UNIVERSITY OF CALIFORNIA
Santa Barbara

Lowering Barriers to Alternative Management Strategies and Collaborative Fisheries Research

A Group Project submitted in partial satisfaction of the requirements for the degree of
Master of Environmental Science and Management
for the
Donald Bren School of Environmental Science and Management

by

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DONALD BREN SCHOOL OF
ENVIRONMENTAL SCIENCE & MANAGEMENT
UNIVERSITY OF CALIFORNIA, SANTA BARBARA

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The mission of the Donald Bren School of Environmental Science and Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Group Project is required of all students in the Master's of Environmental Science and Management (MESM) Program. It is a three-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

Dr. Hunter S. Lenihan

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Abstract

Historically, California nearshore fisheries have been managed within a rigid, precautionary framework based on complicated and data-intensive stock assessments. This group project analyzed an alternative management strategy, the Decision Tree, which simplifies the assessment method and aligns the scale of management with the scale of biological function. The Decision Tree also integrates marine protected areas into fisheries assessment as an unfished baseline and increases available fisheries data though collaboration between scientists and fishermen, at minimal cost to management bodies. Economic analysis shows data collection costs fishermen $95.22 per day, which translates into an overall cost to the fishery of $1,904.04 per year. Both research set asides and an increase in regional total allowable catch limits are management tools that may be used to recoup data collection costs through an increase in fishing quota. Working with local nearshore fishermen, this project developed new technology that streamlines the data collection process into fishermen workflow while simultaneously increasing data accuracy and reliability. Additionally, effective implementation of the Decision Tree is most efficiently accomplished in conjunction with a cohesive fishery organization. We conceptualized this as an organic, step-wise process from the current organizational structure under University Funded Collaborative Research, progressing in complexity to an Association, and finally a Cooperative. Within a cooperative framework, data collection and management goals are achieved, and the burden of management responsibility can be shared between the California Department of Fish and Game and local fishermen. The Decision Tree management strategy has the capacity to transition the nearshore finfish fishery from precautionary to science-based management, while simultaneously increasing collaboration between fishery stakeholders, fulfilling legal mandates, and improving economic and biological sustainability.

Executive Summary

Introduction

Management of the California nearshore rockfish and cabezon fisheries is restricted by a scarcity of data due to difficulties in collecting necessary information for traditional stock assessment models, a lack of staff and resources, and a biologically inappropriate management scale. This management structure relies on complex quantitative assessment models and does not provide incentives for fishermen to engage in data collection nor mechanisms through which populations can be managed on scales appropriate to species life history. These problems have led to the assignment of precautionary catch limits, which contribute to economic inefficiencies and potential ecological harm. Novel approaches to managing fisheries through the use of data-based indicators can address these inefficiencies by reducing the need for quantitatively complex assessment models and aligning management with biological scale. One such approach uses catch and size-based information collected collaboratively by fishermen and scientists inside and outside of marine protected areas (MPAs). This MPA-based Decision Tree (DT) management strategy makes use of fishermen-collected, scale appropriate fishery data at minimal cost and integrates marine protected areas into fisheries assessment (Wilson et al. *in prep*). The goal of this project is to determine how the DT method can be most efficiently implemented to improve sustainability and profitability in the Santa Barbara nearshore live finfish fishery by moving management beyond broad-scale, data-poor, precautionary methods.

Though originally developed for pelagic finfish, the DT addresses a specific problem with management of low-dispersal species. For these species, the scale at which populations function is often much smaller than the scale at which conventional stock assessments are applied (Prince et al. 1998). The Channel Islands nearshore fisheries are good candidates for testing novel management approaches generally, and for the DT in particular. Like many fisheries, historical baseline data is insufficient and fishery-independent data is scarce. Integration of fishermen-collected data can increase scale appropriate fisheries information, alleviating these data scarcity issues. The creation of the Channel Islands MPA network in 2003 offers an additional benefit by providing the necessary unfished baseline reference points utilized by the DT. Furthermore, many fisheries within the Santa Barbara port complex have established collaborative research relationships with University of California researchers (e.g. CALobster). A test fishery employing the DT method in the Channel Islands can potentially provide a framework for integrating MPAs into fisheries management.

Methods

To understand how to most effectively implement the DT, we interviewed participants in the Santa Barbara nearshore finfish fishery and assessed data collection capacity and needs. Based on these interviews, we designed new boat-based data collection methodologies that incorporate the DT's accurate size structure requirements and fishermen's data security needs. We examined the legal barriers to the implementation of alternative management methods and how these methods may integrate with existing management structure. We then developed a progressive organizational framework that delineates how the fishery can efficiently employ the DT management strategy. Lastly, we quantified data collection costs associated with each progressive step in this organizational framework.

Results

These analyses demonstrate the DT has the capability to overcome many of the challenges associated with the assessment and management of California's nearshore finfish fisheries. Interviews indicate that fishermen are dissatisfied with existing management and have a desire to increase their involvement in data collection and future management. The new boat-based data collection methodologies streamline the data collection process into fishermen workflow while simultaneously increasing data accuracy and reliability. Effective implementation of the DT is most efficiently accomplished in conjunction with a cohesive fishery organization. This organizational framework achieves data collection and assessment goals and distributes management responsibility between managers and local fishermen. Quantification of data collection costs reveals the total annual cost of onboard fishermen-collected data is $1,904.40. Fishermen can be compensated for this minimal cost via additional quota allocation in the form of an increase in regional total allowable catch (TAC) or a research set aside (RSA). An additional allocation of 272 lbs of cabezon, which is only 0.46% of the state-wide cabezon TAC, will fully compensate the fishery for annual time costs associated with data collection. Analysis shows not only are legal, political, and financial barriers to DT implementation easily overcome, this management strategy will contribute to the successful realization of long unfulfilled state and federal fishery management mandates.

Next Steps

Continual communication and collaboration between fishery participants and UCSB researchers is essential to the effective implementation of the DT. California Department of Fish and Game (CDFG) must be an active member in this adaptive process. Immediate next steps include workshop development to discuss the science behind the DT, fishery organization options, and the desire of fishery participants to move forward with an alternative management strategy.

Conclusion

Historically, California fisheries have been managed within a rigid framework based on use of complicated and data-intensive stock assessments often leading to precautionary catch limits and management inefficiencies. While there is no precedent for employing alternative management strategies in California, acceptance is developing within the CDFG (Phipps et al. *in prep*). Reforming management to incorporate data on biologically appropriate scales is crucial to sustainable management of many California fisheries. The DT approach not only aligns the scale of management with the scale of biological function, but also decreases data collection costs and integrates MPAs into fisheries management. The Decision Tree alternative management strategy has the capacity to transition the Santa Barbara nearshore finfish fishery from precautionary to science-based management, simultaneously increasing collaboration between fishery stakeholders and improving economic and biological sustainability.

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List of Acronyms

CDFG – California Department of Fish and Game
CINMS – Channel Islands National Marine Sanctuary
CMB – Community Management Board
COPA – California Ocean Protection Act
CPUE – catch per unit effort
DT – Decision Tree
EDF – Environmental Defense Fund
EFP – Exempted Fishery Permit
FMP – fishery management plan
GOA – Gulf of Alaska Rockfish Program
MAFMC – Mid-Atlantic Fishery Management Council
MLMA – Marine Life Management Act
MLPA – Marine Life Management Act
MPA – marine protected area
MSA – Magnuson-Stevens Act
MSY – maximum sustainable yield
NFMP – nearshore fishery management plan
OY – optimal yield
PFMC – Pacific Fishery Management Council
RSA – research set aside
SCR NFP – South Coast Nearshore Fishing Permit
SPR – spawner per recruit
TAC – total allowable catch
TURF – territorial use right
UCSB – University of California, Santa Barbara
VMS – Vessel Monitoring System

1. Introduction

United States fisheries are vital economic, cultural, and consumptive resources, whose sustainability is threatened by management inefficiencies. These inefficiencies are a product of precautionary management due to a shortage of fisheries data, inappropriate scales of assessment and management, and a lack of collaboration between fishermen, scientists, and managers. Traditional stock assessment methods demand large amounts of data over both time and space, resulting in considerable uncertainty and under-informed management decisions when data is unavailable. Novel approaches to managing fisheries through the use of data-based indicators can potentially reduce the need for quantitatively complex stock assessment models. One such approach uses catch and size-based information gleaned from collaborative sampling of fish populations inside and outside of marine protected areas (MPAs). This MPA-based Decision Tree (DT) management strategy taps fishermen as a resource for collecting scale appropriate fishery data at minimal cost and integrates marine protected areas into fisheries assessment (Wilson et al. *in prep*). These increases in data, effectively contribute to better-informed decision making and management (Prince et al. *in prep*). This method is especially useful in fisheries like the nearshore live finfish fishery in the Northern Channel Islands that exhibits sub-population dynamics characterized by short dispersal distances, small adult home ranges, and little connectivity between populations. Implementation of the DT management strategy can improve efficiency and encourage the integration of collaborative research with science-based management.

Current management of the nearshore rockfish and cabezon fisheries is limited by a scarcity of data due to difficulties in collecting and aggregating information, a lack of staff and resources, and a biologically inappropriate management scale. Additionally, the current management structure does not provide incentives for fishermen to engage in data collection nor are mechanisms available through which populations can be managed on a scale appropriate to the species life history. Species within California's nearshore finfish complex exhibit short larval dispersal distances and sedentary adult life stages, resulting in distinct sub-population dynamics (Gunderson et al. 2008). As a result of these small-scale population dynamics as well as data limitations, little is known about the status of regional stocks. These problems have led to the assignment of precautionary catch limits, which contribute to economic inefficiencies and potential ecological harm (Fig. 1).

Passage of the 1998 California Marine Life Management Act (MLMA) requires the assessment and management of all state fisheries under Fishery Management Plans (FMPs). Of the 19 fish stocks occurring in the nearshore fishery, only five species have been assessed, primarily due to limitations in funding, staffing, and data needed to properly evaluate the fish stocks. In addition, the establishment of no-take marine protected areas throughout the Channel Islands in 2003 has increased the complexity of managing fisheries in this area. This has prompted fishermen, managers, and regulators

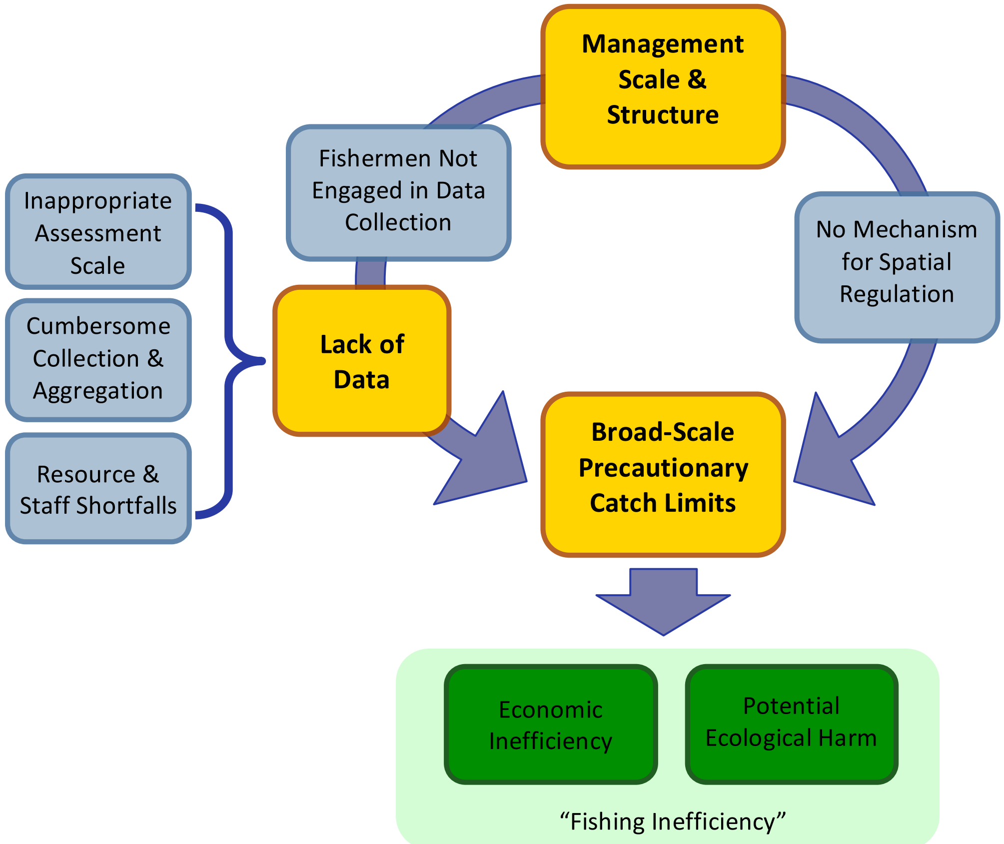

Figure 1. Conceptual diagram of the factors leading to "fishing inefficiency".

to seek workable and cost-effective methods for fisheries data collection, assessment, and management.

This project evaluated the potential for fishermen in the Channel Islands nearshore cabezon and grass rockfish fisheries to collect data for use in an alternative management strategy using the DT model. Through interviews with fishermen and development of data collection techniques, our group developed scenarios through which fishermen can organize in order to efficiently implement the DT method. Establishing more accurate stock assessments will move the nearshore fishery out of data-poor status and lead to sustainable fishery profits and fish stock health, fulfilling the interests of fishermen, managers, scientists, and conservation groups (Restrepo et al. 1998).

The mission statement of our client, the Environmental Defense Fund (EDF), aims to link "science, economics and law to create innovative, equitable and cost-effective solutions to society's most urgent environmental problems" (EDF 2008a). EDF has a commitment to sustaining American fisheries with innovative methods (EDF 2008b), but has yet to evaluate the DT management strategy. This group project will inform further EDF decisions concerning fisheries management within California and the potential for alternative research and management within the United States.

Furthermore, this project stems from existing collaborative research spearheaded by Jono Wilson, a University of California, Santa Barbara (UCSB) researcher and member of CaLobster. Working collaboratively with Santa Barbara nearshore fishermen, Wilson's research focuses on quantifying local sub-population dynamics of grass rockfish and cabezon and developing simple rules for managing marine resources, including the use of the DT. Wilson has extended Jeremy Prince's pioneering work on the DT to incorporate MPAs as reference points for unfished biomass, utilizing the sub-population dynamics at play at the Northern Channel Islands. In conjunction with Wilson's work, this project seeks to understand how the DT method can most efficiently be implemented to improve sustainability and profitability in the Santa Barbara nearshore live finfish fishery by moving management beyond broad-scale, data-poor, precautionary methods. Testing the DT with a case study fishery will advance general understanding of its strengths, weaknesses, and requirements. University researchers, EDF, the California Department of Fish and Game (CDFG), and the Channel Islands fishing community will benefit from the results of this study and the collaborative process through which it will take shape.

1.1 Current Fishery Legislation and Management

Due to the wide spread spatial distribution of fish populations, a variety of federal and state agencies have jurisdictional authority derived from multiple pieces of legislation. At the federal level, the Magnuson-Stevens Act (MSA), first enacted in 1976, divided coastal states into eight regions and established Fishery Management Councils to oversee fisheries management in each area. At the state level, California's MLMA, enacted in 1998, implemented regulations for nearshore fisheries. These fisheries, both commercial and recreational, target certain finfish species in nearshore waters (species list in Table 1). Nearshore waters are defined as waters extending from the shore to depths of 20 fathoms (~40 meters), including rocks and islands (California Seafood Council 2001).

Under both the MSA and the MLMA, agencies create Fishery Management Plans (FMPs) for individual species and groups of closely related species, which are used by enforcement agencies such as CDFG to regulate fisheries. When the MLMA was enacted in 1998, it called for stock assessments of the nearshore California fisheries. California's nearshore finfish complex includes 19 species (Family: *Scopaenidae* (15 species), *Hexigrammidae* (2 species), *Labridae* (1 species) and *Stichaeidae* (1 species)). Sixteen of these 19 species are managed concurrently at the State level under California's Nearshore Fishery Management Plan (NFMP) as well as at the Federal level by the Pacific Fisheries Management Council (PFMC) under the Groundfish Management Plan (PFMC 2008). Typically the State provides management recommendations that must be accepted by the PFMC at the Federal level (Field et al. 2008). The remaining three species (California sheephead, rock greenling and monkeyface prickleback) are managed solely at the State level, as their home ranges are entirely within state waters.

Primarily due to data limitations, only 5 of the 16 species managed by the PFMC have been formally assessed (gopher rockfish, cabezon, California scorpionfish, blue rockfish and black rockfish), and most of these assessments are considered to be data-poor or data limited (Field et al. 2008). The remaining 11 species have even less data available for conventional stock assessments; with little to no fishery-independent trend data and fairly small amounts of species specific life history data. Without a formal stock assessment, these species are managed under an approach that is considered precautionary. For these species the total allowable catch (TAC) level is set at a fraction of the catch levels that have been considered stable historically, and is thus highly conservative (Wilson et al *in prep*).

Species Name	2007 Commercial Landings (lbs)
Black rockfish *	178,413
Black-and-Yellow rockfish	22,729
Blue rockfish *	38,236
Brown rockfish	48,318
Calico rockfish	N/A
China rockfish	9,246
Copper rockfish	11,549
Gopher rockfish	44,155
Grass rockfish	41,986
Kelp rockfish	1,008
Olive rockfish	2,414
Quillback rockfish	14,491
Treefish	2,452
Cabezon *	56,053
California scorpionfish *	7,831
California Sheephead *	67,869
Kelp Greenling *	3,295
Rock Greenling	1
Monkeyface Prickleback	50

Table 1. Species covered by the CA Nearshore Fishery Management Plan and 2007 commercial landings, in pounds. Species in italics are the focus of our case study. * Indicates a stock assessment has been performed for that species. Source: CDFG 2009a.

This scarcity of data stems from a lack of resources to collect and aggregate the data, as well as an inability to build spatial variation into current stock assessments on appropriate scales (Fig. 1). Engaging stakeholders, such as fishermen, in data collection may assist in overcoming some of these barriers to data collection. Both the MLMA and the MSA contain language that supports collaborative research methods (see Section 3). Cooperative data collection and management, coupled with increased cooperation among scientists, non-profits, and Channel Islands fishermen, is a promising option for the Channel Islands nearshore live finfish fishery.

1.2 Traditional Stock Assessments

Traditional fisheries stock assessments use complex, quantitative population dynamic models to establish the status of single species fish stocks, specify Optimum Yield (OY), and develop reference points to guide management decisions (Restrepo et al. 1998). These traditional stock assessments require large amounts of data across time and space, and as a result estimates of actual stock size and unfished biomass are most associated with uncertainty that scales with the lack of data (Hilborn 2003; Hilborn & Walters 1992). Conventional stock assessments usually apply to large habitat areas, and thus overlook biological heterogeneity as well as spatial variability in fishing behavior and economic drivers. While these complicated models are the convention within the United States, growing consensus shows that these methods are inappropriate in many nearshore finfish fisheries, whose life history characteristics and population dynamics are not well suited for large-scale stock assessment methods (Grafton et al. 2006; Gunderson et al. 2008). Species within California's nearshore finfish complex are characterized by meta-population dynamics and dominated by sedentary adult stages that result in distinctive sub-populations more susceptible to depletion through localized fishing pressure (Orenzans 2005; Gunderson et al 2008). Conventional stock assessment methods based on fitting population models to available fisheries data have the power to be informative under data rich circumstances. However, when data availability is limited, so too is the power of these conventional assessments to inform management.

In 1998, Fisheries Management Councils were directed to change their management paradigms and "adopt a precautionary approach to specification of OY" by the Guidelines for National Standard 1 (Optimum Yield) of the MSA (50 CFR Part 600). This precautionary approach to fisheries management sets conservative catch limits in situations where there is little scientific evidence of stock overexploitation (Restrepo et al. 1998). As such, Restrepo et al. (1998) guides stock assessors to exercise increased precaution as data uncertainty grows. Restrepo et al (1998) is a technical NOAA Memorandum and is now considered to be the ultimate guide for managers on specifying OY and developing appropriate harvest reference points.

1.3 Alternative Management Strategies and the Decision Tree

Alternative management strategies can use data more easily collected and employ models that are less complicated than traditional assessment models. The most locally applicable and adaptable of these methods to date is the DT (Prince et al. 2008). The DT derives population dynamics information from the size structure of fish catches and catch per unit effort (CPUE) to create a snapshot of stock status relative to a selected baseline (Prince et al. 2008). Catch rates are then adjusted according to the relationship between current catch and size structure relative to target reference points gleaned from the selected baseline. The model is informed primarily by a relative measure (i.e. size structure and CPUE), and not an absolute measure (e.g. unfished biomass), enabling application at the scale most appropriate to the species being assessed. The DT can be used on spatially-explicit scales, enabling managers to collect, monitor, interpret, and adjust catch levels in a circumscribed area, or alternatively at a fishery-wide scale, to monitor the overall status of sub-populations. In the context of this project, the DT is modified to utilize MPA data as an unfished baseline, in accordance with the model currently under development by Bren School doctoral candidate Jono Wilson (Wilson et al. *in prep*). Additionally, this model assesses populations on a spatially explicit scale in order to align the scale of management with the scale of biological function. Furthermore, an innovative method of obtaining the necessary model input data at such fine resolution involves incorporating local fishermen in data collection.

The Channel Islands grass rockfish and cabezon fisheries are excellent candidates for alternative management strategies such as the DT. They are small, data-poor fisheries, and an established relationship with between fishermen and UCSB researchers currently exists. However, knowledge of size and age distribution, and the historical baseline against which these are measured, is severely limited. The Channel Islands no-take marine protected areas present an opportunity to establish reference points against which fishery-based data can be compared, leading to better-informed management decisions. Furthermore, the CDFG is open to considering new approaches to estimating stock status that are peer-reviewed and quantitative (Phipps et al. *in press*). The DT method may provide an appropriate first test case in the nearshore live finfish fishery. While reference points for many West Coast rockfish stock assessments are difficult to set due to a lack of data required by traditional assessments (Hilborn et al. 2002), data required by the DT is easily collected for both species. Both fisheries management and conservation efforts stand to be improved by the integration of MPAs into fisheries assessment.

1.4 Alternative Data Collection

In addition to engaging fishermen in data collection, alternative management strategies can potentially resolve the problems associated with data scarcity for fisheries where traditional assessments have been ineffective. Traditional assessments require large amounts of data and are often applied at large spatial scales that are poorly matched with the biology of target species and effort distribution of the fishery. Data collection for stock assessments has traditionally relied on a mix of fishery-dependent and fishery-independent data sources (Cooper 2006). Fishery-dependent data include landing records, port sampling, onboard observers, log books, and vessel trip reports. Fishery-independent data comes from scientific surveys conducted with standardized sampling gear appropriate to the fishery being assessed. Some of these data sources have characteristics that limit their contribution to stock assessments. For example, landing records usually do not provide precise enough sample size structure information to be useful in a stock assessment, and the expense of scientific dive surveys limits the scope and volume of data that can be collected. However, the greatest limitation to comprehensive stock assessments is a fundamental lack of continuous datasets through time. The resources needed to collect data for traditional stock assessments are extensive, and it is unlikely data requirements will be met for most fish stocks.

The development of novel approaches to data collection, however, has improved fisheries data. New techniques and equipment can solve many of the shortfalls (expense, staffing, handling time/effort) inherent in traditional data collection practices. For example, Northwest Canada's British Columbia groundfish fishery has instituted the use of 200 video-based monitoring systems for its 230-vessel fleet. In so doing they have achieved 100% at-sea monitoring for the entire fleet at a cost of roughly $150 per seaday, fostered unprecedented cooperation between fishermen and regulators, and created a data-rich platform for solving fishery problems (McElderry 2008). The fishery's technology partner, Archipelago Marine Research, has developed video-based fishery monitoring technology, and conducted over 25 studies over the last decade, spanning a range of geographies, fisheries, and vessel/gear types (McElderry 2008). Other promising technological applications have been employed in assessing fish stocks for the aquaculture industry. Providers like Iceland-based Vaki Aquaculture Systems employ a variety of optical, electric, and mechanical techniques for scanning and recording fish sizes for a range of fisheries (McElderry & Gislason 2008). Together these technology providers offer hope for overcoming the staffing and resource barriers to creating robust stores of fishery-dependent data.

2. The Santa Barbara Nearshore Fisheries

The commercial live finfish fishery in California began in the late 1980s, and by the 1990s had evolved from a specialty market to a multimillion-dollar industry. This success resulted from consumers' increasing willingness to pay for live fish, particularly plate-sized fish (Lucas 2006). Since 1994, when the differentiation between live and dead landed fish in recordkeeping began, the number of fishermen landing live fish has decreased, in part due to stricter regulations, while the average price for live fish has increased (Lucas 2006).

With the implementation of the Nearshore Fishery Management Plan (NFMP), CDFG established a restricted access program that reduced the number permits and landings over a set time period (CDFG 2002). In 1999 there were 1,100 nearshore permittees. In 2003 this number was reduced to 276, and gear endorsements for trap use were introduced (CDFG 2004a). That same year, the California Fish and Game Commission established a cumulative trip limit, restricting each permittee to a maximum trip limit for any given two-month period (CDFG 2004b). Once the total allowable catch is reached for the season, the fishery is closed until the next year. While limited to a small number of individuals, fishery profits and market prices continue to increase each year (Lucas 2006).

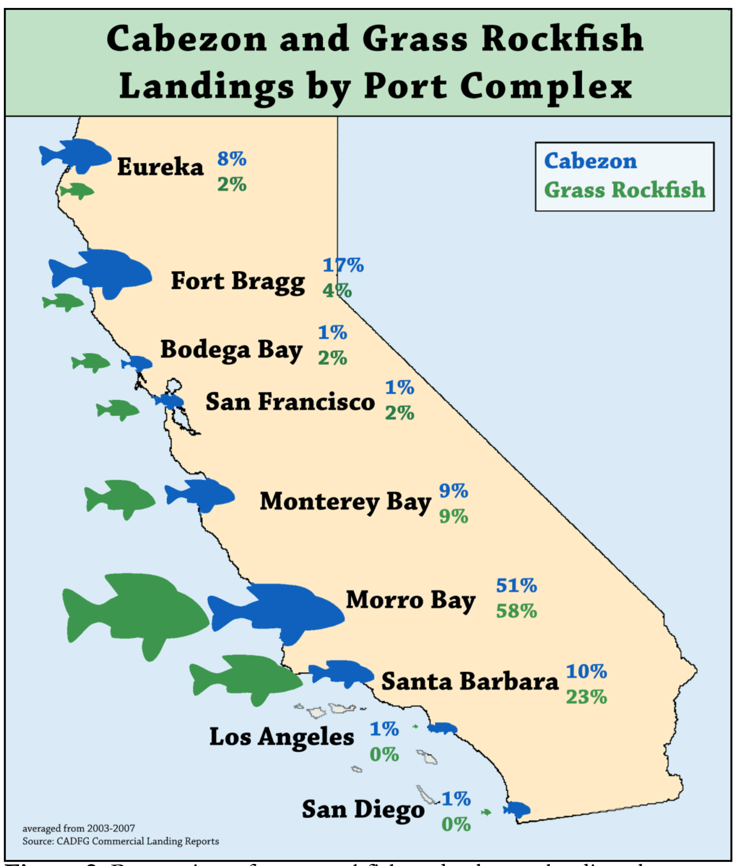

Figure 2. Proportion of grass rockfish and cabezon landings by port complex for CA, averaged from 2003-2007. Source: CDFG 2009b.

To commercially fish cabezon and grass rockfish, each fisherman is required to obtain a South Coast Region Nearshore Fishery Permit (SCR NFP). Three primary methods used to fish these species are sticks, rods and traps. An additional trap endorsement (trap permit) is required for fishermen using traps. Currently, CDFG issues and regulates these permits. During the initial years of the fishery, bycatch of non-targeted species was

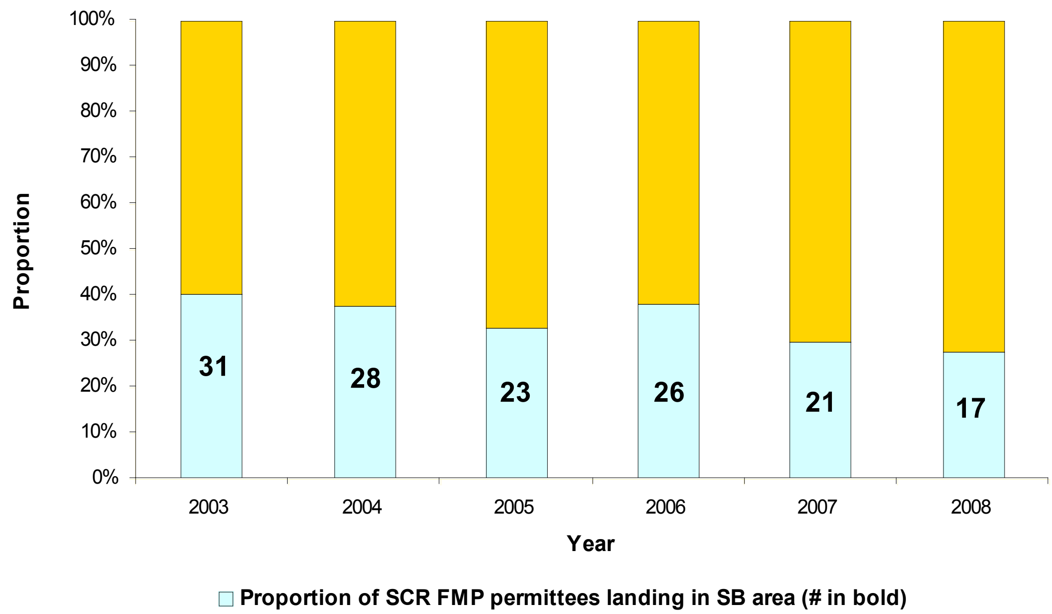

Figure 3. Proportion of SCR NFP permittees (# in bold) landing nearshore species in the Santa Barbara port complex (2003-2008). Source: Key 2008.

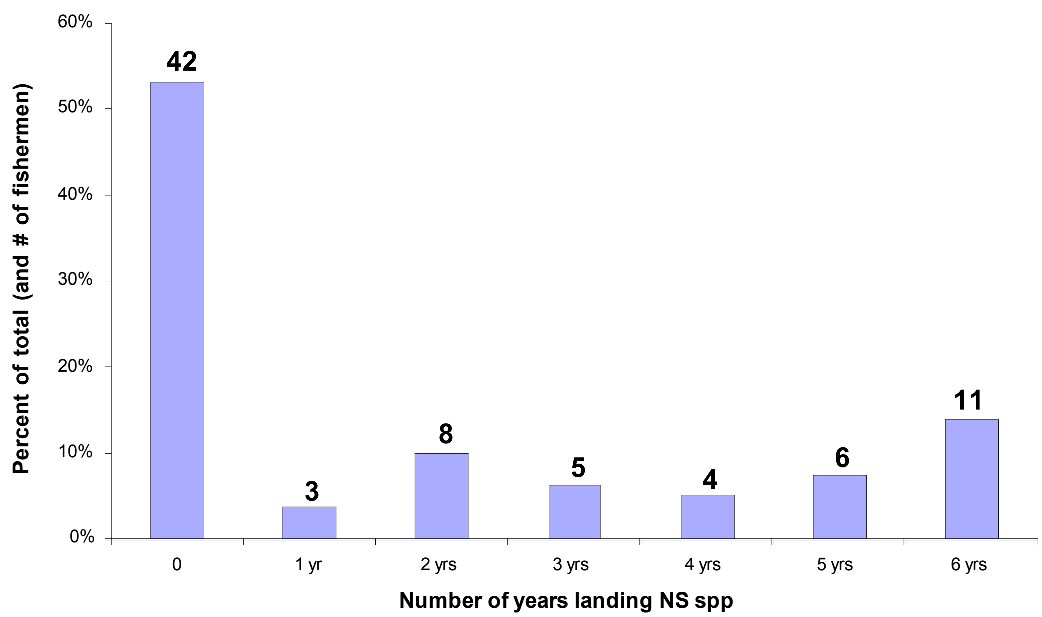

Figure 4. The proportion of South Coast Region Nearshore Fishery Permit (SCR NFP) holders making nearshore landings (by number of years) in the Santa Barbara port complex (2003-2008). Source: Key 2008.

a concern as rockfish often live in multi-species aggregations. This is especially a problem for deeper-dwelling species whose low survival upon release results from swim bladder over-inflation as they are quickly brought up to the surface. Area and depth closures implemented by CDFG, implemented in 2001, have been used to reduce bycatch of species of concern that are found at deeper depths, such as copper rockfish (Bergen et al. 2008; Lucas 2006). Grass rockfish and cabezon are fished in shallow waters, so the Nearshore fishery does not experience problems associated with this type of bycatch.

Fisheries data from the Santa Barbara port complex includes landings from ports at Gaviota Beach, Port Hueneme, Oxnard/Channel Islands Harbor, Santa Barbara Harbor, Ventura, Goleta Beach, Guadalupe Beach, Surf Beach and Carpinteria. The Santa Barbara port complex is an important contributor to the California nearshore fishery (Fig. 2; Table 2). Approximately 40% of active fishermen in the South Coast nearshore fishery made landings in the Santa Barbara area in 2008 (Key 2008; Fig. 3). While there are a total of 42 permits not landings in Santa Barbara, many of these individuals may be landings in other ports, such as Los Angeles or San Diego (Key 2008; Fig. 4).

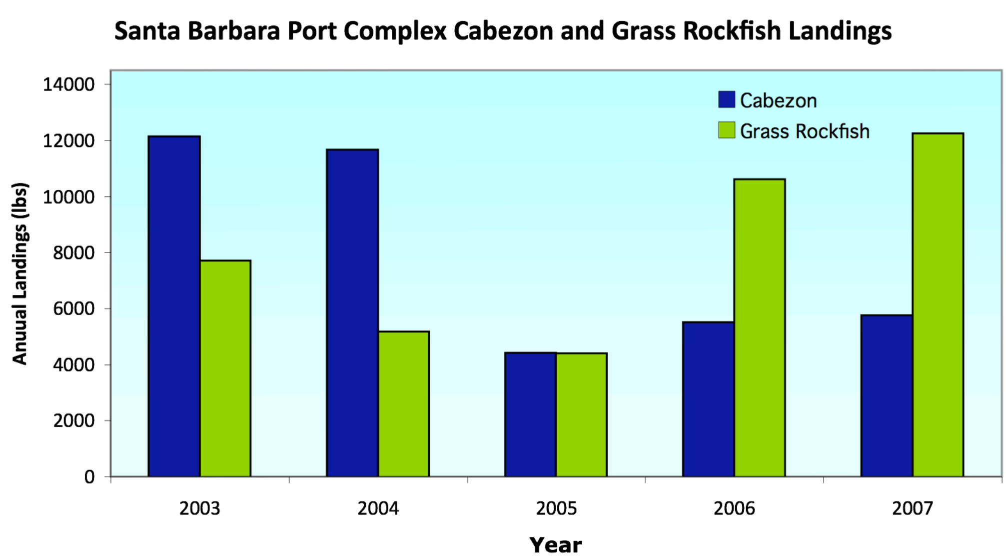

Figure 5. Landings of grass rockfish and cabezon from the Santa Barbara port complex for 2003-2007. Source: Key 2008.

This study chose to focus on the cabezon and grass rockfish live finfish fisheries because they are good candidates for alternative management strategies, and the DT method in particular. The small nature of the fishery enables more coordinated organization of the fishermen involved and increases the potential for consensus building. Grass rockfish is considered data-poor, while cabezon falls into the data moderate classification (Restrepo et al. 1998). In 2007, there were 16 nearshore permittees landing cabezon and 13 landing grass rockfish in the Santa Barbara port complex (Key 2008). These numbers have remained relatively constant over the last five years. This consistency through time has assisted in the development of collaborative research efforts between the fishery and UCSB researchers.

In the last five years, grass rockfish landings have increased, while cabezon landings have remained relatively constant, with the exception of a decline in 2005 (Fig. 5). Prior to a 2003 restructuring of the fishery, state-wide cabezon landings had been declining due to decreasing TACs, leading to unmet market demand in California. Live fish brought to California from Oregon filled this demand. In 2003, 39% of the live cabezon sold in California came from Oregon (CDFG 2004b). Low catch of cabezon in 2005 may reflect out-of-state competition, adjusted fishing effort, or shifts in the market price for alternative seafood. For example, in 2008 many of the 61 permits in the nearshore fishery in the South Coast also held permits in other fisheries, including southern rock crab (40), lobster (39), urchin (15), and sea cucumber (11) (Key 2008). The average price per pound for grass rockfish and cabezon has increased in recent years. Both the cabezon and grass rockfish fisheries in the Santa Barbara port complex receive the highest price per pound in the state. (Table 2). Fishermen in Santa Barbara currently receive $11.75 per pound for grass rockfish, $8.50 per pound for a plate-sized cabezon, and $3.50 per pound for a large cabezon (fishermen interviews).

Port Complex Rankings							
By Average Annual Landings				By Average Annual Price/lb			
Grass	lbs	**Cabezon**	lbs	**Grass**	Price/lb	**Cabezon**	Price/lb
Morro Bay	19158	**Morro Bay**	38928	**Santa Barbara**	$10.94	**Santa Barbara**	$5.77
Santa Barbara	8029	**Fort Bragg**	13626	**Morro Bay**	$9.39	**Monterey**	$5.44
Monterey	3046	**Santa Barbara**	7899	**Monterey**	$8.78	**Morro Bay**	$5.36
Fort Bragg	1356	**Monterey**	7048	**Fort Bragg**	$7.18	**San Diego**	$4.75
Eureka	708	**Eureka**	5892	**Eureka**	$6.19	**San Francisco**	$4.46
San Francisco	674	**Bodega Bay**	1073	**Bodega Bay**	$5.75	**Fort Bragg**	$4.39
Bodega Bay	554	**San Francisco**	970	**San Francisco**	$5.67	**Los Angeles**	$3.86
San Diego	33	**San Diego**	634	**San Diego**	$5.46	**Bodega Bay**	$3.57
Los Angeles	4	**Los Angeles**	450	**Los Angeles**	$4.65	**Eureka**	$3.50

Table 2. Landings totals and values are averaged from 2003-2007. Source: CDFG 2009b.

The nearshore live finfish fishery is an important component of Santa Barbara's fishing economy, and available data does not provide sufficient information for accurate management decisions. Employing an alternative management strategy, such as the DT, has the potential to increase profits to the fishery and reduce the risk of overfishing by collecting spatially explicit data on fish populations. In addition, the formation of a formal nearshore live finfish fishermen organization, such as a cooperative, may help establish trust between fishermen and CDFG, incentivize participation in data collection for an alternative management strategy, and make the fishery more efficient and profitable.

2.1 Cabezon and Grass Rockfish Biology

Cabezon (*Scorpaenichthys marmoratus*) populations are found from Point Abreojos, Baja California, Mexico to Sitka, AK, USA, typically occurring in the nearshore region at depths from the intertidal zone to 102 meters. As individuals mature, cabezon are also found in deeper water. Spawning begins in October, reaching a peak in January, and ending in March. Females lay eggs in crevices and under rocks in the intertidal and subtidal zones and the males fertilize and guard the eggs for a 2-3 week maturation period (CDFG 2002). Adult cabezon eat small spiny lobster, mollusks, small fish, fish eggs, and crabs (CDFG 2002). Cabezon prefer rocky reef areas and kelp beds and are considered "sit and wait" predators, typically resting on the bottom rather than actively swimming to pursue their prey (CDFG 2002). Additionally, relatively large numbers of cabezon inhabit offshore oil platforms. Over the course of their life span, cabezon typically do not move more than 5 m^2 from the initial location where they settle (Nakamura et al. 2009).

Grass rockfish (*Sebastes rastrelliger*) are found from Yaquina Bay, Oregon to Baja, Mexico, occurring in the nearshore region as deep as 43 meters, but mostly found shallower than 14 meters (Fishbase 2008). After their pelagic juvenile phase, grass rockfish settle on kelp beds and rocky reefs as residents and tend to stay within their home range (CDFG 2002). The maximum recorded age for grass rockfish is 23 years, and the maximum recorded length is 22 inches. Spawning for grass rockfish in California occurs between November and March, with a peak in January (CDFG 2002). Grass rockfish are commonly found from the intertidal zone to 6 meters and have one of the most shallow and narrow depth ranges for rockfish species (CDFG 2002). No stock assessment has been completed for this species and due to the narrow and shallow depth range where they occur; they may be heavily impacted by recreational and commercial fishing (CDFG 2002).

2.3 Existing Management Context

Until recently, both cabezon and grass rockfish fisheries were operating under data-poor fisheries management conditions. According to the NFMP, 2002 stock status data for cabezon had "limited information available on population biology or changes in biomass over time" (CDFG 2002). In 2003, a formal stock assessment for cabezon was undertaken, resulting in a reduction in the TAC. This assessment moved the cabezon fishery from data-poor status to data moderate. While the TAC decreased, the allocation ratio of 61:39 between recreational and commercial fisheries remained the same (CDFG 2004b). Grass rockfish have not been assessed and are managed using the precautionary principle under the NFMP. However, the TAC for grass rockfish has increased since 2005, while the TAC for cabezon has decreased (Fig. 6). Garnering additional data about these species would allow the fishery to move out of this data-poor, conservative management scenario.

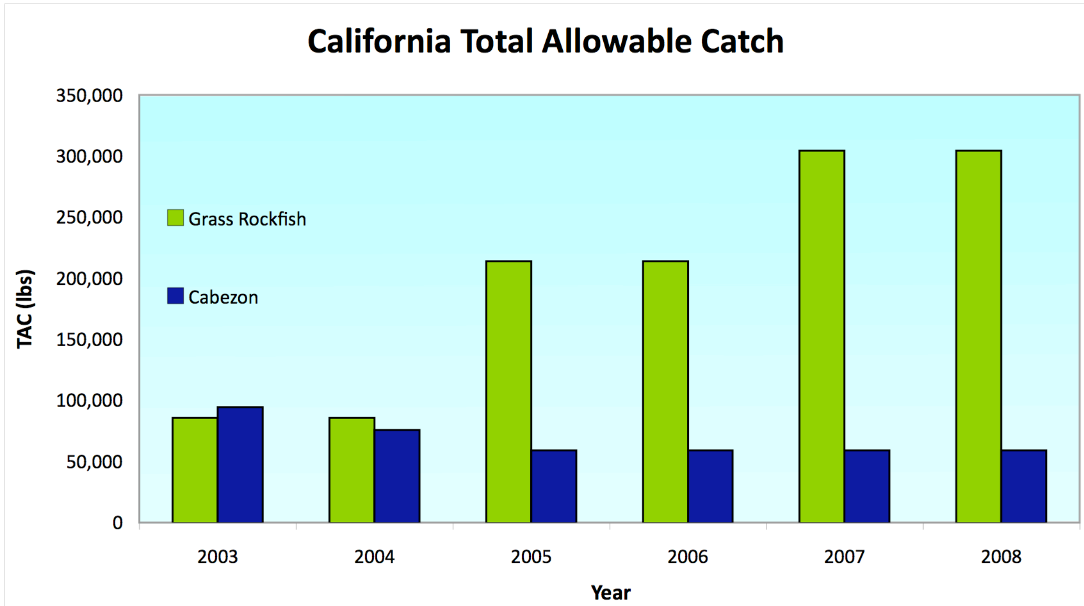

Figure 6. Total allowable catch (TAC) for cabezon and grass rockfish from 2003-2009. Source: CDFG 2008.

It is clear the limited nature of California's fishery data has led to management of many nearshore species under severely draconian and under-informed catch regulations. Likewise, this lack of data has also hindered adequate implementation of both the recent MLMA and Marine Life Protection Act (MLPA) (Culver et al. 2008). The MLMA requires state managers to develop fisheries management plans for all species within their jurisdictions (CDFG 2002). However, as mentioned previously, only a handful of species have formal assessments.

The MLPA further requires collection of essential fisheries data to evaluate the effectiveness of the State's burgeoning MPA network. Due primarily to the high costs associated with the collection of fishery data, many of California's fishery related policies are not being implemented to the fullest extent and management decisions remain under-informed. Thus, to improve the assessment and management of California's fisheries resources and comply with state-mandated legislation, it is necessary to develop and implement alternative management strategies. To perform spatially explicit management strategies (e.g. the DT), a fishery needs both a spatially capable data collection method and the data-management infrastructure to obtain the required inputs. These methods, combined with alternative strategies, may be better equipped to diagnose the status of stocks and sub-stocks while keeping data collection costs at a minimum.

3. Legal Setting

Due to the extensive nature of the legal jurisdictions concerning fisheries issues, this section will highlight a few key national and state acts that pertain to the grass rockfish and cabezon fisheries. These are:

- Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. §§ 1801-1884)
- California Marine Life Management Act (MLMA) (Cal. Fish & Game Code §§ 7050-7090)
- California Marine Life Protection Act (MLPA) (Cal. Fish & Game Code §§ 2850-2863)
- California Ocean Protection Act (COPA) (Cal. Public Resources Code §§ 35500-35650)
- California Assembly Bill No. 1280 (Cal. Public Resources Code § 35650)

In addition to an overview of pertinent statutes, this section will also discuss how the DT alternative management strategy fits into the current legislative framework.

3.1 Magnuson-Stevens Act

First enacted in 1976, the Magnuson-Stevens Act (MSA) is the primary law establishing federal regulations for fisheries management and assessment within the United States. The act was originally developed to phase out foreign fishing within the nation's Exclusive Economic Zone and aid in the establishment of fishery management policies to help reduce overfishing. The MSA also created federal Fishery Management Councils for eight regions throughout the United States. The Pacific Fishery Management Council (PFMC) regulates species along the United States West Coast and includes members from Washington, Oregon, Idaho, and California. As mandated by the MSA, the PFMC creates FMPs for West Coast species, such as cabezon and grass rockfish, whose ranges straddle state boundaries. Conversely, species confined to one state's waters, like California sheephead, are regulated exclusively through California FMPs. State FMP regulations are required to be at least as stringent as federal FMPs (CDFG 2008b) and must meet all ten MSA National Standards. The MSA Standards include preventing overfishing, utilizing the best scientific information available, allocating fishing privileges equitably, and minimizing bycatch (MSA § 301).

In addition to mandating the management of national fish stocks, the Magnuson-Stevens Act also requires the development of a cooperative research and management program. The MSA states:

> The Secretary of Commerce, in consultation with the Councils, shall establish a cooperative research and management program to address needs identified under this Act and under any other marine resource laws enforced by the Secretary. The program shall be implemented on a regional basis and shall be developed and conducted through partnerships among Federal, State, and Tribal managers and scientists (including interstate fishery commissions), fishing industry participants (including use of commercial charter or recreational vessels for gathering data), and educational institutions. (MSA § 318 (a))

The MSA clearly calls for the joint cooperation between fishery managers and participants, such as commercial fishermen. By utilizing the DT and incorporating fishermen-collected data into the decision-making process, local fishermen and state managers can create a program that fits the MSA's legal requirements.

In support of mandated cooperative programs, the MSA sets aside funding for priority projects as determined by the Councils. As stated in section 318 (c) of the MSA, priority projects are:

> (1) Projects to collect data to improve, supplement, or enhance stock assessments, including the use of fishing vessels or acoustic or other marine technology.
> (2) Projects to assess the amount and type of bycatch or post-release mortality occurring in a fishery.
> (3) Conservation engineering projects designed to reduce bycatch, including avoidance of post-release mortality, reduction of bycatch in high seas fisheries, and transfer of such fishing technologies to other nations.
> (4) Projects for the identification of habitat areas of particular concern and for habitat conservation.
> (5) Projects designed to collect and compile economic and social data.

The MSA Appendix also calls for the creation of a Fisheries Conservation and Management Fund (P.L. 109-479, § 208). Monies in this fund are to be used for a variety of activities that correlate with the DT method. They include the following:

> (1) Efforts to improve fishery harvest data collection including—
> (A) Expanding the use of electronic catch reporting programs and technology; and
> (B) Improvement of monitoring and observer coverage through the expanded use of electronic monitoring devices and satellite tracking systems such as VMS on small vessels;
> (2) Cooperative fishery research and analysis, in collaboration with fishery participants, academic institutions, community residents, and other interested parties; and
> (3) Improving data collection under the Marine Recreational Fishery Statistics Survey in accordance with section 401(g)(3) of the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1881(g)(3)).

The DT falls within project categories of both funding sources described above. Specifically, the DT method contributes to "[p]rojects to collect data to improve, supplement, or enhance stock assessments" (§ 318 (c)(1)) and "efforts to improve fishery harvest data collection" (P.L. 109-479, § 208 (1)). These goals can be achieved by empowering fishermen to collect fish size and location data both inside and outside reserve boundaries. This increases opportunities for data collection and therefore the amount of information gathered over a specific period. The additional fishery data will in turn help inform stock assessments and management decisions. The DT clearly creates an opportunity for "cooperative fishery research and analysis, in collaboration with fishery participants" (P.L. 109-479, § 208 (2)) by directly incorporating fishermen into the data collection process. Though the DT method represents a departure from conventional assessment, the Magnuson-Stevens Act nevertheless contains language supporting its use.

3.2 California Marine Life Management Act

Adopted in 1998, the California Marine Life Management Act (MLMA) established California commercial and recreational fisheries policy by requiring all state fisheries to be assessed and managed under fishery management plans. A central tenet of the MLMA is collaboration and public involvement in fisheries management, assessment, and monitoring activities (Cal. Fish & Game Code § 7050 (b)(7); § 7059). The MLMA maintains:

> Successful fishery management is a *collaborative* process that requires a high degree of ongoing communication and participation of all those involved in the management process, particularly the commission, the department, and those who represent the people and resources that will be most affected by fishery management decisions, especially *fishery participants* and other interested parties. (Cal. Fish & Game Code § 7059 (a)(1), emphasis added)

The Master Plan further states "[t]he public at large, and more specifically members of the fishing community, have a collective knowledge of fisheries which should be used by resource managers" (CDFG 2001 § 4.6). The MLMA mentions data collection as one venue for establishing working relationships between parties. It states, "[s]uccessful collaboration [ ] involves fishermen in research design, and in the objective collection and analysis of data. Collaborative research recognizes and values the fishing industry's experience, knowledge and observations" (CDFG 2001 § 5.2.4). The DT manifests this collaborative effort through the cooperation among local fishermen, scientists, fisheries managers, and state and federal policy makers. Collaborative research among these stakeholders through the use of the DT method increases general knowledge about the fishery, improves data collection efficiency, and creates a forum for improving management practices.

According to the MLMA, essential fishery information, gathered from fishery-dependent and independent methods, is vital for successful fisheries management (CDFG 2001). Such information contains data on "fish life history and habitat requirements; the status and trends of fish populations, fishing effort, and catch levels; fishery effects on fish age structure and on other marine living resources and users" (Cal. Fish & Game Code § 93). Fishermen-collected data gathered specifically for use in the DT would include information on fish stock status, catch per unit effort, landings, discards, and fishing effects on age structure within a population. The MLMA also states "…that acquiring essential fishery information can best be accomplished through the ongoing cooperation and collaboration of participants in fisheries" (Cal. Fish & Game Code § 7060 (a)). Furthermore, the MLMA asserts that CDFG "…shall encourage the participation of fishermen in fisheries research within a framework that ensures…the collaboration of fishermen in research design, and the cooperation of fishermen in carrying out research" (Cal. Fish & Game Code § 7060 (c)). Not only does the DT increase essential fishery information through the use of spatially explicit fishermen-collected data, but it also establishes a framework for collaboration between managers and fishermen.

The MLMA specifically allows fishermen involvement in the creation and implementation of management plans (Cal. Fish & Game Code § 7073 (b)(4)). Along with the benefits of shared knowledge, partnering fishermen and managing agencies reduce costs associated with the assessments inherent to FMPs and the collection of essential fishery information. Collaborative research, as described in the DT, is clearly supported, and even encouraged, within the MLMA.

3.3 California Marine Life Protection Act

Passed by state legislators in 1999, the California Marine Life Protection Act (MLPA) dictates CDFG to establish and manage a network of MPAs along the California coastline in all state waters (three nautical miles from shore). Such a system would help protect the state's natural resources and biodiversity, rebuild fish stocks, and provide a biological baseline for research purposes. The MLPA is a vehicle for reassessing and potentially redesigning existing MPAs that were not initially established under a comprehensive plan. CDFG has already constructed an MPA network in California's Central Coast region, and a North-Central Coast network is expected soon. The focus of this process has now turned to Southern California.

Thus far, proponents of MPAs have focused on benefits to conservation and recreation. However, the potential to use MPAs as a fishery management tool has not been fully explored. MPAs have potential to provide baseline information that can inform stock assessments required under the MLMA. According to the MLPA, "The designation of certain areas as sea life reserves can help expand our knowledge by providing baseline information and improving our understanding of ecosystems where minimal disturbance occurs" (Cal. Fish & Game Code § 2851 (e)). The MLPA Master Plan also states that "[o]ne role of MPAs is to act as reference sites for comparison with less protected populations or communities" (CDFG 2008b). Due to the prohibition of fishing inside reserves, the DT specifically uses MPAs as comparative baselines in order to determine a total allowable catch limit for the fishery, a method supported by the MLMA.

The MLPA also stresses the importance of monitoring and evaluating California's reserves. For example, the Marine Life Protection Program developed under the MLPA must "include provisions for monitoring, research, and evaluation…to facilitate [ ] management of MPAs" (Cal. Fish & Game Code § 2853 (c)(3)). In addition, the MLPA Master Plan states "[t]he law embeds…monitoring [ ] and evaluation into the state policies relating to the management of MPAs. This approach will require the state to develop and implement a monitoring, evaluation, and adaptive management program" (CDFG 2008b Sec. 6.0). Furthermore, the Act emphasizes the importance of fishermen involvement in this process stating, "monitoring and evaluation programs can benefit from engaging commercial and recreational fishermen…The Channel Islands National Marine Sanctuary Foundation supports a Cooperative Marine Research Program which helps coordinate and fund fisheries/science cooperative monitoring projects" (CDFG 2008b Sec. 6.2.2). Finally, the MLPA Master Plan acknowledges the additional cost savings associated with engaging the general public in monitoring and evaluation activities.

> A cost effective approach in many areas may be to link these activities to other ongoing monitoring activities. Similarly there may be many opportunities to involve affected stakeholders and members of the general public in monitoring and evaluation activities as well, thus leveraging further the resources available. (CDFG 2008b Sec. 6.0)

Fishermen-collected data gathered from inside reserves for use in the DT model could easily be used in other monitoring and evaluation frameworks. For example, the Channel Islands National Marine Sanctuary (CINMS) is currently focused on "evaluating ecosystem health, collecting data on living marine resources, assessing the impact of human activities, [and] implementing effective resource management strategies" around the islands (CINMS 2009). Data gathered for use in the DT could also be used in CINMS research and evaluations. This dual use would foster increased understanding of populations within MPAs while cutting costs and involving fishermen in the data gathering process. Such practice is clearly supported in the MLPA and its associated Master Plan.

3.4 California Ocean Protection Act & A.B. 1280

Authorized in 2004, the California Ocean Protection Act (COPA) established the Ocean Protection Council, a state entity charged with reconciling ocean and coastal management between multiple agencies. COPA shifts management focus away from single species toward entire ecosystems, and promotes the creation of protected reserves, conservation areas, and public parks. COPA acknowledges the link between land-based activity and ocean health, as well as the importance of science and monitoring. It states: "A goal of all state actions shall be to improve monitoring and data gathering, and advance scientific understanding, to continually improve efforts to protect, conserve, restore, and manage coastal waters and ocean ecosystems" (Cal. Public Resources Code § 35510 (b)(4)). Using the DT framework to gather information inside and outside reserves, fishermen-collected data would answer the COPA mandate to increase monitoring efforts and scientific understanding.

In addition to launching the Ocean Protection Council, COPA created the California Ocean Protection Trust Fund. The fund, which receives money from the California State Treasury, is intended for "grants or loans…for, or direct expenditures on, projects or activities" that protect or enhance ocean and coastal ecosystems (Cal. Public Resources Code § 35650 (b)(2)). With the signing of A.B. 1280 in 2007 by Governor Schwarzenegger, Trust Fund money can also be allocated to developing and implementing fishery management plans. Sections 35650 (b)(2)(B) and 35650 (b)(2)(C) were amended to state that monies in the fund can be used for the following activities:

(B) Improve the management of fisheries through grants or loans for the development and implementation of fishery management plans…that promote long-term stewardship and collaboration with fishery participants to develop strategies that increase environmental and economic sustainability…Eligible expenditures include, but are not limited to, costs related to…fishery research, monitoring, data collection and analysis to support adaptive management, and other costs related to the development and implementation of a fishery management plan developed pursuant to this subparagraph.

(C) Foster sustainable fisheries, including grants or loans for one or more of the following:

- (i) Projects that encourage the development and use of more selective fishing gear.
- (ii) The design of community-based or cooperative management mechanisms that promote long-term stewardship and collaboration with fishery participants to develop strategies that increase environmental and economic sustainability.
- (iii) Collaborative research and demonstration projects between fishery participants, scientists, and other interested parties.

Assembly Bill 1280 altered COPA to include the development and implementation of FMPs, cooperative management, and collaborative research between fishermen and scientists. COPA also enables Trust Fund money to be used on activities that "[p]rovide monitoring and scientific data" (Cal. Public Resources Code § 35650 (b)(2)(G)). The DT utilizes this type of data.

Money for collaborative research, data gathering, and monitoring is available through COPA and the Ocean Protection Council. The DT model falls under the purview of COPA funding due to collaboration between fishermen and scientists in data gathering efforts. COPA may also provide an outlet through which money could be obtained to compensate fishermen for collecting data and funding future cabezon and grass rockfish assessments.

3.5 Synthesis

The MSA, MLMA, MLPA, and COPA all mandate collaboration among policy makers, managers, and fishery participants. The legislation also acknowledges the need for more data in order to effectively manage the nation's fisheries. As previously mentioned, the MLMA requires California fisheries to be managed under FMPs, an objective requiring a large amount of population data. Unfortunately, due to resource restrictions, very few of the nearshore fish stocks have been assessed. Even species with stock assessments, such as cabezon, are managed under a strict precautionary approach, due in part to a lack of spatially-explicit data. It is important to note that no current state or federal legislation specifies a stock assessment method, thus creating an opportunity for the development of alternative models. The DT management strategy model provides a finer-scale approach to stock assessments, decreases monitoring costs, increases the knowledge base, and creates a unique opportunity for collaborative research and management. Although new to fisheries management, the DT is a viable option for improving management while simultaneously fulfilling the legal requirements of national and state fisheries policies. Fishermen-collected data has yet to be incorporated into fisheries management, however, collaborative efforts between UCSB researcher Jono Wilson and the Santa Barbara nearshore fishery has the capacity to translate these data into management decisions using the DT method.

4. Using MPAs in Fisheries Management

Marine protected areas have been used primarily as conservation tools, but also have the potential to be a useful instrument in fisheries management. As management tools, MPAs have been suggested as mechanisms that may increase local target fish yield (Tetreault & Ambrose 2007) and buffer against uncertainty in environmental stochasticity and poorly made management decisions (Field et al. 2006). In addition, MPAs may mitigate negative impacts on non-target species and reduce habitat impacts from fishing (Murray et al. 1999; NRC 2001; Halpern 2003). Using marine reserves as reference areas for unfished biomass estimates and trends in local fish production and stock structure provides potential benefit to fisheries assessment and management (Hilborn et al. 2004, Field et al. 2006). Many stocks lack historical information on total biomass, and MPAs provide the opportunity to observe stock biomass in an unfished state (Smith et al. 1998; Wilson et al. *in prep*). While MPAs have the potential to decrease uncertainty in management decisions, using an unfished population in a no-take reserve as a proxy for unfished biomass may be problematic. Reserves that have not been in place long enough for populations to recover may not contain populations whose size structure accurately reflects an unfished state. MPAs may provide more accurate estimates of unfished biomass and egg production than those obtained from historical catch data for species whose life-history characteristics lend them to the small-scale protection provided by MPAs (e.g. more sedentary adult stages, short larval and juvenile dispersal distances) (Parrish 1999; Field et al. 2006; Hilborn et al. 2004). Specifically, MPAs can protect populations from significant fishing-induced mortality, allowing them to reproduce, rebuild, and, over time, attain a close approximation of unfished biomass and size structure (Field et al. 2006).

The recent push for protected areas in the marine environment has led to a debate over their efficacy as fisheries management tools. The success of MPAs as tools depends on how reserves are designed and managed, in addition to specific characteristics of target fishery populations (Hilborn et al. 2004). Certain species characteristics, such as sessile or small adult ranges and low dispersal rates, imply that these species will be less affected by outside fishing pressures and better able to recover to an unfished population structure (Murray et al. 1999). For many organisms with these characteristics, traditional assessments and management are not successful (Hilborn et al. 2004). Most fisheries management and assessments occur on large scales; the United States West Coast fisheries are managed either on a state-wide or coast-wide scale. This large scale prevents efficient stock management for species with local variability and little connectivity throughout their range (Gunderson et al. 2008). Even if spatially significant data collection suggests that shifts in fisheries management are necessary, the large scale of fisheries management zones do not currently allow for fishery decisions to be enacted at local scales. Spatial explicitness of the MPA baseline data will be lost when applied at the current management scale. Moving toward spatially based management that incorporates reserves can address many of the problems in managing these species as well as addressing issues of spatial variation within populations (Berkeley et al. 2004; Gunderson et al. 2008).

Recent work suggests that groundfish populations along the United States West Coast exhibit higher spatial variability than previously believed (Berkeley et al. 2004; Gunderson et al. 2008). These species' slow growth rates mean that a reserve will have to be established for decades before inside-reserve populations can be considered unfished. New methods have been developed to incorporate the slow maturation of the protected areas to account for this time lag between reserve implementation and a population that can be considered unfished (See Section 8 for DT method details). The Channel Islands National Marine Sanctuary is one of the largest and most mature MPA networks in California. The CINMS provides an opportunity within California to establish baselines for species found within the reserves. In addition to the CINMS, the MLPA process is currently placing new marine reserve networks along the California coast. Additional data collected within reserves has the capacity to significantly increase certainty in stock assessments. To provide the maximum benefit to fisheries, data from these reserves will have to be appropriately incorporated into management decisions (Hilborn et al. 2006). Fishery legislation provides opportunities for integrating reserve baselines into management decisions (See Section 3.5). The future California MPA network can potentially provide spatially explicit stock data for populations along the entire coast, informing management decisions and increasing management efficiency.

The Channel Islands no-take marine protected areas present an opportunity to significantly improve upon precautionary estimates. Theory suggests using MPAs as reference points for unfished biomass may allow for a refined estimate of natural and fishing induced mortality as well as comparisons of fished and unfished egg production and biomass (Smith et al. 1998; Wilson et al. *in prep*). Jono Wilson's adaptations to Jeremy Prince's DT are the first to successfully incorporate MPAs into a management strategy of which we are aware. Results of this group project suggest that the integration of existing marine reserves and fishermen-collected data into fisheries management decisions is a realistic management option and should be pursued.

5. Fishermen Collected Data & Alternative Fishery Management

Fishermen-collected data has the potential to be a useful, if not essential, part of stock assessments and fisheries management. Integrating fishermen into research allows access to a knowledge base that many researchers would not otherwise have, and provides opportunities for fishermen to become involved in managing their fishery (Johannes 2002). This valuable data reflects the ecological knowledge-base fishermen have built from years of fishing (Johannes 2002; Prince 2003). There is also potential for cost-savings, as data can be collected more frequently (increasing the amount of data) at a cost less than traditional data collection (Ticheler et al. 1998). The increase in temporal and spatial data points can also increase the accuracy of information used by managers. In addition to drawing on a wide knowledge base and potential for cost savings, fishermen-collected data may greatly assist California achieve its coastal resource management mandates. Funding and other resource shortfalls that have prevented completion of mandated stock assessments for state fisheries (Cal. Fish and Game Code § 7070) can be addressed by engaging fishermen in data collection to fill in data gaps at a lower cost to CDFG.

Potential increases in data quality will only help to inform management if measures are taken to ensure the accuracy and consistency of fishermen-collected data. Training and periodic onboard observers will be necessary to ensure the scientific merit of the data. Costs will be incurred by the fishermen to collect data on their own, which may necessitate fishermen compensation for the time lost fishing and spent collecting data. Periodic onboard observers will be needed to ensure data collection consistency. Furthermore, onboard observers are required for fisheries with bycatch issues. Neither the cabezon nor the grass rockfish fisheries have bycatch problems, so a fishermen-collected data methodology does not need to include bycatch reduction costs. If the impetus for data collection comes from a regulatory body or outside organization, funding (or funding sources) for the initial training and equipment costs should be supported by that organization.

Management efficiency can be increased with additional data to inform management decisions. This provides an incentive for fishermen to participate in research collection since it presents the opportunity to move away from precautionary management for species in data-poor situations. More informed decisions also increase long-term fishery sustainability, providing an additional incentive for fishermen participation. Increased participation leads to increased stewardship, as demonstrated by examples from fisheries all over the world, including Chile (Parma et al. 2003), Vanuatu (Johannes 1998), and the United States (Leal 2008). Personal connection to local resources and their management incentivizes the long-term preservation of those resources (Hardin 1968). Stewardship is an intangible benefit to fisherman participation that often leads to long-term sustainability. Fishermen alter their perception of the fishery to ensure long-term resource viability (Jentoft 2000).

There are many areas where fishermen-collected data has been a valuable part of fisheries management, from Zambia to the United States (e.g. Ticheler et al. 1998; Parma et al. 2003; Weber & Iudicello 2005; Leal 2008). In Zambia, one year of fishermen-collected data demonstrated the reliability and low cost of this type of data, in addition to increasing local awareness of exploitation patterns. The total volume of data increased threefold at less than half the cost of traditionally collected data. Zambian fishermen involvement in data collection has opened up community dialogue about possible management changes and the concept of stewardship (Ticheler et al. 1998). In Chile, local fishermen participating in their own data collection and experimentation initiated a bottom-up change in management (Parma et al. 2003). An example from Oregon has shown fishermen collecting data can assist the state where the government does not have the resources to collect necessary information (Leal 2008). However, fishermen in many areas have historically been reluctant to collect and/or provide such data to managers and regulators, perceiving the likely harms (restricted quotas and disclosure of coveted fishing areas) to exceed the potential benefits (Scholz et al 2004). Spatially-explicit data tied to local fishing grounds is economically valuable to individual fishermen, and its value may diminish when shared. Appropriate incentives (such as an increase in TAC or cash compensation), and a guarantee that the potential benefits outweigh the potential harms, need to be incorporated into the management of fishermen-collected data.

Though rarely seen in the United States, alternative management strategies have been employed in a number of fishing communities worldwide (Johannes 2002). These strategies include territorial use rights fisheries (TURFs), community cooperatives, and customary marine tenure. While differing slightly in implementation, all alternatives focus on community-based fisheries management, often integrating local knowledge with government agency resources. Community-based management usually provides incentives for fishermen to fish at sustainable levels, often by creating or allocating private property rights in the form of dedicated access, specified fishing areas, and/or fishing quotas (Hilborn 2007).

Channel Islands fishermen have significant interests in sustainable fishery management (Smith et al. 1999), specifically in long-term profitability and stock stability. Aligning fishermen interests with reliable data collection is a significant challenge to implementing alternative assessment methods successfully. In order to provide incentives for information sharing, a system must be developed based on trust, cooperation, and the recognition of the information's uniqueness and value (Parma et al. 2003; Scholz et al. 2004). There are currently programs in the Northeast region, managed by the Northeast Fishery Management Council, that utilize Exempted Fishery Permits (EFP) and research set asides (RSA) (NOAA 2008a). These programs support collaborative research between commercial fishermen and scientists in scallop, monkfish, herring, and mid-Atlantic multi-species fisheries (NOAA 2008b).

Empowering fishermen to gather and report data offers great potential to simultaneously increase the spatial resolution of fishery data and defray much of the cost associated with data collection (Prince 2003). Application of this knowledge can generate more accurate stock assessments at little additional cost and potentially benefit the entire fishing community. Research collaboration between fishermen and regulators can increase management efficiency, lower costs, and increase stewardship, all of which are components of sustainable resource management.

6. Fishery Cooperatives and Organizations

Cooperatives and other social organizations provide opportunities for fishermen to achieve a range of benefits not possible without organization. In fisheries, a cooperative refers to an entity cooperatively managing fishing with formal leadership, that has the power to control access to the cooperative and vessel fishing activity (50 CFR 679.2). These organizations are sometimes formed via legislation and/or regulation (top-down), or more often through the efforts of fishermen who want more control over their resources (bottom-up). Cooperatives are typically formed with specific goals (e.g. restricting access to a species or limiting the race to fish). Organizational structure can range from formal cooperatives with binding legal agreements, loose associations with verbal agreements, to organizations with no formal membership or leadership.

There are many benefits of community-based fishery management and collaborative research (e.g. Johannes 2002; Parma et al. 2003; Weber & Iudicello 2005). Reasons fishermen organize themselves in a cooperative include:

- Increased control over resources and access (Peacock & Annand 2008)
- Potentially increased negotiating power with regulatory agencies
- Reducing the race to fish (Leal 2008; Sylvia et al. 2008)
- Access to funding opportunities to address problems (e.g. lack of data) that regulatory agencies may not be able to solve due to resource limitations (Leal 2008)
- Ability to increase fishery profits through application of certifications such as Marine Stewardship Council
- Increased resource stewardship (Parma et al. 2003; Ticheler et al. 1998)

There are also drawbacks to participating in a cooperative: extra time spent in meetings, membership dues, and less autonomy as fishermen work within the bounds of the cooperative rules. Despite these drawbacks, many examples of successful fishery organizations exist in both developed and developing countries. These organizations originated from bottom-up pressures (Chile, parts of the United States) as well as top-down regulation (United States, Canada). Although the original impetus for formation varied, the ultimate goal of these organizations is similar; they aim to increase efficiency in fishery management to the benefit of all stakeholders.

The following examples highlight management inefficiencies and how either managers, or the fishery itself, organized fishermen to address these inefficiencies:

In the Chilean loco fishery, fishermen organized to collect data and conduct experiments within their own fishery due to a lack of government action addressing data gaps. This led to the creation of a TURF system for the loco fishery that guaranteed each fisherman a portion of the catch and reduced the race to fish (Parma et al. 2003).

In Oregon, the race to fish in the herring roe fishery had reached a point where the fishery would remain open for no more than one day per year. In addition to intense competition, profits were motivating other fishermen to enter the fishery and a lack of data meant the TAC was not an accurate reflection of stock status (some fishermen thought it was too high, others thought it was too low) (Leal 2008). The fishermen petitioned the state to limit access to the fishery and then formed a cooperative, mainly to stop the race to fish. In addition to allocating a portion of the TAC to each cooperative member, the cooperative pooled their resources to assist the Oregon Department of Fish and Wildlife in funding a stock assessment.

In eastern Canada, rapid decline in groundfish harvest rates from decades of overfishing led to a series of poor management decisions that created conflicts between fishing communities and continuation of unsustainable harvest rates (Peacock & Annand 2008). To address these issues, the Canadian government implemented a trial management program, the Scotian Shelf Community Management Boards (CMB). Each community is organized geographically by port area and is managed by its own CMB. Each community receives a TAC allocation, and the local CMB makes decisions regarding TAC distribution, harvest limits, and penalties. The CMBs are comprised of elected members, usually local fishermen, who implement the Community Harvest Plan through civil agreements rather than going through the Department of Fisheries and Oceans. The placement of decision-making power in the hand of the fishermen has dramatically reduced conflicts, increased scientific understanding of the stock (through the inclusion of fishermen in data collection), and decreased fishing effort.

In Alaska, harvest declines closed onshore processing facilities and increased unemployment. Decreases in fishing-related tax revenue prompted government action to reduce fishing effort to address this decline. The Gulf of Alaska Rockfish Program (GOA) is a trial program that will eventually lead to rationalization (effort reduction). GOA permits fishermen to form voluntary cooperatives that each receive a cooperative quota based on the total amount of rockfish quota allocated to the individual fishermen within the cooperative (NPFMC 2008). Fishing under this program began in 2007, and thus far, there have been reductions in bycatch and more temporally stable incomes for fishing communities (G. Merrill, *personal communication*).

The preceding examples highlight methods by which fishermen and managers can work together to overcome inefficiencies in fishery management. Cooperative organizations can work in tandem with regulators within the current United States top-down regulatory framework (Fujita et al. 2009). Sweeping infrastructure changes are not necessary to integrate fishermen-based organizations into management; many rules and regulations call for collaboration between managers and fishermen (see Section 3). The potential benefits for both fishermen and regulators outweigh the added costs of the regulatory changes required to formally merge fishermen organizations with fisheries management.

7. The MPA-Based Decision Tree Management Strategy

Due to the high costs and manpower associated with increasing conventional fisheries data collection, alternative management strategies are being proposed to more accurately assess data-limited fisheries while reducing data collection costs. One alternative method proposed is the MPA-based DT model, which establishes catch levels at spatially explicit and biologically significant scales (Wilson et al. *in prep*). By comparing catch per unit effort (CPUE) and size structure of fish landings to established reference points, catch levels can be established to ensure a specified level of spawning potential ratios (SPR) (Wilson et al. *in prep*). For this model, two separate reference points are used to establish how healthy the fish stock in question is: (1) the status of the species within a MPA and (2) the hypothetical status of the species under equilibrium conditions. The size structure of the population within the MPA serves as a reference point for how the stock would appear without any fishing pressure, and is considered a proxy for "unfished biomass". Equilibrium conditions are a hypothetical modeled state that represents what the population would look like at fishing levels that achieve maximum sustainable yield (MSY). For species with low resilience to fishing pressure, a proxy for MSY is used that maintains the SPR at 50%. Together, these two reference points provide a static and dynamic relationship to optimizing harvest and therefore hedge against environmental variability and uncertainty in life history characteristics. This method not only aligns the scale of management with the scale of biological function, but also decreases the costs associated with data collection by using fishermen-collected data.

The DT management strategy derives population dynamics information from the size structure of fish catches and CPUE. This creates a snapshot of stock status relative to the selected baseline (Prince 2008; Wilson et al. *in prep*). Though originally developed for pelagic finfish, the DT addresses a specific problem with management of low-dispersal species. For these species, the scale at which populations function is often much smaller than the scale on which conventional stock assessments are applied (Prince et al. 1998). Populations of low-dispersal species, like cabezon and grass rockfish, are often made up of discrete sub-populations. Research suggests that connectivity between sub-populations of rockfish along the West Coast of the United States is lower than previously believed (Gunderson et. al 2008). As a result, traditional assessments often overlook sub-population-level differences, making small-scale information especially important for such fisheries (Prince 2003).

The DT assessment method uses fishermen-recorded location data, in addition to fish size structure and CPUE information, to inform managers on significantly smaller scales. Aggregating size structure data by location improves overall management performance, and can be used to set per-location catch limits. Thus, spatially-informed assessments can reduce the burden of precautionary catch limits and help managers simultaneously improve fishery yield and reduce the risk of overfishing (Hilborn 2007).

The Channel Islands nearshore fisheries are good candidates for management strategies generally, and for the DT in particular. Like many fisheries, they are data-poor: limited funds restrict gathering of fishery-independent data, fishermen have historically resisted collecting and reporting fishery-dependent data, and landings data is limited to fish size and weight (Cooper 2006). Where available, historical data is often confined to rudimentary landings information, which severely limits understanding of current size and age distribution and the historical baseline against which these are measured. These fishery characteristics lend themselves well to the spatially-based assessment techniques unique to the DT method.

Additionally, the Channel Islands contain a host of commercially fished species, with life-history and fishery characteristics appropriate for MPA and DT-based assessments (NOAA 2008c). Cabezon and grass rockfish are both appropriate candidates for the DT based on their dispersal distance, age-to-maturity, and data availability, as well as the fishery's small size and lack of adequate regulatory oversight. Reference points for many West Coast rockfish stock assessments are difficult to set because they lack data required by traditional stock assessment methods (Hilborn et al. 2002). However, the data required by the DT is easily obtained for both cabezon and grass rockfish, and reference points and assessments stand to be improved by the use of MPAs as baselines. This setting offers a promising framework for evaluating the DT management strategy.

The Channel Islands offers an additional benefit due to the establishment of the MPAs in the area five years ago. An alternative fisheries management strategy, like the DT method, that uses MPA data to establish reference points, could set a standard for integrating MPAs with fisheries management. The MPA planning process is currently underway for the Southern California coast under the MLPA (CDFG 2008a). Using the DT method as a management tool integrates MPAs into nearshore fishery management in addition to meeting conservation goals along the Southern California coast.

7.1 Decision Tree Dynamics

The DT approach to stock assessment uses four stages of adaptive analysis to set and refine TAC estimates. In the first level, CPUE is compared spatially (i.e., inside/outside marine protected areas) for an initial understanding of the stock. In the following levels, CPUE and the size structure of the fish catch are compared with baseline reference points (i.e., against hypothetical equilibrium states), and over time. This model separates the fish stock into three distinct age classes (old individuals, prime individuals, and recruits, or small individuals) to better understand the stock dynamics in relation to growth and recruitment overfishing (see Fig. 7 for visual representation).

In Level 1 the TAC is initially estimated by comparing CPUE for prime sized individuals in the fishing grounds with the CPUE for prime sized individuals in the marine reserve. The CPUE level inside the marine reserves is assumed to be a proxy for natural abundance. The sustainable target CPUE level is then set at 40% of the marine reserve

CPUE level based on optimization techniques that maximize yield and spawning stock biomass (Wilson et al. *in prep*). This is the only step that uses an MPA comparison (inside/outside reserve) as a proxy for the stock's unfished biomass level.

The next three levels refine the TAC set in Level 1 by analyzing the CPUE and length frequencies of different size classes, either over the last five years of catch data, or by comparing these data to expected equilibrium states, depending on the step. The equilibrium state here is defined as the stock state that achieves a SPR of 0.5, which is the recognized proxy for MSY according to west coast fisheries managers (MacCall *personnel communication*).

In Level 2, the CPUE trend for prime individuals ($CPUE_{prime}$) is assessed over the last 5 years of data. Prime size is defined as the age class when fishable biomass is at its maximum (Froese 2004). This information will be used to determine if the stock has been rising, falling, or remained stable over this time period. This will in turn determine which branch of the DT will be followed in Level 3; the rising, falling, or stable branch.

Having determined which branch (rising, falling, or stable) of the DT will be followed in Level 2, Level 3 establishes the inferences drawn about the status of the stock. To identify the suitable inferences, Level 3 incorporates another comparison based on the length frequency of old individuals, in addition to comparing the CPUE of old individuals to equilibrium levels. Here the CPUE and proportion of old individuals is assessed as either above or below equilibrium status. This third level enables the assessor to determine the proportional abundance of old fish within the population. Thus, this proxy indicates the stability of the stock's age structure as compared to the age structure expected under equilibrium conditions. The comparisons performed in Level 3 provide for one or two final inferences to be drawn concerning the stock's health, abundance, and stability, as well as the appropriateness of the TAC estimate.

Finally, Level 4 is used to determine which of the inferences drawn in Level 3 is most indicative of the actual status of the fish stock. Because CPUE does not easily distinguish changes in fishermen's targeting behavior from actual biological shifts in fish stock abundance, Level 4 must differentiate between these two possibilities. In this final level the CPUE of recruits is compared to equilibrium conditions, to complete the tree's quality control. The outcome of this comparison dictates the final adjustments to the TAC estimate.

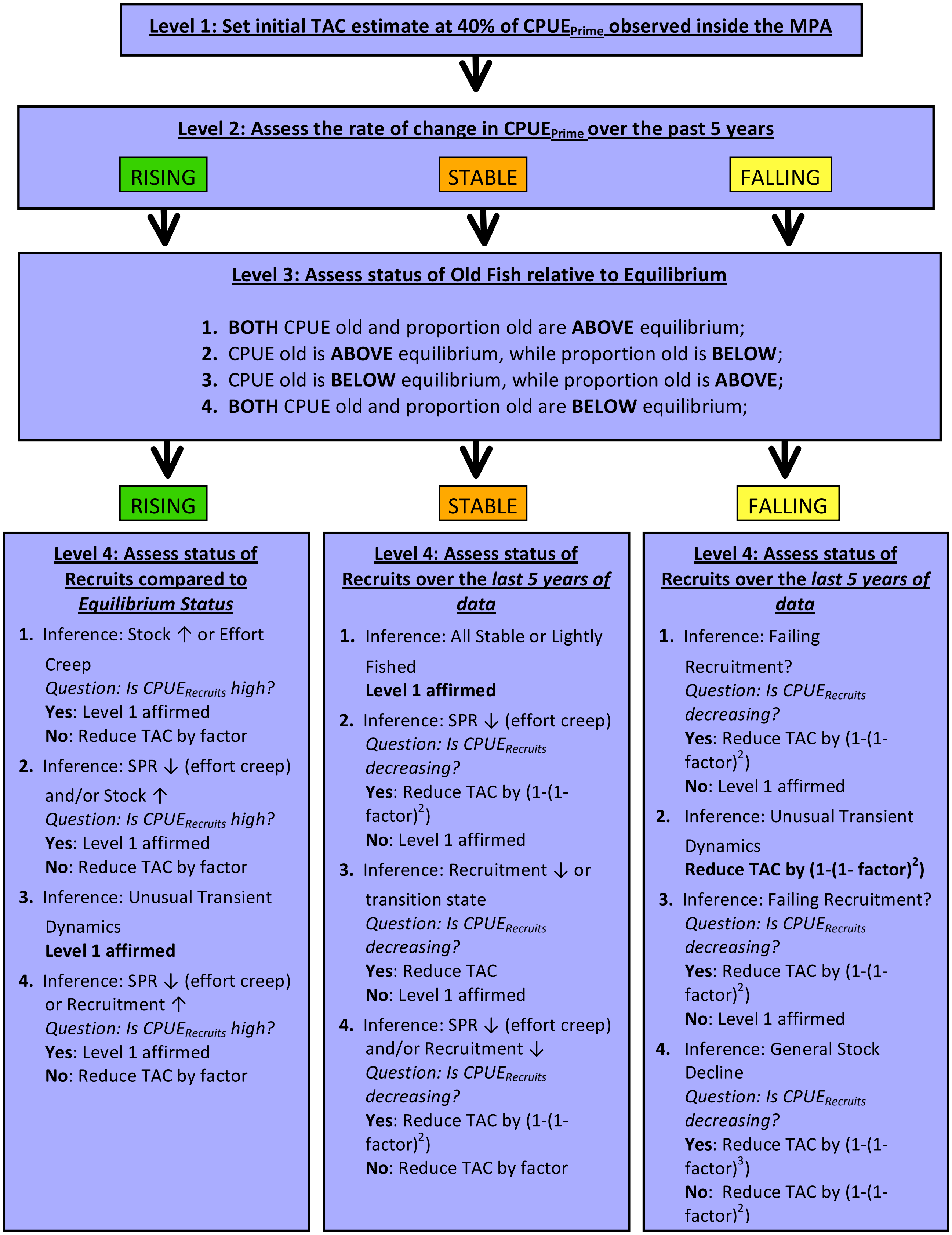

Figure 7. Flowchart diagram of the four levels of the DT model.

7.2 Decision Tree Walk-Through

To facilitate a more thorough understanding of the DT model, we have chosen hypothetical examples to guide the reader through the actual use of the DT.

Example 1: If the CPUE of prime individuals is STABLE

This first example exhibits a stock in which the sustainable target TAC has been estimated at 60% of the marine reserve CPUE in Level 1. Level 2 is then used to determine the trend in CPUE data of prime individuals over the last five years. In this scenario the CPUE of prime individuals has remained **STABLE**. Therefore, we can infer that the fish stock abundance has not changed greatly in the last five years and the CPUE and TAC estimates are appropriate.

From CPUE data alone, it is difficult to determine whether actual biological shifts in fish stock abundance have occurred, or whether these changes in the catch data are more accurately attributed to changes in fishermen's targeting behavior. Additionally, Level 1 and Level 2 have limited the scope to only prime size individuals rather than the entire stock. Therefore, this interpretation of the CPUE trend line needs to be reviewed further to better understand the population's abundance and its ability to withstand the TAC's associated fishing pressure sustainably. Level 3 will help to more accurately depict stock status.

Level 3 is now used to further refine the TAC estimates by assessing the CPUE and proportion of old individuals within the stock as either above or below their values in a hypothetical population at equilibrium. This results in four possible scenarios that describe the stock better:

Level 3: Assess status of Old Fish relative to Equilibrium

(scenarios)

1. **BOTH** CPUE old and proportion old are **ABOVE** equilibrium
2. CPUE old is **ABOVE** equilibrium, while proportion old is **BELOW**
3. CPUE old is **BELOW** equilibrium, while proportion old is **ABOVE**
4. **BOTH** CPUE old and proportion old are **BELOW** equilibrium

Figure 8. Level 3 Scenarios

In the **scenario 1**, since both CPUE and proportional abundance of older individuals are above equilibrium, the stock seems stable or only lightly fished. Under these conditions the model affirms the Level 1 TAC estimate. If, however, the proportional abundance of old individuals is below equilibrium estimates, as shown in **scenario 2**, then this could indicate two alternate possibilities. Either, the stock is high, as suggested by the higher than normal CPUE, or fishermen may be shifting their effort to target older individuals (an effect known as "effort creep"). To distinguish between these two possibilities, the status of the recruits within the population in Level 4 of the DT must be studied. Here, the determination is made whether recruit CPUE has been decreasing over the past five years. If so, effort creep may be depleting the spawning potential ratio and the TAC estimate should be reduced 1-(1-factor)^2. Otherwise, if recruit CPUE is stable or increasing, the Level 1 TAC is affirmed.

Another possibility, shown in **scenario 3,** is that CPUE for old individuals may be below equilibrium even though their proportional abundance is still above. If this is the case, recruitment may be depressed or the stock may be in a transition state. Here, a decrease in recruit CPUE must again be tested. If decreasing, reduce the Level 1 TAC by a factor. If not, the initial Level 1 TAC estimate is affirmed.

Level 4: Assess status of Recruits over *the last 5 years of data*

1. Inference: All Stable or Lightly Fished
Level 1 affirmed

2. Inference: SPR ↓ (effort creep)
Question: Is $CPUE_{Recruits}$ decreasing?
Yes: Reduce TAC by (1-(1- factor)^2)
No: Level 1 affirmed

3. Inference: Recruitment ↓ or transition state
Question: Is $CPUE_{Recruits}$ decreasing?
Yes: Reduce TAC
No: Level 1 affirmed

4. Inference: SPR ↓ (effort creep) and/or Recruitment ↓
Question: Is $CPUE_{Recruits}$ decreasing?
Yes: Reduce TAC by (1-(1- factor)^2)
No: Reduce TAC by factor

When both the CPUE and the proportion of old individuals are below equilibrium, as shown in **scenario 4**, recruitment could be dwindling, spawning potential ratio may be diminished due to effort creep, or both. Once again, assess whether the CPUE of recruits is decreasing. If so, then reduce the TAC by 1-(1-factor)^2. If not, reduce it by only a factor.

Other Hypothetical Stock Situations

If the CPUE of prime individuals is FALLING or RISING:

In other cases when the rate of change in CPUE of prime individuals over the last five years is not stable, the steps of the DT model are the same, but the inferences about stock status may be different and the ultimate TAC adjustments may vary. To determine which branch of the DT describes the stock's status, one must assess the CPUE and proportional abundance of old individuals against equilibrium states. The scenarios stay the same (Fig. 8, both above, one above-one below, or both below) but the inferences and eventual actions may change.

Similar to Example 1, the following examples also exhibit a stock in which the sustainable target TAC has been estimated at 60% of the marine reserve CPUE amount in Level 1. Level 2 is then used to determine the trend in CPUE data of prime individuals over the last five years. In Example 2, the CPUE of prime individuals has been **FALLING**, and in Example 3 the CPUE of prime individuals has been **RISING**

Example 2: CPUE trend of prime individuals is FALLING:

Level 3: Assess status of Old Fish relative to Equilibrium
(scenarios)

1. **BOTH** CPUE old and proportion old are **ABOVE** equilibrium
2. CPUE old is **ABOVE** equilibrium, while proportion old is **BELOW**
3. CPUE old is **BELOW** equilibrium, while proportion old is **ABOVE**
4. **BOTH** CPUE old and proportion old are **BELOW** equilibrium

Figure 8. Level 3 Scenarios

Similar to the "stable" branch, this branch poses the question, "is CPUE of recruits decreasing?" to discriminate between alternative inferences. Even though CPUE and proportional abundance of old individuals is high, the **scenario 1** could still describe a situation of failing recruitment. This is likely if CPUE of recruits is decreasing and suggests a reduction in TAC by $1-(1\text{-factor})^2$. If CPUE of recruits is rising, there may not be a need to change the TAC estimate.

Level 4: Assess status of Recruits over the *last 5 years of data*

1. Inference: Failing Recruitment?
Question: Is $CPUE_{Recruits}$ decreasing?
Yes: Reduce TAC by $(1-(1\text{- factor})^2)$
No: Level 1 affirmed

2. Inference: Unusual Transient Dynamics
Reduce TAC *by* $(1-(1\text{- factor})^2)$

3. Inference: Failing Recruitment?
Question: Is $CPUE_{Recruits}$ decreasing?
Yes: Reduce TAC by $(1-(1\text{- factor})^2)$
No: Level 1 affirmed

4. Inference: General Stock Decline
Question: Is $CPUE_{Recruits}$ decreasing?
Yes: Reduce TAC by $(1-(1\text{- factor})^3)$
No: Reduce TAC by $(1-(1\text{- factor})^2)$

The combination of a high old fish CPUE with a lower-than-expected proportional abundance, as shown in **scenario 2**, indicates the existence of what Prince calls "unusual transient dynamics" (Prince et al. 2008a). In this situation, the TAC estimate will need to be reduced by $1-(1\text{-factor})^2$. In the inverse case of a lower than expected CPUE and a higher than expected proportion, as shown in **scenario 3**, the stock may be experiencing failing recruitment. If the trend of the CPUE of recruits is decreasing, failing recruitment threatens the stock and the TAC should be reduced by $1-(1\text{-factor})^2$. If it is not decreasing, the model implies the Level 1 TAC estimate is appropriate for the stock's condition.

In situations when both proportion and CPUE of old fish is below equilibrium, shown in **scenario 4**, the model suggests the overall stock is declining. The degree of this decline is indicated in the CPUE trend of recruits. If decreasing, the TAC must be reduced by $1-(1\text{-factor})^3$, an order of magnitude more than the TAC reduction $(1-(1\text{-factor})^2)$ if the CPUE recruits is not decreasing.

Example 3: CPUE trend of prime individuals is RISING:

Level 3: Assess status of Old Fish relative to Equilibrium

(scenarios)

1. **BOTH** CPUE old and proportion old are **ABOVE** equilibrium
2. CPUE old is **ABOVE** equilibrium, while proportion old is **BELOW**
3. CPUE old is **BELOW** equilibrium, while proportion old is **ABOVE**
4. **BOTH** CPUE old and proportion old are **BELOW** equilibrium

Figure 8. Level 3 Scenarios

Note: Contrary to the data analysis in Level 4 used in the Stable and Falling branches that assess whether the CPUE of recruits has been decreasing *over the past five years*, the **RISING** branch instead compares the CPUE of recruits *against equilibrium conditions*. This is a subtle, but important difference in the DT method.

Level 4: Assess status of Recruits compared to *Equilibrium Status*

1. Inference: Stock ↑ or Effort Creep
  Question: Is $CPUE_{Recruits}$ high?
  Yes: Level 1 affirmed
  No: Reduce TAC by factor

2. Inference: SPR ↓ (effort creep) and/or Stock ↑
  Question: Is $CPUE_{Recruits}$ high?
  Yes: Level 1 affirmed
  No: Reduce TAC by factor

3. Inference: Unusual Transient Dynamics
  Level 1 affirmed

4. Inference: SPR ↓ (effort creep) or Recruitment ↑
  Question: Is $CPUE_{Recruits}$ high?
  Yes: Level 1 affirmed
  No: Reduce TAC by factor

In the **scenario 1**, the high CPUE and proportionally higher abundance of old individuals indicates two alternative inferences: a high stock or effort creep. The comparison of recruit CPUE to equilibrium states discriminates between these two alternatives. When the CPUE is above, the stock is high and the TAC is affirmed. Conversely, when the CPUE is below, the TAC estimate needs to be reduced by a factor to accommodate for effort creep.

Scenario 2 describes a situation when the stock could be high (indicated by the high CPUE value), or have a low spawning potential ratio due to effort creep (indicated by the low proportional abundance), or both. If CPUE of recruits is still above equilibrium, the Level 1 TAC is affirmed. Otherwise, the CPUE is too low and the TAC must be reduced by a factor. When CPUE of old individuals is below equilibrium while proportion old is above, shown in **scenario 3**, unusual transient dynamics that verify the Level 1 TAC may be at play.

Finally, for instances in which both CPUE old and proportion old are below equilibrium, as displayed in **scenario 4**, either the stock is high or effort creep is underway. An above-equilibrium CPUE value for recruits corroborates the high stock assumption and the Level 1 TAC. If recruit CPUE is lower than the equilibrium value, this indicates effort creep, and Level 1 TAC should be reduced by a factor.

Through using these four steps of adaptive analysis the DT is able to set and refine TAC in a quantitative science-based manner. Using these methods of quality control allows assessors to distinguish between various possible population conditions to most accurately set TAC at sustainable levels.

8. Methods and Results

8.1 Survey Methods

We developed a survey to build relationships with fishermen and further address our research question. The survey served three main purposes: (1) Provide demographic information used to characterize the fishery, (2) Discuss local fishery management and gauge fishermen's desire for change, and (3) Discern the feasibility of various data collection techniques for the DT alternative management strategy.

Survey development began in the summer of 2008. A 2007 survey of the Santa Barbara Channel infrastructure needs (Culver et al. 2007) was used to help phrase the initial survey questions. A conversational tone was decided upon to serve as a first step toward developing a relationship with the fishermen. In addition to surveys, group members visited the Saturday fish market and assisted in port sampling in an attempt to establish relationships with other individuals in the fishery. In 2008, there were 16 individuals with South Coast Region Nearshore Fishery Permits making landings in the Santa Barbara Port Complex (Key 2008; Fig. 3). As of January 2009, seven of these fishermen have been interviewed. The analysis of the interview data may not be representative of the entire nearshore live finfish fishermen population in Santa Barbara, due to the small number of respondents in the survey. However, a large percentage of participation was not required to achieve the goals of the survey. These initial contacts have led to successful collection of demographic information and opinions regarding fishermen satisfaction with the current management regime; establishment of relationships with fishermen through which information dissemination can take place; and development of data collection techniques that can be used with the DT to assess grass and cabezon stocks.

8.2 Survey Results & Analysis

Of the 16 permits in the nearshore live fish fishery in the Santa Barbara area, we interviewed seven individuals, or 44% of the fishermen in the fishery. The survey (App. A) can be divided into four major sections: 1) demographics, 2) current management evaluation, 3) data collection technology evaluation, and 4) economic indicators and conversational questions. Each section helped to serve a specific purpose, as described in the methods section above.

One of the survey's goals was to understand the characteristics of the fishermen in the nearshore fishery and their fishing practices. This corresponded to the demographics section of the survey; the results are compiled in Table 3. The fishermen we spoke with have many years of experience in this fishery (range of 10-23 years) and have spent even more time fishing in other fisheries. All rely completely on fishing for their income and fish 100-200 days of the year. However, they are only spending an average of 35% of their time fishing for grass rockfish or cabezon, with a wide range of time investment (6-100%), depending upon the individual. Conversationally, they have indicated that this is less time than they used to spend fishing for grass and cabezon due to declines in cabezon TAC that have lead to a decrease in the fishery profitability. Many fishermen also hold permits in an average of three other fisheries as they cannot rely solely on the nearshore fishery. These fisheries include sea urchin, southern rock crab, gill net, and lobster permits.

All fishermen are required to hold a Nearshore Fishing Permit, and many also hold deeper nearshore permits (86%) and trap endorsements for the nearshore fishery (43%) (Table 3). There are three main gear types used in this fishery: sticks, traps and rods. Fishing with sticks is the technique most often used by the interviewed fishermen (86%). A stick is a piece of weighted PVC pipe with five attached hooks, which rests on the seafloor with a line attaching the stick to a surface buoy. Sticks are left on the ocean floor for about an hour before fishermen return to retrieve fish, a term commonly referred to as "soaking." Live fish traps, used by 43% of respondents, are similar to lobster traps: each trap is set with bait; fish are caught in the trap and are then retrieved after soaking for about one day. The trap methodology requires a trap endorsement, in addition to the nearshore fishing permit. The least-used method is rod fishing (29%), in which fish are caught with a simple fishing pole and multiple baited hooks. With this

Characteristics	Average (Range)
Total years fishing	26 (18-36)
Total years in Nearshore live fish	15 (10-23)
Average number of years left in the fishery	20 (5-24)
Days spent fishing per year	150 (100-200)
% income from fishing	100%
% of time fishing for grass and/or cabezon	35% (6-100%) Average # permits in other fisheries: 3
Gear (% of individuals)	Sticks: 71% Traps: 43% Rods: 29%
Permits (% of individuals)	**NFP:** 100% **NFP + Trap:** 86% **DNFP:** 43%

Table 3. Survey results for fishery demographics. Based on 7 interviews with nearshore live fish fishermen (out of a total of 16 permittees in Santa Barbara). Other fisheries where fishermen held permits include: sea urchin, sea cucumber, lobster, general trap, southern rock crab, tidal invertebrate and general gill net. NFP: Nearshore fishing permit; NFP + Trap: NFP and trap endorsement; DNFP: Deeper nearshore fishing permit.

understanding of fishing practices, the next portion of the survey addressed current management practices in the fishery.

Through information available via CDFG we were able to track the history of management and regulations in the nearshore fishery. However, with the survey we aimed to determine the degree of fishermen satisfaction with management. On average, fishermen were not satisfied with the overall management of the nearshore fishery (Table 4). In particular, they do not think the information used to manage the fishery is very accurate for either the grass rockfish or the cabezon fisheries (Table 4). This highlights the need for better management of the nearshore fishery and increased data collection for use in management.

Survey Question (Scale of 1 to 5; 1 lowest and 5 highest)	Response Average (± standard error)
Satisfaction with current management	1.6 ± 0.2
Accuracy of current information (grass)	1.2 ± 0.2
Accuracy of current information (cabezon)	1.1 ± 0.2
How well TAC meets sustainable fishing level (grass rockfish)	3.1± 0.4
How well TAC meets sustainable fishing level (cabezon)	1.0 ± 0.0
Desire to participate in future management	4.8 ± 0.3

Table 4. Survey results of satisfaction with current management practices. Based on 7 interviews with nearshore live finfish fishermen.

When asked about the current catch levels, the fishermen agreed that both grass rockfish and cabezon fisheries had inaccurate data. When asked about current TAC levels, they were more satisfied with the grass rockfish TAC, believing it to be appropriate. For cabezon they believe the TAC does not meet a sustainable fishing level (Table 4).

The final interview question regarding current management addressed the degree to which fishermen would like to be included in management of the fishery, as compared to their current level of participation. They strongly responded that they would like to participate to a greater degree in management than their current role (Table 2). This result could be biased toward the positive because their willingness to participate in the interview itself indicates a desire to collaborate with researchers and therefore denotes an interest in management. However, these individuals comprise almost half of the fishery; communications with CDFG would likely improve even if just these individuals became involved in management.

Through the first two portions of the survey the history and practices of the fishery were described and opinions regarding the management of the fishery were established: fishermen (1) are not satisfied with current fishery management, (2) do not believe the information used to assess the stock and assign catch levels is accurate, and (3) are interested in participating to a greater degree in management of the fishery. In addition to the opinions of the fishermen, feedback was also garnered from open-ended questions and conversations. This information, coupled with research on existing management frameworks, was used to create the organizational scenarios through which data for an alternative management strategy could be collected.

The value of the interview sessions with the fishermen go beyond the explicit answers to the survey questions asked. Much of the information used in the general analysis of the dynamics of this fishery, as well as the specific economic analysis information, were garnered from more casual conversations that group members had with fishermen. While this information cannot be depicted or compared quantitatively, it has proven extremely useful in the formation of the potential organizational scenarios as well as creating a general understanding of the fishing community. These conversations also assisted in building relationships between fishermen and researchers.

Through conversations with fishermen an understanding of the daily fishing practices common to this fishery resulted. Fishermen in the nearshore live finfish fishery most commonly use sticks to target grass rockfish and cabezon in very shallow rocky reef areas (<7 m depth). They typically catch an equal number of grass rockfish and cabezon in a fishing day. However, due to quota limitations, size restrictions, and market incentives, the number and size of the fish they land does not reflect this even distribution.

The cabezon quota is typically much less than the grass rockfish quota (Fig. 6). As a result, fishermen fish until they have reached their 2-month cabezon quota, and then continue until the end of that fishing day only keeping grass rockfish they catch and throwing back any cabezon, which is inefficient. Due to the disparity between the cabezon and grass rockfish quotas and common fishing practices, grass rockfish quotas that are never met. This quota disparity is a major concern for fishermen.

Fishermen throwback small fish of both species based on each species' minimum size limits; the grass rockfish limit is 12 inches and the cabezon limit is 15 inches. However, the cabezon market is also unique in that the market prefers "plate-sized" fish: medium-sized cabezon fetch over two times the market price of large cabezon (medium are $8.50/lb, large are $3.50/lb). As a result of these market characteristics, fishermen usually throw back both small and large (>4 lbs) cabezon. This information indicates simply measuring the length of fish brought back to port will not result in a representative size structure of these populations as fishermen are artificially selecting fish to land. To account for this artificial selection, on-board sampling is crucial to assure accurate length frequency data.

Ultimately, the fishermen communicated a general sense of disenchantment in regard to current management practices in the nearshore fishery, as well as with the data used to inform these management decisions. All fishermen interviewed indicated alternative cooperative methods to increase fishery data should be pursued further. The fishermen were also interested in being involved in collaborative data collection methods discussed, especially in cases where these data have the potential to inform management decisions. All fishermen also indicated that the live finfish fishery once provided a significant portion of their annual income. However, due to the tightening of precautionary management restrictions in light of limited data availability, the economic viability of this fishery has decreased significantly since these fishermen became involved in the fishery. Many fishermen communicated that a significant portion of the problem with current management is the paucity of accessible data required to assess these fisheries. They were frustrated by the perceived lack of any governmental actions to increase data collection efforts in the region. While fishermen were clearly interested in increasing data acquisition through collaborative efforts, they also clarified a monetary reward for their efforts may be necessary to assure involvement.

8.3 Data Collection Technology

Fishery data management has a detailed lifecycle including collection, transfer, processing, analysis, and reporting. The use of task-specific, high-throughput equipment and standardized methods can maximize the volume and quality of data available for analysis. Building redundancy, auditing, and security into this lifecycle can ensure data integrity and its access only by authorized analysts or managers.

Acquiring substantial spatially-explicit data means developing a framework for collecting baseline data in MPAs, as well as gathering data aboard fishing vessels, at the docks where fishermen unload their catch, and from the buyers who keep records of fish purchased. To better understand how a data collection system might be implemented in this fishery, we focused on the human, technology, and cost factors relevant to engaging fishermen in data collection. We began by interviewing UCSB researchers and fishermen about current data collection infrastructure and practices, then conducting an assessment of their needs. We used this information to formulate a set of design goals, and conducted a technology search and design process to meet them.

Practices, Technology, and Infrastructure

The nearshore live finfish fishery does not have a standardized data collection infrastructure or methodology. Fishermen obtain rough length measures to determine whether fish are of legal size, but do not record fish lengths unless being paid to do research (fisherman interviews). Vessels are required by law to use and maintain a Vessel Monitoring System (VMS), which transmits location data to an onshore NOAA monitoring facility (Mark O'Brien, *personal communication*). However, this information is used by regulators to enforce MPAs and Rockfish Conservation Areas and data is not used to endow fishery data with spatial information.

At the completion of each fishing trip, fish are sold to a buyer at the Santa Barbara Harbor. Buyers weigh fish (separated by species) in bulk, and pay fishermen based on the market price per pound (J. Wilson, *personal communication*). For each transaction the buyer generates a record known as a fish ticket, and provides a copy to the fisherman. Fish tickets record the total number/weight of fish purchased for each species and a rough measure of location, but these do not include length data for individual fish, and thus no information yielding sample size structure. Boats are spot-checked by CDFG (at either the harbor or on the water) for adherence to species quota and size limits, but these checks are infrequent and moreover designed only to identify below-size-limit catch, not to provide thorough size structure information for all fish onboard.

Jono Wilson has begun to address the fishery's scarcity of data with a scientific sampling program. Fish lengths are sampled dockside (port sampling) for size structure and on board skiffs to include the length of throwbacks. Fishermen are also periodically paid to measure throwbacks while at sea, recording the species, location, and length. This data is combined with port sampling data from the same trip to provide samples of overall size structure. However, only two of 16 fishermen are participating, and fish are measured with rudimentary fish boards, waterproof log sheets, and rough estimates of catch location (e.g. "Western shore of San Miguel Island") (J. Wilson, *personal communication*).

This program represents a leap forward in the availability of spatially-explicit size structure data for this fishery. However, the sampling frequency and coverage is highly constrained by time and funds available to permit researchers and fishermen to collect data, and less precise and spatially resolved than achievable with improved tools and infrastructure.

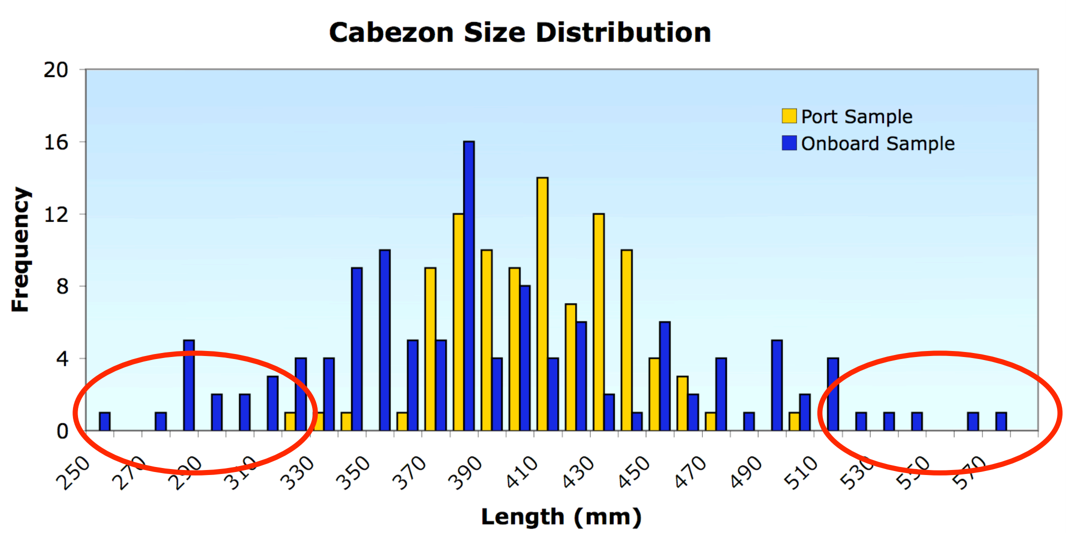

Figure 9. Size distribution differences in cabezon for two different data collection locations, on-board (with throwbacks recorded) and port sampling. The red circle indicates size classes not represented in landings data alone. Source: J. Wilson, unpublished data.

Needs Assessment

Fishermen and researcher interviews revealed that grass rockfish and cabezon are caught almost exclusively with sticks as fishing gear. The fine-scale maneuvering required for collection necessitates that sticks be collected on the 12-16 foot skiffs fishermen keep aboard their larger (22-38 foot) fishing boats (John Colgate, *personal communication*). The skiff is also the location for initial fish size screening and throwbacks. Fish estimated to be close to their minimum size limit or critical price point (4 lbs for cabezon) are more closely evaluated by holding the fish next to a ruler or reference marks on the skiff's hull. Fish of illegal or economically undesirable size are then thrown overboard. This is the only opportunity for fishermen to record throwback lengths, as they are required by law to throw undersized fish back immediately. Because throwbacks represent a significant percentage of overall catch information (Fig. 9), accurate sample of population size structure can only be obtained by measuring the length of throwbacks.

Interviews also included visual inspection of boats and skiffs, as well as visual demonstrations of fishing workflow. Skiffs varied in size, shape, and layout, as did the exact process for launching/retrieving fishing gear and processing fish. These differences highlighted the need for flexibility and customizable measuring and data storage equipment. All boats and skiffs had significant deck space constraints.

A technology search (literature, Internet, and telephone) was conducted in parallel to the interviews, including an examination of current monitoring technologies applied to measuring fish in fishing and aquaculture settings and speaking to experts in the field. Our group developed a portfolio of available technologies and associated benefits and shortcomings, which formed a toolbox for selecting, joining, and creating new solutions appropriate to data collection and management for this fishery.

Design Goals

The needs assessment process helped us generate a series of general design goals for fish measuring equipment:

<u>Yield desired inputs</u>: The solution must provide species, length, and location data for each fish measured. Ideally, collection will create a permanent, redundant data record from which measurements can be checked, calibrated, and re-created in case of data loss.

<u>Minimize time and effort required</u>: Measurement technology must integrate smoothly with fisherman workflow and minimize time investment.

<u>Easy to use</u>: The interface should be simple with a small number of operations, ample tolerance for input error, and be easy to use, even in rough conditions.

<u>Rugged</u>: Technology should be water-resistant or waterproof, robust to a range of temperatures, and resistant to salt corrosion and shock.

Minimize Footprint: The system should occupy a minimum of skiff/boat workspace and avoid physical intrusion into fishing workflow.

Easy maintenance: Maintenance should be infrequent, with fast turnaround time with readily accessible, low-cost replacement parts. Ideally, the system will be serviceable by fishermen.

Minimize cost: Both the up-front purchase cost and any ongoing costs should be as low as possible. Where feasible, design should minimize the marginal cost of adding additional systems.

Scalable: The system should be designed for the current fishery size and configuration but also accommodate possible changes in number of vessels or level of fishing activity.

Minimize power draw: The system should seek to minimize the amount of electricity, if any, drawn from the boat's battery in a given unit of time.

We used these design goals to guide us in the selection of appropriate technology from the following list generated from our technology search.

Equipment/Methods

Our technology search and interviews produced the following collection technologies and methodologies.

Geotagging technology. Many GPS logging technologies are available: GPS-enabled cameras and camera add-ons, GPS-enabled personal digital assistants (PDA) and mobile PCs, and standalone GPS units or GPS loggers. These can be coupled to measurement technologies below to provide high-precision spatial information for each fish or sample group.

Fish board. Similar to those used by researchers at the Bren School, these low-technology boards have low cost, a small footprint, and negligible maintenance costs. These are more labor-intensive and likely less precise than other automated methods.

Camera. Static visual images create a permanent data record and the ability to automate fish length measurement with image recognition software, linked to GPS coordinates with geotagging hardware. However, species cannot be easily encoded by recognition software, requiring species tags at capture or during analysis.

Video. Dynamic visual images also create a permanent record, and offer opportunity for automatic image recognition. However, automation is likely to be substantially more complex than that for still images.

Electronic fish board. Boards like those manufactured by the Limnoterra Corporation (www.limnoterragroup.com) are equipped to automatically encode length and species information, requiring only the touch of a magnetic stylus to mark fish length and encode species information. This can be used on both skiffs and the larger boats, and paired with a GPS logging device to record location based on recording time.

Fish tickets. Completed at the point of sale by buyers, these sales slips record species, total weight, and CDFG block number (a rough location measure, cells roughly 100mi^2) for each group of fish purchased in one transaction. Though this provides some spatial resolution, the lack of per-fish length measurement makes this data unsuitable for the DT.

Onboard observers. Paid or volunteer observers accompany fishermen aboard boats and/or skiffs to measure catch and throwbacks. Observers use a measuring technology. The major drawbacks associated with this method include expense, space occupied by an additional person, and feeling of intrusion experienced by fishermen.

Diving surveys. Visual transect sampling, (such as conducted by PISCO in the Santa Barbara Channel) can support and complement the above fishery-dependent methods, especially for collecting baseline data inside MPAs.

Prototyping

To guide our prototyping process we considered the benefits and drawbacks associated with each of the above methods/technologies, fulfillment of design goals, and collection points at which they might be applied (Table 5).

We used an iterative and adaptive strategy for incorporating user feedback and meeting user needs into collection technology design. Following the initial needs assessment interview, our team discussed individual design options with fishermen in greater detail,

Collection Points vs. Equipment/Methods									
Collection Point	Divers (visual)	Scientific fishing	Fish Board	Electronic Fish Board	Onboard Observers	Camera	Video	Fish Tickets	GPS
MPA	X	x	x	x	x	x	x		x
Dock			x	x		x	x		
Boat		x	x	x	x	x	x		x
Skiff (throwbacks)		x	x	x	x				x
Point of Sale			x	x		x	x	x	

Table 5. Collection points vs. equipment and/or methods for various data collection technology designs.

with special attention to the factors guiding usability and desirability of each design. We incorporated this feedback into prototypes, returning to the fishermen to test equipment designs and garner feedback through observation and dialogue. Fisherman, researcher, and expert input led us through several design and testing cycles. UCSB researchers provided valuable insight into design shortcomings and opportunities throughout the design process, and both fishermen and researchers helped our group understand how to navigate decisions regarding tradeoffs between design goals (e.g. between required time/effort and cost). These suggestions were ultimately incorporated into solution design.

8.4 Data Collection Technology Results

Prototypes

Our needs assessment revealed that for the majority of fishermen who fish with sticks, the only opportunity to collect throwback data in this fishery is onboard skiffs. Thus, for samples to accurately reflect population size structure, the fishery needs a skiff-based solution for measuring throwbacks. Nevertheless, the time, space, and effort constraints on skiffs suggested that *only* throwbacks be sampled on skiffs, while non-throwback catch in a less-constrained location such as the boat deck, dock, or point of sale).

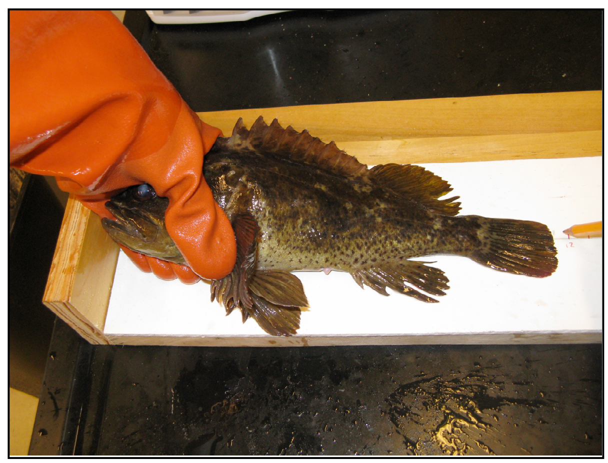

Figure 10. Grass rockfish on simple fishboard.

For our skiff-based design, we recognized that size constraints would necessitate a small footprint size. The simple fish board design currently employed by UCSB researchers is a v-shaped channel with an embedded yardstick, which requires fishermen to write fish lengths on waterproof paper. Using this apparatus introduces time inefficiency, several sources of error, and the possibility of data loss through transcription error or physical damage or loss of data logs. The Limnoterra electronic fish measuring board avoids these risks by allowing fishermen to record length simply by touching a stylus to the board's surface (Fig. 10). This board also offers a number of programmable keys allowing other variables (e.g. species) to be encoded, and internal

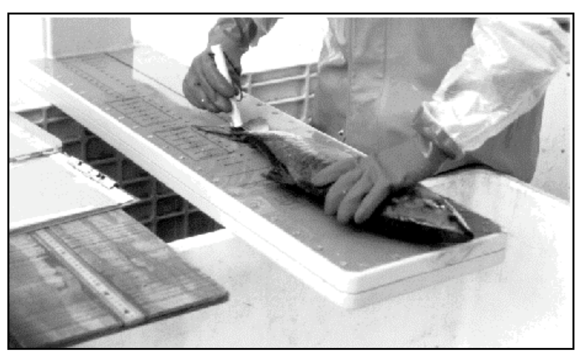

Figure 11. Fisherman using a Limnoterra fish board. Source: www.limnoterragroup.com

hard drive to store recorded data. However this board's cost ($1000 to $3000) would make it difficult for this fishery to purchase one for each fisherman's skiff. The Limnoterra board is currently unavailable for field testing, with the current model sold out and a new version entering production, slated by the firm to be available by the end of 2009 (J. Planck, *personal communication*).

We were able to replicate the core functionality of an electronic board with an inexpensive design, eliminating the need for paper by allowing fishermen to mark fish lengths directly on the board itself. We created a wooden board covered by an insert of PVC dive slate material, sectioned into two horizontal strips, one for each species. Fishermen use this board by holding a fish's nose against the board's left-side ridge, and marking the reach of its tail in the species-appropriate strip. Day and approximate time of fish collection should be recorded for each location. This portable board (or its PVC insert) can be removed from the skiff for laboratory length measurements, and later coupled to GPS data collected with onboard GPS logging technology like TrackStick (www.trackstick.com). Fixed cost for the fish board is minimal (~$30), while basic GPS logging technology currently costs less than $100. As of February 2009, this method is currently being field tested by two fishermen in the fishery.

For the boat-based design, we emphasized small footprint size and minimal required time and effort. Our literature review produced a range of applications with potential for extension to onboard measurement, including acoustic, electrical, and optical sampling techniques. Some of these technologies are capable of measuring fish in three-dimensional tanks (deRosny and Roux 2001), others by passing fish through narrow apertures or sliding them down v-shaped inclines equipped with sensors (Vaki 2008). Some are best suited to installation below deck in a boat's hold, offering the benefit of a small footprint but posing additional challenges for spatial and species identification. Others are better suited to above-board use, but have an imposing footprint which respondents found generally prohibitive. Many systems were also expensive ($5000 per unit and up) and required extensive modification for use on a moving vessel. These were removed from consideration for application to data collection in this fishery.

Figure 12. Camera mounted onboard with grass rockfish positioned underneath on worktable.

Prioritizing integration with workflow and footprint/cost/effort minimization, we integrated fisherman preferences and data needs into a design which allows static photographs to be taken of each fish prior to entering hull storage. This design features an inexpensive (~$300) digital camera mounted on the cabin roof ledge, facing downward to a worktable (4-5 ft. below) where fish are processed. A fisherman brings a fish to the table, holds it close to a ruler mounted on the board, and triggers the camera shutter by hand or foot. The digital image recorded creates a permanent visual record of the fish, its length, and time of image capture. Images can then be processed with automatic image-processing software (like the open-source OpenCV software package) and geotagged with GPS coordinates provided by a GPS logger. The camera and GPS logger can run either on battery power or DC power supply with minimal power demands. Total one-time cost for camera plus GPS logging hardware is roughly $450 per boat. As this method does not provide throwback data, it must be coupled with skiff-based data-gathering in order for samples to reflect the size distribution of fish being caught.

Data Transfer

Once data is acquired, a reliable method is required for retrieving it from boats. UCSB researchers now meet fishermen at the harbor to transfer fisherman-collected data, which depends on coordinating fisherman and researcher schedules. As the number of participating fishermen increases, it becomes highly preferable to find an asynchronous method for transferring data.

The removable PVC inserts from wooden fish boards, GPS loggers, data sticks from electronic fish boards, and flash memory cards from mounted cameras can be stored in a common location accessible to all members of the fishery. This location must be a secure drop-off point, whose contents can be added to by anyone, but only removed by researchers. We suggest a locked drop box, located at the harbor in a location protected from sunlight, weather, and extreme temperatures. Researchers can collect data from these boxes on a regular schedule and eliminate the need for coordinating schedules with fishermen.

A limited amount of data can be transferred to use the onboard VMS required on the fishery's vessels. These systems offer a limited degree of two-way communication, allowing fishermen to send data via plain-text email. This option requires upgrades of the communications plan most fishermen subscribe to, but currently (due to bandwidth restrictions) does not provide for transfer of rich media such as photographs. As such, this method, though desirable for its seamlessness, does not meet the requirements for the current data format. As bandwidth improves, this method may be used to upload data directly to a secure server for analysis by researchers.

Once data returns to the laboratory, it is recorded for analysis. Species and fish length can be recorded from direct fish board measurements. Photographic data can be uploaded via a flash card reader, and measurements recorded automatically (as mentioned above) or by sight, using either the ruler mounted on the fish board, or the standardized photo magnification assured by the fixed focal length between camera and onboard worktable.

Data is stored on secure, password-protected workstations at UCSB, with off-site data redundancy provided by university or third-party data centers. Following entry, data can be analyzed using the DT model. The frequency of data collection and analysis will depend on the model's requirements.

Scenarios

Our group has invested in a prototype version for onboard image capture, and plans to test the design with fishermen and researchers over the course of spring 2009. Recommendations for technology adoption will depend on continued user feedback, refinement of this tool, and funding available to invest in this technology.

Anticipating incremental increases in funding as data collection becomes integrated into fishery workflow, we recommend stages of technology adoption and progress with the fishery's ability to assume costs. The initial (immediate) stage will take advantage of the low cost of wooden fish boards and drop-box method of data transfer. This begins the process of placing data collection in the hands of fishermen and allows for early testing of data transfer, storage, and analysis methods. Stage two includes progressive adoption of electronic fish boards and/or camera apparatus. Stage three will begin as one of these technologies has emerged as the clear choice for the fishery and fishermen and researchers have become comfortable and competent in its use. This will be complemented by a web-based utility for entering, storing, and accessing data - eliminating ties to a single point of access and enabling participation (with differing privileges and levels of access) by fishermen, researchers, and regulators.

Training

Reliable and accurate use of these collection methods will require training in their use by researchers. We recommend that training sessions be conducted in the Santa Barbara Harbor aboard one of the participant's boats. Training will include an overview of data collection methods and equipment, followed by hands-on instruction regarding equipment setup, maintenance, operation (counting, species selection, and position logging), troubleshooting (mechanical failure, computer/user error), operation in a variety of conditions (rain, wind, waves, clouds, time constraints), and data transfer. Quality and methodological standards will be stressed as keys to the program's success and supported with literature, online reference tools, and regular refresher and Q&A sessions. The initial group training session should take approximately two hours. Due to the small size of this fishery and the challenge of gathering all participants together, an alternative is to conduct smaller sessions, or individual 45-minute sessions on each boat.

Associated Costs

As mentioned above, we expect wooden fish boards with removable PVC slate to cost less than $30 per unit, GPS logging units less than $100, camera/remote designs approximately $450, and an electronic fish board $1000 (without internal hard drive) or $3000 (with internal hard drive). These costs can be assimilated into research budgets as fishery data management capacity grows.

8.5 Fishery Organization Scenarios

In order to most effectively utilize data collection technology and the DT method, we developed a progressive organizational framework that delineates how the fishery can efficiently employ the DT management strategy. We highlight three specific scenarios through which the fishery can progressively build organizational complexity in an adaptive step-wise process. These scenarios are: University Funded Collaborative Research, Association, and Cooperative. We developed these scenarios through a literature review and interviews with local fishermen. This section defines each scenario and details fishery-specific benefits and drawbacks, as well as the possible effects on Santa Barbara fishermen. It is important to note that successful implementation of the DT relies upon collaboration among fishermen, UCSB researchers, and fisheries managers through a bottom-up, adaptive process.

Scenario 1: University Funded Collaborative Research

University Funded Collaborative Research utilizes UCSB as the primary motivation and funding source for data collection. This scenario is also the current status quo level of collaboration between the university and local fishermen, as no formal social organization currently exists within the fishery.

Presently, several fishermen work primarily with Jono Wilson to collect data for the nearshore finfish fishery; however, these data are not yet informing management decisions. Data are gathered using two methods: port sampling and onboard sampling. Port sampling consists of a university researcher recording individual fish length and species at the dock. This method, however, constructs an artificial size distribution of the fishery because information from discarded fish is not documented (Fig. 9). Therefore, port sampling alone does not produce sufficient data for use in the DT and must be supplemented with onboard sampling. Similar to port sampling, onboard sampling records individual fish length and species, however catch location can also be recorded. This method also creates a representative size distribution of the fishery, as discarded fish are included in the data analysis. To establish a baseline for the DT, onboard sampling is used both inside and outside reserve boundaries. University scientists play a key role in this process and are onboard each sampling trip. Unlike port sampling, where fishermen are not paid for their time, the university pays fishermen $1200 a day for onboard sampling.

Benefits of University Funded Collaborative Research include the following:

- Data collection results in additional information about the fishery on a finer spatial scale than current datasets, and
- Increased knowledge sharing/educational opportunities between researchers and fishermen via increased communication.

Disadvantages of this scenario are:

- No fishermen input in the progression of fishery research,
- Funding for data collection is wholly dependent upon UCSB and university grants,
- Data collection takes more time and is limited in scope due to the low number of fishermen participating,
- Contact between researchers and fishermen is sporadic and lacks structure, and
- The fishery lacks an official organization in which the CDFG can place trust or management responsibility.

While University Funded Collaborative Research does not create opportunities for modifications to management methods, it does result in additional fishery information, and is the foundation for the successful implementation of the DT. This groundwork is already in place as a result of Wilson's collaborative efforts.

Scenario 2: Association

Building off University Funded Collaborative Research, the second scenario is a loose association of fishermen within the nearshore finfish fishery. Individuals agree to collect data in collaboration with UCSB researchers and conduct regular meetings with formal leadership. University researchers are involved in port sampling, onboard sampling within reserves, and data analysis; however fishermen contribute by collecting length, species, and location data themselves during fishing trips. Although fishermen create a more cohesive social organization with an association, as with scenario one, the fishery is still not formally recognized by CDFG.

Along with the benefits of University Funded Collaborative Research, fishermen who form an association will be eligible to apply for a research set aside (RSA). An RSA is a portion of a fishery's TAC set aside for research that contributes information pertinent to the fishery. There is currently no program on the West Coast that employs RSAs, but the Mid-Atlantic Fishery Management Council (MAFMC) has set up four RSA programs to encourage fishermen participation in data collection in four fisheries (NOAA 2008a). These programs have been successful, and the MAFMC will be producing a comprehensive guide to RSA implementation in spring 2009 (Ryan Silva, *personal* *communication*), which can be used by local fishery authorities (e.g. PFMC) to begin implementing a similar program on the West Coast.

Additional advantages of an association are:

- Increased income for fishermen collecting data via an RSA,
- A larger amount of more spatially-explicit data that covers a wider geographic range is collected due to the increased number of fishermen participating,
- Fishery is able to apply for outside grants and other funding sources and is therefore less dependent upon the university,
- Reduced expenses for university researchers, and
- Increased information sharing between fishermen.

Drawbacks to an association include:

- Time and effort spent away from fishing in order to attend meetings and receive training on data collection methodology, and
- The fishery lacks an official organization in which the CDFGcan place trust or management responsibility.

An association of fishermen is the next logical progression in social organization for this fishery. This structure creates opportunities for more fishermen to become involved in research and data collection as well as provides a venue for university scientists to field test the DT method in order to establish its effectiveness and applicability.

Scenario 3: Cooperative

The most socially complex scenario is a cooperative. Recognized legally as a business or 501(c)(3) non-profit, fishermen in a co-op formally agree to collect data, pay dues, attend regular meetings with formal leadership, and work towards other goals defined by the cooperative. Often the formation of a cooperative leads to group control over fishing behavior of member vessels and less individual autonomy. Potential benefits of belonging to a cooperative could include a TAC allocation for the South Coast region or a TAC allocation for the co-op due to an increase in fisheries population data. Examples of this occurring elsewhere include the East Coast tilefish fishery (Rountree et al. 2008) and the Scotian Shelf groundfish fishery (Peacock and Annand 2008). Currently, there is no regulatory structure to manage regional TACs in California. A cooperative would provide CDFG with an organization in which to place management responsibility and assist in regional TAC management. A similar framework is currently used in the Gulf of Alaska rockfish fishery where individual co-ops comprised of catcher or catcher-processor vessels and processing companies receive a TAC allocation (NOAA 2008a). An illustration of the importance of transitioning from an association to a cooperative is evident as CDFG continues to encourage the California Abalone Association to organize into a more formal cooperative in order to receive its own TAC (Alicia Bennett, *personal communication.*).

The legal pathway to co-op TAC allocation in the United States is quite complex with many layers of regulatory authority. While Alaska's Rockfish Program required a Congressional appropriations act (Glenn Merrill, *personal communication*), the benefits to a co-op from a TAC allocation far outweigh the regulatory burdens necessary to receive one.

Additional benefits include:

- Increased income for South Coast fishermen as a result of a regional TAC or increased income for co-op members as a result of a cooperative TAC allocation,
- Access to University-based scientific expertise,
- Recognition by CDFG leads to negotiating power for co-op members,
- Potential resource pooling of permits, funds, fishing gear, etc.,
- Larger number of fishermen gathering data results in a more complete and credible understanding of the resource condition, and
- Cooperative is able to hire outside consultants and apply for funding, therefore is not dependent upon the university.

Disadvantages of a cooperative are:

- Fishermen pay membership dues,
- Time and effort spent away from fishing in order to attend meetings and receive training on data collection methodology,
- Some loss of individual autonomy,
- Increased responsibility and management burden for the fishery, and
- Possible free riding due to an uneven distribution of benefits.

Suggested members of a fishery cooperative include representatives from CDFG, environmental organizations, federal agencies, and at its core, researchers from UCSB who provide scientific expertise. Including the University as a partner establishes the cooperative as a scientifically informed and legitimate organization in the eyes of state regulators. Scientifically-based adaptive feedback continuously refines the DT and strengthens its capacity as a management tool. Thus, to realize the full benefits of the DT as a management strategy, scientific partnership is vital.

While it is the most time intensive, a cooperative is also the realization of collaborative research being translated into cooperative management. As with any fishery organization scenario, the outcome of a cooperative is not a certainty. However, through the increased spatial knowledge gained by the DT, the fishery can be moved out of data-poor status and hopefully into a more economically profitable state.

8.6 Economic Methods and Results

To compare the three fishery organization scenarios, this project chose to look at annual gross income and the cost of data collection within each scenario. The gross annual income is the portion of fishermen's income derived exclusively from participation in this fishery. Although the nearshore fishery includes multiple species, based on interviews with fishermen concerning their fishing methods, the income calculated is solely from grass rockfish and cabezon. In order to ascertain annual income, fishermen and researchers were consulted to determine what assumptions should be made about fishing behavior. These assumptions are:

- Each fisherman is fishing their total trip limit for cabezon
- Each fisherman is catching cabezon and grass rockfish on a 1:1 ratio
- Each fishing day is ten hours long
- Seven fish per hour are caught
- Each fish weighs 1.5 lbs, which results in a total landed catch of 105 lbs of fish per day
- When the cabezon limit has been reached, the rest of that day is spent on the water fishing, with fishermen throwing back cabezon and keeping only grass rockfish (still caught on a 1:1 ratio)
- A fisherman will receive $8.50/lb for a plate-sized fish and $3.50/lb for larger fish
- Based on this incentive for plate-sized cabezon, we assumed that plate-sized fish are kept 70% of the time and larger fish 30% of the time
- Grass rockfish are always $11.75/lb

Calculations also assumed the monthly trip limit for September/October is 300 lbs. At the beginning of every year, the annual trip limit for cabezon is 1700 ±100 lbs per fishermen (Table 6). CDFG monitors the total monthly landings of cabezon throughout the year, and adjusts the coming months trip limits according to how close total landings are to the TAC. In 2005, the fishery was closed on October 1st since the TAC had already been reached. Every year, months with larger trip limits are modified to reflect the how close the total landing are to the TAC. The Sept/Oct limit has dropped from 900 lbs to either 200 lbs or 300 lbs each year since trip limits have been in place. Instead of 900 lbs, 300 lbs was chosen as a conservative estimate for this analysis.

Year	Jan/Feb	Mar/April	May/June	July/Aug	Sept/Oct	Nov/Dec	Total
2009	300	0	250	150	**900**	100	1700
2008	300	0	250	150	300	100	1100
2007	300	0	250	150	300	100	1100
2006	300	0	250	150	300	100	1100
2005	300	0	250	150	300	0	1000
2004	300	100	250	150	200	100	1100
This analysis	300	0	250	150	300	100	1100

Table 6. Cabezon trip limits from 2004-2009. 2009. In 2005 the fishery was closed on Oct. 1.

Using these trip limits, the amount of each species a fisherman would catch annually, the total number of days fishing until their quota is filled, and the gross income that could be earned from this fishery was determined. The value of one hour is based on the average amount a fisherman earns per day over a year, assuming they fish ten hours/day

Month	J/F	M/A	M/J	J/A	S/O	N/D	TOTAL
Cabezon Trip Limit	300	0	250	150	300	100	1100
Cabezon lbs per Day	52.5	52.5	52.5	52.5	52.5	52.5	
Partial days fishing Cabezon and Grass Rockfish	5.71	0.00	4.76	2.86	5.71	1.90	20.95
Whole days fishing Cabezon and Grass Rockfish	6	0	5	3	6	2	22
Grass Trip Limit	600	0	800	900	800	600	3700
Grass lbs per day	52.5	52.5	52.5	52.5	52.5	52.5	
Grass lbs till Cabezon Trip Limit filled	300	0	250	150	300	100	1100
Additional Grass lbs	7.5	0	6.25	3.75	7.5	2.5	27.5
Total Grass lbs	307.5	0	256.25	153.75	307.5	102.5	1127.5
Total Grass Rockfish Income	$3,613.13	$0.00	$3,010.94	$1,806.56	$3,613.13	$1,204.38	$13,248.13
Total Cabezon Income	$2,100.00	$0.00	$1,750.00	$1,050.00	$2,100.00	$700.00	$7,700.00
Both Cabezon and Grass Income	$5,713.13	$0.00	$4,760.94	$2,856.56	$5,713.13	$1,904.38	**$20,948.13**
$ Earned per fishing day	$952.19	$0.00	$952.19	$952.19	$952.19	$952.19	
$ per hour on fishing days	$95.22	$0.00	$95.22	$95.22	$95.22	$95.22	**$95.22**

Table 7. Methodology used to determine gross annual income and the value of one hour of a fisherman's time during a fishing day. The 52.5 lbs per day of cabezon and grass rockfish assume a catch of 70 fish at 1.5 lbs each, with a total of 105 lbs per fish landed per day.

throughout the year. The one-hour designation is based on the assumption that onboard data collection takes approximately one hour per day. One hour of a fisherman's time on a fishing day is $95.22 (Table 7). Fishermen's gross annual income is based on the amount of cabezon and grass rockfish landed in one year. If a fishermen fished their full cabezon trip limit (which the fishermen interviewed do), and spent the rest of their time fishing only grass rockfish, they would fish for 22 days/year. Under the current

Port Sampling	
15	Seconds/Fish
0.25	Minutes/Fish
17.5	Minutes for 70 fish
$95.22	Value/Hour
$27.77	Time Cost/day

Table 8. The cost per fishing day of port sampling. It takes approximately 15 seconds to measure a fish while port sampling. This results in a total of 17.5 minutes for every fishing day, which is worth $27.77 in time to the fisherman. If a fisherman had fished for three days, then the total port sampling time-cost to that fisherman is $83.32.

scenario, they would earn $7,700 from cabezon and $13,248.13 from grass rockfish, for a total of $20,948.13 (Table 7).

Other costs of data collection, both inside and outside reserves, are based on the current rate of $1200 per day researchers at UCSB pay fishermen to collect onboard samples, which fishermen do not sell. The cost of another method, port sampling, is based on the time it takes to sample one fish, the average amount of fish a fishermen catches in one day, and the value of fishermen's time (Table 8). The resulting port sampling cost is $27.77 for every day that is spent fishing. When a fisherman meets a researcher to port sample, they have typically been fishing for more than one day, so the cost of port sampling if the fishermen returned from a three-day trip would be $83.32.

To determine the value of the RSA, 3% of the current annual statewide TAC was divided among ten fishermen. The assumption of ten fishermen as data collectors was based on the willingness of the interviewed fishermen to participate in data collection and the assumption that some additional fishermen would be willing to collect data for a cash incentive. If there are ten data collectors, each fisherman will receive an additional 178 pounds of cabezon and 913 pounds of grass rockfish. However, based on the 1:1 catch rate of cabezon and grass rockfish, the fisherman will not catch the full 913

	Current TAC	3% RSA	Number Data Collectors *(assumed)*	RSA lbs/data collector	Potential Additional Value to Data Collectors	Additional lbs caught/data collector*	Additional Value	Total Additional Value
Cabezon	59,300	1,779	10	178	$1,245.30	178	$1,245.30	**$3,832.65**
Grass Rockfish	304,238	9,127	10	913	$10,268.03	220	$2,587.35	

Table 9. An RSA, divided among 10 fishermen data collectors will result in an income increase of $3,832.65 per fisherman. * The additional lbs are in additional to the annual total with no RSA. With no RSA, annual cabezon landings are 1100 lbs and grass rockfish are 1127 lbs. With a 3% RSA there are a total of 1178 lbs cabezon and 1348 lbs grass rockfish landed.

additional pounds of grass rockfish. Also assumed, is that fishermen will collect data each time they fish, meaning they will spend one hour collecting data each fishing day, therefore catching 63 fish/day, as compared to the 70 fish they would be catching per day were they not collecting data. Since they are fishing for a higher total amount of fish but at a lower rate, the fishermen will spend more time on the water. With no RSA, they fish this fishery for 22 days per year, while with a 3% RSA they fish for 32 days per year. The value of the RSA per data collector is based on the additional catch and the additional time spent fishing, $3,832.65 (Table 9).

It is possible that the TAC may increase, or that the South Coast region, or a cooperative may receive its own TAC. There is currently no way to predict what increases or decreases may be made to the TAC if this happens, although there is anecdotal evidence

Changes in gross annual income and total number fishing days with trip limit increases.	Annual Gross Income	Fishing Days/Year
Current Trip Limits	$20,948.13	22
1% Decrease	$20,806.50	22
2% Decrease	$20,664.88	22
5% Decrease	$20,240.00	22
10% Decrease	$19,531.88	22
1% Increase	$21,089.75	22
2% Increase	$21,231.38	22
5% Increase	$21,656.25	22
10% Increase	$23,906.56	27
50% Increase	$31,730.63	34

Table 10. Changes in gross annual income from the grass rockfish and cabezon fisheries with various increases in TAC.

that a regional stock assessment will indicate that the cabezon TAC can increase (fishermen interviews). Due to precautionary management of the nearshore fishery, more data will likely lead to an increase in TAC based on a better understanding of the stock. Table 10 demonstrates the range of gross annual income possible with increases in the cabezon TAC. The trip limit changes are based on percentages increases and decreases (1, 2, 5, 10, and 50) chosen to represent a range of possible realistic TAC modifications.

Based on an analysis by MacCall (2008), the amount of data required to lower the covariance of CPUE to a level acceptable by CDFG is 20 samples inside reserves and 20 samples outside reserves (40 total trips) per year. 20 samples outside reserves (20 hours lost collecting data x $95.22 per hour) is a total cost to fishermen of $1,904.40 (Table 11). This amounts to 272 lbs of cabezon, which is only 0.46% of the total cabezon TAC for the state. CDFG can increase the current TAC by less than 1% to allow fishermen to recoup the costs of data collection outside reserves. Involving fishermen in onboard data collection will not only significantly lower costs of data collection, but also the data collected will provide a clearer picture of actual stock status.

Scenario	Inside-Reserve Collection	Outside-Reserve Collection	Total Data Collection Costs
University Funded Collaborative Research	$24,000	$24,000	$48,000
Association	$24,000	$1,904.40	$25,904.40
Cooperative	$24,000	$1,904.40	$25,904.40

Table 11. Total data collection costs in each scenario.

9. Discussion

As shown in our analysis, the DT method is not only politically and logistically feasible, but also socially, biologically, and economically beneficial. Interactions with local fishermen have revealed a desire to participate in collaborative data collection aimed at informing management decisions. Due to the nature of the DT and regional fishing practices, the scale of data collection efforts coincides with the scale of biological sub-population dynamics of nearshore finfish. Additionally, legal barriers appear surmountable, and the implementation of the DT will assist in fulfilling state and federal mandates associated with sustainable fishery management. Furthermore, the economic costs of fishermen-collected data are minimal and easily recouped. New technology streamlines the data collection process into fishermen workflow while simultaneously increasing data accuracy and reliability. While there are political barriers to overcome, our analysis shows the benefits of employing the DT overshadow the complexities of implementation.

This alternative management strategy facilitates data collection on biologically appropriate scales at little cost to CDFG and fishermen. Calculations show data collection costs fishermen $95.22 per day. Both RSAs and an increase in regional TACs can be used as management tools to increase quota for Santa Barbara fishermen. These methods provide strong incentives for fishermen to participate in collaborative research efforts. It is important to note that an additional 272 pounds of cabezon, which is 0.46% of the statewide cabezon TAC, will fully compensate annual time costs associated with data collection. Such an insignificant quota increase will not substantially impact state-wide management efforts. Due to a regional data-rich management strategy produced by the DT method, TACs are projected to increase in excess of the minimum required to recoup data collection costs.

Historically, California fisheries have been managed within a rigid framework based on use of complicated and data-intensive stock assessments. Data collected via collaborative efforts has yet to be significantly incorporated into stock assessments or management decisions. While there is no precedent for employing alternative management strategies in California, acceptance of such methods is developing within CDFG (Phipps et al. *in prep*). Reforming management to incorporate data on biologically appropriate scales is crucial to sustainable management of fisheries that exhibit sub-population dynamics. Furthermore, this integration will allow for the successful enactment of long-unfulfilled state and federal legal mandates.

Although the Santa Barbara nearshore finfish fishery is not in jeopardy of collapse, regionally specific improvements to management and research methods will greatly benefit the fishery and its participants. Continued disregard of local sub-population dynamics and fishermen needs will likely result in the following:

- Persistent data-poor status
- Precautionary management leading to low TACs
- Lack of biologically significant, spatially-explicit population knowledge and understanding
- Over/under fishing of sub-populations
- Continued fishermen frustration with management methods
- Waning economic sustainability
- Fishing effort shifts to other local fisheries
- Inadequate implementation of legal mandates

The DT has the capability to overcome these challenges while also contributing to the integration of MPAs into fisheries management.

To most effectively implement the DT, communication and collaboration between fishery participants and UCSB researchers such as Jono Wilson must continue. The inclusion of CDFG in the dialogue as an active member in this adaptive process is also necessary. Immediate actions include workshop development to discuss the science behind the DT, fishery organization options, and the desire of fishery participants to move forward with an alternative management strategy. Adaptive management is an iterative process based on the progression of continual feedback to reach an optimal state. Full realization of the DT is possible through the integration of fishermen, scientists, and managers in this process.

The need for an alternative management strategy in the grass rockfish and cabezon fisheries is evident. The DT is the most locally applicable and adaptable of these methods to date, and therefore appropriate to use in the Santa Barbara nearshore live finfish fishery. This approach not only aligns the scale of stock assessment with the scale of biological function, but also decreases data collection costs by using fishermen-collected data and integrates MPAs into fisheries assessment and management. Effective implementation of the DT is most efficiently accomplished in conjunction with a cohesive fishery organization. We have conceptualized this as an organic, step-wise process of increasing organization from University Funded Collaborative Research, to an Association, and finally a Cooperative. Within a cooperative framework, data collection and assessment goals are achieved, and the burden of management responsibility can be shared between CDFG and local fishermen. The Decision Tree alternative management strategy has the capacity to transition the nearshore finfish fishery from precautionary to science-based management, simultaneously increasing collaboration between fishery stakeholders and improving economic and biological sustainability.

10. Works Cited

50 CFR Part 679.2.

50 CFR Part 600.

Bennett, A. *Personal communication.* California Abalone Association. 8 January, 2009.

Bergen, M. D.A. Aseltine-Neilson and C. Valle. 2008. Changes in commercial fishery catch and landings for selected fishes and invertebrates in the Channel Islands region and Southern California. *Special Session: The First Five Years of Monitoring the Channel Islands Marine Protected Area Network.* California Department of Fish and Game. <http://www.dfg.ca.gov/marine/channel_islands/specialsession.asp>

Berkeley, S.A., M.A. Hixon, R.J. Larson, and M.S. Love. 2004. Fisheries Sustainability via Protection of Age Structure and Spatial Distribution of Fish Populations. *Fisheries.* 29(8):23-32.

Cal. Fish and Game Code § 7070.

Caselle, J., S. Hamilton, D. Malone, D. Kushner, M. Carr. 2008. How do patterns of abundance and size structure difference between fished and unfished waters in the Channel Islands? Results from SCUBA surveys. *Special Session: The First Five Years of Monitoring the Channel Islands Marine Protected Area Network.* California Department of Fish and Game. <http://www.dfg.ca.gov/marine/channel_islands/specialsession.asp>

CDFG. 2001. The Master Plan: A Guide for the Development of Fishery Management Plans as directed by the Marine Life Management Act of 1998. *California Fish and Game Commission.* 20 Lower Ragsdale Drive, Suite 100. Monterey CA 93940.

CDFG. 2002. Neashore Fishery Management Plan. California Department of Fish and Game. <http://www.dfg.ca.gov/marine/nfmp/index.asp>

CDFG. 2004a. Fisheries Forum Annual Report for 2004. <http://www.dfg.ca.gov/marine/fforum2004.asp#groundfish>

CDFG 2004b State of California Fish and Game Commission Initial Statement of reasons for regulatory Action. Amend Sections 52.10 and 150.16 Title 14, California Code of Regulations Re: Cabezon Total Allowable Catch and Cumulative Trip Limits. <http://www.fgc.ca.gov/regulations/new/2004/52_10isor.pdf>

CDFG. 2008a. Marine Life Protection Act Initiative. May 20, 2008. <http://www.dfg.ca.gov/mlpa>

CDFG. 2008b. California Marine Life Protection Act Master Plan for Marine Protected Areas. *California Fish and Game Commission.* 20 Lower Ragsdale Drive, Suite 100. Monterey CA 93940.

CDFG. 2009a. <http://www.dfg.ca.gov/marine/>

CDFG. 2009b. Final Commercial Fisheries Reports 2003-2007. <http://www.dfg.ca.gov/marine/education.asp>

California Seafood Council. 2001. The California Nearshore Fishery Management Plan: Some Questions and Answers. California Seafood Council. P.O. Box 1951 Buellton CA.

Caselle, J., S. Hamilton, D. Malone, D. Kushner, M. Carr. 2008. How do patterns of abundance and size structure difference between fished and unfished waters in the Channel Islands? Results from SCUBA surveys. *Special Session: The First Five Years of Monitoring the Channel Islands Marine Protected Area Network*. California Department of Fish and Game. http://www.dfg.ca.gov/marine/channel_islands/specialsession.asp

Channel Islands National Marine Sanctuary. 2009. National Oceanic and Atmospheric Administration. 24 January, 2009. <http://channelislands.noaa.gov/welcome.html>

Cooper, A.B. 2006. A Guide to Fisheries Stock Assessment From Data to Recommendations. Department of Natural Resources, University of New Hampshire.

Culver, C., J. Richards, and C. Pomeroy. 2007. Santa Barbara Channel Commercial Fisheries and Associated Infrastructure Needs. Sea Grant Extension Program, University of California Cooperative Extension. 101pp.

Culver, C. S., S.C. Schroeter, H. M. Page and J.E. Dugan. 2008. Essential fishery information for trap-based fisheries: development of a framework for collaborative data collection. "Managing Data-Poor Fisheries: Case Studies, Models, and Solutions" Workshop. November 17, 2008.

de Rosny, J., Roux, P., 2001. Multiple scattering in a reflecting cavity: application to fish counting in a tank. *Journal of the Acoustical Society of America* 109, 2587 – 2597.

Environmental Defense Fund. 2008a. *Mission Statement*. May 5, 2008. <http://www.edf.org/page.cfm?tagID=370>.

Environmental Defense Fund. 2008b. *An Evaluation of Incentives-Based Management*. May 5, 2008. <http://www.edf.org/page.cfm?tagID=1160>.

Field, J.C., A. E. Punt, R.D. Methot, and C. J. Thomson. 2006. Does MPA mean 'Major Problem for Assessments'? Considering the consequences of place-based management systems. *Fish and Fisheries*. 7:284-302.

Field, J., J. Cope, and M. Key. 2008. A descriptive example of applying vulnerability evaluation criteria to California nearshore species. "Managing Data-Poor Fisheries: Case Studies, Models, and Solutions" Workshop. November 17, 2008.

Fishbase. 2008. Species summary for grass rockfish. December 14, 2008. <http://fishbase.sinica.edu.tw/Summary/SpeciesSummary.php?id=3992>

Froese, R. 2004. Keep it simple: three indicators to deal with overfishing. *Fish and Fisheries*. 5(1):86-91.

Fujita, R.M., K.T. Honey, A. Morris, J.R. Wilson, and H. Russell. 2009. Cooperative Strategies in Fisheries Management: Integrating across scales. *In Press*.

Grafton, R.Q., R. Arnason, T. Bjorndal, D. Campbell, H.F. Campbell, C.W. Clark, R. Connor, D.P. Dupont, R. Hannesson, R. Hilborn, J. Kirkley, T. Kompas, D.E. Lane, G.R. Munro, S. Pascoe, D. Squires, St.I. Steinshamn, B. Turris, and Q. Weninger. 2006. Incentive-based Approaches to Sustainable Fisheries. *Canadian Journal of Fisheries and Aquatic Sciences*. 63: 699-710.

Gunderson, D. R., A. M. Parma, R. Hilborn, J. M. Cope, D. L. Fluharty, M. L. Miller, R. D. Vetter, S. S. Heppell, and H. G. Greene. 2008. The Challenge of Managing Nearshore Rocky Reef Resources. *Fisheries*. 33(4):172-179.

Halpern, B.S. 2003. The Impact of Marine Reserves: Do Reserves Work and does Reserve Size Matter? *Ecological Applications*. 13(1):S117-137.

Hardin, G. 1968. Tragedy of the Commons. *Science*. 162(3859): 1243-1248.

Hilborn, R. and C.J. Walters. 1992. Quantitative fisheries stock assessment and management: choice, dynamics and uncertainty. Chapman and Hall, New York.

Hilborn, R., A. Parma, M. Maunder. 2002. Exploitation Rate Reference Points for West Coast Rockfish: Are They Robust and Are There Better Alternatives? *North American Journal of Fisheries Management*. 22:365-375.

Hilborn, R. 2003. The State of the Art in Stock Assessment: Where We are and Where We are Going. *Sci. Mar*. 67 (Suppl. 1): 15-20

Hilborn, R., K. Stokes, J-J. Maguire, T. Smith, L.W. Botsford, M. Mangel, J. Orensanz, A. Parma, J. Rice, J. Bell, K.L. Cochrane, S. Garcia, S.J. Hall, G.P. Kirkwood, K. Sainsbury, G. Stefansson, and C. Walters. 2004. When can marine reserves improve fisheries management? *Ocean and Coastal Management*. 47:197-205.

Hilborn, R., F. Micheli, and G.A. De Leo. 2006. Integrating marine protected areas with catch regulation. *Canadian Journal of Fisheries and Aquatic Science*. 63:642-649.

Hilborn, R. 2007. "Moving to Sustainability by Learning from Successful Fisheries." *Ambio*. 36(4):296-303.

Johannes, R. 2002. The Renaissance of Community-Based Marine Resource Management in Oceania. *Annual Review of Ecology and Systematics*. 33:317-340.

Key, M. 2008. Bren School request for nearshore permittee information in southern California.

Leal, D.R. 2008. A fishermen's agreement and co-op in Yaquina Bay roe herring. *Case Studies in Fisheries Self Governance*. FAO Technical Paper No. 504. pp. 415-423.

Lucas, S. 2006. History and status of commercial live fish fisheries in California and the United States West Coast. *SPC Live Fish Information Bulletin*. 16:19-25.

MacCall, A. 2008. Sample sizes needed to implement the Density Ratio method, based on 2004-2006 RecFIN/CRFS partyboat sampling in Monterey. MPA Reference-Based Working Group, Santa Cruz, CA. July 2008.

MacCall, A. 2008. *Personnel Communication*. National Marine Fisheries Service. 28 July, 2008.

McElderry, H. 2008. British Columbia Groundfish Fisheries – The Role of Electronic Monitoring in Establishing a Fully Documented Fishery. *Traceability and fully documented fishery as a management tool Conference*. <http://www.fvm.dk/Admin/Public/Download.aspx?file=Files%2fFiler%2fEnglish%2fFisheries%2fHoward+McElderry+-+Electronic+monitoring+of+fishing+activites.pdf>

McElderry, H. and G. Gislason. 2008. Video-Based Electronic Monitoring of Fishing Operations. Draft Paper Presented to Managing Data Poor Fisheries Workshop.

Berkeley, California, 2-4 December 2008.

Merrill, G. 2008. *Personal communication.* National Oceanic and Atmospheric Administration. 12 December, 2008.

Murray, S.N., R.F. Ambrose, J.A. Bohnsack, L.W. Botsford, M.H. Carr, G.E. Davis, P.K. Dayton, D. Gotshall, D.R. Gunderson, M.A. Hixon, J. Lubchenco, M. Mangel, A. MacCall, D.A. McArdle, J.C. Ogden, J. Roughgarden, R.M. Starr, M.J. Tegner, and M.M. Yoklavich. 1999. No-take Reserve Networks: Sustaining Fishery Populations and Marine Ecosystems. *Fisheries.* 24:11-25.

Nakamura, R., C. Mireles, D. Wendt. 2009. Site fidelity, home range, and homing behavior of Cabezon (*Scorpaenichthys marmoratus*) in the South Central Coast of California. *In press.*

National Research Council (NRC). 2001. Marine Protected Areas: Tools for Sustaining Ocean Ecosystems. National Academy Press, Washington, DC.

NOAA. 2008a. Cooperative research partners program. November 20, 2008. <http://www.nero.noaa.gov/StateFedOff/coopresearch/rsa.html>

NOAA. 2008b. Research Set Aside Program: An overview for fishermen and other interested parties. <http://www.nero.noaa.gov/StateFedOff/coopresearch/FishermanBrochure.pdf>

NOAA. 2008c. Encyclopedia of Channel Island Sanctuary Species. National Oceanographic Atmospheric Association. May 15, 2008.

NOAA. 2008d. Central Gulf of Alaska Rockfish Program. Accessed 18 November 2008. <http://www.alaskafisheries.noaa.gov/sustainablefisheries/goarat/default.htm>
.

North Pacific Fishery Management Council. 2008. *Gulf of Alaska Rockfish Pilot Program Review*. National Oceanic and Atmospheric Administration.

O'Brien, M. *Personal communication.* Faria Watchdog, Inc. 12 November, 2008.

Pacific Fishery Management Council (PFMC). 2008. Pacific Coast Groundfish Fishery Management Plan as Amended through Amendment 19. Portland, OR. <http://www.pcouncil.org/groundfish/gffmp.html>

Parma, A. M., J.M. (Lobo) Orensanz, I. Elías, and G. Jerez. 2003. "Keynote Address: Diving for Shellfish and Data: incentives for the participation of fishers in the monitoring and management of artisanal fisheries around southern South America." *Australian Society for Fish Biology Workshop Proceedings.*

Parrish, R. 1999. Marine Reserves for Fishery Management: Why Not. CalCOFI Rep. Vol 40.

Peacock, F.G., and C. Annand. 2008. Community management in the inshore groundfish fishery on the Canadian Scotian Shelf. *Case Studies in Fisheries Self Governance.* FAO Technical Paper No. 504. pp. 101-110.

Planck, J. *Personal communication.* Limnoterra Ltd. 8 January, 2009

Phipps, K.E., R. Fujita and T. Barnes. *In press.* From paper to practice: Incorporating new data and stock assessment methods into California fishery management.

Prince, J., C. Walters, R. Ruiz-Avila, and P. Sluczanowski. 1998. "Territorial user's rights and the Australian abalone (Haliotis sp.) fishery." *Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management. Canadian Special Publication of Fisheries and Aquatic Science.* 125 pp. 367-375.

Prince, J.D. 2003. The barefoot ecologist goes fishing. *Fish and Fisheries.* 4:358-371.

Prince, J.D., N. Dowling, C. Davies, R. Campbell, M. Bassoon, and D. Kolody. 2008. Design and Evaluation of Size and Catch Rate Based Harvest Policies for the East Coast Tuna and Billfish Fisheries" (Australia). *In Press.*

Prince, J.D. 2008. Managing data poor fisheries: solutions from around the world. Marine and Coastal Fisheries: Dynamics, Management and Ecosystem Science. *In prep.*

Pikitch E. K., C. Santora, E. A. Babcock, A. Bakun, R. Bonfil, D. O. Conover, P. Dayton, P. Doukakis, D. Fluharty, B. Heneman, E. D. Houde, J. Link, P. A. Livingston, M. Mangel, M. K. McAllister, J. Pope. 2004. Ecosystem-Based Fishery Management. *Science.* 305:246-247

Restrepo, V.R., G.G. Thompson, P.M. Mace, W.L. Gabriel, L.L. Low, A.D. MacCall, R.D. Methot, J.E. Powers, B.L. Taylor, P.R. Wade, and J.F. Witzig. 1998. Technical Guidance On the Use of Precautionary Approaches to Implementing National Standard 1 of the Magnuson Stevens Fishery Conservation and Management Act. National Marine Fisheries Service.

Rijnsdorp AD, G.J. Piet, and J.J. Poos. 2001. Effort allocation of the Dutch beam trawl fleet in response to a temporarily closed area in the North Sea. *International*

Council for the Exploration of the Sea, Copenhagen, Denmark. ICES CM 2001/N:01.

Roberts, C. M., J.P. Hawkins, and F.R. Gell. 2005. The role of marine reserves in achieving sustainable fisheries. *Philosophical Transactions of the Royal Society B.* 360:123-132.

Rountree, B., P.Kitts, & P. Pinto da Silva. 2008. Complexities of collaboration in fisheries management: the northeast United States tilefish fishery. *Case Studies in Fisheries Self Governance.* FAO Technical Paper No. 504. pp. 135-147

Scholz A., K. Bonzon, R. Fujita, N. Benjamin, N. Woodling, P. Black, and C. Steinback. 2004. "Participatory socioeconomic analysis: drawing on fishermen's knowledge for marine protected area planning in California." *Marine Policy*. 28:335–349.

Silva, R. *Personal communication.* National Oceanic and Atmospheric Association, Cooperative Research Program Specialist. 20 November, 2008.

Smith, B. D., L. W. Botsford, and S. R. Wing. 1998. Estimation of growth and mortality parameters from size frequency distributions lacking age patterns: the red sea urchin (Strongylocentrotus franciscanus) as an example. *Canadian Journal of Fisheries and Aquatic Sciences*. 55(5):1236-1247.

Smith, A.D.M., K.J. Sainsbury, and R.A. Stevens. 1999. "Implementing effective fisheries-management systems - management strategy evaluation and the Australian partnership approach." *ICES Journal of Marine Science*. 56:967-979.

Sylvia, G., H.M. Mann, and C. Pugmire. 2008. Achievements of the Pacific whiting conservation cooperative: rational collaboration in a sea of irrational competition. *Case Studies in Fisheries Self Governance.* FAO Technical Paper No. 504. pp. 425-441.

Tetreault, I., and R.F. Ambrose. 2007. Temperate Marine Reserves Enhance Targeted but not Untargeted Fishes in Mulitple No-take MPAs. *Ecological Applications*. 17(8):2251-2267.

Ticheler H.J., Kolding J., Chanda B. 1998. Participation of local fishermen in scientific fisheries data collection: a case study from the Bangweulu Swamps, Zambia. *Fisheries Management and Ecology*. 5(1): 81-92.

Weber, M.L. and S. Iudicello. 2005. Obstacles & Opportunities For Community-Based Fisheries Management In The United States. *Coastal Enterprises, Inc.* <http://www.ceimaine.org/images/stories/pdf/CommunityBasedFish-eriesManagementReport.pdf>

Vaki. 2009. Company website. <http://www.vaki.is/>

Willis, T.J., R.B. Millar, R.C. Babcock, and N. Tolimier. 2003. Burdens of evidence and the benefits of marine reserves: putting Descartes before des horse? *Environmental Conservation.* 30 (2):97-103.

Wilson, J.R., J.D. Prince and H. Lenihan. 2008. Setting harvest guidelines for sedentary nearshore species using marine protected areas as a reference. *In Prep.*

Appendix A

Research Participants Consent Form

You have been asked to participate in a research study entitled Lowering Barriers to Alternative Stock Assessments and Cooperative Fisheries Research. Thank you for your participation. The live fish fishery in the Santa Barbara area has been traditionally managed under conservative principles, in part due to a lack of information available to assess fish stocks. This project is studying ways in which fishermen, scientists and fisheries managers can work together to create accurate stock assessments using information collected by fishermen. Specifically, the focus of the project is on the nearshore Grass rockfish and Cabezon fisheries of the Santa Barbara Channel Islands. The purpose of this survey is to receive input from fishermen in these fisheries about the characteristics of the fishery, how to collect the data needed to assess stocks accurately and role fishermen would like to play in a cooperative fisheries management group. The survey is being used as a part of a master's project at the Donald Bren School of Environmental Science, in association with Environmental Defense Fund. If you have any questions or concerns about the study you can contact the investigators via email at fisheries@bren.ucsb.edu.

We expect that the interview will take about an hour, but we may contact you again in the future if we have additional questions. The information we collect from you will be kept private and stored based on an identification number. When reporting the results of our study we will not identify individuals. Participation in the study is entirely voluntary and you may withdraw your consent to participate without consequence. You or the investigator can terminate the interview at any time and you have the right to receive a copy of the consent form that you sign. The information will be destroyed at the conclusion of the project, within one year. If you have any questions regarding your rights as a research subject you can contact the Human Subjects Committee in the Office of Research. The telephone number is (805)893-3807 or you can email at graham@research.ucsb.edu.

____________________ ____________________ ____________

Print Name Participant's Signature Date

Lowering Barriers to Alternative Stock Assessments and Cooperative Fisheries Research

Final Survey

Name:	What % of that time is spent fishing Grass rockfish and/or Cabezon?
Age:	Percent of income from fishing:
Sex:	From what other source (if any) do you receive income?
Total years fishing:	
Total years in nearshore live fish fishery:	What type of gear do you use to fish? (what % of each if use both traps and sticks)
How many days are spent fishing per year:	Which permits do you hold? (circle) South Coast Region Nearshore Permit (SCR NFP) SCR NFP plus Trap Endorsement (SCR NFP +T) Deeper Nearshore Permit (SCR DNFP) Other: general trap, southern rock crab, lobster, urchin diving , cucumber diving and general gill net

Considering the last 5 years, please indicate what you were fishing for in each month/season (If fishing more than one permit/species please indicate how often by using a percentage of time spent on each):

J F M A M J J A S O N D

Of the fisheries listed above, what percentage of your income is from each (add up to 100%).

EVALUATION OF CURRENT SYSTEM

On a scale of 1 to 5 what is your level of satisfaction with the current management of the nearshore live fish fishery in the Santa Barbara Channel Islands?

Dissatisfied Completely satisfied

1 2 3 4 5

In your opinion, on a scale of 1 to 5, how accurate is the current information used to manage Grass rockfish populations?

Inaccurate Extremely accurate

1 2 3 4 5

For Cabezon?

Inaccurate Extremely accurate

1 2 3 4 5

On a scale of 1 to 5 how well does the limit set by total allowable catch (TAC) reflect the sustainable level of fishing for Grass rockfish in the Channel Islands?

Too low Just about right Too high

1 2 3 4 5

For Cabezon?

Too low Just about right Too high

1 2 3 4 5

On a scale of 1 to 5, how much you would like to participate in the management of the Grass rockfish and Cabezon fisheries, compared with your current participation?

Less participation Satisfied More participation

1 2 3 4 5

EVALUATION OF DATA COLLECTION

In the following question, assume that the data collected would be used to determine TAC levels for the Grass rockfish and Cabezon fisheries, in a collaborative agreement with the CA Department of Fish and Game. Up to what length of time would you be willing to spend per fishing day to collect data? (up to one minute per fish/ 1.5 hours per 100 fish)? ________

Would you be willing to measure every fish you throw back? Yes/No

Would you be willing to measure every fish you catch? Yes/No

The current catch levels set by DFG are limited by the data they can collect about the nearshore fishery. We would like to design a system for collecting data on Grass rockfish and Cabezon that include site specific size data at each island. If you could design a system to gather information that included location and fish weight or length, how would you design it?
Please rank the following data collection techniques by ease of use at sea (1 being the easiest and 4 being the most difficult and assuming you already have the equipment).

___Using a wooden board, ruler and pencil/waterproof paper to record species, length and GPS location.

___Using a scale and pencil/waterproof paper to record species, weight and GPS location.

___Using a scale linked to a small computer which automatically records weight and GPS location (and the push of a button to record species).

___Sliding fish down a small ramp connected to a computer, which automatically records length and GPS location (and the push of a button to record species).

ECONOMIC INDICATORS

What is the current average price per pound that you receive for different size classes of Grass rockfish and Cabezon?

In the last 10 years, has the average price gone up or down?

Has the amount you have earned from fishing overall increased or decreased in the last 10 years?

Has the amount you have earned from the Grass rockfish and Cabezon fisheries increased or decreased in the last 10 years?

Have you shifted your fishing efforts toward/away from the nearshore live fish fishery?

Do the fishermen involved in the nearshore fishery currently have a forum for meetings?

If not, would you be willing to participate in a process to reform management using experimental techniques, such as alternative stock assessments? (Meetings would be held on a quarterly basis during the year, for example) Yes/No