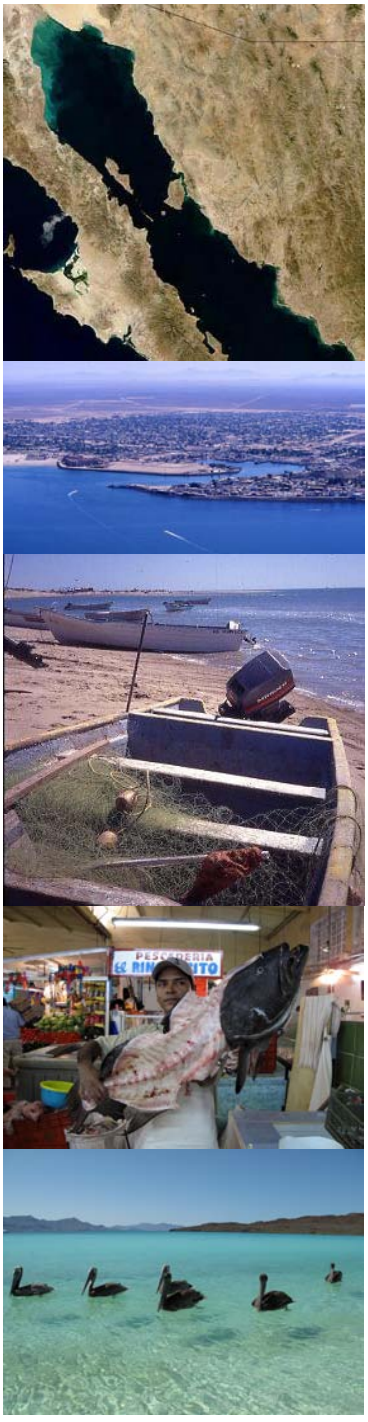

Duke University/Brown University

Artisanal Fisheries of the Northern Gulf of California, Mexico: Environment and Society Project (PANGAS)

A Case Study of Marine Ecosystem-Based Management

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About the Study

Recognizing the declining health of the world's oceans, policymakers, managers and scientists have called for expanded efforts at ecosystem-based management in marine and coastal systems (MEBM). In many places in North America and around the world, collaborative, adaptive planning and management processes have developed to enable scientists, managers and stakeholders to move beyond management of single species and single user groups to incorporate complexity, consider larger scales and longer timeframes, and incorporate measures of ecosystem integrity.

The David and Lucile Packard Foundation invested in the development of science to support management in a number of initiatives in California, Mexico and the Western Pacific. The Foundation also recognized the need to capture the lessons from the experiences at these initiatives as well as the many other places that are trying to move toward an ecosystem-based management approach. Accordingly, they provided grant support to research teams at the University of Michigan and Brown and Duke Universities to develop rich case studies of MEBM, documenting the approaches and their accomplishments, and analyzing the challenges the efforts faced and the factors that have promoted progress. Ultimately, the projects seek to provide lessons that can improve the practice of MEBM.

This document contains one of the complete case studies. Others can be accessed through the project website, which can be reached at: *www.snre.umich.edu/ecomgt/mebm*.

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Introduction

The Gulf of California - also known as the Sea of Cortez - is located between the Baja California Peninsula and mainland Mexico, in the northwestern part of Mexico. It is considered one the most productive and diverse marine ecosystems in the world (Enríquez-Andrade, Anaya-Reyna et al. 2005; Brusca, Findley et al. 2005), and it is the most important fishing region in Mexico, accounting for approximately 50% of national fishery production. It is also a chief supplier of seafood to the southwestern United States and eastern Asia (Ulloa, Torre et al. 2006). Because of its biological importance, the Gulf of California is one of the most closely watched marine systems by the global conservation sector (Lluch-Cota, Aragón-Noriega et al. 2007).

In the northern region of the gulf, there is conflict between fisheries management and marine conservation, mostly fueled by the growth of coastal communities and a significant increase in the size and operations of the small-scale fishing fleet. Along with an increase in effort, the northern gulf has experienced a rise in territorial conflicts over access to fishery resources and declines in production of most species targeted by small-scale fishers (Packard Proposal 2004).

Some small-scale fisheries management problems in the Gulf of California are attributed to past approaches' failure to consider broad ecosystem influences and insufficient understanding of structure and connectivity of marine fishery populations. Coastal marine ecosystems are complex systems influenced by feedbacks between biophysical and human processes. Understanding these feedbacks is critical to successful small-scale fisheries management (Packard Proposal 2004).

In an effort to redress gaps in knowledge and understanding, the University of Arizona received funding primarily from The David and Lucile Packard Foundation to begin a long-term interdisciplinary study of small-scale fisheries in the northern Gulf of California called Project PANGAS (Pesca Artesanal del Norte del Golfo de California: Ambiente y Sociedad)[1] in summer 2005. PANGAS is a partnership of academic institutions and non-government organizations from Mexico and the United States whose goal is "to develop and test an interdisciplinary framework for ecosystem-based research and to translate […] findings into management of small-scale fisheries and policy outcomes" (Packard Proposal 2008). Overall, the initiative may be characterized as an ecosystem-based fisheries management project focused on generating basic scientific information, building local capacity and engaging different levels of governmental authorities in the development of better fisheries policies that promote sustainable use of resources exploited by artisanal fishers. In practice, it has largely involved collecting baseline scientific information.

[1] Translation: Artisanal Fisheries of the Northern Gulf of California: Environment and Society

Ecosystem Characteristics and Stressors

Biophysical Context

The Gulf of California is 1,130 km long and 80-209 km wide, covering an area of approximately 230,000 km^2 (Figure 1) (Lluch-Cota, Aragón-Noriega et al. 2007). The northern part of the gulf is characterized as very shallow (200 m) and an inverse estuary, given the high evaporation rate and the scarce freshwater input from rainfall and the Colorado River (Lavín, Godínez et al. 1998). This area is separated from the rest of the gulf by an archipelago that includes the 2 largest Mexican islands (Ángel de la Guarda and Tiburón) and several sills (Lavín, Durazo et al. 1997), and it is considered one of the most productive portions of the Sea of Cortez (Marinone, Ulloa et al. 2008). PANGAS also focuses on the Midriff region which is dramatically different, with deeper water up to 2000 meters, rocky reef, islands and extreme productivity.

Figure 1. Geographic location of the Gulf of California. The Gulf of California is located in the Northwestern part of Mexico, surrounded by the states of Sonora (1), Sinaloa (2), Nayarit (3), Baja California Sur (4) and Baja California (5)[2].

[2]Modified from: http://www.cet.com.mx/intercet/imagenes/downloads/mapas/mexico_dp.gif

There is a wide variety of coastal and marine environments and habitats in the Gulf of California, which range from tropical mangrove forests and coral reefs to hydrothermal vents with biotic communities supported by chemosynthesis. The gulf's eastern shores are mostly comprised of sandy beaches, vast coastal lagoons that supply large amounts of fresh water, and open muddy bays; whereas its western coastline is mostly rocky, with some pocket beaches and practically no drainage (Lluch-Cota, Aragón-Noriega et al. 2007). The gulf is the only large evaporative basin on the Pacific Ocean (Roden 1958 in Lavín, Durazo et al. 1997) and its climatic conditions range from temperate to tropical (Roden 1958; Badan-Dangon et al. 1991 in Lavín Durazo et al. 1997).

The rich pelagic waters of the Gulf of California are renowned for supporting abundant marine life. Nutrient enrichment of the water column results from tidal mixing around islands and wind-driven coastal upwelling. It has also been demonstrated that agricultural run-off is related to phytoplankton blooms in some areas, especially those directly exposed to the Yaqui Valley discharge (Beman, Arrigo et al. 2005).

This combination of physical and oceanographic/bathometric features has shaped the region's biodiversity, making it a unique, rich ecosystem (PANGAS Handout*). There are 665 species of marine flora, consisting mainly of macroalgae and sea grasses (Aburto-Oropeza and López-Sagástegui 2006). The fauna is highly diverse, comprising at least 5,969 named species and subspecies: 4,854 invertebrates and 1,115 vertebrates (891 fishes, 224 non-fish vertebrates). Of the 224 non-fish vertebrates, 181 are birds, 36 are mammals (31 cetaceans, 4 pinnipeds and 1 bat) and 7 are reptiles (including 5 species of turtles). At least 26 species of seabirds breed in the Gulf of California and the gulf is a feeding and breeding area for cetaceans, although there are also several resident stocks of cetaceans and one pinniped stock. Sea turtles either feed or nest in the region (Lluch-Cota, Aragón-Noriega et al. 2007). Furthermore, the more than 900 islands in the gulf make the region ideal for endemism: there are 770 endemic species and some authors estimate that there are more than 4,000 invertebrate species that remain undescribed (Brusca, Findley et al. 2005).

Social and Economic Context

Although population density is still low, demographic growth in the Mexican northwest is higher than the national average, mainly propelled by a cross-border economic disparity (Stoleson et al. 2005 in Cartron et al. 2005). This growth is particularly conspicuous in coastal communities, where it is directly related to the search for economic alternatives resulting from exhaustion of income sources in the agriculture and husbandry sectors, which is to say that the region's population comes from recent migration and has diverse cultural origins (Luque-Agraz and Gómez 2007).

The Gulf of California region comprises approximately a quarter of the Mexican territory and over 8% of the total population. The per capita contribution of its inhabitants is 5% higher than the national average (Carvajal, Bezaury-Creel et al. 2004). Moreover, 9% of Mexico's gross domestic product (GDP) is attributed to the gulf region primarily due to fisheries, tourism and port activity (Ulloa, Torre et al. 2006).

Fishing is the most important human activity in the Gulf of California. The area is recognized as the country's main source of fishery resources, which account for approximately 50% of national fishery production - generating over 50,000 jobs and involving about 26,000 boats, of which 90% are small-scale boats also known as *pangas* (Ulloa, Torre et al. 2006). The most important products are shrimp, squid (a relatively new fishery), anchovy, tuna and sardines (León y Graizbord 2002 in León 2004; Carvajal, Bezaury-Creel et al. 2004). There is both a small pelagic fishery and a large pelagic fishery. The first primarily targets sardine (*Sardinops caeruleus*) whereas the latter mainly targets tuna (yellowfin *Thunnus albacores*, and skipjack *Katsuwonus pelamis*), billfish (striped marlin *Tetrapturus audax*, blue marlin *Makaira nigricans*, black marlin *Makaira indica*, sailfish *Istiophorus platypterus*, and swordfish *Xiphias gladius*), mahi mahi (*Coryphaena hippurus*), and around 40 species of sharks, including the genera *Mustelus*, *Carcharhinus*, *Alopias*, *Sphyrna* and *Squatina* (Lluch-Cota, Aragón-Noriega et al. 2007).

Small-scale fisheries are very important in the gulf. They exploit approximately 70 species of bony fish, elasmobranches, mollusks, and crustaceans for an annual catch of nearly 200,000 tons (Enriquez-Andrade, Anaya-Reyna et al., 2005). The artisanal fishermen use gillnets, hooks, lines, traps and hookah diving. Over ten years ago, more than 20,000 *pangas* were registered (Cudney-Bueno and Turk-Boyer, 1998).

Another important fishing sector in the Gulf of California is the recreational fishery. The catch has been estimated at 17,000 individuals per year for marlin and sailfish, plus some 54,000 smaller fish like tuna and mahi mahi (Klett-Traulsen et al. 1996). This activity creates employment in many fields that have a direct impact on the local economy (Lluch-Cota, Aragón-Noriega et al. 2007).

The geographic position of the Gulf of California is a key factor in tourism: it is the closest access to the sea for residents from Arizona and other landlocked states in the U.S., and it is a destination preferred by Californians (Ulloa, Torre et al. 2006). Every year, more than 4.8 million visitors come to the gulf and revenues reach nearly US$2 billion (Aburto-Oropeza and López-Sagástegui 2006). The main drivers are recreational fishing and ecotourism opportunities.

Agriculture is also an important sector of the economy in this region. Half of the irrigation crops in Mexico are located in the Gulf of California Ecoregion and it is estimated that 40% of the national crop production comes from the region (mainly from Sonora and Sinaloa, two of the five states surrounding the gulf). Most of the agriculture in this area intensively uses modern technology and fertilizers, and the main crops are wheat, garden produce and oilseed. Further, there is an estimate of 500,000 heads of cattle in this area (Ulloa, Torre et al. 2006, León y Graizbord 2002 in León 2004).

Institutional Context

The Department of Agriculture, Animal Husbandry, Rural Development, Fisheries and Food (SAGARPA) and the Department of the Environment and Natural Resources (SEMARNAT) are the government agencies responsible for fisheries management in Mexico (Figure 2). Even though fisheries management in Mexico has been centralized in the past, in 2007 the

government enacted a new Sustainable Fisheries and Aquaculture Law (Ley General de Pesca y Acuacultura Sustentables, LGPAS), introducing decentralization as one of its primary goals (Cinti, Shaw et al. 2010).

SAGARPA, through the National Commission on Fisheries and Aquaculture (CONAPESCA), is responsible for fisheries regulations, enforcement, and fisheries management tools such as fishing permits, authorizations or concessions[3] (Figure 2). The National Fisheries Research Institute (INAPESCA) is in charge of generating the scientific information that informs the policies created and enacted by CONAPESCA; however, they do not have authority to create or implement policies themselves (Figure 2). One of their main responsibilities is the National Fisheries Chart (Carta Nacional Pesquera, CNP), which is a document that includes cartographic as well as written information regarding the availability and conservation status of fisheries and aquaculture resources that is used to inform and make recommendations to CONAPESCA (INAPESCA, 2006).

SEMARNAT, through the Attorney General for Environmental Protection (PROFEPA)[4], regulates the use of species under special protection and may approve their harvest through a species-specific permit that grants exclusive use rights within a certain area following the guidelines of a management plan (Figure 2) (Basurto and Cinti, 2009, unpublished). The National Commission on Protected Areas (CONANP)[5] helps conserve Mexico's natural heritage and is in charge of establishing and managing marine protected areas.

CONAPESCA and PROFEPA are enforcement agencies; however, their enforcement officers are unarmed. SEMAR, the Marine Secretary, provides support as needed and has among its many objectives to protect marine traffic as well as marine resources and provide surveillance and protection to the marine environment. It is equivalent to the Navy and the Coast Guard of the United States[6].

At the local level there are different state departments (i.e. the Secretary of Fisheries and State of the state of Sinaloa) that are involved in fisheries management; however they do not have authority to issue permits or licenses that would allow harvest of fishing resources. They tend to provide support to fishers through social programs that aid in the acquisition of new boating equipment or programs to build technical capacity (Basurto 2009, pers. comm.).

Fishing permits (granted by CONAPESCA) are the most widely used management tool to regulate access to marine fishery resources (Basurto and Cinti, 2009 unpub.; Cinti, Shaw et al. 2010). Other management tools include national standards (Normas Oficiales Mexicanas),

[3] http://www.conapesca.sagarpa.gob.mx/wb/

[4] http://www.profepa.gob.mx/profepa

[5] http://www.conanp.gob.mx/

[6] http://www.semar.gob.mx/juridico/misiatri.htm

which are species-specific or time-specific and usually entail closures (temporal or permanent), and gear or size restrictions (Cinti, Shaw et al. 2010).

The limited capacity of the government to deal with fisheries management and enforcement is widely recognized. In addition, corruption, growing immigration rates to the coast and the substantial cost for fishers to organize and participate in collective-action processes promote a *de facto* situation of open access (Basurto and Ostrom 2009; Cudney-Bueno, Bourillón et al. 2009; Cinti, Shaw et al. 2010). Environmental legislation in Mexico has increased in the last 20 years and appears to contain the necessary legal instruments to ensure biodiversity and ecosystem conservation; however, enforcement of this legislation continues to be a challenge:

> The real challenge is not the continuous enactment of laws, administrative rules, norms, or provisions, but the strengthening of the country's rule of law to ensure that effective enforcement and implementation of environmental legislation becomes the rule rather than the exception, as is the case now. (Székely et al. 2005 in Cartón, Ceballos et al. 2005)

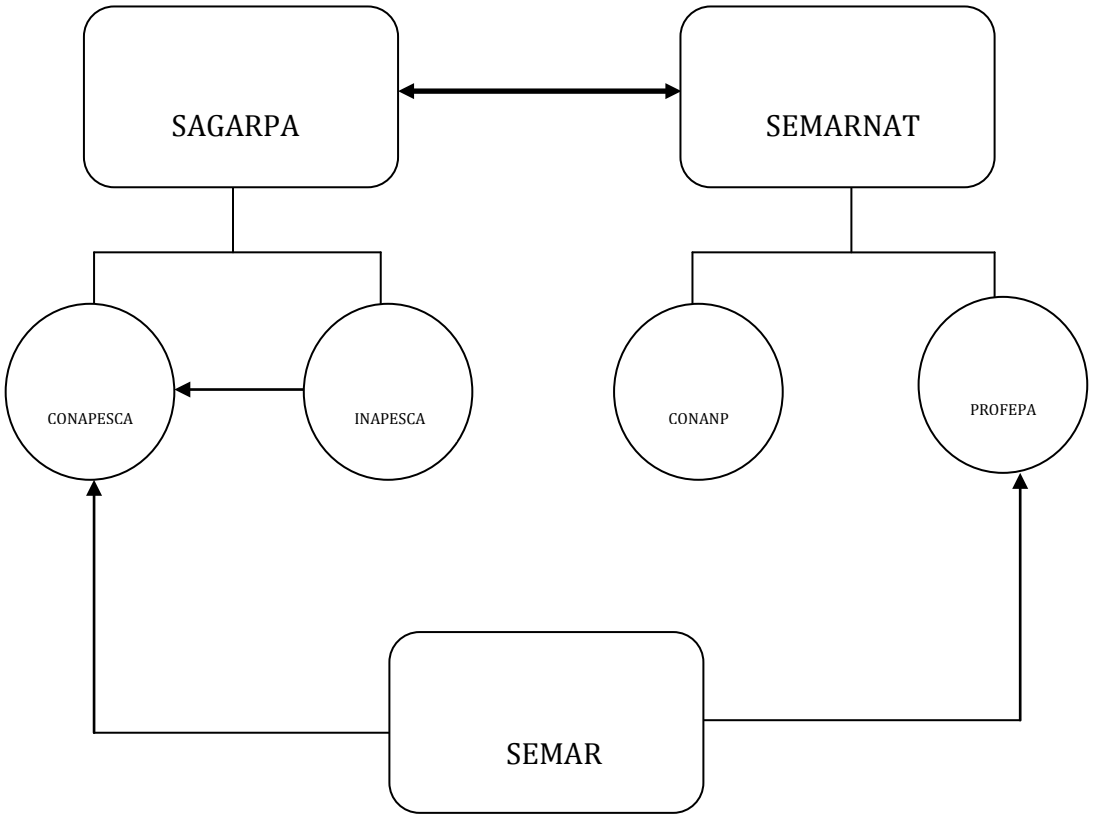

Figure 2. Institutional structure of federal agencies involved in fisheries management in Mexico (adapted from Cinti, Shaw et al., 2010).

Ecosystem Threats

Regional experts such as Lluch-Cota, Aarón-Noriega et al. (2007); Ulloa, Torre et al. (2007); Luque-Agraz and Gómez (2007); and Carvajal, Bezaury-Creel et al. (2005) have identified open access to fisheries, population growth, run-off from industries, aquaculture and agriculture, habitat alteration or destruction, and the introduction of exotic species (whether intentional or not) as the most pressing threats to the Gulf of California.

In 2007, PANGAS partners held a workshop with its institutional partners and other invited guests (including key government officials) at which the key threats to their management/conservation targets in the northern part of the Gulf of California were identified (Packard Proposal, 2008). They consider these to be: the diversion of the Colorado River flow; the lack of defined management schemes for rocky habitats; insufficient scientific understanding of populations' connectivity and life history; coastal development. Because PANGAS focuses on small-scale fisheries in the northern Gulf of California and the environments they depend on, the EBM initiative also identified main threats to marine habitats specifically, all of which were connected to fishing.

Among the issues raised was that species located in target habitats are being overexploited (PANGAS Handout*). EBM partners have been able to witness firsthand the downward trend in fisheries production in the region throughout their careers:

> I've seen fisheries collapse in ten years. They've become commercially extinct in ten years. And not just one - I've witnessed at least four or five in the gulf. So, […] the fishermen who have been active for three decades, they've seen a lot of changes. They've seen that things are going downhill. (Manager)
>
> In Bahia de los Angeles (northern Gulf of California) seven fisheries [have] already collapsed. Historically, all of them were sport fisheries, high value, and most of the catches in the present come from species of lower value. (Scientist)
>
> A professor that taught me years ago used to say that we use most of the renewable resources, particularly fisheries resources, as non-renewable resources. As if we were mining for fish instead of fishing. And that's exactly what goes on. (Manager)
>
> [The fishing resources] have ups and downs, but the trends we have seen in the state [of Baja California], and which are very likely to be going on around Mexico, are that landings are decreasing. (Manager)

While these declines are directly associated with impacts from fishing, an array of issues are playing a role, including bycatch from shrimp trawlers, fisheries operating in open access or near open access scenarios, and increased fishing efforts that target breeding aggregations. In addition, large scale bottom trawling in certain areas, paired with coastal development in estuaries and bays and destruction of nursery grounds, particularly mangroves, has greatly threatened the viability of many fisheries (PANGAS Handout*).

The dire state of fisheries has been recognized by different actors, including the government. INAPESCA declared 60% of Mexican fisheries are exploited to their capacity or are being overexploited (Cudney-Bueno, Bourillón et al. 2009). As one of EBM partners puts it:

> The crisis that Mexico's facing, and fisheries in general in the world are facing, [is] overfishing. According to the FAO - 60 or 70% of the world's stocks are overfished or at the maximum. So […] it was impossible to continue with this policy of the ocean as limitless, [let's increase effort to increase catch]. […] That was the mental framework in the 70's, 80's and early 90's. (Manager)

MEBM Initiative

Project Initiation and Motivation

Project PANGAS (Pesca Artesanal del Norte del Golfo de California: Ambiente y Sociedad)[7] was born with the dual purpose of building a framework for holistic research and management of small-scale fisheries to address coastal and marine ecosystem threats and to apply and test this framework in the northern Gulf of California (PANGAS Handout*). The main impetus for the PANGAS EBM initiative was the need to improve ecosystem health by promoting sustainable fishing and linking research in the biophysical and social sciences to develop better management recommendations for policy makers. Artisanal fisheries are the most prevalent fisheries in the region and are predicted to grow. At present, thousands of *pangas* operate in the northern gulf - targeting over 70 species of fish, mollusks, crustaceans and echinoderms on a regular basis - and each panga is capable of carrying between 1-2 tons of catch. Moreover, because these fisheries are not directly or technologically coupled to the extraction of a particular species and can easily shift as targeted species are depleted or market demands change, there have been production declines for most targeted species (Packard Proposal 2004). As one of the project partners puts it:

> I would say that the focus here was the extreme degradation of the reef communities in the northern gulf. A core group of principal investigators in this project [all realized] how degraded the reefs are of the northern Gulf. The focus had […] an intrinsic element of ecosystem-based management to try to recuperate degraded reefs, but also [to] figure out alternatives so fishers could [continue living and working in their communities]. (Manager)

Currently, there is a lack of enforcement of existing policies in the Gulf of California. In the case of the northern gulf, although there have been considerable research efforts within the social, biological and physical sciences addressing various issues pertaining to small-scale fisheries, most of this data is dispersed and research has historically been uncoordinated and non-integrative. The PANGAS EBM initiative proposed to integrate disconnected knowledge sources

[7] Translation: Artisanal Fisheries of the Northern Gulf of California: Environment and Society

in order to design an interdisciplinary research and management framework for small-scale fisheries and identify and carry out research to fill important gaps in understanding (Packard Proposal 2004).

While a genuine interest in more holistic approaches to fisheries management was acknowledged amongst project partners when asked about their motivation to undertake an ecosystem-based approach to management of small-scale fisheries, some felt the Packard Foundation provided additional motivation:

> When we were in this phase of data gathering and empowering local communities, local fishermen – a Packard Foundation [staffer] in the Gulf of California was talking about how the work in Kino and the work in Peñasco and the work that Pronatura was doing in Bahía de los Ángeles could be magnified - taken to a larger scale. On of the things that we agreed upon was that we needed to [better] understand […] connectivity issues in the northern part of the gulf […]. This was maybe 4 years ago. That's when the idea to establish PANGAS started, and we thought that by understanding the connectivity - the social, ecological, biological connectivity - we could […] make proposals for the management of the small-scale fisheries within an ecosystem context. (Manager)

Goals and Objectives

The ultimate goal of the PANGAS initiative is "to develop and test an interdisciplinary framework for ecosystem based research and management of small-scale fisheries in the Upper Gulf" (Packard Proposal 2004). As part of this overarching goal, PANGAS identified four main objectives:

(1) To conduct a general characterization of small-scale fisheries in the northern Gulf of California;

(2) To develop an in-depth and integrative interdisciplinary approach for research of small-scale fishery management systems;

(3) To engage key stakeholders and decision makers for advice and implementation of the project's results and recommendations;

(4) To use the information generated to develop management recommendations and inform policy makers; and

(5) To provide training for students and local fishers in tools for ecosystem-based research, management and conservation of marine resources (Packard Proposal 2004; Executive Summary 2006-2007).

These objectives came after "a team of key institutions and people that together could bring vast and diverse knowledge of the region's small-scale fishery systems and the biophysical and socioeconomic processes that affect them" got together for a series of workshops in which they identified the following set of priority research questions:

(1) Which and where are the critical habitats for the maintenance of small-scale fishery resources?

(2) What are the levels of connectivity among and between fishery stocks and the underlying oceanographic circulation processes affecting larvae retention and dispersal?

(3) What are the life histories of commercial species particularly as they refer to growth and reproduction?

(4) What is the spatial/temporal distribution of fishing activities and the social-biophysical linkage affecting this distribution?

(5) What are the social institutions in which small-scale fisheries operate?" (Packard Proposal 2004)

That being said, PANGAS operates under two premises: that by working towards healthy, resilient small-scale fisheries they will move towards healthy coastal marine ecosystems; and that the performance of small-scale fisheries is a result of interacting bio-physical and social processes, which need to be understood to allow for any effective management (PANGAS Handout*).

In short, and on the ground, partners identified the main objective of PANGAS to be:

> To produce management proposals for small-scale fisheries that consider this ecosystem perspective - proposals that are based on solid science, that have some social consensus, that are viable to implement in the short term, and that produce answers to solve problems. (Manager)

> To maximize the flow of benefits that society obtains from marine ecosystems. (Manager)

Project Structure

PANGAS is an interdisciplinary, multi-institutional and bi-national project. In Phase I it was designed to operate as a consortium of five organizations from Mexico and the United States that bring together expertise from different fields to address ecosystem-based research and management of artisanal fisheries. During Phase II, another NGO joined the team to make the current structure of PANGAS.

The core participating organizations can be classified into two groups: research institutions and non-government organizations (NGOs). The research institutions are mainly responsible of providing scientific information and are heavily invested in creating coupled biological-oceanographic models, understanding population structure using molecular genetics, marine spatial planning using GIS, ecological connectivity in the region, and performing studies on social networks. The NGOs play a more operational role by providing technical field support; organizing meetings with the advisory committee, stakeholders and government; and

compiling information and developing both Regional Management Plans for specific small-scale fisheries targeted species and *Planes de Ordenamiento* (management plans) for three different locations. NGOs have also participated in different programs supported by PANGAS, such as a subtidal monitoring program, fishers' logbooks and a fisheries monitoring program, and they have been instrumental in providing regional policy outreach (for a more detailed description of responsibilities, please refer to the Appendix).

Key Project PANGAS partners include (Packard Proposal 2004; Packard Proposal 2008):

(1) Research Institutions:

University of Arizona's School of Natural Resources is primarily responsible for managing the grant and providing the central coordination of the project. In the first two phases graduate students did the majority of the analysis on the data collected resulting in 4 Phds and 2 Masters degrees.

Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) has been in charge of research projects regarding physical oceanography and the development of coupled biological-oceanographic models, as well as the co-development of connectivity matrices and bathymetric studies.

University of California Santa Cruz (UCSC) focused on developing the framework for the coupled biological-oceanographic models, conducting research in molecular genetics and trace elements, and assisting in capacity building for subtidal monitoring.

(2) Non-Government Organizations:

Comunidad y Biodiversidad, A.C. (COBI) conducted the rapid appraisal to characterize the fishery, led efforts in capacity building for subtidal monitoring, incorporated PANGAS results into fishery ordinance plans and species specific management plans, and provided outreach to policy makers.

Centro Intercultural de Estudios de Desiertos y Océanos, A.C. (CEDO) participated in the rapid appraisal, developed management plans for the species mentioned using PANGAS data, and built capacity among fishers for catch monitoring.

PRONATURA A.C. joined PANGAS in 2008 and is responsible for compiling information for, and writing, the regional management plans for snappers, groupers, and sea cucumbers, and developing the Plan de Ordenamiento for the Bahía de los Ángeles Biosphere Reserve, and leading efforts in catch monitoring protocols.

In Phase II, PANGAS established a board comprised of its founding members and new head collaborators. Overall, over 40 researchers, technicians, and management practitioners are directly involved in PANGAS (PANGAS Handout*; Packard Proposal 2008). Other key partners PANGAS is working with include fishing cooperatives and permit holders, the fishery commission CONAPESCA, the commission for Protected Areas (CONANPthe U.S. National Oceanic and Atmospheric Administration (NOAA)

National Marine Fisheries Service (NMFS), SCRIPPS Institution of Oceanography, and The Nature Conservancy.

Strategies and Tools

Strategies

PANGAS was conceived as a long-term project. To accomplish its objectives, its overarching strategy has been "to translate research to the development of policies and management actions" (Figure 4) (PANGAS Handout*; Packard Proposal 2008). During Phase I, the project team focused on generating baseline information to better understand the region's small-scale fisheries and the processes that govern their performance. They also focused on establishing monitoring protocols, training graduate students and local fishers, and establishing partnerships with government entities and concurrent regional research and conservation initiatives. In Phase II, they have mostly focused on development of management guidelines.

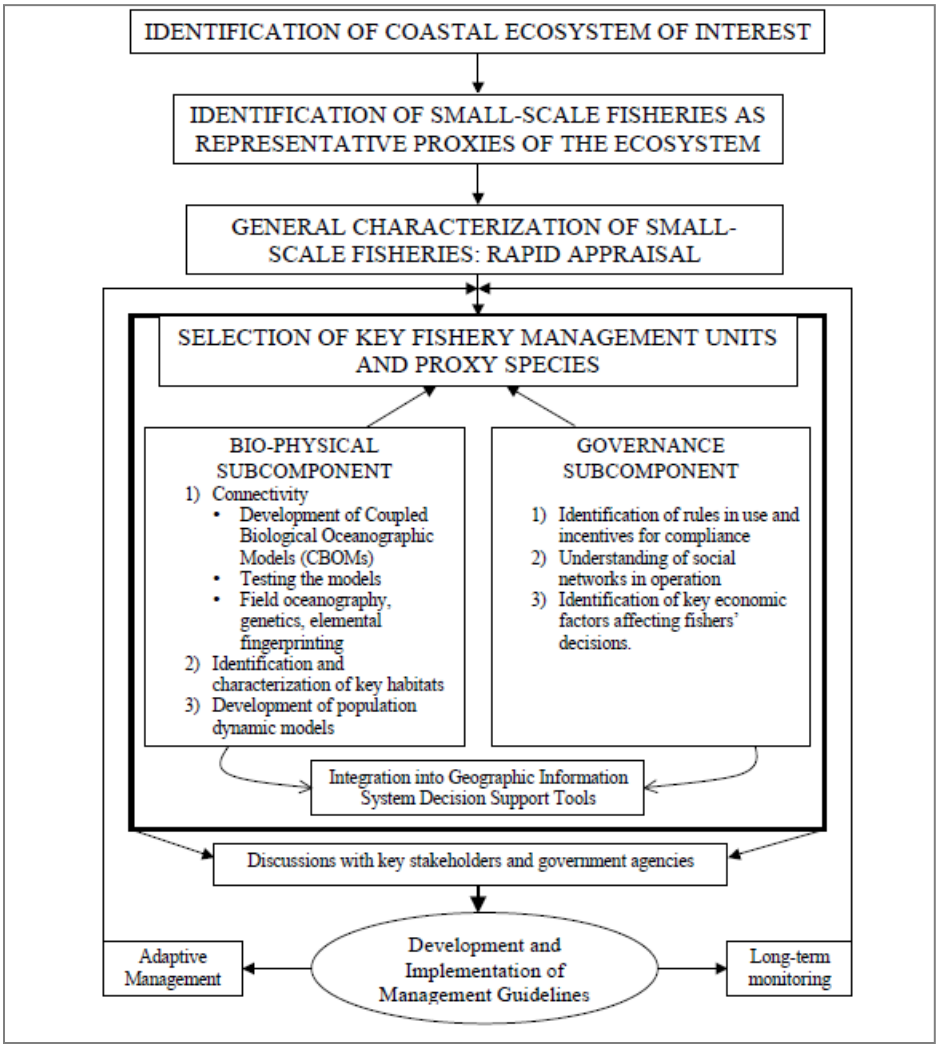

Figure 4. PANGAS' research and management framework (PANGAS Handout*).

In 2007, PANGAS conducted a strategic planning process facilitated by Foundations of Success (FOS) (www.fosonline.org) during which they identified key threats to their conservation targets and developed a conceptual model from which various strategies to address these threats emerged. To prioritize their strategies, they responded to the following set of questions:

(1) Is the strategy necessary to reduce the threat?

(2) Are there other groups that are implementing the strategy?

(3) Are they doing it well, or could we complement their efforts?

(4) Do we have the ability and experience to implement the strategy?

PANGAS came up with four specific strategies to address key threats to their conservation targets and fulfill their goals and objectives (Packard Proposal 2008):

Develop Regional Fisheries Management Plans: These plans are intended to address insufficient existing regulations, the open access situation and general lack of knowledge of the system.

Develop Specific Fisheries Management Plans: As with the regional fisheries management plans, the intent is to address the lack of and/or inadequate regulations for individual fisheries, the open access situation of fisheries and meager understanding of the system.

Establish Monitoring Program and Increase Technical Capacity in Monitoring: The rationale for this strategy is to better address compliance with existing regulations and the need for economic alternatives, and to increase the knowledge base.

Build Capacity for Students And Managers/Decision Makers: The intent is to create a lasting cohort of scientists and managers working towards ecosystem-based management and marine conservation.

As a PANGAS partners explains, one of their most important strategies has been that they are "in a unique position to translate sound science into applicable policy outcomes for fisheries management. This is based on the current political climate of Mexico, our established rapport and partnerships, and key advances on our science for EBM of these fisheries" (Packard Proposal 2008).

Fisheries Population Models

Since the beginning, PANGAS has focused on developing models for population dynamics that reflect population connectivity of species targeted by small-scale fisheries in order to predict how they will respond to different levels of extraction (Packard Proposal 2008). In Phase II, PANGAS started collaborating closely with researchers from NOAA, who are using the *Atlantis* EBM model in the Gulf of California. *Atlantis* links sub-models for socioeconomics and oceanography to biological information. In this partnership, PANGAS' main role is to provide background information, such as general descriptions of the natural history and fisheries in each region, population dynamic models, social and institutional data, and connectivity matrices. NOAA's role is to incorporate the information into the *Atlantis* EBM model to help develop management alternatives that incorporate food web dynamics (Packard Proposal 2008).

Role of Science

PANGAS has been generating science with the primary goal of using it to guide decision-making for fisheries management. As mentioned above, information on which to base management decisions is currently scarce, particularly with regards to the populations targeted by small-scale fisheries. This dearth of knowledge and understanding prompted the design of the PANGAS EBM project. As one of the partners explains:

> The whole idea at the beginning was, "We need to understand how these places are connected to the rest. […] We need to gather more information, we need to characterize all the fishing communities - we need to narrow [the number of species] down to a number that is manageable". (Manager)

In order to integrate the analysis of the topical subcomponents in this project into a cohesive framework, EBM partners plan to adapt the Institutional Analysis and Development (IAD) framework (Ostrom et al. 1994) as the project's overarching methodological approach (Packard Proposal 2004, 2008). This framework allows for the integration of data representing the "physical world" (i.e., physical oceanography, larvae retention and dispersal, species' life histories), "cultural world" (i.e., fishing organizations, social capital, social networks) and "set of rules" (i.e., government-crafted fishing rules, local arrangements) that govern the common pool resources situation (Ostrom et al. 1994) (First Annual Report 2006).

Natural Science

The role of natural science in this project has mainly been to characterize key habitats, reproductive sites/times and connectivity of targeted populations (First Annual Report 2006). During Phase I, researchers at PANGAS implemented a region-wide monitoring program for subtidal rocky reefs to provided baseline estimates for use in tracking long-term changes in biodiversity and community structure in these habitats. They also characterized the physical and biological structure of key rocky habitat sites; they fully developed two connectivity

models -the HAMSOM and ROMS models- to further address population connectivity patterns in the northern gulf; and they collected a considerable amount of genetic samples from various species at different sites for future studies of population connectivity using genetic and trace element (i.e. elemental fingerprinting) approaches (First Annual Report 2006).

In addition, PANGAS researchers developed a comprehensive Geographic Information System (GIS) database support tool that incorporates, among other things, more than 3000 layers of spatial information depicting spatial-temporal fishing distribution for 52 species, local ecological knowledge on key nursery and reproductive grounds, and sites of historical exceptional catches (First Annual Report 2006).

An important component of the project is capacity building. PANGAS has implemented various training courses in molecular genetics for marine conservation applications. They have also trained students and fishers in ecosystem-based monitoring of rocky reefs (Executive Summary 2006-2007).

Social Science

The role of social science in PANGAS is mainly to understand the spatial-temporal distribution of fishing activities (including gear/methods used and species targeted), and the existing institutional/social framework (First Annual Report 2006). PANGAS has conducted extensive field research, visiting 20 communities and fishing camps, to interview over 300 fishers regarding spatial-temporal patterns of fishing zones use, sites and times of reproduction of key species, social networks, rules in use, local market processes affecting small-scale fisheries, problems with fishing and fishers' recommendations for management, historical changes and shifting baselines, and general information about fishing organizations and fishers' backgrounds (First Annual Report 2006;Executive Summary 2006-2007).

As one partner explains, however, integrating the social science data and natural science data to better inform decision-making is still not optimal:

> I believe that we are trying [to integrate social and natural science], but we are not there yet. There is still too much emphasis on the ecologic, biologic and oceanographic components; and it is very important, it is the foundation [of the project], but I think we need to approach the social and institutional component of fisheries more. […] The NGOs that are involved in this project are the ones […] that will try to cover these issues: involving the community and observ[ing] the social and economic characteristics of the community. […] What we [and I specifically] have done […] is more about research and obtaining information that can be used in management or by people who are making decisions on the ground. (Scientist)

Local and Traditional Knowledge

In terms of local/traditional knowledge, PANGAS has included fishers mainly through a voluntary region-wide fishers' logbook program, in which fishermen record basic information

regarding their daily fishing activities such as where, what, and how much they fished. The information obtained through this program will help assess the long term dynamics of the region's data-poor small-scale fisheries, provide an additional means to involve the fishing sector in research and management, and inform management guidelines that truly reflect local and regional fishing dynamics (Executive Summary 2006-2007).

Notwithstanding, as with social sciences, within the PANGAS team there is the perception that natural science has overpowered local knowledge:

> I think we've tried really hard to take traditional fisher's knowledge and incorporate it into the science […] and present the best holistic management scenarios that we can […], but I think that PANGAS is falling short on the community involvement and giving back to the community. […] We've developed a tremendous amount of biophysical data […], but we're a little shy on the core component, which is community-based management. (Manager)

Outcomes

In terms of outcomes, the PANGAS project has been very successful at producing scientific information and creating a professional network that has enhanced capacity to achieve PANGAS' goal and objectives. This is how some of the partners regard the performance of this EBM initiative:

> It's in a very early stage of its development. It has been successful in its goal of promoting teamwork between diverse organizations – academic and NGOs working together, sharing experiences and resources, fieldwork and producing some first sets of recommendations that the government may use. We have […] submitted to the INAPESCA some recommendations for the national fishing chart […]. In that way it's working. And some interesting research opportunities for students and researchers [are] also a success. And some very interesting research is being done within the PANGAS framework. (Manager)

> I think if you're picky, we are not successful. The students are not finishing. We aren't publishing enough. The databases are not as clean as we want. It's a mess. But I think we have a lot of good things to provide and good plan designs and CONAPESCA and INAPESCA are starting to look and say, "Okay, maybe you can help me." […] We have an MOU with INAPESCA which is great. (Manager)

Thus far, it is unlikely this initiative is making a measurable difference in the ecosystem, mainly because project outcomes to date have been such things as creation of knowledge and a scientific basis for future decision-making in fisheries management.

In PANGAS's first year (2005-2006), the initiative grew from 5 principal investigators to 32 participants, including professors, conservation practitioners, biophysical and social science researchers, graduate students and field technicians (First Annual Report 2006). By 2008,

PANGAS' membership surpassed 40 people (Packard Proposal 2008), which is considered a very important outcome to partners in this initiative.

In terms of information, PANGAS has produced and published a number of papers in peer-reviewed journals, including, but not limited to:

Connectivity in the northern Gulf of California from particle tracking in a three-dimensional numerical model. By Marinone, S. G.; Ulloa, M. J.; Pares-Sierra, A.; Lavín, M.F.; Cudney-Bueno, R.

Establishing a Baseline for Management of the Rock Scallop, Spondylus calcifer (Carpenter 1857): Growth and Reproduction in the Upper Gulf of California, Mexico. By Cudney-Bueno, R.; Rowell, K.

Predication of sea surface elevation and currents in the Gulf of California: scales from tides to seasonal. By Marinone, S. G.; Gonzalez, I.; Figueroa, J. M.

Rapid Effects of Marine Reserves via Larval Dispersal. By Cudney-Bueno R.; Lavín M. F.; Marinone S. G.; Raimondi P. T.; Shaw W. W.

Lack of Cross-Scale Linkages Reduces Robustness of Community-Based Fisheries Management. By Cudney-Bueno R.; Basurto X.

Governance and effects of marine reserves in the Gulf. By Cudney-Bueno R.; Bourillón L.; Saenz-Arroyo A.; Torre-Cosío J.; Turk-Boyer P.; Shaw W.W.

The unintended consequences of formal fisheries policies: Social disparities and resource overuse in a major fishing community in the Gulf of California, Mexico. By Cinti A.; Shaw W.; Cudney-Bueno R.; Rojo M.Linking bio-oceanography and population genetics to assess larval connectivity. Soria G.;. Munguía-Vega A.; Marinone S G.; Moreno-Báez M.; Martínez-Tovar I,; Cudney-Bueno R.;

Effective ecosystem based management must encourage regulatory compliance: A Gulf of California case study. Ainsworth C H.; Morzaria-Luna H.; Kaplan J C.; Levin P S.; Fulton E A.; Cudney-Bueno R.; Turk-Boyer P..; Torre J.; Danemann G D.; Pfister T.

Insights from the users to improve fisheries performance: Fishers' knowledge and attitudes on fisheries policies in Bahıa de Kino, Gulf of California , Mexico Cinti A.; Shaw W.; Torre-Cosio J.

Integrating the spatial and temporal dimensions of fishing activities for management in the Northern Gulf of California, Mexico. Moreno-Báez M.; Cudney-Bueno R.; Orr Barron J.; Shaw W.;, Pfister T.; Torre-Cosio J.; Loaiza R.;, Rojo M.

Other PANGAS products and accomplishments include:

- A spatial and temporal GIS database characterizing all small-scale fishing activity in the northern Gulf of California
- An operational first draft of a northern Gulf of California commercial species life history database.
- A library of species of interest to the fisheries of the Gulf of California .

- A field research protocol manual for the PANGAS project that is useful for anyone conducting large-scale interdisciplinary marine EBM research.
- The first characterization of the physical oceanography and ecological conditions of the Upper Gulf of California including the vaquita refuge
- Completed a baseline study characterizing the ecosystem health of the rocky reefs of the northern Gulf of California
- Extensive information about population structure and dynamics using molecular genetics for several important commercial species
- An interactive project website: www.pangas.arizona.edu
- Development of some of the first population connectivity models for the northern Gulf of California.
- Development of numerous regional maps with information on such things as sea surface temperature, bathymetry, surface currents, location of rocky reefs, and key coastline sites as known by fishers.
- Development of one of the first comprehensive regional management plans for a fishery in the northern Gulf of California: the rock scallop fishery. This plan is endorsed by the federal government and it incorporates the use of harvest refugia, seasonal closures, and size limits, among other management tools.
- Establishment of a fishing concession for commercial divers of Puerto Peñasco, assigning exclusive fishing access rights and enhancing stewardship for management of benthic resources and the use of marine reserves.
- Development and implementation of a two-week training course in coastal oceanography and marine ecosystems for Mexican and U.S. students, paired with Duke University.
- Collection of extensive baseline information on each fishery and community of the northern gulf.
- Development of species-specific management recommendations.
- Pangas has been encouraged to develop Planes de Ordenamiento in the region, especially for to protected areas and a biological corridor (Packard Proposal 2008).

Additionally, PANGAS has created a suite of indicators to monitor and evaluate the progress of the project. These indicators are divided into 6 categories, none of which are related to biophysical data. They are summarized as follows (Packard Proposal 2008):

Funding:

- Enough additional funds to cover all salaries of personnel and continue the project through 2012.

Development of Management Plans:

- A signed formal collaborative agreement with the government.
- Complete research necessary to provide recommendations to government to develop regional management plans for blue crab, penn shell scallop, octopus, and several species of reef fish
  - As of 2012, the blue crab plan has been approved by government and stakeholders
- Fully developed ROMS model for two sites.
- Two fully developed coupled biological-oceanographic models for two proxy species
- Complete analysis of applicability of *Planes de Ordenamiento* for proposed sites.
- Run operational ATLANTIS model for sites of interest.
- Complete first drafts of *Planes de Ordenamiento* for 3 sites.

Monitoring:

- Clear protocols for long term monitoring of fisheries catches.
- At least 10 people trained in subtidal monitoring of rocky reefs.
- Two research cruises to establish a baseline for the health of the rocky reefs of the Northern Gulf
- A collaborative agreement with CONANP on monitoring within existent marine protected areas in the region.
- Incorporation of data gathered in the field via monitoring into management plans.
- Catch monitoring programs established in 3 regions of the study region
- A transferable protocol and data management system for monitoring.

Capacity Building:

- Four students to have completed their PhD studies.
- Two students to have completed master's studies.
- Five students selected for marine conservation genetics course.
- Twelve commercial divers trained and participating in sub-tidal monitoring
- Community members trained and employed to monitor catch in at least three communities

Coordination Meetings and Outreach:

- A preliminary communications strategy for PANGAS and a refined web page.
- Submission of papers for publication.
- Comprehensive outreach program with CONANP and INAPESCA

Challenges

Translating Science into Policy

Translating scientific results into policy has been difficult as politics and economic considerations are often prioritized over ecological concerns in this context. From the onset, the PANGAS team was aware that translating science into policy recommendations was likely be a significant obstacle "given political uncertainties", which is the case for most science-based projects (Packard Proposal 2008). Most interviewees recognized these issues as impediments to the emergence of EBM in Mexico where historically fisheries management decisions are not solely on science:

> As scientists, our recommendations are limited to technical aspects. The managing agency has more criteria to base their decisions on, if the community has no food, etc. The technical is just one of the many criteria they use to decide if they will issue a permit or not. (Scientist)

> I don't know if ecosystem considerations are considered. […] In most of the cases not even biological considerations are used. […] Everything is market-driven. (Scientist)

> Some of the decisions are made based on social or political pressure, and dismiss the scientific background. And PANGAS is a project that really tried to go the other way around. (Manager)

A good example of the pressures the Mexican fisheries agency (CONAPESCA) faces is provided in the following statement:

> If you are in a small [fishing] community[…] you pretty much know everybody and the proposal would be to lobby at high political levels in a way that CONAPESCA issues permits to those [fishermen] who don't have them. The National Fisheries Chart says that you can't give any more permits in the Gulf of California, but we argue that you are not issuing more permits: these people were here before the National Fisheries Chart. We are not increasing effort; we are making people be in compliance. (Manager)

Lack of Capacity and Ability to Enforce Regulations

A widely recognized hindrance to EBM implementation in Mexico is government agencies' lack of financial and human resources necessary to ensure regulatory compliance and engage in enforcement activities. This impairs their ability to ensure fisheries are exploited sustainably. As respondents put it:

> The fisheries management agency has a research branch that is the National Fisheries Institute, INAPESCA. It's getting weaker and weaker, because of cuts in budget and lots of problems with unions and things like that. So, people [are]

> retiring and [they are] not being able to hire new researchers, and [have] shrinking budgets, and just an inability to come up with information at a pace that society needs. So, a project like PANGAS […] is filling a niche that government is not able to, or not interested in filling, in terms of producing information and proposals. (Manager)
>
> The problem is that INAPESCA in the present has no capacity to study or analyze small-scale fisheries. [They prioritize fisheries that generate a lot of revenue]. […] But the role of [small-scale] fisheries in local economies and ecosystems is huge. (Scientist)
>
> The other challenge is, not the fact that the government isn't open or inaccessible, but that they're under-funded, under-powered, under-staffed. They're completely over-extended. (Manager)

Like in many other contexts, financial and human resource limitations translate to minimal enforcement and surveillance. The government is viewed as absent:

> In many of these places, […] the government presence is zero. The governance is really low. […] It's like the Wild West. (Manager)
>
> The new fisheries law is better than the old one [but][…] it's probably more advanced than the capacity of the public administration to use it. […] So we may have the best environmental law, but the administration is very limited in their capacity to use that. And at the same time you have tradition, cultural limitations, corruption […] to consider. (Manager)
>
> Particularly in the Gulf of California, we have absolutely no background whatsoever. There's a tremendous amount of regulations on the books and then in the Mexican federal law, but [for the most part] none of them are being enforced. (Manager)
>
> The thing is that you can say the [MPAs] are protected, but […] they are not so protected because in practice you don't have enforcement. […] The fact that it's been declared as an MPA doesn't mean [it is]. (Manager)

Poverty

It is difficult for environmentally-oriented management strategies to gain traction in a context where poverty is pervasive; the population is primarily concerned with providing for their families. As one interviewee stated:

> It is difficult to think about EBM in an environmentalist fashion in a context where […] there is poverty. I think the biggest challenge of the implementation of EBM in a country like Mexico is how to find a way to use resources sustainably and to incorporate people in management. (Manager)

Lack of Information

Regarding the information used in management decisions, PANGAS partners identified a plethora of concerns. First, there is not enough basic information on the life histories of species, their critical habitats, or small-scale fisheries catch data to inform management decisions. Second, there are not enough interdisciplinary efforts to gather information across the broad range relevant fields:

> In Mexico one of the biggest challenges is to have enough information to make a decision, to base a decision. (Manager)

> Coupling the speed of the production of information and the speed that the government needs that information [is a challenge].[…] And I guess another is to be able to incorporate some of the empirical information that fishermen have and put it into a framework that is useful for managers and respected by scientists. (Scientist)

> There is a tremendous amount of [information] requirements […] for projects like us to be able […] [get] the work done, for example, catch data. There's no catch data at all. […] There's just no organized fashion in which catch data is collected. There's no systematic way in which the fisheries inspectors have any idea what's going through the different points of entry. […] We had to develop the system […] to catch our own catch data because the federal government has no structure there. (Manager)

> Given budget constraints and political pressures, the Mexican government has seriously overlooked monitoring of small-scale fisheries other than the shrimp fishery and blue crab. […] No program is in place to address catches of the small-scale fishing fleet. (Packard Proposal 2008)

> We're talking basic, basic information: who has permits; who doesn't; how many fishers are in the region; how many boats; what are the species compositions? None of this stuff was known or recorded, or it was in a very loose, disorganized way until we started this project, which the whole first year was spent doing nothing other than characterizing the fishery of the northern gulf. […] It took us almost two years just to get the basic level of understanding. (Manager)

Lack of Input from Multiple Disciplines

Integrating knowledge and information from multiple fields has been challenging, and, in the Mexican context, scientific research is dominated by the natural sciences:

> I have always felt that the educational system in Mexico is very compartmentalized. […] There are very few institutions that promote interdisciplinary studies. […] There are people doing EBM [research] that are too focused on natural sciences and they don't move from there. (Manager)

> You have people that are oceanographers and then biologists and geneticists – so how do you start to talk in the same way?[…] And there's not a lot of people in Mexico working with social issues associated with management. […] There are not a lot of researchers doing research associated with conservation and marine management. […] They don't combine the different tools to solve a problem in conservation. (Manager)

Lack of Formal Mechanisms to Integrate Findings Into Government Processes

The process by which a non-government or academic institution can contribute towards fishery management plans or ordinance plans are unclear and poorly defined.

Resistance to Change

In the northern gulf, it has been difficult for the government to break away from "business as usual" to adopt marine ecosystem-based management, which is an innovative management approach that is more sophisticated than current fisheries management practices:

> The Mexican government is very traditional in their way of doing things. They always do things in the same way that has been done forever, so it's breaking those traditions, which represents the main challenge. […] We need to be able to produce those changes in a way that it would not be a radical change. […] We need to think about what can realistically be changed. (Manager)

> Well, I think the biggest challenges have been the fact that […] in some ways Mexico is in the Jurassic when it comes to fisheries management. (Manager)

Institutional Arrangements

Different existing institutional arrangements and circumstances have made adoption of EBM difficult. First, the *de facto* situation of open access in the Gulf of California has impeded EBM implementation. As two partners mentioned:

> The Mexican agencies in charge of governing marine resources are so understaffed that they can only focus on one or two resources – one of which is shrimp, the other sardine. So most of the coastal management is left to the users themselves and since there [are] no clear rights as to who owns the resources, most management takes the form of open access. (Manager)

> One of the root problems is that access rights are not yet settled. So, until we resolve the problems associated with access rights, there will always be problems with EBM in the seas of Mexico. (Manager)

Second, enforcement in the Gulf of California requires at least 3 agencies: CONAPESCA, PROFEPA and SEMAR; and within protected areas, another agency, CONANP, has authority.

Various interviewees explained how conflicting mandates and minima communication among these agencies are challenges for EBM implementation:

> [One challenge is] the separation of agencies or institutions; one is involved with fisheries and the other one with the environment. Generally, those parts of the government do not communicate very well; many times they are in conflict. (Manager)

> MPA establishment was the closest one could get to a full multi-species and habitat-based EBM approach. The problem with MPA's, however, is that while their administration falls under the Ministry of the Environment (SEMARNAT), fisheries found within MPA's are ultimately the jurisdiction of the Secretariat of Fisheries (SAGARPA). Jurisdiction discrepancies in governance have led to inefficient management of fisheries issues within MPA's, ultimately resulting in the over harvest of many fishery resources. (Packard Proposal 2008)

> I believe that one thing affecting the adoption of the concept [of EBM] is that in Mexico fisheries was taken out of SEMARNAT and put into SAGARPA, so there is a secretary regarding the environment and another one with a different institutional culture that has to do with fisheries, and everything is completely separated - from the programs they manage to the subsidies. I mean their whole institutional behavior, mandate and culture is very different. (Manager)

> I think that one of the mistakes that we made in the past is that NGOs - conservation NGOs - thought that we could solve fisheries management or marine conservation problems by creating marine protected areas and working with the environmental ministry only. […] We've recognized that we need to [also] have [a] fisheries management authority that is powerful and with good staff, with good training, with good budgets, with gear and with boats. (Manager)

Insufficient Infrastructure for Using Scientific Findings

Currently, Mexico does not have the institutional infrastructure to receive the scientific information being generated by the EBM effort and apply it to relevant policy-making processes:

> The new fisheries law calls for ecosystem-based management aspects in management plans by species or an ordinance plan by region[…], but that law doesn't really have any structure behind it. There's no framework of how to develop a management plan. […] What's the process? […] There are no guidelines, framework, or anything for the government to receive [management plans]. (Manager)

Facilitating Factors

New Fisheries Law

The new Sustainable Fisheries and Aquaculture Law (LGPAS) in Mexico is regarded as a facilitating factor for EBM as it strives to promote a more holistic view of fisheries management and consideration of environmental impacts. Decentralization of management is also discussed by this law:

> New opportunities have opened within the current fisheries administration and Mexico's new fisheries law that can set the stage towards a more EBM approach to fishery management. The new law calls for the need to establish *Planes de Ordenamiento Pesquero* as well as *Planes Regionales de Manejo Pesquero* (Regional Fisheries Management Plans). In the broadest sense, both of these measures incorporate, for the first time, a more regional approach to fisheries management. In this regard, addressing the coupling of biophysical connectivity (i.e. larval retention/dispersal, identification of genetically distinct stocks) with social connectivity (i.e. regional social networks, spatial temporal distribution of fishing activities) will be essential for the development of any regional management approach and a line of work that PANGAS will be instrumental in and in a key position to address. These Plans also call for a comprehensive view to management, one that can aim at avoiding open access situations and incorporate, for instance, combinations of harvest refugia (*refugios pesqueros*), season closures, and quotas. *Planes de Ordenamiento* could also take a multi-species approach to management, aiming to address the various key fisheries of particular regions. (Packard Proposal 2008)

> This is positive: the change in law has incorporated tools that […] could formalize EBM or a coastal zoning - assigning different uses to different parts - depending on how these affect one another. (Manager)

> The government really wanted to have this ecosystem perspective on fisheries management, move away from single species […] and go to multi-species and the connection between species and habitats. […] More and more we're figuring out that [the PANGAS' project ideas and proposals are] information that's very valuable [to the government]. (Manager)

Progressive Agencies

Fisheries management authorities in Mexico are beginning to have a more progressive attitude towards management approaches than in the past: the head of the Fisheries Research Institute (INAPESCA) is regarded as a champion of EBM in the gulf and CONAPESCA has daringly decided to implement a catch shares pilot project, which is a clear signal the government is open to alternatives to "business as usual." As two interviewees explain:

> Now that we have had many discussions about refugios pesquerios (fishing refugia), we have spoken much more regarding critical spaces for the life history of certain species - how to protect them or protect certain places. And this discussion has been mostly with CONAPESCA. […] We have [discussed with them] how to use […] no take zones to promote fishing much more based on the ecosystem and ecological processes. (Manager)

> I believe that there is much echo in certain government sectors to implement these kinds of reforms and promote EBM. (Manager)

Increased Human Capital

Human capital in the gulf has also increased recently, which has enhanced acceptance and facilitated implementation of new and sophisticated management approaches such as EBM:

> In 15 years, I have seen the amount of people working in the gulf multiply immensely, and not only the number of people, but also the sophistication and the ways, the depth of what we talk about. (Manager)

> Never before have there been so many people interested in making positive changes. Never before so many Mexicans involved; people with emotional connection and high technical abilities. (Manager)

Receptivity to Conservation

Although fishers do not use the term "EBM", it is a concept that is "*intuitive"* and that "*resonates*" with them. Fishers believe it is not only important to manage fishing sites, but also the nursery, reproductive and feeding grounds of fish. Fishermen also recognize inter-species relations and linkages between ecological, institutional and management systems. Ultimately, according to the people that were interviewed, EBM makes sense to resource users and they are willing to negotiate an acceptable configuration of management measures:

> What we found is that it's an idea that resonates a lot with fishing communities. […] A lot of the projects that we do are based on negotiation. […] We don't give a recipe or only one scenario. We explore with them different possibilities, different networks, and different shapes of networks, and then they decide what network they can implement. (Manager)

In addition, the critical state of fishery resources has facilitated EBM adoption by increasing stakeholders' interest in stock recovery and conservation efforts. As two interviewees explain:

> Another opportunity I think is the crisis that fisheries are facing. When you have a system that is booming and everybody's happy and there's a lot of money and everybody's into how to fish more, they're not open to some possibilities, some ideas that are probably controversial like closing areas or limiting effort or finding alternatives or something. So, I think that crises are also opportunities. (Manager)

> The resources are being degraded, and so when natural resources are in crisis, then the users demand better management. Before they are, "Oh no, here they come bothering us again," but when the resources are gone they will say, "Ay! There're gone!" and I believe a lot of the resources are already in that stage. (Manager)

Collaboration

Collaboration among the government, NGOs and other stakeholders has also enhanced the EBM effort as it is enabling work, which historically would not have been pursued, to be accomplished:

> From a top-down perspective, the fact that government is reaching out to NGOs, that [a] new legal framework [is being developed] in the fisheries regulations has an ecosystem-based element in it, that the *Carta Nacional Pesquera* also is changing [how fishery species are classified from broad categories to more specific groups] […] - that's headway towards not just mono-specific fisheries management, but looking at systems or groups, functional groups […]. Also, now we're trying to take it to deep water and shallow reefs. The fact that this is actually part of the legal framework, even though it's in the initial stages, is a huge opportunity. The fact that the government itself, by mandate, […] is saying that they need management plans, ordinance plans - that's huge right there. (Manager)

> One example, in Bahia Kino, the *subdelegado* in charge of fisheries in Sonora, we approached him and said that we're interested in helping because they're in charge of doing the *ordenamiento*. We've been working with CONANP and want to start the *ordenamiento pesquero*. […] The guy has to manage the whole stream fisheries, but he said, "Okay, I will help you, but will you help me with the *ordenamiento de Kino*." (Manager)

International Conservation Interest

At the moment, there is abundant interest among funding agencies in the Gulf of California, which means there are more opportunities to acquire the resources needed for EBM-related activities:

> The amount of attention that the gulf has been generating for years [has made it] a place where a lot of resources are invested. There is a lot of money that can be used for research, stimulating awareness in people, creating programs towards EBM implementation. […] There are a lot of funds that are being well used and it is a very big opportunity. (Manager)

> The fact that there are so many economic resources - foundations - being devoted to the gulf right now is a huge opportunity. Knowing how foundations work, those funds may not be there in the future. (Manager)

Lessons Learned

The PANGAS project has taught its implementers key lessons. First, it is important to establish mechanisms and pathways through which information can flow from researchers and community members to relevant government agencies for use in management decisions before copious amounts of data and knowledge accumulate. Second, while engaging graduate students in research activities helps builds capacity, the timeframes in which student projects are completed and information is needed to inform management decisions do not always coincide. The following quote demonstrates this issue:

> [Another] thing we learned in [this project] is we collected this information with students, […] but between the time that we collect the information and the students finish processing it, it's too much. Like four to five years for a PhD. Unfortunately, we often need information as soon as possible […] It's better to work with PostDocs – or have Master's and PhD [students] with certain questions, but know you will have that information later. (Manager)

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Executive Summary 2006-2007

PANGAS. Executive Summary 2006-2007.

Appendix: PANGAS Project Structure

Institution and Personnel	Main Role in PANGAS
University of Arizona	
Richard Cudney (PhD)	UA Co-PI, PANGAS advisor; governance; scientific writing; policy outreach
Bill Shaw (PhD)	UA Co-PI; student mentoring
Kirsten Rowell (PhD)	Associate Researcher; elemental fingerprinting-laser ablation; studies on age/growth of fishes
Program Coordinator (TBD)	Coordinate PANGAS' operations

Administrative Assistant (TBD)	Administrative support for Program Coordinator
Cecily Westphal	Business Manager
Marcia Moreno (PhD student)	GIS Analyst Coordinator
Ana Cinti (PhD student)	Field research in socio-economic studies; database analysis; life history database
Jennie Duberstein (PhD student)	Field research in socio-economic studies ; database analysis; webpage design
Gaspar Soria (PhD student)	Field research in larval flow; life history of mollusks; subtidal monitoring
Adrián Munguía (PhD student)	Development of genetic microsatellites; microsatellite fingerprinting for blue crab.
Alejandro Castillo (MSc student)	Development of MPA feasibility study for San Jorge-Borrascoso corridor.
Iván Martínez (MSc)	Field support in Puerto Peñasco; studies on fish recruitment; fishery fellow working with Puerto Peñasco Cooperative of commercial divers.
Data Capturists (2 work-study students (TBD)	Data capturing/GIS support
Rocío Covarrubias (contractor)	Web maintenance; translator of documents.
UCSC	
Pete Raimondi (PhD)	UCSC PI; analysis of monitoring data; co-development of connectivity matrices
Giacomo Bernardi (PhD)	UCSC co-PI; Coordinator of genetic studies
Ricardo Beldade (PhD)	Post-doc; genetic and elemental fingerprinting
Yvette Alva (PhD student)	Genetic studies on yellow snapper
PhD student (TBD)	Participation in monitoring; analysis of monitoring data; codevelopment of connectivity matrices
Mark Readdie (PhD)	Co-Instructor, monitoring program
Amanda Jensen (MSc student)	Subtidal monitoring; genetic studies on mullet

Mark Carr (PhD)	Associate Researcher; advice on monitoring
CICESE	
Miguel Lavín (PhD)	CICESE PI; field oceanography; scientific writing
Guido Marinone (PhD)	CICESE co-PI; numerical modeling (HAMSOM); scientific writing
Alejandro Parés (PhD)	CICESE co-PI; modeler (ROMS); scientific writing.
Manuel Figueroa (PhD)	Numerical modeling
Post-doc (TBD)	Numerical modeling; CBOMs; development of connectivity matrices; scientific writing
María E. Allende (MSc)	Programming technician
Victor Godínez (MSc)	Field technician; analysis of observational data
Arturo I. Ocampo (MSc)	Field technician for observational data
Carlos Cabrera (M.I)	Programming technician; analysis of observational data
Gustavo Alvarez (PhD)	Development of bathymetry
Rafael Cervantes (MSc)	Field technician for development of bathymetry
CEDO	
Peggy Turk-Boyer (MSc)	CEDO PI
Verónica Castañeda (PhD)	PANGAS Program Coordinator for CEDO
René Loaiza	Logistical and field support; regional expert; subtidal monitoring; boatman
Angeles Sánchez	Research technician
José R. Salazar (fisherman)	Subtidal monitoring; regional expert
Valentín León (fisherman)	Subtidal monitoring; regional expert; boatman
COBI	
Jorge Torre (PhD)	COBI PI
Luis Bourillón (PhD)	COBI Co-PI; policy outreach

Andrea Sáenz-Arroyo (PhD)	Scientific advice
César Moreno (economist)	PANGAS Coordinator for COBI; socioeconomic field research and support; data analysis; local and regional policy outreach
Mario Rojo (MSc candidate)	Coordinator for logbook program; biophysical field research and support; data analysis
Nabor Encinas (fishery biologist)	Field research technician in Kino-Pto. Libertad region
Magdalena Borbón (fishery biologist)	Data capturer for fishers' logbook and subtidal monitoring program
10 fishers from Kino trained in SCUBA, First Aid and subtidal PANGAS censuses methodology	Subtidal monitoring
Dive master (TBD)	Diving instructor; first aid training
PRONATURA	
Gustavo Danemann (PhD)	PRONATURA PI
Octavio Aburto (PhD candidate)	Subtidal monitoring; analysis of breeding aggregation sites; Director of science for Pronatura; life history of snappers/groupers; elemental fingerprinting yellow snapper
Esteban Torreblanca (MSc)	Coordinator of field operations in Bahia de los Angeles
Gustavo Paredes (PhD)	Postdoc at SCRIPS; ecosystem studies in the Bahía de los Ángeles area
Victor Valdez Ornellas (fishery biologist)	Fishery analyst; stock assessment María de Jesús Millán Project administration for PRONATURA; accounting