensing system. This lead to increased effort, decreased catch, and a lack of cooperation between the fishermen and government agents. Although the Fisheries Division was in charge of monitoring and controlling the stock, their limited resources lead to a lack of research, surveillance, and data analysis. In response, 120 ethnic groups came together in a campaign to curb illegal fishing. They organized themselves into beach fishery management units (BFMUs) responsible for the management of their resources similar to how TURFs are used to define property rights. Bulayi (2001) argues that, given the stakeholder interest, cooperative management could be used to improve upon the areas of fisheries management in which the government failed.

Although Tanzanian fishermen have already organized themselves into BFMUs (similar to a cooperative), they could reorganize these groups according to the activities they perform as to increase group homogeneity. In tern, the government should hand over the responsibility of managing the resource to the BFMUs (Bulayi 2001). This would require a formal MoA to provide legal backing. Bulayi (2001) also recommends that they elect a chairperson to act as their formal leader, pay membership dues and form a local constitution. He also recommends that they seek the advice of external members to play an advisory role. The general management plan for each BFMU should address by-laws, data collection, law enforcement, and monitoring. Bulayi (2001) also gives credence to the importance of homogeneity within the groups to promote smooth operation; a characteristic that is encouraged and initiated in many cooperatives as discussed in this study. Despite the fact that this description of a Lake Victoria cooperative operating plan is fictional, this does not negate the points made in regard to its setup and operation.

Co-management in South Africa

During the Apartheid era in South Africa, traditional fishing practices and rights were banned and eliminated (Hauck & Sowman 2001). This lead to the majority of the TAC distributed to white boats with only a minority left for a large number of small-scale black fishermen. Through the Sea Fishery Act 12 of 1988 and the change in government policy in 1994, fisheries management was rethought, taking into account the black fishermen (Hauck & Sowman 2001). In the case of the Hake trawl fishery only minor changes occurred. By 1996 the fishery was dominated by two large companies (Mayekiso et al. 1999). The government supported this arrangement, as it provided for a small number of players, consisting of relatively homogenous opinions. These two characteristics had lead to the promotion for a sustainable stock given the high degree of commitment made by the two companies and their collaboration with government officials (Mayekiso et al. 1999). However, it was agreed upon that the commitment could be assured by awarding licenses and quota allotments for 10 years as opposed to the current system that only allows for one-year agreements. More dramatic changes occurred in the case of the South African small-scale fisheries.

Most co-management cooperatives in South Africa have been implemented in the last ten years. The degree of government cooperation, as well as the type of fishery, vary across the board for different associations. While some cooperatives have been fairly successful others have failed within a couple years of their implementation. For example, the Kleinmond Inshore Fishery and the St. Lucia Gillnetting associations were terminated early on. Both associations dealt with subsistence fisheries and they both had a consultative relationship with the government (Hauck & Sowman 2001). On the other hand, the Kosi Bay Gillnetting, Olifants River Gillnetting and Sokkulu Mussel cooperatives were considered artisanal or artisanal/subsistence fisheries and shared a cooperative working arrangement with the South African government (Hauck & Sowman 2001). Furthermore, Kosi and Sokkulu were organized through the nature conservancy agency that helped to provide capacity building and external funding. Hauck & Sowman (2001) suggest that the termination of the other two cooperatives was likely due to a lack of commitment and support (including financial) from the government. They also suggest that the success of the other cooperatives stems from ten requirements: a secure access right over the resource (can be priority access); government support (but moving away from command and control); capacity building through external agents (NGOs) and the government (sustainable resource use); a fair representation of local individuals in order to provide trust and accountability; clear-agreed upon objectives; availability of alternative employment (in Lake Victoria groups switch between fishing and farming and are not entirely dependent on fish stocks (Geheb & Binns 1997; Sarch & Allison 2000); adequate enforcement and compliance that dissuades from illegal activity; adequate resources and patient/realistic time-frames; "long-term champion" (1-2 individuals who stay with the cooperative through all stages); and frequent monitoring and analysis of data to ensure sustainability. Meeting these requirements does not necessarily ensure the success of the cooperative but in the case of the associations in South Africa they have helped to prevent termination.

Comparisons in Cooperative Success

Namibia gained independence from South African in 1990 (Arnason 2002). Due to the pressure from foreign fishing fleets, Namibia's fisheries are managed through TACs and IQs granted through a licensing system. Their Sea Fisheries Bill states: "No person shall in Namibia or in Namibian waters harvest marine biological resources for commercial purposes except in term of a right" (Iyambo 2000). Originally the licenses were granted to cooperatives or sometimes individuals, but they did not ensure rights to annual quotas and were therefore not very efficient. The Fisheries Act of 1992 extended these rights for 4-10 years and also allowed for limited transferability (Arnason 2002). What is unique about this arrangement is that the longevity of the right is 4,7, or 10 years is based on the opinion of the community involved and dependent on the amount of investment they are willing to make to the fishery (Iyambo 2000). Managers were also faced with the issue of how to address transferability. As stated by Iyambo (2000), "to be comfortable with the outcome of full transferability of rights, a community or a government has to be broadly indifferent to who holds the rights." Because Namibia was concerned with how this might affect the future of their country's progress the rights are not officially transferable, although they are sometimes traded within equity companies (cooperatives). The fishery is co-managed with the government and individuals pay a significant amount of fees (quota, bycatch, research, license, observers) and in, return enforcement, monitoring, control, and surveillance are maintained by the cooperatives themselves, third-parties, and government agents. Despite the evidence that Namibia fisheries are not managed in the most efficient matter, the steps they have taken within their own comfort level has made the fishery profitable and lead to a sustainable stock.

Madagascar is a large island that required a great deal of work to manage its 5000 km of coastline properly. The fishery resource is very important to the economic wellbeing of the country, and being such has faced significant pressure (Couteaux 2000). Furthermore, the fishery consists of three sub-sectors: industrial, artisanal, and traditional. Based on historical precedence the prawn fishery was divided into 14 fishing zones in which licenses are granted to each boat (Couteaux 2000). Madagascar also displays cooperative management by which five exclusive zones are distributed to two companies. However, this arrangement was not a safeguard to the ever-changing government and therefore the various fishing companies banded together in an association to protect their future. The association received help through start-up subsidies from French bilateral co-operation but is now entirely self-funded (Couteaux 2000). The association began to address management perspectives of the prawn fishery including enforcement, research, and restrictions, but were unorganized and therefore struggled to accomplish their goals. Finally they organized into a committee of "wise men" who suggested to freeze the number of licenses, increase license fees, receive funding from the government, set up an official system of surveillance and enforcement, as well as other aspects of the management system (Couteaux 2000). These measures and their cooperative arrangement have moved the prawn fishery in the direction towards sustainability. The case studies discussed have demonstrated the varied results of cooperative management throughout Africa. This comparison can be more closely understood by the work done by Viswanathan in 1999.

Eight cooperatives in Africa were compared in terms of transparency, conflict resolution, compliance, decision-making, sustainability, and the overall attitude of the members. Four out of the eight cooperatives found improvements in conflict resolution, compliance and sustainability (Viswanathan 1999). The study also determined the decision making process was simplified and made more efficient in the case of the three cooperatives consisting of members from all stake holders compared to the other five only consisting of chiefs, gear owners, and males. Finally, only in two out of the eight cooperatives, were the members satisfied with the co-management structure. This study suggests that cooperative success should be evaluated case by case in order to determine those elements leading to profitability and sustainability and those leading to collapse.

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Europe

Fishing Cooperatives Gaining Momentum in Europe

Fisheries management in Europe is controlled through many international joint agreements, country legislations, and local management rules. Only in the case of the former Soviet Union was cooperative management used traditionally (Knudsen & Toje 2008). In some cases this broad management scheme has acted as a barrier to new innovative management approaches in the community. It is therefore not surprising that there are relatively few cooperative or rights based systems at work in Europe, the exception being Iceland. Those cooperatives that are formed are typically producer organizations with the purpose of forming a joint venture to help market and distribute their products, not necessarily with the ecology of the species in mind. The following paragraphs will discuss, in detail those producer organizations in Europe that have contributed to the economic and ecological success of the fishery. Finally, we will also examine the extensive formation and use of cooperatives in Turkey.

The Use of Producer Organizations

The Danish Pelagic Producers Organization (DPPO) was formed in 1984 to include purse-seiners and expanded in 2001 to trawlers to meet MSC standards and qualify as sustainable seafood. The fishery works in the North Sea and targets North Sea Herring, Skagarrak/Kattegat Herring, Norwegian Spring Spawn Herring, and Atlanto-Scandian Herring (Det Norske Vertitas 2009). As is the case in most European Union fisheries the quota is allocated to the country and then allocated to the individual fisheries. In this case, 70% of the Danish quota is allocated to the DPPO in the form of ITQs (Det Norske Veritas 2009).

The DPPO consists of 8 members, three of whom are trawlers and five combined (Det Norske Veritas 2009). The general assembly is lead by seven board members who are democratically elected. They have one primary administrator, Christian Olesen who is also elected. The formal role of the DPPO is to represent its members in matters relating to stakeholders. In return, the members agree and abide to a Code of Conduct. The rules include: avoiding unwanted catches and unnecessary fuel consumption, not discarding waste oil or biowaste, avoidance of bycatch, open collaboration, and catering to a safe working environment (Det Norske Veritas 2009). These rules are enforced by the members, who have the formal right to take action against cases of non-compliance. Their enforcement efforts are simplified through the use of VMS (vessel monitoring systems) that are required for each member and capable of tracking their harvest. In addition, their landings are weighed at the port by an independent party (Det Norske Veritas 2009). Management by the DPPO has resulted in MSC certification, proving that the stock is sustainably harvested by the organization. A similar system was installed by the Scottish Pelagic Sustainability Group Ltd (SPSG) for the harvest of Western Mackerel (Carleton et al. 2008) and North Sea Herring (Carleton et al. 2008).

The SPSG consists of a group of Scottish pelagic fishermen, processors, and traders. This includes 23 pelagic vessels, 2 producer organizations, and all the main processors and traders (Carleton et al. 2008). As in the case of the DPPO, the SPSG has also formed rules that are binding on its members. The rules are as follows: to ensure the fisheries are fished and managed responsibly, cooperate with all other stakeholders and regulatory authorities, make an effort to minimize bycatch and discards, use scientific advise given by ICES, maximize the quality of the product, and abide by the precautionary approach (Carleton et al. 2008). In this case the members are held to these rules with the threat that non-compliance results in the fishermen paying back the quota to the organization. These two organizations are similar in many ways, particularly regarding their membership rules. Furthermore there are additional organizations and associations that have been formed elsewhere under similar structural arrangements. Examples include the Pelagic Freezer-Trawler association consisting of 10 vessels spanning across Europe (Andrews et al. 2009), the Spanish POs of the celtic sea (Garza-Gil & Varela-Lafuente 2008), the Danish matjes herring fishery (Nielsen & Olesen 2008), and the Stornoway Nephrons Trawl Fishery (Young's Bluecrest Ltd) who has ten vessels operating under a catch traceability system (Andrews et al. 2009). Although producer organizations and associations appear to be the primary form of cooperative management throughout the EU there are a few examples of traditional cooperative structure.

Cooperatives in the EU

The cutter fishery is a small but very prosperous sector in the Netherlands. In 1985 the government issued a licensing system as well as a voluntary decommissioning scheme to reduce the fleet size (OECD 1997). Additional management measures were imposed including limiting days at sea and access. Specifically, in 1993 the Dutch government delegated the national quota for the cutter sector to the fishery in the form of individual quotas that are primarily granted to groups or producer organizations through the use of positive incentives (such as extra days at sea) (OECD 1997). Within the organizations the fishermen form their own rules and regulations and pool their individual quotas and sea days. By pooling their quotas and sea days they are able to increase their efficiency by allowing for more flexibility. However, because this sector interacts with many other sectors both economically and geographically it is difficult to determine whether or not the use of fishery organizations will necessarily ensure a sustainable stock. In the case of the Swedish shrimp fishery of the Gullmar Fjord enforcement measures are more easily managed.

The Gullmar Fjord is a marine reserve on the west coast of Sweden (Eggert & Ulmestrand 2008). The fishery is primarily managed by the use of fishing licenses that run SEK$500 initially with a renewal every fifth year for SEK$300. In 1999 additional legislation was introduced limiting vessel days to 100 distributed over the year from Monday to Thursday of each week (Eggert & Ulmestrand 2008). This system allows for flexibility by the fishermen while still providing a limit making the fishery more enforceable by the coast guard. Each vessel is required to receive permission from the coast guard before they enter the Fjord, allowing the coast guard to monitor all fishermen activities. Together these specifications have maintained stable catch while still encouraging a decrease in effort (Eggert & Ulmestrand 2008). Effort is now significantly reduced due to passage of an amendment to the Act of Fisheries that granted sovereign access rights to a limited number of shrimp fishermen within the Fjord. From 2004 to 2006 only six vessels (chosen based on historical catch) were granted permits to fish the Fjord (Eggert & Ulmestrand 2008). As is often the case after rights are allocated to the industry, the six vessels agreed to joint management rules. Although the mandated mesh size was 35 mm the vessels agreed to increase to 38 mm and test 45 mm mesh over four days in the season (Eggert & Ulmestrand 2008). Furthermore, even though trading is not officially allowed, the vessels have used informal trading measures for US$150/day to increase the fleet's efficiency. In order to determine the success of this operating scheme additional data is required, but thus far random inspections and underwater robotic cameras have not found any violations in compliance (Eggert & Ulmestrand 2008).

The Shetland Community Quota Scheme

The Shetland Isles consist of a group of islands 150 miles north of Scotland (Anderson 2008). The communities within the Isles are very dependent on the fishery with 2,000/22,500 employed by fishery operations (Anderson 2008). The whitefish fishery is predominant with an estimated worth of E$243 million (Anderson 2008). The Shetland Fishery Producer Organization was created in the 1980's to allocate the UK quota. This was done is response to legislation granting direct management to the industry of the whitefish sector. The SFPO is made up of 34 member vessels who bring in $E34 million annually (Anderson 2008). In addition to the SFPO the Scottish Fishermen's Organization (SFO) was formed with 200 vessels with an annual net of $E115 million (Anderson 2008). Both organizations have developed their own operating rules which are quire complex.

The SFPO is managed through a pooled quota plus IQ system (Anderson 2008). The majority of the quota is pooled and then distributed to the individual vessels similar to a catch share, however members can chose to operate independently of the group through an IQ. In the case of the SFO members can only receive benefits through the pooled quota and do not have the option of an IQ. This system of rights based management lead to concern by some communities who feared the quotas would become concentrated in a few hands and those truly dependent would be negatively affected. Therefore in some cases CQ (community quota) schemes have been implemented to combat these free-market characteristics.

In 1993 the community of Shetland owed loan repayments on two boats. The vessel members financed the loan repayments after which the vessels were sold out of the Shetlands taking with them the fishing license but not the FQA (fishing quota). Therefore the member vessels were left with additional quota that could be distributed throughout the fleet. Distribution of the quota was allocated to SFPO members through a ring-fenced pool system in order to guarantee equal benefits. SFPO founded this quota to encourage vessels and profits to remain in the community. Then in 1998 the Shetlands Islands Council invested two million Euros into the purchase of additional whitefish FQA (Anderson 2008). Together the ring-fenced pool and the additional FQA (referred to as the SLAP/SDT) resulted in 35% held community ownership worth approximately $16.9 million Euros (Anderson 2008). It was therefore necessary to determine how to fairly distribute the ring-fenced and SLAP/SDT quota pools.

The SFPO used a scatter plot to visually assess the relationship between each member's FQA and its catching capacity, VCU (Anderson 2008). They were able to fit a trend-line to the data and allocate the pools accordingly. Those vessels above or around the trend-line were granted equal allotments of the pool outright given the assumption they would contribute equally to the group (Anderson 2008). On the other-hand, those vessels below the trend-line were required to purchase additional quota from others or lease additional quota from the ring-fenced pool in order to access both pools and their benefits (Anderson 2008). Those vessels without a historical track record were charged 5% to lease in addition to a 1% administrative charge (Anderson 2008). Over the next two years members of the SFPO enjoyed higher profits and benefits than those members of other POs. In 1999 other industry members accused the SFPO of "distorted competition". The EU concluded this was the case and that SFPO's purchase of quota provided an economic disadvantage over non-members (Cabinet Office 2004). Since then the SFPO has adjusted its management by letting go of its ring-fenced pool while retaining the other. Similar attempts were taken in Orkney and Cornwall, as well as in the case of the Connemara Shellfish Farming Cooperative, however unfavorable rulings by the EU and free-riding have lead to their failures (Anderson 2008; Steins & Edwards 1999). Currently a Cornwall non-profit, the Duchy Quota Company, is attempting to purchase quota and lease these to existing fishermen and groups (Cabinet Office 2004). These cases demonstrate the necessity of government involvement and support or the use of private funds in the development of fishing cooperatives and the allocation of fishing rights.

Turkey

One of the foremost experts on Turkish fishery cooperatives, Dr. Vahdet Unal states, "fishery cooperatives in Turkey have great potential to play an important role to help insure environmental and economic success in fisheries management." However, at this time the cooperatives do not play an important role in fisheries management because there is not system in place to allow for local level management. Furthermore, according to Unal (2009), those cooperatives currently in place are faced with a lack of enforcement and are not granted true property rights and can therefore not properly manage their resource. The following analysis is based on research conducted from 2006-2009 by Unal and others.

In order to understand fisheries management in Turkey it is necessary to understand the legislation governing it. The Ministry of Agriculture and Rural Affairs (MARA) is the primary body responsible for fisheries management (refer to Figure 1). Through Law No. 1380 the primary responsibility of enforcement was granted to MARA personnel. As previously stated there are no legal previsions that grant fisheries management to the local level, making it difficult for cooperatives to self-manage (Unal 2009). Therefore the fisheries are managed through fishing circulars/rules. The majority of these regulations are based on technical measures, similar to those found throughout Europe. However, species based fisheries management does not exist (Unal 2009) and quotas are not in place for the majority of the species. This, along with a lack of licensing and encroachment from outside vessels, has threatened the Turkish stocks.

Turkey has 517 fishery cooperatives, 13 fishery cooperatives associations and 1 central association of fishery cooperatives (Unal 2009). Although high in number the majority of these cooperatives have been implemented in only the last ten years. Without historical precedence cooperatives were slow to catch on in Turkey. Subsequently, many are still in the development phase, having not yet fine-tuned their operations. One study by Unal in 2006 focused on six districts; Foca, karaburun, Mordogan, Akyaka, Akcapinar, and Marmaris. In these districts there has been considerable conflict between the large-scale and small-scale fisheries, despite the fact that some of the cooperatives consist of members from both groups. Other problems found in these districts include fishing in restricted areas, fishing without a license, member conflicts, and other breaches in policy. In order to determine how these problems arise Unal (2006) interviewed cooperative members and leaders from all six districts. Unal et al (2009) followed up with their research in order to explain their earlier results. The tables below provide in depth details of fishing cooperatives in Turkey.

Examination of the six cooperatives finances revealed that the running costs and vessel costs are the most important element determining financial profits. In many cases labor costs are not of primary concern because typically the fishermen fish alone. This is in part to save costs but also due to an unwillingness of crew to work in a share system. Costs also fluctuate based on proximity to the ports, with those cooperatives fishing closer generating fewer costs. Marketing has been another important element influencing the cooperatives. Almost 70% of the total catch is marketed by the cooperatives themselves. Typically those cooperatives that sell at the local market receive a higher price than those who sell through an auction where the price is set. This results in differing incentives relative to the locations in which the cooperatives operate.

Despite having relatively low operating costs and controlling the market, only 65% of the six cooperatives studied achieve satisfactory financial and economic results. Furthermore, two of the cooperatives have a negative return on their investment, which is likely due to the types of gears used and species involved. The cooperatives' membership structure has also influenced their success.

All cooperatives follow a one-member-one-vote principle. Unlike other cooperatives found in Europe, membership is not strictly restricted only to fishers and they do not hire professional managers to oversee their operations. Based on interviews with the members their primary complaints are related to funding, the fishing grounds, other fishermen and members, the local administration, the coast guard, and the cooperative in general. It is not surprising then that none of the six cooperatives studied reflected all the characteristics of a successful fishery cooperative. According to Unal et al. (2009) a successful co-op is "founded by local initiative, provides input to members, has access to capital, combats illegal fishing, has qualified business management, increases capital over time, provides a patronage refund, has solidarity among members, and provides an education service." The majority of cooperatives in Turkey have not yet met these standards. The case of fishery cooperatives in Turkey demonstrates the importance of clear legislation and access to the resource as well as proper operational strategies.

Through additional research and understanding by decision makers and fishermen there is a potential for fishery cooperatives in Turkey to properly manage their marine resources in the future (Unal et al. 2009).

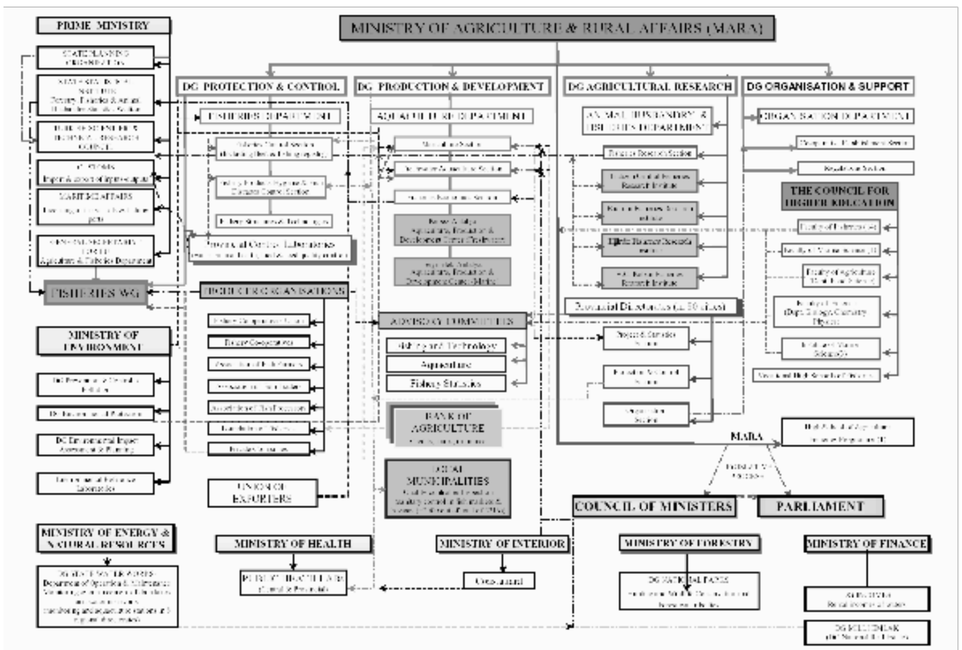

Figure 5. Turkish government structure

Socio-demographic characteristics	Foca Co-op	Karaburun Co-op	Mordogan Co-op	Akyaka Co-op	Akcapinar Co-op	Marmaris Co-op
Age of fishermen (Min-Max) Mean ± SD	(24-71) 47.9±12.6	(38-74) 56.5±10.6	(23-64) 44.5±11	(20-64) 43.2±10.1	(23-62) 45±9.3)	(29-70) 45.9±12.8
Experience of fishermen (year) (Min-Max) Mean ± SD	(6-55) 26.2±13.3	(6-60) 31.7±13.7	(10-50) 26.5±11	(8-42) 23.4±9.1	(5-40) 23.5±9.2	(6-45) 28.1±11.8
Household population (Min-Max) Mean ± SD	(1-9) 4.1±1.6	(2-9) 4.3±1.6	(2-6) 3.8±1.1	(2-11) 4.4±1.9	(2-7) 4.3±1.3	(2-7) 4.4±1.4
Dependent family members (Min-Max) Mean ± SD	(0-5) 2.5±1.2	(1-3) 1.9±0.8	(1-5) 2.6±1.1	(0-9) 2.4±2	(0-6) 2.6±1.7	(0-4) 2.2±1.3
Defining fishery as a main occupation(%)	53	13	67	95	100	100
Fishermen declared fishery as his only income source (%)	34	none	57	63	46	56
Having social Security (%)	37	93	24	58	77	75.5
House Owner (%)	40	100	73	62	8	21
Married (%)	95	100	96	77	89	82
N=176 n=127	N=51 n=32	N=18 n=14	N=27 n=20	N=24 n=19	N=26 n=26	N=30 n=16

Fig. 6 Structure of Turkish Fishing Cooperatives

Distribution of total costs %	Foca Co-op	Karaburun Co-op	Mordogan Co-op	Akyaka Co-op	Akcapinar Co-op	Mamaris Co-op
Running cost	33.6	22.2	31.6	47.1	38.9	45.6
Labour cost	38.1	59.4	43.6	27.1	39.8	33.3
Vessel cost	19.7	11.9	15.4	19.3	12.3	14.3
Depreciation	6.0	4.7	6.5	5.1	6.6	5.2
Other cost	0.5	-	-	-	-	-
Opportunity cost	2.3	1.9	2.9	1.4	2.1	1.6

Fig. 7 Costs of Turkish Cooperatives

Operational indicators	Foca Co-op	Karabun Co-op	Mordan Co-op	Akyaka Co-op	Akcapinar Co-op	Marmaris Co-op
Crew Size (Min-Max) Mean±SD	(1-3) 1.5±0.6	(1-2) 1.4±0.5	(1-3) 1.9±0.7	(1-2) 1.1±0.2	(1-2) 1.6±0.5	(1-3) 1.3±0.6
Days at the sea (Min-Max) Mean±SD	(60-300) 184.7±75	(70-330) 192.1±84	(30-330) 219±73	(100-330) 224.2±58	(100-270) 185.6±46.3	(50-250) 147.8±63.7
Fishing days without catch (Min-Max) Mean±SD	(0-200) 29±38.6	(10-150) 57±40	(5-100) 40.4±27.5	(0-50) 11.4±15.4	(2-50) 18.5±13.7	(2-50) 15.4±16.5
Running costs per fishing day (US$) (Min-Max) Mean±SD	(2.1-27.8) 6.3±4.8	0.7-4.2 2.5±0.9	2.1-17.6 6.6±4.5	3.3-18.9 8.9±4.2	3.0-13.4 7.7±2.3	2.5-18.6 8.5±4.2
Per Vessel Day Share Income ($/Day)	16.2	7.8	30.2	25.1	8.0	14.1

Fig. 8 Demographics of Six Turkish Cooperatives

Economic Performance	Foca Co-op	Karaburn Co-op	Mordogn Co-op	Akyaka Co-op	Akcapinar Co-op	Marmaris Co-op
Total landing value	133,011	27,677.5	161,165.8	144,982.4	75,779.1	53,541.6
Running costs	36,941.9	6,691.2	28,763.7	37,918.2	37,357.0	20,074.8
Labour costs	41,900.6	17,940.1	39,700.4	21,808.6	38,201.3	14,671.2
Vessel costs	21,636.2	3,582.2	14,061.4	15,512.1	11,796.3	6,286.3
Other costs	559.9	0	0	0	0	0
Gross cash flow	31,9731	-536.0	78,640.3	69,743.5	-11,575.5	12,509.3
Depreciation	6,558.0	1,417.3	5,899.1	4,116.8	6,401.6	2,267.8
Imputed Oportunity Cost	2,487.0	574,5	2,640.2	1,126.8	2,106.7	702.8
Net Cash Flow	22,928.1	-2,527.8	70,101.0	64,499.9	-20,083.8	9,538.7

Fig.9 Economic Performance of Six Turkish Cooperatives

Problems of cooperatives	Foca Co-op	Karaburun Co-op	Mordogan Co-op	Akyaka Co-op	Akcapinar Co-op	Marmaris Co-op
Tax system				X	X	X
Illegal fishing				X	X	
Conflicts among fishermen				X		
Lack of marketing facilities	X	X	X			
Marketing problems				X		X
Limited fishing ground	X		X	X	X	
Difficulties on collecting membership fee			X			X
Lack of interest among fishermen	X		X			X
Limited financial source	X	X	X		X	
Fishery circular	X		X			
Conservation and control services	X	X	X	X	X	X
Government policies on fishery cooperatives	X	X	X	X	X	X

Fig.10 Most commonly identified internal cooperative problems

Key indicators of success-failure (%)	Foca Co-op	Karaburun Co-op	Mordogan Co-op	Akyaka Co-op	Akcapinar Co-op	Marmaris Co-op
Participation to general assembly	60	59	52	92	100	90
Members having conflicts with the cooperatives	3	0	30	8	8	12
Years in fishing	10	3	9	10	29	28
Members find cooperative successful	78	64	10	81	62	71
Membership is attractive enough	51	75	55	37	100	9
Members who sell their fish through his cooperative	-	-	-	80	100	20

Fig.11 Key Indicators of Success and Failure

Table 2: The functions and some key indicators of fishery cooperatives along Turkish Aegean coasts in 2007

		Functions and key indicators (%)										
Groups	Fishery cooperatives	Existing marketing facilities	Providing inputs to members*	Availability of capital	Combating illegal fishing in cooperative area	Qualified business management	Increases in capital	Providing patronage refund	Solidarity among members	Education service on cooperation	Existing auction	Fulfilment of objectives*
I	Izmir	37.9	20.7	27.6	70.4	27.6	17.2	24.1	67.9	58.6	17.9	40.8
II	The rest	50.0	50.0	50.0	82.1	35.7	39.3	14.3	73.1	81.5	30.8	98.0
All –TR	Aegean	43.9	35.1	38.6	76.4	31.6	28.1	19.3	70.4	69.6	24.1	69.0

*There were found significant differences between two groups considering input supply χ^2 (Fisher's Exact Test; $p = 0.02$) and the rate of fulfillment of cooperative's objectives ($U = 0.500$; $p = 0.000$)

Table 3: The analysis of the responses of the heads of the fishery cooperatives on the problems of the cooperatives along Turkish Aegean coasts in 2007

		Problems (%)										
Groups	Fishery cooperatives	Tax system	Illegal fishing	Conflicts among fishers	Marketing problems	Limited fishing ground	Difficulties on collecting membership fee*	Lack of interest among fishers*	Limited financial source	Fishery circular	Conservation and control service	Government policies on fishery cooperatives
I	Izmir	31.0	72.4	27.6	69.0	48.3	62.1	69.0	69.0	58.6	34.5	82.8
II	The rest	46.4	78.6	32.1	60.7	60.7	25.0	46.4	67.9	60.7	50.0	75.0
All-TR	Aegean	38.6	75.4	29.8	64.9	54.4	43.9	57.9	68.4	59.6	42.1	78.9

*There were found significant differences between two groups considering membership fee; χ^2 (Fisher's Exact Test; $p = 0.005$), lack of interest among fishers; χ^2 (Fisher's Exact Test; $p = 0.004$)

Fig.12 Additional Indicators of Cooperative Success

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Japan

The Sakuraebi Fishing Cooperative[10]

Coastal fisheries in Japan have a long history of cooperative management, dating back to the 16th century when feudal lords would assign a stretch of coast to a specific village for the exclusive use of their fishing guilds. The general principles of this system have persisted through the years, before the current general form was established by the

[10] For a thorough description of the history and current state of Japanese fisheries management policies, see Makino & Matsuda 2005

Fishery Cooperative Law in 1948 (Uchida & Wilen 2004, Yamamoto 1995). The Fishery Cooperative Law developed a TURF style of fisheries management, in which fishing rights to an area are exclusively provided to associated cooperatives, termed Fishery Cooperative Associations (FCAs). Once provided rights to the fishery, it is left up to the FCA to determine how the catch will be divided among the cooperative members (Uchida & Wilen 2004).

Three fishing districts target the sakuraebi fishery in Suruga Bay, comprised of two FCAs (two of the fishing districts have formed a joint FCA) which in turn work together in the Sakuraebi Harvesters' Association (SHA). The fishery in Suruga Bay is the only major source of sakuraebi shrimp in Japan, and represents a very profitable enterprise for the local FCA. The fishermen of Suruga Bay have developed a cooperative method of pooling effort and profits to effectively manage their resources, allowing for increased profits while reducing competition.

Industry Structure

Prior to the development of the SHA, the three fishing districts of the bay all competed for the shrimp resource. The shrimp migrate in a counter-clockwise direction around the bay, moving south along the western edge in the fall and north along the eastern edge in the spring. In addition, the shrimp are not uniformly distributed, but occur in "hot-spot" congregations (Uchida & Baba 2008). As a result of these characteristics, while fishermen within each individual FCA would cooperate with each other, they would race against the other bay cooperatives in order to gain control of hotspots and harvest as many shrimp as possible while the animals were closest to their home ports. This not only resulting in overcapitalization of the fishery but also led to violence, in the form of flaming sticks thrown into competitors nets and fights spilling out on the docks (Uchida & Baba 2008). This situation persisted for several years, until leading members of the fishing community in the bay realized the unsustainable and impractical nature of this arrangement and developed the current system coordinating the bay's fisheries through the SHA (Uchida 2009). The choice to rationalize competition in the fishery coincided with a crash in the sakuraebi stock, which led industry members to realize the exhaustible nature of their resource (Uchida & Baba 2008).

Under the current form of the cooperative system, the SHA operates through a highly coordinated pooling arrangement, in which all members of the bay fishery work together to harvest the shrimp. In accordance with Japanese fishing law, only members of one of the local FCAs may fish in the fleet. This has led to the development of an innovative mechanism for controlling membership size in the fishery. The law contains a clause that in order to become a member of an FCA, a fishermen must have actively worked in the fishery for a period of at least 90 days. The only way to work in the fishery though is to be hired by a current member of the FCA. In this way, cooperatives are able to control their size; if they do not want any new members, they simply do not hire any new people. The day-to-day operations of the fishery are run by the Fishing Committee (Committee). The Committee meets every day during the fishing seasons, and decides whether or not fishing will occur that day, what time it will go, where it will fish and who will do the fishing (Uchida & Baba 2008). They also decide how much will be caught on that day, based on estimations of market demand.

Shrimp fishing is done in units of two boats, which operate a single net between them. Currently, the Japanese government has limited the number of licenses issued to the fishery to 60 units, equaling 120 boats. On a given day, only about half of these units will be assigned by the Committee to actively fish, though all boats go out on each fishing day. Non-fishing boats may search the area for hot-spots, or engage in fishing if the committee decides more effort should be assigned to that particular day. Each day of fishing, the committee sets a total catch goal, which is then divided into a number of boxes to be caught by each actively fishing boat. Once that number is met, fishing is halted for the night. At that time, boats trade catch so that each unit has an equal number of boxes on board. This is done not for the sake of the fishermen, but rather the processors. Since profits are pooled in the SHA system, it doesn't matter to individual fishermen how much catch they bring in. However, shrimp processors are confined to their individual harbors, therefore some may be at a disadvantage if more catch goes back to particular ports. As such, the SHA chooses to divide the catch between the boats to ensure that the shrimp are evenly distributed between the ports. This does not appear to provide any real benefit to the fishermen, besides maintaining good relations with the processors who they depend on to sell their goods (Uchida 2004).

Once the shrimp are landed and sold at auction, revenue is pooled, following the subtraction of certain fixed costs (variable costs such as boat maintenance are not included, though gas sometimes is, making this a revenue, not profit pooling system). These fixed costs include a percentage fee[11] that is returned to the SHA for operating costs, a port fee and a cold storage fee. Once these fees are subtracted, the remaining revenue is then divided between the boat owners and crewmembers, based on the particular role of individuals within the system (mechanics earn more then box packers for example). As an interesting side note, the pooling arrangement was actually proposed and developed by the most profitable members of the fishery at the time, despite the fact that they would likely lose money through the process. Uchida (2004) hypothesize that as the most profitable, these fishermen were also the most involved in the fishery, and so were most able to see the destructive impacts that the race for fish was having on the future of their industry.

Performance

One of the most significant improvements to come out of the development of the SHA has been the market control the industry has been able to exert since coming together as a cooperative. As the only commercial harvesters of sakuraebi, the SHA is effectively able to match their fishing effort to demand, allowing them to command price premiums for their product. By aiming to catch enough shrimp to be effectively processed in its highest value form (sun-dried), the SHA has been able to get

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[11] Under the original system, the percentage fee was not pooled, but instead given to the district in which the shrimp were landed. This resulted in districts competing to bring catch to their own ports. The SHA decided to then pool the percentage fee across the industry to resolve this issue.

consistently higher prices per kilo than they were able to in years past (Uchida & Baba 2008).

The SHA has also served to reduce effort in the fishery, allowing boats to focus on efficient fishing rather than competing for better access to the shrimp. In addition, the sharing of information on locations of hot spots should lead to reduce gas costs. However, in an interesting example of balancing community needs with fishing efficiency, the cooperative structure of the industry has not reduced the number of boats to the level it could. Since on a given night only about half of the fleet actually engages in fishing, it stands to reason that the fleet could effectively function at half its current size. That the SHA elects to maintain its size at 60 units has been explained as a by-product of the community mindset of the industry. While under the pooling system reducing the size of the fleet would increase profits to those that remained in the fishery, it would also result in the loss of jobs for the other half, a situation which the local fishermen apparently do not wish to see (Uchida & Baba 2008).

Free riding is a common concern associated with revenue pooling systems. This problem has not proved especially large in the sakuraebi fishery however, largely due to societal pressure than to any particular management strategy. Industry members report that it is simply not in their nature to shirk their fishing duties. In addition, boxes delivered to market bear the mark of the boat they were caught on; as such it is easy for other industry members to see if a particular vessel is not carrying its weight. These community pressures appear to have kept the free-rider problem at bay for now (Uchida & Wilen 2004).

Fishermen of the SHA state that the management of their resource is a significant role of their cooperative (Uchida & Baba 2008). In an effort to allow more shrimp to reach spawning size, the SHA has decreased the amount of catch they bring in during the fall season (this has also served to produce more high value, large specimens in the spring harvest). They have also voluntarily closed down fishing during the winter months, as this period requires greater fishing effort since the shrimp stay deeper in the water during this time. However, the SHA does not engage in some of the more active ecosystem monitoring or enhancement projects undertaken by other fishing cooperatives. While they will alter their catch levels in response to yearly fluctuations or perceived threats to the fishery, they have no real knowledge of the population size, and hence no true estimation of the sustainability or impacts of their fishery on the local ecosystem (Uchida & Baba 2008).

Discussion

In analyzing the SHA, the spatial realm in which the cooperative finds itself must be considered. In the Bay, the cooperative has access to a completely self-contained population; the entire life cycle of the sakuraebi shrimp stock they target is enclosed by the waters the fishermen live around (Uchida & Baba 2008). As such, by forming a bay-wide cooperative, their fishery essentially becomes a TURF with exclusive access to the resource. This both allows the SHA greater control over the state and management of the fishery and provides them with a monopoly over the market. As a monopoly, the sakuraebi fishery is also extremely profitable; the combination of exclusive access and a high value fishery provides an ideal ground for the functioning of a TURF based cooperative.

While the revenue pooling system of the SHA has proved successful in increasing the economic power of the fishery, some members of the industry report that there is talk of moving towards a profit, rather than revenue, sharing system (Uchida 2009). By fully internalizing costs, an incentive may be created to further increase the efficiency of the system. It will be interesting to see if the voluntary overcapacity of the fleet is maintained if the costs of keeping extra ships on the water are borne by the fishery as a whole**.**

Despite these highly organized marketing and effort allocation practices of the SHA, it is interesting to note that they have not adopted many of the stock assessments practices of other well developed cooperatives in the world. This might be explained by the fact that stocks have remained fairly stable since the inception of the cooperative, as well as through the lack of a TACC system imposed by the Japanese government. Many other cooperatives engage in thorough stock assessments in the hope of achieving an increased in allowable catch from the government; since the SHA is already permitted to catch as much as they want, there is not much incentive to spend money on additional research. The lack of environmental research could prove detrimental to the fishery though; while the cooperative has responded to isolated threats to the stock, they do not appear to be currently able to notice or respond to more long-term threats to the sustainability of the stock.

For the time being though, the SHA exists as a strong example of the positive impacts of community-based fisheries management. The cooperative also illustrates need for management to match the scale of the fishery. While cooperatives were in place prior to the unification of the SHA, fierce competition still occurred due to the mobile nature of the stock. In order to stop the racing nature of the fishery, it was necessary to incorporate the entire range of the shrimp into a joint cooperative. Doing so has allowed the SHA to become a highly successful and stable fishery, both to the shrimp stock and for the community.

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Cooperative Fisheries in the Shiretoko Peninsula UNESCO World Heritage Site

The Shiretoko peninsula of Japan contains an extremely interesting case study in cooperative fisheries management. The area contains a long established, highly productive and economically important fishery, mostly targeting salmon and walleye pollack (Makino et al. 2009). However, the peninsula and its near shore waters have also recently been designated, at the request of the Japanese Government, as a UNESCO World Heritage Site, creating the Shiretoko World Natural Heritage area. This unlikely pairing of fishing and conservation activities creates an ideal site to examine the role of cooperative fisheries in managing and preserving marine resources (Matsuda et al. 2009).

Industry Structure

The fisheries of the Shiretoko peninsula are the primary source of income for the region, targeting primarily walleye pollock and salmon, but also species such as kelp, squid, rockfish and cod (Matsuda et al. 2009). As with other fisheries in Japan, the local industries operate in a co-management system in which the government sets general restrictions such as TACC, licensing requirements, minimum catch sizes and general seasons, while the local FCAs are left to develop their own operating structure and specific management plans, often resulting in more stringent regulations than those imposed by the government (Ministry of the Environment 2007).

While each of the FCAs within the Shiretoko operate independently, the UNESCO process has brought these groups together at the table with other relevant parties such as scientists and environmental groups. This resulted through the need to improve the sustainability of the local fisheries in order to satisfy the requirements for listing as a UNESCO World Heritage Site. Initial evaluation by UNESCO reported that not enough measures were in place to ensure the sustainability of local fisheries such as the walleye pollack, or to monitor the health of the ecosystem as a whole. In response, the Shiretoko Word Natural Heritage Site Regional Liaison Committee was formed, consisting of all major stakeholders in the region, including representatives from the fishing industry. This Committee produced the Multiple Use Integrated Marine Management Plan, the objective of which is to "Satisfy both conservation of the marine ecosystem and stable fisheries through the sustainable use of marine living resources in the marine area of the heritage site" (Makino et al. 2009). This Plan represents an important tool for the coordination of fishing in the area, as it calls for the use of adaptive management, in which knowledge obtained from both the fishing industry and the scientific community is pooled to continually monitor and refine the operations of local fishing groups.

The resulting actions of the walleye pollock fisheries of the peninsula are the most described of the local fishing groups. The local pollock fishermen have collected data on their fishery for over 50 years, representing a vast trove of local knowledge available to supplement scientific data. During this time, the stock of walleye pollock has decreased dramatically; TACCs have dropped over 90,000 tons over the past two decades. The initial response of the fishermen was to close fishing in seven areas deemed as important spawning grounds. When stocks continued to decline, they added an additional six areas to these privately created MPAs (Matsuda et al. 2009). In an additional effort to protect the sustainability of the stock, fishermen voluntarily increased the mesh size of their nets, so as to allow for increased escapement of smaller individuals (Makino et al. 2009, Ministry of the Environment 2007).

The coordination brought about by the UNESCO designation of the area has allowed fishermen to improve upon their already established management actions. Under the new process, fishermen collect fishery data such as population estimates, size and sexual maturity, and time and place of capture. They then provide this data to the scientists, who use the data to analyze the state of the fishery and the impact of management efforts. Scientists and fishery members then utilize the data to refine their actions, resulting in the modification or movement of MPAs, and changes in minimum size limits, gear restrictions or season lengths for example (Makino et al. 2009, Ministry of the Environment 2007).

The walleye pollock fishermen of the peninsula have also taken steps to reduce the number of vessels actively fishing the area, concentrating effort and in doing so saving costs and potentially reducing environmental impacts. Since 1996, the pollock FCA has cut the number of vessels in their fleet in half. The fishermen who remained in the industry, aided by the funds of the FCA and the government, paid for this reduction. More recently, the FCA has developed a cooperative system in which 5 vessels are now assigned to a group, with only one vessel conducting all the fishing for the group on a given day (Makino et al. 2009).

Other fishing groups have also engaged in similar activities, though detailed descriptions are unavailable. The examples provided by the pollock fishermen illustrate though the positive impact that cooperative actions between scientists and fishing groups has had on the availability and impact of ecological data. Current indicators as to the effect of these measures on the economics of the fishery appear to be positive. The fishermen of the Shiretoko region currently produce on average four times the value of catch per fishermen than the national average (Makino et al. 2009). Trends in total yield and price per unit weight varied greatly depending on the particular stock being examined; while more specific data appears to be available, only course-scale comparisons have been published to date (see below from Matsuda et al. (2009).

Common name	Academic name	Order in		Catch amount (ton)			Yield (thousand yen)			Price (yen/kg)	
		Catch	Yield	1985–1989	1998–2002	CV (%)	1985–1989	1998–2002	CV (%)	1985–2002	1998–2002
Chum salmon	*Oncorhynchus keta*	2	1	12,509	33,459	47	6660	8466	23	532	253
Walleye pollock	*Theragra chalcogramma*	1	2	88,580	12,433	84	11,063	1846	78	125	148
Kelp	*Laminaria japonica*	9	3	648	586	27	1274	1486	26	1967	2534
Common squid	*Todarodes pacificus*	3	4	225	13,182	100	38	1518	93	170	115
Rock fish	*Sebastolobus sp.*	8	5	935	367	53	1318	947	35	1410	2580
Pacific cod	*Gadus macrocephalus*	6	6	4637	3443	41	662	905	38	143	263
Arabesque greenling	*Pleurogrammus azonus*	4	7	6299	6187	34	810	805	23	129	130
Pink salmon	*Oncorhynchus gorbuscha*	5	8	1060	5362	80	429	637	50	405	119
Sea urchin	*Strongylocentrotus intermedius*	26	9	48	35	34	508	372	29	10,591	10,711
Scallop	*Patinopecten yessoensis*	7	10	1767	1665	53	302	140	45	171	84
Octopus	*Enteroctopus dofleini*	10	11	313	471	34	120	198	25	384	420

Fig. 13 Trends in catch, yield and price for a variety of commercially harvested fish in the Shiretoko Peninsula (From Matsuda et al. 2009).

Administrative costs for the current marine management efforts represent only 0.8% of the income brought in by fisheries and tourism (Makino et al. 2009). The management actions of the Shiretoko FCAs are funded through two means; commissions charged at auction by the FCA, and by a fee charged to members in proportion to their total individual catch (generally 7%) (Makino 2009). This variable rate of membership fees functions because while catch is pooled and sold collectively by the FCA, individual fishermen still appear to be paid in proportion to their individual catch (Makino 2009). Interestingly, there is no official monitoring system set in place by the Shiretoko FCAs to enforce decided upon management actions. Instead, they rely on the strength of community trust and social norms to ensure that rules are followed. Experts in the region's fisheries estimate that this form of enforcement is strong enough in these communities to result in 100% compliance with FCA regulations (Makino 2009).

Trends in the health of local fisheries are mixed, with some stocks exhibiting increases, while others have declined over the years (Matsuda et al. 2009). The data shown in Fig.13 represents fishery dependent data though, and as such is not necessarily reflective of the true state of the Shiretoko marine ecosystem; other factors could explain trends in catch levels. That fishermen are collaborating with research groups to evaluate the health of the Shiretoko peninsula is an encouraging sign though, doing so should allow for higher resolution data on the impact of fishing practices on oceanic habitats and organisms. It should also be noted that the unusual arrangement in which the fisheries of the Shiretoko find themselves has only been in place for a short time; as the co-management system of the region matures, more quantitative analyses of the ecological impact of cooperative fishing may be possible. In addition, as a UNESCO site, the ecology of the Shiretoko peninsula has been extensively researched, resulting in detailed information on the local food web and ecosystem state (Makino et al. 2009). As a result, future studies on the ecological impact of the fishery may be able to benefit from a level of scientific environmental knowledge not often available in fisheries science. Regardless of its future impacts, the coexistence of extensive fisheries and ecological interests in the Shiretoko peninsula of Japan provides an ideal opportunity to study both the potential benefits and shortcomings of utilizing cooperative fisheries to attain marine conservation goals.

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Consequences of Straddling Stocks: The Walleye Pollock Fisheries of Japan

While the sakuraebi fishery illustrates the benefits of pooling between competing cooperatives, the walleye pollock fishery in the Nishi region of Japan provides an example of the externalities induced by incomplete coordination of fisheries sharing straddling stocks. Walleye Pollock migrate along the northern coast of Japan, crossing the borders of several different fishing districts in the process. This has created conflict and reduced incentives for sustainable management within individual TURFs, as each blames another group further along the coast for the troubles of the fishery (Uchida & Watanobe 2008).

Industry Structure

In an effort to reduce this conflict, a group of fishing districts in the Hiyama district of the coast decided to organize themselves into the Hiyama Fishery Cooperative Association (HFCA). The HFCA serves as a co-management cooperative through which the individual TURFs of the organization can harvest and market their catch. The Nishi region of the HFCA provides some of the best examples of resource and effort pooling within this cooperative system, and has also implemented a private MPA. The Nishi subset of the HFCA is comprised of three separate fishing districts. In order to coordinate efforts and prevent inter-TURF competition, the Nishi region utilizes a complex rotational system to allocate fishing grounds to individual boats, preventing a chaotic race for the best spots in the fishery.

This rotation scheme is described in detail by Uchida & Watanobe (2008). Each fishing day, the management council of the local fishing organization informs the fishermen of the day's activities and locations. Locations are assigned by a complex, three tiered rotation system, consisting of village groups, teams within the village groups, and individual vessels within the teams. Each one of these groupings is rotated such that all vessels gain access to all parts of the fishery at some point during the year. This program was instituted in order to prevent congestion and damage to vessels and nets resulting from all the fishery's vessels congregating on the same lucrative locations. While this system did serve to efficiently space vessels apart, it also created economic externalities; due to the rigidity of the system, vessels would often be forced to fish an area that was relatively devoid of fish, even if there was ample room for all vessels to target the current school location. In addition, during portions of the rotation system vessels must travel extensive distances, resulting in high expenditures on gas.

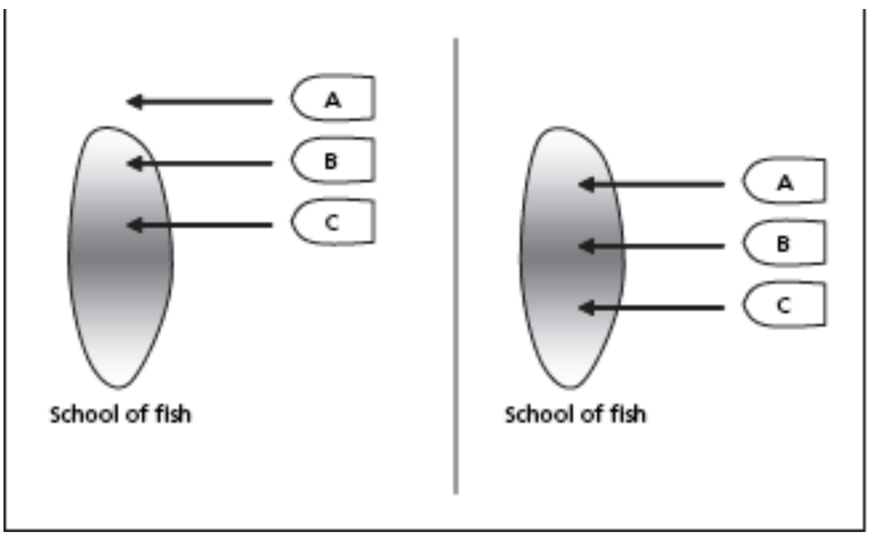

Fig.14 Alteration of rotational fishing structure under cooperative management (Uchida & Watanobe 2008)

In order to resolve some of these shortcomings, the Nishi section of the HFCA has recently developed a revenue pooling system, as well as introduced some flexibility to the rotation system. Under the Nishi pooling system, daily earnings are pooled and distributed among those vessels that fished on that day, in proportion to the amount of effort (generally defined as the amount of longline that they put out). This system served to realign the incentives of the rotation. Without pooling, each fisherman was only concerned with their own days catch, and they viewed bad days or inferior locations as simply the result of luck. By developing a pooling system though, fishermen in the Nishi region gained the incentive to ensure that the total catch from the region was maximized. They therefore began altering the rotation system as a group in order to increase economic efficiency. Fig.14 from Uchida & Watanobe (2008) illustrates this phenomenon. Under the strict rotation system, the scenario on the left unfolds, in which vessel A catches nothing, while B & C catch their own individual amounts. Under the pooling system though, rather than count the poor catch of vessel A as simply bad luck, the fishermen coordinated and all shifted locations to maximize the catch of each individual vessel, and through the pooling system increase all their individual earnings. In this way, while the rotation system in general is maintained, fishermen now coordinate to ensure that the system as a whole is operating as efficiently as possible.

In addition to utilizing pooling to increase fleet efficiency, the Nishi region of the HFCA has also put in place a private MPA within their TURF. The fishermen of the Nishi region primarily target walleye pollock for their roe. In order to help sustain their industry and the pollock stock, the Nishi fishermen voluntarily closed down an area of high pollack density to any fishing, as this area was known to be a primary spawning ground for the fish (Uchida & Watanobe 2008). Members of the cooperative are assigned to monitor the area and ensure that all members are complying with the closure.

Performance

Economically, the members of the HFCA have seen mixed results from their actions. Profits as a whole have dropped over the course of the last several years. However, profit per day has remained fairly stable, and costs have decreased. This reflects the fact then that the loss in overall profits is related to a drop in volume landed and number of fishing days (Uchida 2009 (2)). In fact, within the Nishi region industry members report that as a result of the pooling system, profits actually increased for this section of the fishery despite a drop in landed volume. They attribute this to the extensive cost savings that the coordination resulting from the pooling arrangement has created (Uchida & Watanobe 2008). However, while the pooling system has had a positive economic effect on the Nishi system as a whole, some individual members feel that the system does not adequately account for or reward differences in individual crew skills.

As an added measure to the attempts to increase the economic efficiency of their fishery, the HFCA has also embarked on a collective marketing campaign. Rather than simply selling their catch, in this case the roe, individually, the cooperative has begun pooling their catch and marketing it as their own high-quality brand. As part of this system, they have begun providing roe buyers with samples of their collective product prior to auctions, resulting in increased prices and providing an incentive for the fishermen of the cooperative to focus on the quality rather than the quantity of their roe (Uchida & Watanobe 2008).

In summary, it appears that while industry profits as a whole have declined, the severity of the decline has been dampened by the efforts of the HFCA. The underlying cause of this drop in revenues is of serious concern though; pollock stocks, as well as recruitment levels have been in continuous decline since 1989 (Uchida & Watanobe 2008). Breaking down the trends in pollock populations within its total range shows an interesting pattern though. While catch rates for the fishery as a whole have continually declined, they have remained fairly stable in the Nishi region of the HFCA (Uchida 2009 (2)). In addition, stocks in the southern range of the pollock (the area fished by the HFCA) are far higher than in the un-coordinated northern region of the stock. This trend may be a result of the efforts taken by the HFCA such as voluntary catch reductions, closure of spawning grounds to fishing, and economic rationalization, and hence effort reduction, by the fleet.

Economic and environmental data suggests that the cooperative structure of the HFCA functions better than the un-coordinated TURFs targeting the northern range of the pollock fishery. The existence of several different management structures operating within the walleye pollock fishery makes it hard for a consensus to be reached as to the cause (and subsequent solutions for) the total decline in the fishery. Fishermen of the HFCA assert that the decline is the result overfishing by trawlers in the north, while the northern fishermen maintain that the roe harvesting by HFCA is the true root of the problem. Without total coordination, each subset of the fishery is able to pass the blame for the decline in the walleye pollock to their competitors. This creates a powerful disincentive for sustainable management, as fishermen fear that any efforts they take to conserve the stock will simply be offset by rival vessels. While the HFCA has so far maintained its efforts to preserve the sustainability of the stock, it remains to be seen if they will continue to do so if the pollock population continues declines sufficiently to offset the recent cost-savings brought about through the pooling system and marketing efforts of the HFCA.

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Conclusion

When initially confronted with the task of delving into the operational mechanisms and economic results of fishing cooperatives worldwide, our intent was to utilize existing data to develop quantitative analyses of cooperative fisheries. In attempting to do so however, we found a surprising lack of comprehensive published works evaluating or even describing the structure of fishing cooperatives. In order to fill this gap, we have pooled the information we were able to collect into this review in hopes that it will serve as a useful tool and reference point for other fisheries researchers.

As our research shows, cooperative fisheries have sprung up in countless different forms in all corners of the world. Fishermen, managers, and researchers can and should seek to improve on fishing practices by examining the successes and failures of these institutions. It is our hope that by compiling descriptions and data on a broad selection of fishing cooperatives, this survey provides a step forward in our understanding of catch-share management, and in doing so helps in the development of profitable and sustainable fisheries.

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Appendix 2: Expanded Calculation of NPV

This appendix expands on the NPV methods and results presented in the body of the paper. For the base-case scenarios, likely values of costs and benefits were selected and added in order to obtain total profits to the cooperative. However, in order to perform our Monte Carlo sensitivity analysis, it was necessary to break our costs and benefits into functions of solely the number of abalone harvested in a given year. For those wishing to repeat or expand on these results, below we present the methodology for calculating the NPV of the fishery over a length of time, given desired inputs to the model. In the following section, the subscript *i* denotes iterations and *y* denotes year. This method was used for the calculation of our AH model.

Uncertain Costs (U_C)			
Parameter	Low	Medium	High
Data Collection	$20,059	$40,118	$60,176
Data Coordinator	0	10,400	20,800
AAUS certification (year 1)	0	N/A	14500
AAUS certification (year 2+)	0	N/A	500
Marketing Coordinator	0	$10,400	$20,800
Decision Tree (Year 1 and adaptive harvest only)	10000	$12,500	$15,000
Enforcement Costs	Year 1: $0 ; $25,000 ; $50,000 : $75,000 ; $100,000		
	Year 2+: $0 ; $16,250 ; $32,500 : $48,750 ; $65,000		

Fixed Annual Costs	
Parameter	**Value ($)**
Trace Register	$3,000
Third Party Audit	$5,000
Administrative Costs	$10,000
Legal	$5,000
Accounting	$5,000
Website	$1,920
Phone	$500
Total Fixed Costs (F_x):	**$30,420**

Harvest Dependent Cost (HDC): $/abalone	
Parameter	**Cost**
Tags	$1.0000
Landing Tax	$0.0125
Enhancement Tax	$0.1950
Landing Receipts	$0.1036
HDC=	**$1.3111**

Boat Dependent Cost (BDC): $/round trip to SMI	
Parameter	**Cost**
Insurance	$39.20
Boat Slip	$94.10
Boat Maintenance	$58.82
Gas	$300.00
Dive Gear Maintenance	$24.50
BDC=	**$516.62**

The following calculations will depend on the variables M_e (members), H (harvest), F_x (total fixed costs), U_C (uncertain costs) BDC (boat dependent costs), HDC (harvest dependent costs). Given the values presented in above, calculation of NPV through our model depends on two variables; number of members (M_e) and harvest (H). Number of fishing trips (F_t) can be inputted manually, or calculated by the following equation.

Number of fishing days is constrained by two parameters, a maximum number of abalone per boat (260) and a maximum number of fishers per boat (3). For most levels of harvest then, the number of boat days is simply constrained by the maximum number of abalone per boat. This is assuming that fishers develop a method to ensure that each boat fills its maximum capacity of abalone on every fishing trip. As the TAC grows larger, more fishing trips are needed, and as the TAC grows smaller, less trips are needed to capture the seasons allowance. However, once the ratio of catch/member (T_m) drops below 86 (in other words, 86 abalone per member per year to catch the allocated harvest), it becomes impossible for the cooperative to reduce boat days any further. This value of 86 represents the maximum amount of abalone that each member of a three person crew can catch to total 260 abalone per boat. Below this value, the total number of abalone caught by three fishers becomes less than 260, which ideally would mean that another fisher would be added. However, since the boat is already at capacity, no more fishers may be added and hence no additional boat days may be reduced. Therefore, once T_m drops below 86, the number of fishing trips is simply equal to the number of fishing trips required for every member to travel to SMI, with a total of three fishers per boat. Mathematically, this is quantified as:

$$\text{if } T_m \geq 86, \text{ then } F_t = H/260$$

$$\text{if } T_m < 86, \text{ then } F_t = M_e/3$$

Given then these total fishing trips, the fishing costs (F_c) are for a given iteration *i* and year *y* are

$$F_{ciy} = F_{tiy} \times BDC$$

The harvest costs (H_c) for a given iteration and year are

$$H_{ciy} = H_{iy} \times HDC$$

Revenues, assuming 4 lbs per legal sized abalone caught, are

$$R_{iy} = 4 \times P_{riy} \times H_{iy}$$

Then, the profits in a given year ($\prod_y$) are

$$\Pi_{iy} = R_{iy} - (Hc_{iy} + Fc_{iy} + Uc_{iy} + Fx)$$

The NPV, dependent on the discount rate *r* and the probability of the fishery remaining open (theta) then is

$$NPV_i = \sum_{y=0}^{y} \frac{\Pi_{iy}}{(1+r)^y} \times \Theta_y$$