Can the success of the MLPA be evaluated?

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Executive summary

The coast of California has been the location of one of the largest experiments in the use of Marine Protected Areas (MPAs) to produce societal benefits from marine ecosystems. This was done by the establishment of 124 protected areas along the California coast instituted as a result of the Marine Life Protection Act (MLPA), and earlier MPAs set up under a range of other mechanisms, most notably the Channel Islands MPAs in 1998. In this paper we try to determine if the objectives of the establishment of the MPAs have been met – that is are MPAs doing what they were designed to do.

We have reviewed the legislation governing the establishment of the MPAs, and the scientific literature resulting from the process and follow-up evaluations. We have done 18 interviews with key participants and identified what data have been collected, and what evaluations have been done.

The core of the paper addresses the MLPA, which has specific statements about its goals. What we find is that few of the goals are well defined enough to actually be evaluated. This is illustrated by the first goal (1) "To protect the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems." Without a definition of structure, function, and integrity we can't ask whether this has changed. We can certainly ask if the abundance of marine life has changed, but the most common metric used for this is the relative abundance inside the protected areas compared to outside. We show this is an invalid comparison because areas outside the reserve have presumably been fished harder because of the effort that is displaced inside the reserve.

The second goal of the MLPA is the most amenable to evaluation if we interpret "rebuild those that are depleted" to mean the increase in fish abundance and catch. The third goal relates to "recreational, educational and study opportunities," which the MLPA has supported through outreach opportunities and scientific study through monitoring. The fourth goal calls for the protection of "unique marine life habitats" which was achieved through the protection of said habitats by MPAs. The fifth goal pertains to "clearly defined objectives…, adequate enforcement and …sound scientific guidelines," two of which are achieved through CDFW enforcement and the support of science throughout the MLPA process. "Clearly defined objectives" is not achieved. The sixth and final goal calls for adaptive management of the MPAs as a network, both of which have been little studied within the context of the MLPA. There is no evidence that adaptive management has been implemented, and it seems impossible to evaluate any aspects of networks except the fact that there are multiple MPAs.

While an incredible amount of data has been collected during MLPA monitoring, no rigorous evaluations of the ecologic or economic effect of MPAs exist. The only exception is a chapter in a Ph.D. thesis asking if targeted fish abundance has increased due to the MLPA. The key problems are a general lack of significant "before impact" data, but more importantly how to identify controls that represent what would have happened in the absence of MPA establishment. Continued monitoring of MPA and reference sites is critical for future evaluation but it seems unlikely that there can be quantitative evaluation of any results of the MLPA beyond the question of whether abundance inside MPAs increased after implementation.

One perspective on the six primary goals is that any time the goal states "protect" the establishment of the MPAs is by itself proof of this having been achieved. This view fails to ask if anything that is being "protected" has changed as a result of the MPA establishment.

Beyond the specific objectives of the MLPA we believe most people expect the impact of the MLPA should have been to increase the abundance of targeted fish species. We find that none of the evaluations conducted by the state agencies and NGOs as follow-up have even asked this question, and the one study that has done this, a Ph.D. thesis at UC Santa Barbara, estimated that there has been no increase in targeted species.

1. INTRODUCTION

1.1 THE MPA MOVEMENT

Unregulated fisheries are often subject to the “tragedy of the commons” in which the lack of ownership of a resource leads to overall depletion [1]. As a response to declining fish stocks, fisheries managers have traditionally taken three paths to management: limiting access, limiting effort, and limiting spatial access [2]. Spatial management can come in many forms including Marine Protected Areas (MPAs), marine reserves, Territorial Use Rights Fisheries (TURFs), and Locally Managed Marine Areas (LMMAs). Commonly, MPAs exclude fishing access and other consumptive resource extraction in “no-take areas”.

Aside from using spatial management in fisheries management, conservation groups, ecologists, and politicians have used MPAs to try to meet conservation goals [2–4]. MPA networks are increasingly being proposed worldwide, claiming benefits to biodiversity and fisheries [4]. Currently, MPAs exist in many countries including Australia, Belize, New Zealand, Ecuador, Kenya, South Africa, and the United States [3]. The Marine Life Protection Act (MLPA) in California is the largest network of MPAs in the United States and during the planning process declared the Act’s potential for benefits to biodiversity and fisheries [5].

Broadly, use of MPAs have the potential for many benefits to marine life, but also consequences to the ecologic and human communities using the area. MPAs can be effective in buffering against uncertainty in management, increasing yields of sedentary organisms, protecting important breeding and feeding grounds, providing opportunity for scientific study, and serving as ecological tourism [3,4,6]. The disadvantages of MPAs include displacement of fishing effort, economic costs to commercial and recreational fisheries, and loss of credibility of fisheries management [4]. These benefits and consequences depend on how clearly defined the objectives of the MPA are, the ability to enforce area closures, and the capacity to monitor and evaluate success.

1.2 EVALUATION OF MPAS

In order to maintain confidence in management decisions, systematic evaluations of management are necessary to determine success. The ability to evaluate a management decision requires clearly defined objectives or goals and monitoring using the best available science [7,8]. The monitoring of MPAs should be robust and include before-after-control-impact (BACI) designs, adequate replication (of taxa, samples, and sites), estimates of impacts of fishing inside and outside of MPAs, multiple years, and habitat comparability among sites [9]. Once the evaluation is complete, the managing agency is responsible for an organizational response to the evaluation, ranging from continued use of the management tool to rejection and development of a new management tool [7].

Often institutions in charge of MPA management partner with other institutions for the purpose of evaluations. This is to presumably reduce bias. Calls for monitoring will be answered by regional scientists while the evaluation compiles the separate monitoring efforts into a larger report to the managing agency. The management legislative texts regularly call for evaluation and monitoring but fail to put enough resources behind the evaluation and monitoring for it to be considered scientifically robust.

1.3 PROBLEMS IN DESIGN

1.3.1 Evaluating the impacts of MPAs

In theory MPAs are a management experiment that can be evaluated using statistical analysis building on work on the experimental method developed by R.A. Fisher for agricultural experiments. The three basic elements of the experimental method are replication, control, and randomization of treatments. Ideally there would be a number of possible sites for the implementation of the "treatment", that is, where MPAs would be established. MPAs would be assigned to some sites, and other sites would not have MPAs and be the controls. Ideally the choice of treatments would be randomly assigned. Within this framework the BACI design, "before-after and control-impact" can be used to evaluate the impact of the treatment. The essence of BACI is that you look at how much the factor of interest (i.e.: fish abundance) changed from before the MPAs was established, to how much the abundance changed in the control sites, and the difference in the change is the impact of the MPAs. This design and analysis has been commonly used in evaluating MPAs.

While the MLPA does have replicates, there are very serious difficulties in evaluation associated with randomization and control.

1.3.2 Randomization

As far as we know, MPAs have never been randomly assigned to areas and certainly within the MLPA the assignment was not randomized. Many factors were involved in the selection of MPAs (access to site, habitat type, ecological diversity of the site), but it seems likely that there may have been pre-existing differences between those areas that were designated for MPA status and those that were not. The alternative to randomization is to identify controls (commonly referred to as "reference" sites) that have similar characteristics. This is commonly done in MPA evaluation and was done in the MLPA process. For example, it is not meaningful to compare the response of a rocky bottom MPA to a "reference" site that was sandy. Instead the comparison should be between the response inside MPAs and reference sites in the same habitat and with similar fishing pressure prior to MPA establishment.

1.3.3 Control

The most fundamental flaw in most MPA analysis is the assumption that areas not designated as MPAs are controls. A major consequence of MPAs is the movement of fishing effort, because by definition effort is displaced outside the MPAs. Thus, we would expect the fishing effort outside MPAs to increase, and the abundance outside MPAs to decrease. Even if abundance stayed the same inside MPAs, the decline in abundance outside MPAs would say, via the BACI design, that the MPA had a positive effect. More commonly abundance increases inside the MPA and declines outside, thus exaggerating the apparent impact of the treatment on abundance. A second reason areas outside MPAs are not adequate controls is the possibility that the build up of fish inside MPAs has caused areas outside to increase as well – the so-called "spillover" effect. Given either effort displacement, or spillover, areas outside of reserves cannot be considered as good controls on MPA establishment.

An additional problem is that in many areas, such as the coast of California, there are large environmental changes, such as El Niño, that affect marine ecosystems. If the environmental signal covers the entire region, then the areas outside MPAs do act as controls. However, an increase in abundance both inside and outside MPAs may be interpreted as evidence of spillover, rather than evidence that good environmental conditions affected areas both inside and outside of reserves.

We also want to know if the development of the MLPA has increased the total abundance of fish or the catch. It has often been argued that MPAs can do both, but the problem of the control remains. Total abundance or catch may have increased or decreased due to environmental changes, not because of the MPAs. To get around this problem, scientists have identified areas far removed from the MPAs but still subject to the large-scale environmental signal as controls. An alternative, used by Dr. Dan Ovando, is to use non-targeted species as the control on targeted species [10]. This requires two assumptions which can be evaluated from data. First, Ovando assumed the non-targeted species responded to environmental signals in the same way as targeted species. Ovando's analysis suggested they did prior to the establishment of MPAs. Second, it is possible there is a trophic interaction between species, so that an increase in targeted species due to reduced fishing pressure might impact the abundance of non-targeted species through predation or competition. This must be evaluated on a case by case basis.

1.3.4 Evaluation of the MLPA

The MLPA specifically addressed learning and evaluation as key elements when it specified that adaptive management should be a guiding principle. Adaptive management is defined as “a management policy that seeks to improve management of biological resources, particularly in areas of scientific uncertainty, by viewing program actions as tools for learning.” To learn you need to know the impact of your actions.

Unfortunately, within the MLPA goals, only goal 2 “To help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted” seems amenable to statistical evaluation. And only if we interpret the objective to be to increase the abundance of fish and the catch of fish – this is surely the metric of “rebuild those that are depleted.” Because the objectives of the MLPA are so vague, it is hard to be definitive, but we don’t think there is any dispute that the expectation of the advocates of the MLPA was that it would increase the overall abundance of fish.

1.4 PAPER STRUCTURE

This report is split into five sections. We will first introduce the history, actors, and the goals of the Marine Life Projection Act (MLPA). We will summarize the different stages of the MLPA and set up a timeline of major events. Second, we will describe in detail the main sources of data and the monitoring programs involved in the MLPA process. We will compare data sources and across different methods. Third, we will evaluate the monitoring capability associated with each of the MLPA’s specific goals. Fourth, we will determine, using the data available and the studies published, if the MLPA has the ability to evaluate the economic and ecologic impacts of their no-take marine reserve network. We will make no conclusions on the effectiveness of the no-take marine reserve network. Fifth, we will conclude the paper by looking forward and summarizing what we have discovered. Additionally, a sixth section in the appendix addresses specific questions outlined in the grant text.

2. THE MLPA

2.1 HISTORY

The MLPA process began when conservation groups lobbied for state-wide marine protected area legislation after the successful planning process of a network of MPAs in the Channel Islands [11]. Ultimately, concern about the decline of and threats to marine species pushed the MLPA legislation through [12]. The MLPA passed in 1999 outlining 6 goals to redesign and implement new MPAs to function as a network. Two attempts to implement the MLPA failed due to lack of funding resources and negative reactions from key stakeholder groups [11,12].

In 2004, more funding (from the state, private foundations, and the Resource Legacy Fund) was allocated to the decision-making process, establishing the MLPA Initiative (MLPAI) [11,13]. Additionally, a “Memorandum of Understanding,” among the funders, established a strict timeline for implementation and policies surrounding public transparency [12,13]. The staff of the MLPAI were selected for their negotiation, facilitation, spatial planning, and policy analysis skills, and began the step-wise implementation of 4 of 5 areas of California’s coastal waters. The 4 areas, or study regions, are: the Central Coast (initiated 2003, established 2007), North Central Coast (initiated 2007, established 2010), South Coast (initiated 2008, established 2012), and North Coast (initiated 2009, established 2013). The fifth area proposed was the San Francisco Bay where there has been no progress [11].

In each area, the MLPAI staff appointed a Science Advisory Team (SAT) and regional stakeholder group (RSG) with representatives from all user groups (commercial and recreational fishing, tribal groups, federal and state agencies, conservation organizations, education, research sectors) [13]. The state Secretary of Resources department and the Governor's office then created a Blue-Ribbon Task Force (BRTF) of four to five policy makers to oversee the actions of the RSG and SAT and uphold the timeline and transparency of the MLPAI [5,11]. The BRTF selected the 3 best plans offered by the RSG and SAT to send to the California Department of Fish and Wildlife Commission to make the final decision on study region MPA plans [5,12].

More specifically, in each area, the California Department of Fish and Wildlife (CDFW) and the MLPAI created a regional profile that outlined the ecology, economics, and human uses of that study region. The SAT then developed a set of guidelines for MPAs in the region based off that profile, published science about the region, and science surrounding MPA design [5]. The RSG put together proposals about the spatial configuration of the MPAs, in accordance to the SAT guidelines, to be evaluated by the SAT and BRTF [11].

After a plan for each study region was approved by the Commission, implementation and baseline ecologic, and sometimes economic, studies began. These baseline studies were intended to collect information on the status of the study region before MPAs were established, although these studies often coincided with actual implementation. These studies were to later be used to investigate the impacts of MPA designation. Baseline area studies typically ran for 1-3 years in each of the study regions at minimum collecting data on the abundance, density, and diversity of fish and invertebrate species. In the North Coast study region, for example, baseline studies typically lasted 2 years and collected data on a range of matters like oceanographic conditions, algal, fish, and invertebrate communities on rocky reefs, movement of rockfish, seabird communities, economic costs to commercial fishers and charter captains, and sandy beach and estuary communities [14–24]. These studies were organized by the Ocean Protection Council and undertaken by university scientists in the area as well as environmental non-governmental institutions like PISCO and Reef Check.

Currently, the Ocean Science Trust and CDFW are working together to develop a state-wide Long-Term Monitoring Program (LTMP). A draft monitoring plan was released in July of 2018 [25]. The goal of the monitoring program is to collect data to be used as the "best available science" for adaptive management as prioritized by the MLPA goals. Between the end of study region baseline periods and the start of the LTMP, organizations like PISCO, Reef Check, and CCFRP, in addition to university and state scientists, have been collecting data on the status of protected and non-protected waters on California's coast.

Overall, the 20 year process of the MLPA has established 124 MPAs along the coastline of California, covering roughly 16% of the state's waters, 9.4% of which has a no-take designation [5,11]. The seven year implementation process cost $19.5 million in charitable foundation funds and $18.5 million in public funds [5]. Countless studies have been published with data collected as some part of the MLPA process, from baseline studies to ongoing or long-term monitoring.

2.2 INSTITUTIONS, STAKEHOLDERS, ACTORS

There have been many stakeholders, institutions, and actors involved in the many different stages of MLPA implementation, design, and evaluation. Here we will outline the roles of a few key groups.

2.2.1 CDFW

The California Department of Fish and Wildlife (CDFW) was tasked with the implementation and management of the MLPA. They are ultimately responsible for the provisions of the act and will need to report yearly to the state resources agency and CDFW Commission once the LTMP is implemented. Overall, CDFW has prioritized four main areas in regard to the MLPA: outreach and education, enforcement and compliance, policy and permitting, and research and monitoring.

During the implementation stage, CDFW led the first two unsuccessful attempts and then partnered with private foundations, and the Resource Legacy Fund to create a "Memorandum of

Understanding" to set up the MLPAI [11]. They developed regional profiles for each of the four study regions to inform the SAT of the general ecologic and economic layout of the area.

During baseline monitoring and continued monitoring, CDFW did not collect any of its own data or use any of their data collected for fisheries management purposes. CDFW was not involved in actual monitoring, although they partnered with the Ocean Protection Council to allocate and distribute funds. Less formally, CDFW has worked with scientists at monitoring non-profit organizations, like Reef Check, to give recommendations to create robust monitoring protocols for baseline and continued monitoring. Currently, CDFW and the Ocean Protection Council are working with university scientists to create the LTMP.

CDFW is also in charge of all the public outreach, enforcement of closed areas, and policy reporting associated with the MLPA.

2.2.2 Ocean Protection Council

The Ocean Protection Council partnered with CDFW to assist in implementation of the MLPA and the monitoring associated with it (both baseline and long-term). The Council was established by Governor Arnold Schwarzenegger in 2004 through the California Ocean Protection Act. They are tasked with coordinating activities of ocean-related state agencies, establishing policies for the collection of ocean-related data, and identifying and recommending changes to federal and state law. For the MLPA, the Council directly contributed funds and helped distribute the $16 million in baseline funds between the four study regions [5]. Generally, they distribute funds to scientists through a competitive RFQ (request for qualifications) process led by California Sea Grant. They have partnered with CDFW to develop the LTMP and will distribute funds in the same way as they did with the baseline studies. They plan to prioritize studies that will investigate the function of the MLPA as a network.

2.2.3 Fishermen

Fishermen, both commercial and recreational, were involved in the four study region RSG's tasked with developing proposals for the spatial design of MPAs [26]. Fishermen were appointed to the RSG by the MLPAI and from nominations from local community members [11]. They negotiated with the SAT under supervision by the BRTF to come up with these draft proposals that the BRTF took to the Commission.

During monitoring, fishermen were essential in the development of the CCFRP Program and participate as volunteer anglers on surveys.

2.2.4 Scientists

Scientists were involved in the implementation of the MLPA by being appointed to the SAT that worked with the RSG to develop regional MPA spatial plans [27]. The SAT was tasked with using best available science and the regional profiles of the area to determine the habitats that needed to be prioritized and the amount of area to be protected in each study region. They determined how MPAs would work with existing spatial designations like sea bird rookeries, wastewater outfalls, and pinniped haul-out sites [11]. They also developed size and spacing guidelines using expert opinion on MPA design. Over the four study regions, this included over 50 scientists [27].

Scientists are also involved in the monitoring of the MLPA. Scientists competed for funding for baseline assessments in the competitive RFQ process initiated by the Ocean Protection Council. These scientists are either from universities or organizations like PISCO, CCFRP, and Reef Check. Scientists also advised PISCO, CCFRP, and Reef Check on the design of their monitoring protocols. Currently, many scientists are involved in the creation of the LTMP and will likely compete for funding to do that monitoring.

2.3 Goals of the MLPA

The appendix of the MLPA text includes the 6 goals which guided the development of the MPA network. Table 1 contains the data collected by each goal. These goals are listed below:

(1) To protect the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems.
(2) To help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted.
(3) To improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance, and to manage these uses in a manner consistent with protecting biodiversity.
(4) To protect marine natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic value.
(5) To ensure that California's MPAs have clearly defined objectives, effective management measures, and adequate enforcement, and are based on sound scientific guidelines.
(6) To ensure that the state's MPAs are designed and managed, to the extent possible, as a network.

2.4 Existing evaluations

Currently, a comprehensive review of the state-wide impacts of the MLPA does not exist. The LTMP will help guide such efforts in the future. Although, comprehensive evaluations do not exist, many papers have been published in scientific journals investigating species within and outside the MPAs. Most of these papers are from independent university scientists and thus are only a few years in length and pertain to a specific MPA or species. Some longer studies have been published using data from groups like PISCO, most of these also focus on single species.

3. Monitoring the MLPA

3.1 Data Sources

3.1.1 PISCO

The Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) is the main source of monitoring data for the MLPA. PISCO was founded in 1999 with the purpose of collecting long term ecological data on a broad scale, spanning the west coast from California to Oregon. It is run by scientists from four main universities: Oregon State University, Stanford University’s Hopkins Marine Station, University of California Santa Cruz, and University of California Santa Barbara. Initially, PISCO was funded by the David and Lucile Packard Foundation and now is funded by the Gordon and Betty Moore Foundation, the Packard Foundation, and many smaller public and private grants. PISCO has received funding to collect data for of MLPA baseline studies from CDFW and will receive funding from the LTMP to continue to collect data. All data collected by PISCO is publicly available.

PISCO operates dive and intertidal transects in rocky intertidal and subtidal areas. Initially monitoring locations were chosen to span different biogeographic areas and co-locate across intertidal and subtidal rocky reefs. When funding increased and PISCO began working with CDFW on the MLPA, sites were added to include MPA areas and paired adjacent “control” areas of similar habitat type. Broadly, PISCO use transects to collect data on the count, length, and species ID of marine fishes, invertebrates, and algae.

PISCO split their sampling protocol into fish surveys and invertebrate/algae surveys. Fish surveys occur by scuba dive transects (2m wide, 2m tall, 30m long) that are depth stratified, meaning one diver conducts a benthic transect directly under a diver sampling the mid-water column at each depth of 5, 10, 15, or 20m. Three transects happen at each depth at each site.

Then, the dive pair conduct a canopy transect with the first diver surveying fish and the second diver estimating kelp canopy cover and counting kelp stipes. All identifiable, non-cryptic fish species are counted, their total length estimated to the nearest centimeter, and their locations are categorized into surface canopy, midwater, and bottom.

Benthic invertebrate and algae surveys occur at shallow (5m), mid (12.5m), and deep-water areas (20m) to allow sampling of then inner and outer edges of a reef. There are two 30m transects per depth at each site. Divers use three methods to assess invertebrate and algae assemblages. First, uniform point contact methods are used to assess percent cover of benthic species and characterize substrate. These data are collected every 1m on the 30m transect by the diver picking one point under the meter mark and identifying the species or substrate at that specific point. Second, swath surveys determine the density of kelps and specific macroinvertebrate species and extend 1m to each side of the transect tape. Each macroinvertebrate larger than 2.5cm in diameter is counted and identified. Additionally, sea star aboral length is measured and their disease status is recorded. Third, the size frequencies of abalones and urchins are recorded. Abalone length in measured while urchin diameter is measured.

The data collection has remained consistent since 1999, with only small adjustments in species counted if oceanographic conditions caused unusual species to show up in mass (i.e: 2015-2016 Blob) or invasive species monitoring was added (i.e: European Green Crab). A challenge to this data set is the consistency of sites. As funding fluctuates over time, so does the ability to monitor sites, introducing inconsistencies to the overall dataset.

3.1.2 CCFRP

The California Collaborative Fisheries Research Program (CCFRP) is an important source of fish abundance and CPUE data for the MLPA. The CCFRP was established in 2007 and operates through collaboration with 6 universities: Humboldt State University, Bodega Marine laboratories, Moss Landing Marine Laboratories, Cal Poly San Luis Obispo, UC Santa Barbara, and Scripps Institution of Oceanography. Originally the program only monitored the Central Coast but has since expanded to the entire California coast, covering at least 30 marine reserves, and is included in the LTMP. Methods and monitoring sites were chosen during a workshop with academic scientists, managers, and fishermen.

Sampling sites were chosen using seafloor mapping data and fishermen knowledge of the sites. Sites are equally distributed between inside and outside MPA areas and categorized by a 500m by 500m grid. Sites from this grid are randomly chosen during each sampling trip on charter boats with local fishermen and scientists. These volunteer anglers fish a variety of gear (metal jigs, feathered lures, and barbless baited hook) for a standardized amount of time to get the CPUE for the vessel and gear type. Each fish caught is tagged, measured (total length), and released back into the water for a mark recapture survey. The location and depth of capture and release are recorded. The program has tagged over 80,000 fish and has a volunteer database of 1,000 anglers. These data are not yet publicly available.

3.1.3 Kelp Forest Monitoring Program

The Kelp Forest Monitoring (KFM) Program is run by the National Park Service (NPS) and monitors the kelp forest ecosystem in the Channel Islands National Park (CINP). CINP is located off the coast of Southern California and encompasses 5 islands and their waters within 1 nautical mile of the coast. While the State of California manages the living resources in the park's boundaries, the NPS is tasked with evaluating the health of the larger ecosystem, developing the KFM Program to manage it. In 1981 the KFM program established 13 long term monitoring sites, and over time more have been added including 16 more to help "assist the State of California in assessing the effectiveness of the newly established Marine Reserves around the Channel Islands" (KFM Handbook). Since 2007, their data has been used in baseline monitoring and continued monitoring of the South Coast MPAs.

The current protocol used for monitoring was adopted in 1997 and has remained consistent with the addition of new sites. Monitoring focuses on 16 algae or groups of algae, 41 invertebrates, and all identifiable fish species. These taxa were chosen through a scientific review process to ensure that the KFM has the capability to evaluate both short-term and long-term changes in the kelp forest environment. The KFM uses 12 different sampling techniques to collect data at 12 permanent transects between May and October each year. Paired dive transects using 1m and 5m quadrats document the counts of sedentary species, and 1.5m band paired dive surveys are used to additionally sample sedentary species. Random point contact surveys sample the substrate and sedentary organisms using knotted rope; divers identify all species and substrate types directly under the rope knots.

To monitor non-sedentary open-water species, KFM uses 100m paired diver surveys that differentiate fish counts by species and age-class. They also use roving diver fish counts to collect data on the abundance and species diversity of fish, separating counts into 5-minute time intervals to estimate relative densities of fish species in an area. During one of the 100m paired dives or roving diver surveys, an experienced diver will estimate the total length, and gender if observable, of all fish species encountered. In addition to diver counts, each 100m transect is supplemented with video footage of the transect environment.

3.1.4 Reef Check

Reef Check is an international, non-governmental organization that monitors rocky and coral reefs worldwide to promote education, research, and conservation of these areas. Reef Check was established in 1996 in Los Angeles to monitor and conserve California rocky reefs and international coral reefs. In 2005, Reef Check became involved in collecting data on the MLPA and began monitoring California reefs state-wide in partnership with PISCO in 2007. Some of the data have been used in baseline monitoring programs.

Reef Check uses trained volunteer divers and the same methods as PISCO to conduct 2m x 2m x 30m transects at each site. Reef Check and PISCO have collaborated in site selection to ensure maximum coverage of MPA locations and paired “control” locations. Reef Check goes to each site once a year, the same month, weather permitting, and conducts three transects in two habitat zones (offshore and inshore rocky reef) at aa maximum depth of 18m. They use the same fish and invertebrate/algae survey methods as PISCO but identify fewer fish and invertebrate species (35 fish species, 31 invertebrate species, 8 algae species). Instead, they identify groups of species like rockfish that will taxonomically nest into the PISCO data set to allow use and comparison of both datasets.

3.1.5 CDFW

The California Department of Fish and Wildlife (CDFW), while ultimately responsible for the MLPA, does not directly collect any data to monitor the MLPA. CDFW does regularly collect data on commercial and recreational fish and invertebrate species for the management of the specific fisheries, and this data is sometimes integrated into publications about the MLPA. This includes data from the invertebrate team (abalone, lobsters, urchins), the highly migratory species team (tunas), and the groundfish team (rockfish). These data vary in the method of collection, spatial coverage, and length of time series. Because this data varies with time and species, it is outside the scope of this report to list all data collected by CDFW. For example, in one year on the Marine Invertebrate Survey and Assessment Project, a part of the larger invertebrate team at CDFW, data was collected on the abundance and distribution of abalone predators, the abundance and distribution of abalone, the prevalence of harmful algal blooms, the effect of harmful algal blooms on abalone, oceanographic conditions, and larval Dungeness crab abundance.

Some fishery specific data collected by CDFW includes commercial vessel logbooks, angling and dive records, and report cards from recreational fishers. According to CDFW, commercial vessel, including charter vessel, logbooks are used to evaluate the catch per unit effort and contain information on catch, location, depth, gear, and environmental conditions. These data are not public. Angling and dive records are public and contain data on the record catch by species. Reports include information on the species' weight, length, and location of catch. CDFW collects report cards for specific fisheries: steelhead, sturgeon, abalone, spiny lobster, and salmon (salmon in the Klamath, Trinity and Smith Rivers only). Report cards are not public but contain information on the location and size of each catch.

3.1.5.1 CRFS

The California Recreational Fisheries Survey (CRFS) is run by CDFW and collects information on marine recreational fisheries catch and effort. It was founded in 2004 with the purpose to collect data to use for CA recreational fisheries management. It produces monthly catch and effort estimates on private and rental boats, commercial passenger fishing vessels (CPFVs, also commonly called charter boats or party boats), man-made structures, and beaches and banks. It divides recreational fishing into 6 main districts: the south, Channel, central, San Francisco, wine, and redwood districts. The CRFS uses many methods to collect information, including field sampling of catch, effort, and demographic data, telephone surveys of licensed fishers about fishing modes and times, data from sport fishing sales, and CPFV logs.

3.2 General

We are considering general monitoring as the data that was collected prior to MLPA implementation in each area. Ecological monitoring of California's coastal waters occurred long before the MLPA process began. These data were collected by university scientists, CDFW, and groups like PISCO, Reef Check, and KFM. We consider this monitor to encompass any monitoring in each study region done prior to MLPA implementation and baseline studies.

3.3 Baseline

Baseline studies occurred in each of the four study regions as mandated by the MLPA. These studies typically lasted from 1-3 years and collected data on the habitat conditions, oceanographic conditions, ecological communities, and sometimes the economic and social structure of the region. Funding for baseline studies represented a mix of state and private foundation grants and was distributed via a competitive RFQ process by the Ocean Protection Council and CDFW. Baseline studies were ran by university scientists as well as PISCO, Reef Check, and CCFRP.

3.4 Continuing

We are considering any data collected between the termination of baseline studies and the start of the LTMP in April of 2019 to be continued monitoring. This includes surveys by PISCO, Reef Check, and CCFRP, any data collected by CDFW for fisheries management, and any data collected by university or private researchers that is published in a scientific journal.

3.5 Long term monitoring plan

The LTMP is a joint effort organized by CDFW and Ocean Science Trust to develop a state-wide plan for monitoring of the MLPA. It will likely involve groups like PISCO, Reef Check, and the CCFRP, as well as university scientists. The LTMP was released in July of 2018 and the RFQ was released in November of 2018 to solicit monitoring proposals. The monitoring associated with the LTMP will take place from April 2019 – 2021, culminating in a ten-year management review to the Commission in December of 2022 [25].

4. MONITORING AND EVALUATION SPECIFIC TO GOALS

In this section we will evaluate the monitoring capability associated with each of the MLPA's specific goals. Table 1 contains information on the data collected as part of each goal.

4.1 PROTECT THE NATURAL DIVERSITY AND ABUNDANCE OF MARINE LIFE, AND THE STRUCTURE, FUNCTION AND INTEGRITY OF MARINE ECOSYSTEMS.

4.1.1 Habitats focused on

The text of the MLPA specifies that four key habitat types be protected: rocky intertidal, kelp forest, deep reef, and sandy beaches. Most monitoring has focused on the rocky intertidal and kelp forest ecosystems [28–31] through PISCO, Reef Check, and CCFRP surveys (plus the KFM in the Channel Islands). The deep reef ecosystem was studied in the Central Coast study region via manned submersible [32,33]. Additionally, deep reef ecosystems in each of the four study regions were studied via Remotely Operated Vehicle (ROV) Surveys [28–31]. There are plans to include deep reef ecosystem monitoring in the LTMP using submersibles and ROVs [25]. Generally, deep reefs have less spatial and temporal coverage than kelp forests or the rocky intertidal because they are more expensive to study.

4.1.2 Monitoring and papers published

Most data collected in association with any part of the MLPA can fall under this goal due to the vagueness of the language and the associated broadness of the goal. This includes any general, baseline, continued, or LTMP monitoring.

4.1.3 Conclusions about effectiveness

As stated above, the vagueness of the language makes this goal very broad. One could argue that the process of MLPA implementation by its very nature protects "the natural diversity and abundance of marine life… [and] marine ecosystems." Additionally, this goal should define a metric of "natural diversity" to be able to evaluate its success.

When looking at the information available by habitat type, it becomes clear that the deep reef ecosystems need more attention. Increasing spatial and temporal coverage of deep reef ecosystems will make evaluations of the effect of MPAs in this ecosystem more feasible.

4.2 HELP SUSTAIN, CONSERVE AND PROTECT MARINE LIFE POPULATIONS, INCLUDING THOSE OF ECONOMIC VALUE, AND REBUILD THOSE THAT ARE DEPLETED.

4.2.1 Species of economic value and of depleted populations

Economically valuable species in California, relevant to the MLPA coastal zone, include but are not limited to: rockfish, lobster, red abalone (fishery closed 2018), Chinook salmon, Dungeness crab, lingcod, cabezon, white sea bass, market squid, red sea urchin, and coastal pelagic finfish (sardine, anchovy, mackerel).

Species with depleted populations, relevant to the MLPA coastal zone, include the black and red abalone. Black abalone are found in the South Coast, Central Coast, and North Coast study regions. They are federally listed as endangered species due to mass mortality from disease in the late 1990s. Red abalone were recreationally harvested in the North Coast study region until the fishery closed in 2018. They are found throughout the coast of California. Yellow-eye rockfish, dark-blotched rockfish, cow cod, and bocaccio are depleted species, but are found further offshore and so are less relevant to the MLPA.

4.2.2 Monitoring and papers published

SCUBA surveys by PISCO, KFM, and Reef Check all collect data on economically valuable and depleted species. Intertidal surveys collect data on red sea urchin, red abalone, and black abalone populations, among other fish and invertebrates. CCFRP surveys collect data on all fish species caught by hook and line. CDFW must collect data for the management of any state fisheries. This information has not been integrated into MLPA monitoring.

A series of papers documented that lobsters in the Channel Islands, South Coast study region, are more abundant and larger in MPAs than areas open to fishing and spillover to non-protected areas [34–36]. In the Central Coast region, endangered black abalone and recreationally harvested owl limpets increased in size inside MPAs [29]. We did not find any papers on population rebuilding.

4.2.3 Conclusions about effectiveness

This goal is the most unambiguous and thus is amenable to statistical evaluation, assuming "rebuild" to be the increase in abundance and catch of fish. By integrating CDFW fishery management data with CCFRP CPUE data, we think this goal can be evaluated in a statistically robust manner. Monitoring programs already prioritize collecting information on both economically valuable and depleted populations. However, any evaluation is constrained by the control, so this goal could be improved by specifically defining the control to answer the question if fish species increased in abundance and catch.

4.3 IMPROVE RECREATIONAL, EDUCATIONAL AND STUDY OPPORTUNITIES PROVIDED BY MARINE ECOSYSTEMS THAT ARE SUBJECT TO MINIMAL HUMAN DISTURBANCE, AND TO MANAGE THESE USES IN A MANNER CONSISTENT WITH PROTECTING BIODIVERSITY.

4.3.1 Monitoring and papers published

There have been few papers published explicitly tracking recreational, educational, and study opportunities. The baseline studies in each region provided funding to monitoring, supporting study opportunities, as will continued monitoring with the LTMP.

Broadly, each 5-year review of the four study regions documented outreach and education in the form of developing guidebooks, brochures, and signage about the MPAs and ecology of the region. Additionally, citizen science programs like Reef Check, CCFRP, and LiMPETS (a citizen science group focused on sandy beach and intertidal monitoring) provide educational opportunities. In the South Coast study region, the Wishtoyo Foundation's Chumash Tribal MPA Program teaches 6,000 K-12 students yearly about marine science and the cultural history of the area [28]. The North Coast study region was the first to include traditional ecological knowledge (TEK) to baseline monitoring efforts, working with the Tolowa Dee-ni' Nation [23,31].

The data about recreational opportunities are sparse. On the Central Coast, charter captains became more involved in scuba diving and whale watching trips, forms of recreation, after MLPA implementation [29]. This is because some of their fishing grounds were put in no-take MPAs. The North Central Coast baseline documented that scenic enjoyment of coastal areas is the most popular reason for trips to the coast, but did not compare before and after implementation [30].

4.3.2 Conclusions about effectiveness

Broadly, this goal has been effective because of the science and educational opportunities generated from monitoring. However, having a public database of the science, outreach, and education efforts being conducted in each study region would be useful so that tracking study opportunities is more feasible. Evaluation of this goal would require collecting information on recreational opportunities. Overall, more clearly defining what "recreational, educational, and study opportunities" would be necessary for evaluation and to increase transparency in the reporting of these metrics. Additionally, the limited data available on this goal only applies to after MLPA implementation. In order to make conclusions about whether the MLPA increased these opportunities, data before implementation and at reference sites must be included in any analyses.

4.4 PROTECT MARINE NATURAL HERITAGE, INCLUDING PROTECTION OF REPRESENTATIVE AND UNIQUE MARINE LIFE HABITATS IN CA WATERS FOR THEIR INTRINSIC VALUES.

4.4.1 Monitoring and papers published

Baseline monitoring in each of the four study regions collected valuable information on ecologic communities. In the Central Coast region, sea floor mapping illuminated regional scour depressions that provided habitat for young-of-the-year rockfish, and SCUBA surveys identified six distinct kelp forest community types [29]. In mid-depth and deep ecosystems, seven distinct fish communities were documented and the Soquel Canyon was identified as its own unique community [33]. In the North Central Coast region, estuaries were documented to contain many distinct habitats that support high biodiversity of shorebirds, fish, and invertebrates. Additionally, 99% of half-a-million seabirds were documented to breed adjacent to MPAs [30]. In the South Coast region, rocky intertidal ecosystems have 14 distinct sessile and 9 distinct mobile community groups, kelp forests have 17 distinct communities driven by temperature and substrate gradients, and sandy beaches represent a biodiversity hotspot of macroinvertebrates. Also, the California Least Tern, an endangered species, was shown using estuarine MPAs for breeding [28]. In the North Coast region, estuaries were included in baseline assessments, and rocky intertidal ecosystems were documented to have two clear bioregions [31].

The protection of "representative" marine life habitats is documented in section 4.1.

4.4.2 Conclusions about effectiveness

The MLPA has succeeded in placing MPAs around specific marine life habitats in each of the four study regions. This does create a problem for monitoring. Often MPAs are placed in areas that have increased diversity to begin with. This, in addition to protecting unique habitats, can make it difficult to find a comparable reference site. In order to robustly test the effect of a MPA, data on the area before and after implementation and data on the reference site before and after implementation must be collected. These data may not be sufficiently available for each of the MPAs in the MLPA network.

We assumed that "representative" marine life habitats meant the four key habitat areas outlined in the MLPA text. The goal would be improved by more clearly defining what "representative" refers to.

Additionally, this goal mentions "natural heritage" and "intrinsic value" which without a clear definition are difficult to collect data on and evaluate. "Natural heritage" generally refers to the biodiversity of species, ecosystems, and geologic structures, but for the purpose of evaluation needs to include a "when" or a state of comparison. Specifically, what time period are we striving to preserve the "natural heritage" from: pre-civilization, pre-industrialization, or another time? A similar problem arises for the evaluation of "intrinsic value." What would the measure of this be? This question is not new or unique, in fact this has been debated by philosophers for many years. However, in order to have goals that can be evaluated, some measurement metric must be specified.

4.5 ENSURE CALIFORNIA'S MPAS HAVE CLEARLY DEFINED OBJECTIVES, EFFECTIVE MANAGEMENT MEASURES AND ADEQUATE ENFORCEMENT AND ARE BASED ON SOUND SCIENTIFIC GUIDELINES.

4.5.1 Sound scientific guidelines

As described in detail in section 2 of this report, the SAT was charged with grounding MLPA regional spatial plans in the best available science. This was done to some extent, but over the 8 years of implementation population models drastically improved. These models were not included in SAT implementation because the MLPAI was concerned about comparison across the four study regions, implying that the "best available science" was not used consistently across the four study regions [11].

Expert opinion was used in the development of size and spacing guidelines that directed the development of MPA plans for each of the four regions. The size guidelines drew from tagging studies of California's nearshore reef fishes and literature reviews of California species' movement patterns [27]. These guidelines recognized that large mobile species, like tunas and sharks, would not be impacted by the MPAs due to the small relative size of the areas in comparison to their large home ranges [27]. The spacing guidelines were based on studies of larval dispersal distances of marine organisms, specifically using estimates of genetic similarity across space and knowledge of oceanographic currents and timing of larval life stages [27]. These studies demonstrated that almost all algal species disperse less than 1 km, most invertebrates disperse less than 100 km, and most fish species disperse between 10 and 200 km. This information led to the development of the spacing guideline that MPAs in a region should be placed in similar habitat types within 50 to 100 km of each other [27]. Additionally, the size and spacing guidelines allowed for some flexibility between the regions. In the North Coast region, for example, concern for fishery impacts and the relatively lower fishing pressure relaxed the spacing guidelines.

The MLPA size and spacing guidelines are critiqued in Rassweiler et al [37]. Rassweiler demonstrated that guidelines alone are not good for selecting an optimal design from the many options available. They instead argue for the guidelines to serve as the initial design plans to be altered by stakeholders [37]. The MLPAI planning process engaged stakeholders in the development of the regional plans, but the perceived success of this engagement varies by region and the opinion of the individual involved.

Baseline monitoring and plans for the LTMP have been and will be based in best available science. The RFQ processes involved in funding the projects are highly competitive and select for the best work. Additionally, CDFW and the Ocean Science Trust have helped organizations like PISCO, CCFRP, and Reef Check, among other monitoring groups, develop robust protocols.

4.5.2 Enforcement overview

Effective enforcement is necessary for the integrity of the MLPA. CDFW is in charge of enforcing the MLPA and collects data on the violations and their locations. On the Central Coast, 9.5% (47 instances) of the region's violations occurred within MPAs between September of 2007 and March of 2012 [29]. On the North Central Coast, 6% (215 instances) of the region's violations occurred within MPAs between January of 2010 and December of 2014 [30]. On the South Coast, 8% (760 instances) of the region's violations occurred within MPAs between January of 2012 and December of 2015 [28]. On the North Coast, 2% (26 instances) of the region's violations occurred within MPAs between January of 2013 and July of 2017 [31].

4.5.3 Monitoring and papers published

Science about the MLPA process is contained in the baseline, continued, and LTMP monitoring. This science is contained in reports from CDFW and the Ocean Science Trust and publications in peer-reviewed journals and will inform the management of the MLPA after the 2022 10-year review.

CDFW tracks enforcement information and the only reports we have found it mentioned in are the 5-year reviews of each of the study regions.

Fox et al. 2013a described the "strong legal mandate" of the MLPA and its specific flexibility in its goals as one of the main factors that made the third MLPA implementation effort a success. This is the only paper we have found documenting "clearly defined objectives."

4.5.4 Conclusions about effectiveness

Ultimately, the MLPA has been effective in establishing and using scientific guidelines and ensuring adequate enforcement in its multiple stages. The MLPA did not succeed in having "clearly defined objectives," because we have found ambiguity in each of the six goals.

However, there is room for improvement in both the scientific guidelines and enforcement sections. Increasing attention could be given to advancements in population modelling and to using historical data to model MPA and reference sites before MLPA implementation to achieve more robust comparisons. Enforcement could be increased in problem areas like the Channel Islands where rates of poaching are highest. More staff could be allocated to the area or fines could be increased.

Most importantly, the goals of the MLPA should be edited for increasing specificity and clarity to create a transparent evaluation process. Currently, many goals could refer to a suite of data which can bias an evaluation.

4.6 Ensure the State's MPAs are designed and managed, to the extent possible, as a network.

4.6.1 Network and adaptive management

The MLPA text does not define "network" but does define "adaptive management" as "a management policy that seeks to improve management of biological resources, particularly in areas of scientific uncertainty, by viewing program actions as tools for learning." In regard to adaptive management, in the early stages of MLPA implementation a "Memorandum of Understanding" amended the implementation timeline [5]. However, the SAT was not allowed to use updated population models for the sake of continuity, which is in direct conflict with adaptive management [11]. Ultimately, adaptive management has not yet been considered in the MLPA monitoring and management process but will be considered after the 2022 10-year review.

4.6.2 Monitoring and papers published

We did not find any papers about the function of the MLPA as a network or the adaptive management of the MLPA.

4.6.3 Conclusions about effectiveness

This goal has not been effective, for network function or adaptive management. First, "network" should be defined in relation to the MLPA and California coastline. The ability to detect network effects on the California coastline will require an incredible amount of data, and most likely some large assumptions to simplify the coastline into a network model. The monitoring data collected has not yet been analyzed for network effects. It is too early in the MLPA process to look for information on adaptive management.

5. Overall Evaluation Capacity

In this section, we will determine, using the data available and the studies published, if the MLPA has the ability to evaluate the economic and ecologic impacts of their MPA network. We will make no conclusions on the effectiveness of the MPA network or of MPAs in general.

5.1 Ecologic: impact of MPAs on the abundance and size of harvested and other species of fish

The 5-year reports of the four study regions document some initial changes. In the Central Coast study region, black abalone increased in size inside MPAs, owl limpets had greater increases in size inside MPAs, and some fish species (cabezon, lingcod, black rockfish) increased in relative abundance in MPAs compared to reference sites [29,39,40]. In the North Central Coast study region, Sea Lion Cove MPA had increases in the total and legal sized abundance of red abalone [30]. In the South Coast study region, older MPAs had significantly higher biodiversity than sites outside of MPAs [28]. In the North Coast study region, an MPA established in 1975 had double the abundance of fish, larger fish, and higher abundances of red sea urchins and commercially and recreationally fished rockfish relative to reference sites [31].

These initial changes documented by the 5-year reports do not represent an adequate evaluation of the ecologic effect of MPAs. These studies achieve a control-impact comparison, but do not achieve a before and after MLPA implementation comparison. As we have shown above abundance outside of reserves is not a control as required in a BACI design. In order to make conclusions about the effect of MPAs, a full BACI design is needed because MPA sites could have had increased abundance, size, or diversity of species relative to reference sites to begin with. Additionally, baseline studies only collected data for 1-3 years, which in the case of the North Coast study region, did not reflect normal environmental conditions. The years of the North Coast baseline data collection coincided with abnormally warm ocean conditions associated with the oceanographic phenomenon termed "the Blob" [14]. Species distributions during this time were altered, compromising the ability of the data to serve as true site condition studies.

However, one case study using data collected by the KFM represents an adequate evaluation of the ecologic effect of MPAs. In the Channel Islands, KFM SCUBA surveys were combined with historical and current logbook data to achieve a true BACI design. Logbook data and local ecological knowledge of lobster fishermen recreated lobster abundance before MPA implementation in MPA and reference sites. Kay et al found that after six years of MPA protection, trap yield increased four- to eightfold, mean size of legal-sized lobsters increased 5–10%, and there was larger size structure of lobsters trapped inside vs. outside of three replicate MPAs [34]. While this study shows increases in MPAs, this is to be expected with the removal of fishing effort and it does not show overall increases in the size or abundance of the species in the region. The study also has the problem of an adequate control.

Researchers have started developing ways around the BACI design when data about pre-MPA fishing pressure is unavailable. Zellmer created a database of harvest intensity in Southern California using Pacific Coast Fisheries records [41]. White developed a Bayesian state-space integral projection model (SSIPM) to get around uncertainty in pre-MPA fishing pressure [42]. Both can be used in future MPA evaluations, helping achieve a BACI design. Additionally, Ovando's work using non-targeted species as the control on targeted species, provides a way around estimates of fishing pressure, but found no evidence that the MLPA increased the overall abundance of fish [10].

Overall, a lot of data has been collected during MLPA monitoring, but no true evaluations of the ecologic effect of MPAs exist to date. The main limitation of existing studies is the absence of a BACI design, but with advancements in population modelling seen with Zellmer, White, and Ovando, the ability to do robust evaluations is closer. The data associated with the LTMP will be incredibly useful, in combination with these new methods, if it continues to prioritize associated MPA reference sites.

5.1.1 Species variation

Importantly, the ability to detect MPA effects will vary with monitoring priority, life history, and mobility. Currently, commercially and recreationally valuable species and depleted species are being prioritized by monitoring, in accordance to MLPA goal 2. These species will be easier to evaluate due to the large amount of data associated with them. Shorter lived and sedentary or sessile species will also be easier to study and evaluate within the context of the MLPA.

5.2 ECONOMIC: IMPACT OF MPAS ON THE COMMERCIAL AND RECREATIONAL FISHERY, BOTH THE CATCH, VALUE OF CATCH, AND ECONOMIC PERFORMANCE

Much less attention has been paid to economic data than ecologic data. The MLPA does not mention fisheries in the act text and did not call for any social or economic monitoring [11]. Luckily, the MLPAI added the collection of economic data to each study regions' baseline monitoring. Baseline data was collected on commercial passenger fishing vessels (CPFV), commercial fishermen, recreational fishermen, and other non-consumptive users (divers, hikers, surfers, etc.). The MLPAI also supported the inclusion of two economic models in the design of study region MPA spatial plans. A short-term "worst case scenario" assumed no spillover or reallocation of effort and a long term dynamic bioeconomic assessment of catch and biomass investigated expected spatial distribution changes [43]. The data used in these economic models, collected by Ecotrust, was criticized for lacking meaningful fisheries groupings and for not being linked to CDFW landings data [44].

Initial impacts of the MPAs were reported in the 5-year reports of each study region. In the Central Coast study region, CPFV operators switched to whale-watching and leisure cruises to diversify their customer base when rockfish fishing was impacted. Commercial fishermen have decreased by almost 70% and over half of commercial fishermen stated in interviews that MPAs have negatively affected their activity, with the largest impacts on nearshore finfish and Dungeness crab fishermen [29]. In the North Central Coast study region, landings, ex-vessel value, and the number of fishermen increased [30]. In the South Coast study region, overall, landings and revenue have decreased, while the number of fishermen has stayed relatively stable [28]. In the North Coast study region, 73% of commercial fishermen stated that MPAs had directly affected their fishing, preventing them from going to traditional fishing grounds. However, 66% of the same fishermen reported no change to fishing income following MPA implementation. Additionally, 79% of CPFV operators specializing in the rockfish/lingcod fishery reported they could no longer fish in traditional grounds [31].

Aside from North Coast study region, the changes documented in the 5-year reports cannot be attributed to MPAs. The changes could be a result of other fishing regulations, environmental change, or economic and social conditions. It will be difficult to separate out the MPA effects on commercial and recreational fisheries, and no evaluation has done so to date.

A case study of California spiny lobster in the Northern Channel Islands used logbook data and fishermen interviews to reconstruct catch history. They found a 5% reduction in total trapping effort after MPA implementation, but no loss of income. Interestingly, they found no evidence of "fishing the line" or concentrating efforts at reserve borders and actually a 5-10% decrease in trapping effort immediately around the MPAs (within 1 km of border) [45]. This study while valuable for its results on "fishing the line," also does not attempt to separate out environmental conditions, fishing regulations, or economic and social conditions from MPA effects.

Notably, CDFW collects data on commercial and recreational fishing and the fished species including information on catch, location, depth, gear, and environmental conditions. These data have not been analyzed in the context of the MLPA but would be very valuable in evaluating MPA effects.

6. CONCLUSIONS

Ultimately, we found that current reports do not evaluate the economic or ecologic impact of MPAs. While an incredible amount of data has been collected on MPA and reference sites on the California coast, it has not yet been used to evaluate any of the goals of the MLPA. Some papers have attempted to document changes but fail to do so in a scientifically robust manner due to problems in design.

The lack of BACI design was the most common reason reports were not considered true evaluations of MPAs. Many reports had information on the control-impact comparisons (or MPA and reference sites) but lacked information on before-after comparisons. Many reports also did not contain adequate replication, although the data should exist with multiple paired MPA and reference sites per habitat type in all study regions. With both economic and ecologic reporting, the problem of controls was introduced, especially when only the control-impact comparison was highlighted instead of a full BACI design.

The MLPA act text itself never mentions monitoring explicitly and instead calls for "sound scientific guidelines." This draws attention to the ambiguity in each of the MLPA's six goals that causes evaluation to be difficult due to lack of discrete and definable objectives. While the MLPA was praised for strong and clear goals, it seems that these are for a flexible legal framework to leverage for conservation objectives rather than for robust evaluation of MPA effects. Additionally, the MLPA text does not mention fisheries or call for any economic or social monitoring. The inclusion of these types of data occurred with the MLPAI during implementation.

During implementation of each of the four study regions, new quantitative methods and population models were ignored for the sake of consistency among regions. Moving forward, the MLPA process should embrace new quantitative methods as researchers are coming up with ways around conventional BACI designs that could make evaluation more feasible. Integrating these methods with the collection of oceanographic and environmental data and continued study of MPA and reference sites will set the LTMP up for success.

In looking over the amount and extent of data collected, we are impressed with what the MLPA actors were able to do with limited resources. This process serves as an example of the need to allocate adequate resources when implementing any management action as large as a state-wide network of MPAs. Baseline data was not collected for enough years to capture site conditions, especially on the North Coast during abnormally warm "blob" years. Increasing site condition study data would have made BACI designs more achievable. Gaps in reporting between the 5-year reviews and LTMP would have caused the loss of monitoring without groups like PISCO, CCFRP, KFM, and Reef Check.

Gathering all of the scientific papers published about coastal California was unfeasible. We attempted to find all of the papers relevant to MPAs and the MLPA, but we undoubtedly missed a few. This report is by no means a comprehensive review and relies heavily on the reports issued by CDFW and Ocean Science Trust.

In our research, we did document many good outcomes of the MLPA process. The North Coast study region baseline was the first to incorporate local ecological knowledge to monitoring and will continue to do so in the LTMP. An incredible amount of data was collected during baseline and continued monitoring, increasing our understanding of California's coastal ecosystems. Baseline monitoring in the North Central Coast was one of the first to document sea star wasting disease. Hundreds of publications using MLPA data have been published in peer-reviewed journals, increasing information available on many California species. The state of California will continue to benefit from the monitoring programs involved with the MLPA like PISCO, Reef Check, KFM, and CCFRP. The creation and involvement of citizen science groups like CCFRP, Reef Check, and LiMPETS will continue to engage communities and provide educational opportunities.

6.1 WHAT NEEDS TO CHANGE

To continue to improve the MLPA evaluation capacity we recommend creating a public map of monitoring sites with an overview of methods of data collection and the program involved. This would provide a venue for making data publicly available in an easy to access format. We also recommend exploring integration of data across ecosystems and study regions to begin to formulate a plan for evaluating a network effect. Dr. Eve Robinson, a post-doctoral researcher at Humboldt State University and Ocean Science Trust, has been working on project integration of the North Coast study region baseline projects. Additionally, since we cannot go back and collect more baseline data, we recommend pursuing quantitative population models and other options for controls to assist in evaluation of MPA effects.

6.2 LESSONS FOR OTHER SYSTEMS

In reviewing the many phases of the MLPA and evaluating its ability to evaluate itself, we have documented some key lessons for other MPA systems. First, allocating adequate financial and human resources early on in the process is necessary for designing a successful monitoring program and implementing a MPA network. Second, specifying clear and definable goals is important to guide monitoring efforts and ensure evaluation of the MPAs is possible. Third, specifying adequate time and resources for baseline and site condition studies will set up the evaluation capacity. Fourth, in the design of monitoring and site condition studies attention must be paid to creating a BACI design with adequate controls and replication. Fifth, all monitoring should collect environmental and oceanographic data to integrate in evaluations. Finally, it is beneficial to develop monitoring plans at same time as legislation, if possible, to ensure there are no gaps in data.

7. Appendix

7.1 Point by point discussion of Steve Scheiblauer's questions

7.1.1 What site condition studies were done prior to MPA designation which might serve as a comparison?

Baseline studies, of MPAs and reference sites, occurred in each of the four study regions as mandated by the MLPA. These occurred at the same time as MLPA implementation. Some MPA or reference sites, mostly in the South and Central Coast study regions, have data on them before MLPA implementation from PISCO surveys.

7.1.2 If none were done, how are changes or "benefits" from the MPA regulations measured?

Changes from the MLPA regulations are measured by comparing MPAs to their reference sites and across other pairs of sites in a study region. This represents the control-impact aspect of a BACI design but does not achieve the before-after aspect. It also continues the fallacy that reference sites are true controls.

7.1.3 Were habitats of similar composition, outside of the MPAs, measured for biodiversity, fish sizes, density, etc, to also serve as a basis for comparison?

Yes. MPA reference sites were chosen by similarity in habitat type, ocean and environmental conditions, and ecological communities. These areas were monitored during baseline studies, continue to be monitored by monitoring programs (PISCO, CCFRP, Reef Check, KFM), and will be integrated into the LTMP.

7.1.4 Are the data sufficient to determine if the MPAs increased or "restored" biodiversity?

This is addressed in section 5.1. To evaluate if biodiversity is "restored," a target number of each species would have to be specified and current abundances compared against that number. The simple answer is no this cannot be evaluated except in so far as the approach of Ovando is used, and this concluded there was no "restoration" of biodiversity.

7.1.5 Are the effects of large predators (sea lions, otters, seals, large top predator fish—e.g. ling cod) being measured inside the MPAs?

Data on the number of marine mammals and large top predator fishes has been collected but not analyzed in reference to California's MPAs. Data show that California Sea Otter populations are increasing in the southern end of their range near the Channel Islands National Park. Overall, the effects of predators, in relation to MPAs, are currently not being measured.

7.1.6 Do the California monitoring efforts center on the six goals of the MLPA? If so, are there other important monitoring questions or data development that are missing with that approach? If so, what are they?

This is addressed in section 4.

7.1.7 Given that not all MPAs have monitoring, on what criteria were those that are decided? Are there any gaps in monitoring, especially for the "network" value, that have been missed by this selective monitoring?

The MLPA implemented 124 MPAs along the coastline of California. There are gaps in the monitoring of these and their associated reference sites due to lack of time and economic support. Changes in site coverage has varied with funding, reaching a peak during baseline monitoring, and decreasing during continued monitoring. Baseline monitoring saw the addition of new sites. Waning funding causes sites to be sampled every other year.

Sites are prioritized for monitoring by the length of their time series and in the more remote and less populated North Coast study region by their accessibility.

7.1.8 Has monitoring been performed in the likely areas to which fishing effort was displaced by the MPAs? If so, is a measurement of the net benefit (protected area vs area of focused effort) possible, or been made?

Yes. MPA reference sites were chosen by similarity in habitat type, ocean and environmental conditions, and ecological communities. We assume that fishermen have displaced their effort to areas of similar habitat and ecological communities. Thus, direct comparison of trends in abundance inside and outside the reserve is not valid. Dan Ovando's dissertation has attempted to estimate the net benefit by using non-targeted species as the control and found no evidence that the MLPA increased the overall abundance of fish.

7.1.9 How have monitoring results been measured against the effects of the large federal MPAs (EFH), the RCAs, and other rules for TAC, bag limits, etc? In other words, can the results of the state's MPAs be distinguished?

Monitoring results from the MLPA have not been measured against other fisheries management rules to date. They are treated as completely separate. Notably, the EFH and RCAs have closed more area. It will be difficult to separate the effect of the MLPA from other fisheries management activities.

7.1.10 What efforts have been taken to assure that monitoring and evaluation are unbiased.

All programs associated with monitoring (PISCO, KFM, CCFRP, Reef Check, etc.) have comprehensive management protocols and require extensive training of volunteers and scientists before they collect any data. Each program reports their observers, so an observer effect can be calculated, although it has not been done yet. However, these are not double-blind surveys.

Another way to investigate observer effect is by distributing a questionnaire to observers with questions like "do you think MPAs are a good idea?" and compare the inside and outside MPA data they have collected. An issue none of the evaluations address is evidence that fish are more visible to dive counting within MPAs because they are not fished thus exaggerating the increase in abundance within MPAs.

7.1.11 What has been the role of consumptive users (commercial and recreational) in the evaluation process?

This is addressed in section 2.2.3.

7.1.12 Is there any publication bias – that is are positive results more likely to be published than negative results?

This question is outside of the scope of this report. In order to address it, a detailed set of surveys would need to be distributed to field technicians, scientists, fishermen, and other stakeholders that ask questions about their published and unpublished work or the perceptions of published and unpublished work. Researchers would need to access published and unpublished studies involved in the MLPA and compare the results.

7.1.13 Is there any evidence that the state's MPAs, individually or as a network, are contributing to the health of the CCLE?

We did not find any evidence during my research.

7.1.14 Is there any evidence that the state's MPAs are protecting state waters from the effects of climate change?

We did not find any direct evidence during my research. The ability to detect MPAs buffering ecosystems from climate change effects will require a long time frame and data on the specific effects of climate change which remain widely unknown. These data do not currently exist. McLeod et al. 2009 proposes principles for MPA design to better combat the effects of climate change [46].

7.1.15 Are the MPAs being managed in an adaptive fashion?

This is addressed in section 4.6.

8. TABLE

Table 1: The monitoring data collected for each MLPA objective by time frame (general, baseline, continued, or long-term monitoring—defined in sections 3.2-3.5).

MLPA Objective	Objective Text	Data Collected	Time Frame
1	To protect the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems.	All data collected by PISCO, Reef Check, KFM, CCFRP, and any other monitoring programs, CDFW data collected fisheries management	general, baseline, continued, long term
2	To help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted.	PISCO intertidal and kelp forest surveys, CCFRP hook and line surveys, all actions of Reef Check and KFM, CDFW data collected fisheries management	general, baseline, continued, long term
3	To improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance, and to manage these uses in a manner consistent with protecting biodiversity.	Specific education programs, number of people involved in Reef Check and CCFRP citizen science programs	baseline, continued, long term
4	To protect marine natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic value.	All data collected by PISCO, Reef Check, KFM, CCFRP, and any other monitoring programs	general, baseline, continued, long term
5	To ensure that California's MPAs have clearly defined objectives, effective management measures, and adequate enforcement, and are based on sound scientific guidelines.	CDFW data on MPA rule violations, the number of scientists involved in the SAT process	general, baseline, continued, long term
6	Ensure the State's MPAs are designed and managed, to the extent possible, as a network.	None specifically. Would need to integrate across regions.	general, baseline, continued, long term

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