The Influence of Colorado River Flows on the Upper Gulf of California Fisheries Economy

by

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STATEMENT BY AUTHOR

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DEDICATION

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ABSTRACT

Fisheries economics aims to quantify and analyze the effects of interdependent anthropogenic, biological, and environmental influences. Estuaries are an environmental variable and key input to fisheries recruitment, productivity, and profitability for many species. The estuaries of the Colorado River Delta, now degraded due to lack of freshwater flows resulting from upstream damming and diversion, once provided key spawning and nursery habitat for important commercial species such as shrimp and gulf corvina. This thesis analyzes the influence of incidental river flows on the productivity of Upper Gulf of California fisheries and explores potential economic effects that could result from different river flow scenarios, including levels being pursued by conservation organizations in their efforts linked to the implementation of Minute 319.

CHAPTER ONE: INTRODUCTION

1.1 Overview

In the spring of 2014, a historic and iconic reconnection of the Colorado River to the Sea of Cortez occurred, thanks to the implementation of Minute 319, a binational agreement which in part set the framework for international cooperation to bring environmental river flows back to the Colorado River Delta. Prior to that spring pulse flow, what once was a deltaic ecosystem consisting of thousands of acres of lush riparian and estuarine habitat, had been reduced to only a tiny fraction of its former size, driven by upstream diversion and damming of the river. Minute 319 addresses the need to better understand the ecological benefits that result from a release of water such as the one that occurred in 2014. Many benefits accrue to the region beyond and as a result of the ecological benefits. One such benefit is the influence of Colorado River flows on the productivity of Upper Gulf of California fisheries and estuaries. The objective of this project is to identify potential economic benefits and values for Upper Gulf of California marine ecosystems as linked to the effects of freshwater flows from the Lower Colorado River and the implementation of Minute 319 in providing flows.

The Gulf of California (Sea of Cortez) is a shallow sea bordered by Mexico's mainland to the east and the Baja Peninsula to the west. It is characterized by high levels of marine productivity, accounting for roughly 50% of Mexico's national fisheries productivity. The Upper Gulf of California, the northernmost area of the Gulf, encompasses three main fishing communities –

Puerto Peñasco, Sonora; Golfo de Santa Clara, Sonora, and San Felipe, Baja California. These three communities are heavily economically dependent upon fisheries, with much of the product destined for export to international markets such as the United States and Asia. Lack of local economic alternatives, paucity of freshwater resources, and strong incentives for illegal fishing have placed a heavy human burden on the marine ecosystem.

Environmental degradation and overfishing have prompted involvement by Mexico's federal government, as well as domestic and international NGOs in taking actions to protect key areas and species within the Upper Gulf. This in turn has created conflict between fisheries livelihoods and conservation, forcing tradeoffs between fisheries production and conservation goals. Much of the work to date on the economics of fisheries in the Upper Gulf has related to providing economic compensation to encourage reductions in fishing effort and shifting to alternative fishing gear in order to protect vulnerable species.

Data to support this analysis was obtained through government sources, NGOs, academic researchers, and interviews in the field, including fishermen, business owners, conservationists, researchers, and other stakeholders in the Upper Gulf (see Appendix C).

Table 1.1: Fisheries Stakeholders Interviewed and Consulted During Research

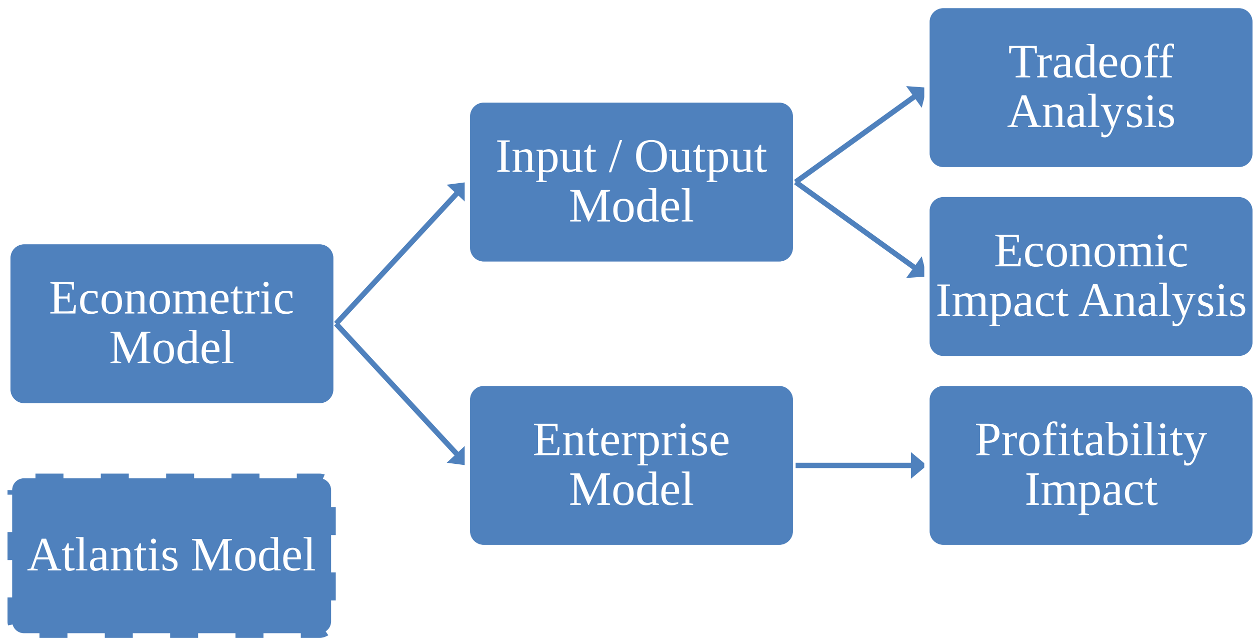
Community	Stakeholders Interviewed / Consulted
Golfo de Santa Clara, Sonora	Cooperative owners Federation leaders CONAPESCA Alto Golfo Sustentable
Puerto Peñasco, Sonora	CEDO Cooperative owners Processing facility managers

	Fishermen Fishing gear dealer
San Felipe, Baja California	CEDO Cooperative owners Cooperative member CONANP
General	CEDO Sonoran Institute US Importers US Retailers Fisheries biologists

This analysis draws upon broad resource economics themes by considering optimal management of scarce resources, more specifically, allocation of water between economic uses and environmental uses and fisheries management. This case provides the opportunity to explore those themes in a specific context, and observe the intersection of the two resource management challenges.

A number of models and methodologies are employed in order to examine the issue from a variety of angles (Fig. 1.1)

Fig. 1.1: Flowchart of Models and Methods



1.1.1 Bioeconomic model

This analysis explores the influence of Colorado River flows into the Upper Gulf of California on fisheries productivity. Working with available time series data for the region, a series of plausible relationships between river flows and fisheries catch were modeled, focusing on the top commercial species in terms of value: shrimp and gulf corvina. Various functional forms were tested for their explanatory power, introducing control variables such as price, the MEI ENSO index to account for other environmental variables, and fishing effort. This process yielded a set of models used to estimate the impact of river flows on fisheries production.

1.1.2 Panga (Single Boat) Enterprise Model

Applying fisheries-wide catch estimates from the econometric models, per-panga (boat) revenues were estimated and annual cost estimates were integrated to provide estimates of annual profits by river flow scenario. The estimated profits by scenario are compared to the baseline scenario of zero river flows to yield estimated changes in profits resulting from each scenario.

1.1.3 Ecosystem modeling

In addition to estimates of changes in productivity due to freshwater inflows using time series data, this thesis employs an ecosystem model, called Atlantis, to predict the response of the ecosystem to changes in Colorado River flows and additional nutrients that it introduces into the marine ecosystem. River flow scenarios were prepared using historical data on river flows and water quality in order to simulate the impacts of current conservation goals for river flow in the Delta, as well as major flood year and pre-dam flow levels. Biomass and catch are modeled, holding all other variables constant.

1.1.4 Input-Output Analysis

An input-output model was developed to estimate the regional economic impacts of changes in fisheries productivity from increases in river flows. This type of analysis accounts for the many rounds of economic activity stimulated by an economic shock, such as an increase in production, that in turn lead to increased demand along sectoral value chains and wages paid to workers who in turn spend money locally on consumption. Accounting for economic output versus simply production is important because fisheries-related businesses are also impacted by changes in production.

1.1.5 Tradeoff Analysis

In order to explore opportunities to shift water from agriculture to the environment, a tradeoff analysis was used to assess the net impacts on economic output of various water tradeoff scenarios. Fallowing crops or shifting to less water-intensive crops is a means of making agricultural water available for instream flows. Changes in productivity were translated into impact on economic output and then compared on their ability to create outcomes mutually beneficial to both the agricultural and fisheries sectors.

1.2 Summary of Findings

The econometric analysis yielded models with statistically significant flow coefficients, all of which were positive, indicating a positive, yet modest relationship between river flows into the Upper Gulf and fisheries catch for shrimp and gulf corvina. Taken alone, these production increases resulting from increased river flows would have a positive economic impact on the region of up to $30 million pesos annually, or roughly $2 million USD. The predicted response in fisheries catch resulting from the changes in river flows was highly sensitive to econometric model specification, with those models containing linear river flow terms predicting a much larger response in catch than models using quadratic or cubic river flow terms. Since there is not a well-established biological functional relationship between river flows and fisheries productivity for the region, the model estimates must be interpreted with some caution in terms of estimated magnitude of predicted change. Additionally, predicted change in value of catch assumes fixed prices for shrimp and corvina, and the economic impact would be sensitive to fluctuations in prices.

Since there is no unclaimed water in the Lower Colorado River, water to support increased flows into the Gulf would need to come from reduced water consumption in some other water using activity. This thesis considers some possible tradeoffs that could be made to free up the water for environmental flows. If the water is obtained from reducing agricultural consumptive use in the Mexicali Valley, in most cases, that tradeoff has a net negative impact on regional economic output when examining economic output in fisheries and agriculture. The analysis did find, however, that shifting alfalfa production to cotton production could potentially free up water for the environment while achieving a net positive impact to both the agricultural and fisheries sectors. This assumes no negative impacts on crop yields from the shift in crop mix. Arrangements with farmers in this area to provide water for environmental purposes generally include compensation to the farmers. These compensation payments represent additional money infused into the local economy and would generate a positive economic effect. It is beyond the scope of this thesis to consider compensation programs and their effects.

A single boat enterprise model was used to analyze changes in fisheries profitability at the micro level. Based upon estimates of changes in fisheries productivity from the econometric model and cost estimates, it was found that increases in river flows from between 1 to 10 cubic meters per second could yield small increases in profitability of up to 14% in the highest scenario. The Atlantis model was run for the Upper Gulf and results initially indicate a small increase in biomass for the region. Difficulties in obtaining estimates of inputs including detritus may explain the small magnitude of projected changes for the region.

These results point to a need to integrate the effects of Colorado River flows on fisheries into the larger context of value generated by water for the environment in the Delta, including recreation values, non-use values, and other non-economic values in order to develop a more comprehensive understanding of the tradeoffs that are being made in diverting river flows for consumptive use.

CHAPTER TWO: BACKGROUND ON STUDY AREA

2.1 Colorado River Delta / Upper Gulf of California geography and physical history

The Colorado River begins high in the Rocky Mountains in Colorado and drains the Colorado River Basin, spanning seven western states including portions of Arizona, New Mexico, Colorado, Wyoming, Utah, Nevada, and California. The Colorado flows south and west, eventually delineating the Arizona-California border, crosses into Mexico, and makes its way to the northernmost portion of the Gulf of California where it empties into the Sea of Cortez via the Colorado River Delta. The Delta formed over millions of years from the deposition of sediments arriving from upstream into the Gulf of California Rift Zone (Cohen & Henges-Jeck, 2001).

The Delta empties into the Sea of Cortez, a shallow sea between the Baja California Peninsula and mainland Mexico. It is renowned for its biodiversity, including numerous species of marine mammals, and home to Mexico's most productive fisheries. Its shallow waters experience dramatic tides and in some locations the sea level can vary up to 10 meters (CONANP, 2007). Until less than a century ago, the Colorado River Delta consisted of 2 million acres of delta ecosystem including marshes, riparian habitat, and estuaries, and supported wildlife, migratory birds, and fisheries. River flows reaching the Delta fluctuated seasonally, with high flows arriving in the spring and summer following from snow melt in the Rocky Mountains. These flows would flush sediment and nutrients into the Delta and estuary zone, providing important nutrients and inputs into the ecosystem. Within the past century, however, the Delta has experienced dramatic ecological changes resulting from anthropogenic influences on the environment.

As a result of upstream diversions and damming the Colorado River through the construction of the Hoover Dam in 1935, Morelos Dam in 1950, and Glenn Canyon Dam in 1963, the Delta has since been reduced to less than 10% of its previous size (Zamora & Flessa, 2009) and fresh water no longer reaches the sea. South of Morelos Dam, the last point of diversion serving agriculture in the Mexicali Valley, there are no designated river flows and the only water reaching the Delta and the Upper Gulf of California is through incidental releases from upstream reservoirs during high flow years such as the ENSO events of 1983 and 1993, seepage from nearby irrigation canals in the Mexicali Valley, operational spills, and agricultural return flows (Zamora & Flessa, 2009). Delta construction through sediment transport from upstream has stopped and is in fact in reversal as tides pull sediment into the sea, making the Delta a net exporter of sediment (Carriquiry, 1999). Today, freshwater resources in the Upper Gulf of California and Colorado River Delta are scarce and the region is characterized by high rates of evaporation (CONANP, 2007), which has led to the creation of an anti-estuarine environment as sea water evaporates in the heat and sun, increasing in salinity compared to the seawater and even forcing changes in oceanic currents in the Northern Gulf (Carriquiry, 1999).

2.2 Upper Gulf of California economy and socioeconomic profile

The Delta region has been inhabited for thousands of years by indigenous peoples, one of which is the Cucupá. They are believed to be the only indigenous community in the area to have practiced agriculture prior to the arrival of the Spanish (CONANP, 2007). Their descendants remain in the Delta, though the community now stands at a population of only roughly 300.

Fig. 2.1. Upper Gulf of California.
Source: Afflerback, et al (2014)

Once subsisting on crops irrigated by the Colorado River and fishing in the rivers and estuaries, their local population has dwindled due to outmigration resulting from the lack of water in the area. The Cucupá are involved especially in the local finfish fishery and are involved in efforts to have their fishing rights observed by Mexico's federal government.

Spanish expeditions to the Upper Gulf first started in the sixteenth century, though they did not make much progress into the Delta given the difficulty of travel due to the strong tides and difficult terrain. In the 18th century, expeditions by Catholic missionaries started and hunters and fur traders began to enter the region. In the mid-19th century, commercial river transport on the Colorado started between the Gulf and Yuma, even reaching as far as the Gila River, until the construction of the railroad in the region in the late 19th century, after which point commercial river navigation through the Delta ceased (CONANP, 2007).

The three major Upper Gulf communities - Golfo de Santa Clara, Sonora, Puerto Peñasco, Sonora, and San Felipe, Baja California - developed as fishing villages in the early 20th century.

Starting in the 1920s, growth of the tree communities was driven by demand for totoaba, a large finfish prized in Asia for its swim bladder, "*buche*" (Flanagan, 1976). Later, demand for shark liver to produce Vitamin A continued to drive growth. Eventually, however, declines in the totoaba population due to overfishing and the introduction of synthetically derived Vitamin A forced the three communities to diversify towards other species, at which point all three communities began fishing for shrimp, which to this day is the most important commercial species for the region (Cudney-Bueno & Turk-Boyer, 1998).

In the 1980s, tourism began to grow as an industry with the devaluation of the peso, particularly in Puerto Peñasco, as well as in San Felipe (Cudney-Bueno & Turk-Boyer, 1998). Today, tourism is a key sector for the regional economy. Of the three Upper Gulf communities, Puerto Peñasco has the most heavily developed tourism sector, with 71 hotel and lodging businesses (INEGI, 2014), not including the large market for private condominium rentals. San Felipe follows with 49 temporary lodging establishments. With the exception of a handful of lodging establishments, Golfo de Santa Clara has an undeveloped tourism sector and its economy is almost entirely dependent upon fishing and fishing related activities. It is also the only of the three communities that falls inside the Upper Gulf of California and Colorado River Delta Biosphere Reserve (Reserva de la Biosfera Alto Golfo de California y Delta del Río Colorado), officially created in 1993. Growth in land use arising from tourism and urban development in the three communities has been fragmented, creating a need for additional infrastructure, placing demands on already limited water

Table 2.1: Population of Major Upper Gulf Communities, 2010

Location	**Population**
San Felipe, Baja California	16,702
Golfo de Santa Clara, Sonora	3,967
Puerto Peñasco, Sonora	56,756

Source: INEGI, Censo de Población y Vivienda 2010 resources, and disrupting coastal ecosystems (Diaz Garcia et al, 2013).

Promotion of tourism as an economic development strategy places increased pressure on water supplies, and lack of freshwater resources is a pressing constraint for their future economic growth and sustainability. Morzaria-Luna et al (2014) assess the social vulnerability of twelve Northern Gulf communities, including the three Upper Gulf communities, to anthropogenic stresses and climate change, including increased drought, and those stressors impact on fisheries. The communities' vulnerability was assessed based upon their exposure, sensitivity, and capacity to adapt to changes. Those communities most dependent upon fisheries were most vulnerable to the stressors; those with greater levels of economic diversification were less vulnerable. Of the three Upper Gulf communities, Puerto Peñasco and San Felipe were some of the least vulnerable communities in the Northern Gulf. Golfo de Santa Clara had a higher level of vulnerability than the other two communities. Some adaptive strategies already being observed in the Northern Gulf include outmigration, transition to alternative economic activities, pursuing flexible seasonal occupations, and seeking new markets for goods and services.

Even with the possibility of alternative economic activities, fishing remains one of the most attractive occupations in the Upper Gulf. As of 2002, artisanal fishermen in San Felipe, Baja California earned on average four times the official minimum wage, earning on average a monthly income of $4,819 pesos (Vasquez Leon, 2010). Though the number of fishing permits in the Upper Gulf has held steady or even declined in recent years, the potential for relatively high wages compared to other occupations continues to attract illegal fishing activity. In Golfo de Santa Clara, 50% of the economically active population worked in fisheries, 15% in San

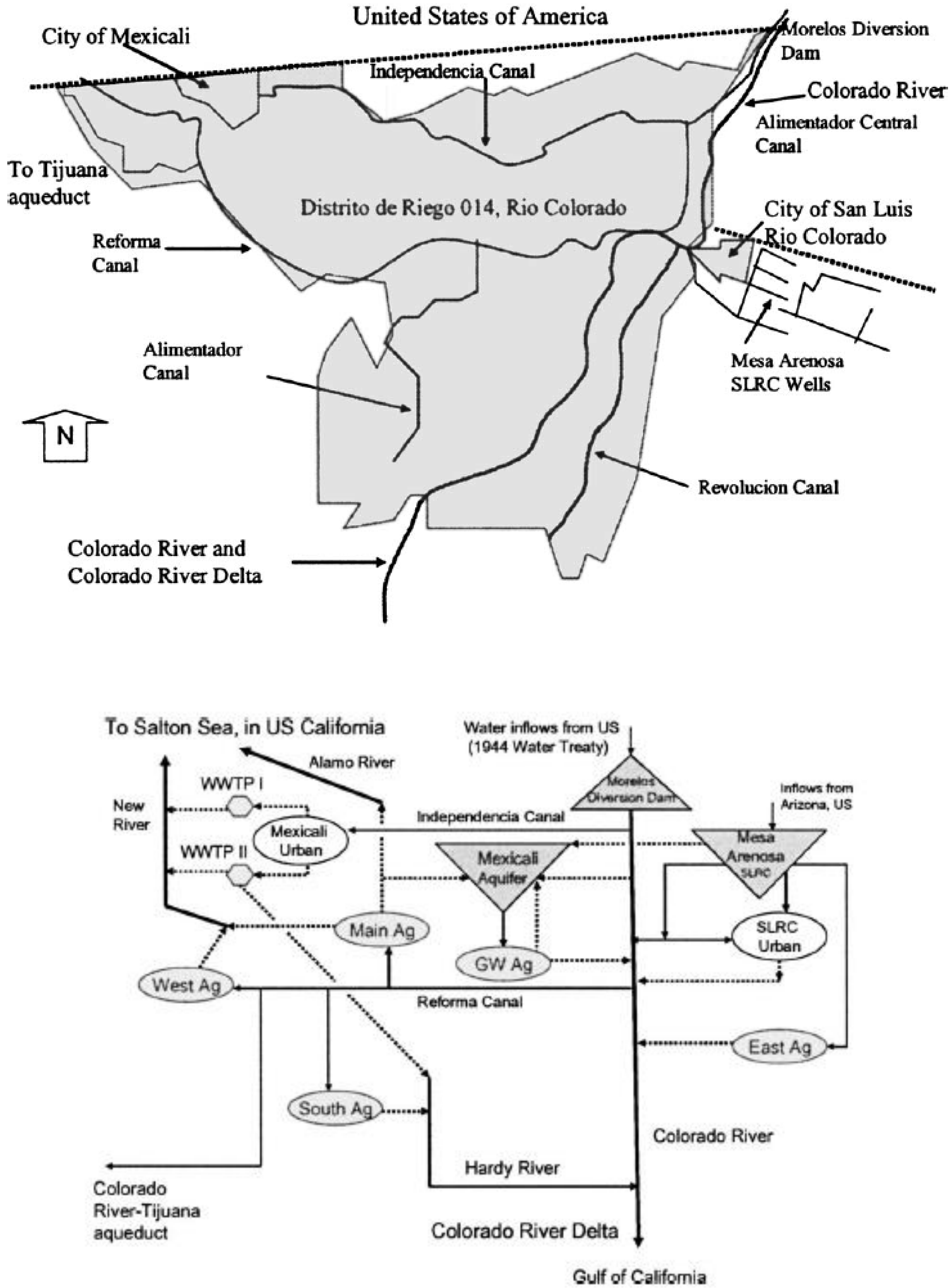
Felipe, and 10% in Puerto Peñasco. Another 30%, 64%, and 59% worked in tourism, respectively (Avila-Forcada, et al, 2012). An important factor influencing livelihoods in the Upper Gulf is the lack of retirement benefits and access to healthcare, leading many fishers to continue fishing late into life and sustaining a larger number of fishers active in the workforce (WWF, 2006).

2.3 Economic Uses of Water in the Colorado River Delta

A 2001 Pacific Institute report (Cohen & Henges-Jeck, 2001) provides an accounting of water uses and sources for the Colorado River Delta region from 1991 to 1998. Major agricultural activity began in the region after the 1930s when the ejido system was established and US-held land was returned to Mexican ownership. Investment in irrigation infrastructure and groundwater pumping supported this growth. Cohen and Henges-Jeck found that in non-flood years, agriculture consumed roughly 50% of inflows with roughly 1 million acres of irrigated agriculture. Urban uses represented only around 2% of consumption, met largely by groundwater, and water use for the environment used roughly 10% of inflows. Of major agricultural crops grown in the region, the largest users of water were alfalfa, wheat, and cotton, also the crops with the largest planted acreage.

A later study by Carrillo-Guerrero, et al (2013) found that within the Mexicali Valley (the valley surrounding the Colorado River running from the US-Mexico border south towards the Sea of Cortez) wheat, alfalfa, and cotton are the primary crops, using 74% of cultivated area and 71% of irrigation water (Carrillo-Guerrero, et al, 2013). A total of 36,377 hectares of aquatic habitat, including marshes, riparian corridors, wetlands, and tidal estuaries, is supported by agricultural return flows and occasional river flows (Carrillo-Guerrero, et al, 2013). Agriculture in the Mexicali Valley consumes 90% of water entering Mexico via the Colorado River in non-flood years (Carrillo-Guerrero, et al, 2013). They estimate total consumptive use in Irrigation District 14, the irrigation district fed by the Colorado River that serves the Mexicali Valley, for 2004-2005 at 2,801 million cubic meters (2.3 million AF), of which 190 million cubic meters (154,000 AF) is urban use and 1,903 million cubic meters (1.5 million AF) is crop ET. Of that urban use, 115 million cubic meters (93,232 AF) was exported westward to the city of Tijuana through the Tijuana Aqueduct. By comparison, environmental uses, evapotranspiration from the riparian floodplane and marches, represented 96 million cubic meters (77,828 AF). Urban demand for water in the nearby cities of Mexicali, San Luis Rio Colorado, Tijuana, and Tecate will continue to place additional stress of water supplies in the Delta region. Demand in Mexicali alone is projected to grow from 86 million cubic meters (69,721 AF) per year to 100.9 million cubic meters per year (81,800 AF) (Schuster, 2012). Meanwhile, water supply targets for environmental flows established by conservation organizations and specialists range from 2 to 4 cubic meters per second in base flows (roughly 63 million to 126 million cubic meters in annual base flows (51,074 AF to 102,149 AF)) and a pulse flow of 20 to 40 cubic meters per second every four years (Carrillo-Guerrero, et al, 2013).

Fig. 2.2: Colorado River Delta Water Infrastructure



Source: Medellin-Azuara, et al (2007)

Medellin-Azuara, et al (2007) apply the CALVIN economic-engineering optimization model used in California to the Colorado River Delta / Mexicali Valley region, creating projections of water shortfalls based upon potential policy scenarios, including the introduction of minimum environmental flow mandates, the use of water markets, and opening of water treatment facilities. They note that for Mexicali, water use is divided by use as residential (75%), commercial (10%), industrial (8%), and governmental (7%) (Medellin-Azuara, et al, 2009). They found that the marginal cost of water from the Mexicali Valley would be $50 USD per thousand cubic meters of water at recommended environmental flow levels for restoration efforts and $80 USD per thousand cubic meters of water for double those flow levels..

Schuster, et al (2012) provide an estimate of the value of water in agriculture in the Mexicali Valley using a Net Returns to Water (NRTW) method. The NRTW method uses a farm budget equation, estimating the value of water as the difference between gross crop revenues and non-water input costs (Schuster, et al, 2012). It is considered to be a minimum price that an agricultural user would consider accepting in exchange for fallowing their fields (not growing their crop). The authors calculated NRTW for the Mexicali Valley as $1,060.68 pesos per 1,000 cubic meters of water (1,233 m3 = 1 acre foot) per hectare for durum wheat, equivalent to $111.78 USD. For cotton, NRTW were $194.79 pesos per 1,000 cubic meters of water per hectare, roughly $20.53 USD.

Schuster (2012) examines agricultural response to water supply variability in the Mexicali Valley, assessing the feasibility and adoption of two risk management strategies, cement lining of parcel-level canals and crop diversification. The author surveyed 180 farm households to gauge their response to water supply variability and shocks to production, and through an econometric analysis determined the characteristics associated with the adoption of the risk management strategies (cement lining of canals, crop diversification, and geographic diversification). The study analyzes responses to water supply variability by breaking it down into delivery delays and delivery shortfalls, identifying those characteristics associated with the farmers that choose each risk management strategy. The survey also includes a question on willingness to support ecosystems in the Delta. Schuster found that water delivery delays are associated with crop diversification, suggesting that delays lead farmers to choose crops that better withstand delays in irrigation, or shifting production to times of year when water reliability is higher. She also found that water-conserving technology adoption is associated with irrigation delivery shortfalls. Regarding farmer support for environmental restoration of the Delta, 97% of survey respondents reported willingness to contribute water, time, or money for ecological restoration of the Delta (Schuster, 2012). These results indicate that nearby agricultural water users have strategies at their disposal to adapt to changes in water availability and suggest that those strategies could potentially be used to make water available for transfer to environmental uses.

In an effort to address the lack of river flows available for the environment in the Colorado River Delta, a binational agreement, called Minute 319, was passed in 2012, expanding upon the 1944 treaty between the US and Mexico governing delivery of river flows to Mexico. Minute 319 calls for a series of conservation programs in the delta, a pulse flow which occurred in the spring of 2014, and a monitoring program to document the environmental effects of the pulse flow.

Furthermore, it allows Mexico to store water in Lake Mead (Sonoran Institute, 2013). In March of 2014, a pulse flow of roughly 130 million cubic meters of water was released, and on May 15, the waters reached the Gulf of California, though the water that reached the Gulf was estimated to be less than 1% of the total pulse flow volume (IBWC, 2014).

130 million cubic meters (105,393 AF) of water released over an 8 week period averaged to roughly 27 cubic meters per second of flows, though in actuality flows were greater at the beginning of the release and attenuated towards the end. This quantity, released primarily through Morelos Dam but also through the Mexicali Valley irrigation system, was sufficient to connect the river with the sea. The release contributed to elevated groundwater levels around the river course, which later declined again following the peak of the pulse flow (IBWC, 2014).

Another agreement to provide water for the environment occurred in 2008 between the Sonoran Institute, Pronatura Noroeste, and Baja California state agencies surrounding the Las Arenitas treatment plant. Las Arenitas treats municipal wastewater from Mexicali and in the past experienced challenges meeting required water quality standards. An agreement was brokered to dedicate one third (12,000 acre feet per year) of the plant's treated effluent to the Hardy River, a tributary to the Colorado, in exchange for the construction of a wetland used to enhance the plant's treatment capacity. Plans are in the works to secure an additional 12,000 acre feet of treated effluent per year. (Sonoran Institute, 2013)

2.4 Upper Gulf of California fisheries history and policy

Native peoples of the Gulf of California, including the Cucupá and the Seris, have relied on the sea as a source of food for thousands of years. Commercial fishing in the Gulf of California started in different areas and at different times, targeting a variety of species. In the Upper Gulf, the totoaba fishery led to the establishment of the three fisheries camps, Puerto Peñasco, San Felipe, and Golfo de Santa Clara (Arvizu-Martinez, 1987). Totoaba was targeted primarily for its swim bladder ("buche") for export to Asian markets where it is used in soups. These Upper Gulf communities later targeted shark, and eventually transitioned to shrimp as a primary target species. The Pacific industrial shrimp fishery started in the 1920s with American and Japanese ships, later expanding to the Gulf of California in the 1940s and 1950s (Magallon-Barajas, 1987). Mexico's Pacific shrimp fishery generates $4.111 billion pesos ($436.8 million dollars) (1998), most of which is exported to the US, and accounts for 37,000 direct and indirect jobs (Calderon, 2011). Today, industrial shrimp trawling occurs in both Puerto Peñasco and San Felipe, but not, however, in Golfo de Santa Clara because of restrictions on industrial trawling in the Biosphere Reserve. Industrial shrimp trawls are notoriously destructive to benthic marine habitat (the sea floor). One study estimates that industrial shrimp trawls in the Gulf of California incur social costs of $1.6 pesos per $1 peso of income through shrimp trawling, due to high rates of bycatch (roughly 10:1) and taxpayer-financed subsidies to help boost profitability of the ageing fleet (Garcia-Caudillo, et al, 2005). The largest commercial shrimp ports are located further south in the Gulf, such as Guaymas and Mazatlan; within the Upper Gulf, artisanal fisheries dominate due to the Biosphere Reserve restrictions. The artisanal or small-scale fishing fleet, in this context, is defined as the fleet of small boats with off-board motors, called pangas, which fishes in coastal zones. The Gulf of California fisheries, both industrial and artisanal, generate roughly 50% of the value of Mexico's national fisheries production, employ around 50,000 people, and roughly 90% of vessels operating in the Gulf are small artisanal boats (Cudney-Bueno, 2010). The Northern Gulf of California (NGC) consists of approximately 35,170 square kilometers of overlapping fishing zones corresponding to 17 different fishing communities, or approximately 60% of the area of the Northern Gulf (Moreno-Baez et al, 2010).

The artisanal fleet operates using small boats called "pangas" powered by off-board motors. The number of pangas has varied over time and is regulated by the federal government through a permit system. Mexico's federal fisheries agency, Comision Nacional de Acuacultura y Pesca (CONAPESCA), is charged with managing fisheries and issuing permits to fishermen. Permits are issued by species and entitle the permit holder to an unlimited catch within the designated fishing season. There are three CONAPESCA fisheries offices in the Upper Gulf, one in each of the three communities. There are roughly 2,100 small boats operating in the Upper Gulf of California, of which 606 are dedicated to shrimp fishing and 882 to finfish (Rodriguez-Quiroz, 2012). Fishermen typically hold permits for multiple species, allowing them to fish throughout the course of the year over different seasons (Afflerbach et al, 2013).

Cudney-Bueno (2010) examined the fishing permit system in the Gulf of California in Bahia Kino, Sonora and found that the permitting process is prohibitively time-intensive and difficult for individuals with limited education, leading to a situation in which the owning of permits is increasingly detached from actual fishing. Permit holders tend to be wealthy, socially well-positioned individuals who hire fishermen to work under their permits, extracting rent from the fishing operation. My recent field interviews with fishermen supported this observation about permit holders, particularly in Puerto Peñasco where this situation was reported; it was not as salient a theme in Golfo de Santa Clara and San Felipe. Based upon interviews, Cudney-Bueno found that only roughly a quarter of fishermen owned their own equipment and the remainder operate using the permit holder's equipment or purchase the equipment through the permit holder. He found that it was a common practice for permit holders to sell equipment to fishermen to reduce maintenance expenses or to provide financing for equipment and operating expenses, often obligating the fishermen to sell the catch to the permit holder at pre-agreed prices in order to pay back debt. Most government benefits or economic compensation directed towards the fisheries is provided to the permit holders, and therefore does not reach the fishermen who are hired to work under permits they do not own.

Most fishermen in the Upper Gulf organize themselves into cooperatives, though not all fishermen belong to cooperatives. Some fishermen report that the cost and constrains of operating within cooperatives leads people to fish independently. There are over 60 legally constituted cooperatives in the Upper Gulf comprised of 2,418 members (Rodriguez & Bracamonte, 2008). El Golfo de Santa Clara has the highest number of cooperatives. Cooperatives vary considerably in terms of size, structure, and ownership. While some cooperatives have become large, vertically integrated enterprises, owning and operating activities from primary harvest of species to processing, packaging, and transport, most cooperatives are small family-owned businesses, seeking to avoid the complications of managing competing interests of non-family members. Profit and costs are split according to different agreements among members and employees. While most cooperatives in the Upper Gulf operate under the permit system that for most species entitle them to unlimited catch, other cooperatives on

Mexico's Pacific Coast have piloted the use of spatial, territorial concessions for benthic species and self-management and enforcement (McCay et al, 2014).

Illegal fishing is a serious problem threatening the sustainability and profitability of the Upper Gulf fisheries. Fishermen report that the difficulty and cost of obtaining a permit, coupled with the lack of enforcement and potential for sizeable profit margins during strong fishing seasons draw new entrants into the fisheries. Illegal fishing can occur in different ways. Some fishermen arrive in pangas from outside of the Upper Gulf and fish during the most profitable times of the year, such as the corvina season. Others obtain boats and equipment and fish without permits. There are other strategies, too, such as fishing out of season. The demand for "fresh" shrimp (not frozen then thawed) during times of the year when the shrimp fishery is closed leads some fishermen to fish for shrimp beyond the permitted window from September through February. Finally, other strategies include falsifying paperwork or reporting catch from one boat without a specific species permit under another that has the permit, referred to as sheltering, or "amparo" (Cudney-Bueno, 2010). Different studies estimate varying levels of illegal fishing in the Upper Gulf. A recent study by the Universidad Autonoma de Baja California estimated illegal fishing in San Felipe at 10% of fishermen (UABC, 2014). Lozano (2006) estimates illegal fishing of shrimp in the Upper Gulf between 1-14%. Anecdotal reports from the field suggest that the rate of illegal fishing is much higher, some stating even as high as 50%.

As mentioned previously, fisheries in the Upper Gulf are generally regulated under a permit system, entitling the permit holder to unlimited catch of a species, unless agreements have been put in place to limit catch by fishery, as is the case for gulf corvina. Most commercial fisheries are also regulated with temporal restrictions that typically protect species during important times of the year such as spawning season, and provide the species time to regenerate. Spatial and gear restrictions in the Upper Gulf will be discussed in subsequent sections.

Nationally, Mexico's federal government subsidizes both the industrial and artisanal fishing fleets in a number of ways. The marine diesel subsidy was established with the specific objective of increasing operating margins for industrial fishing and aquaculture enterprises. The 2013 and 2014 programs provided a two peso per liter subsidy up to 2 million liters. Gasoline for artisanal fleets is also subsidized. Another past project was the Small Vessel Modernization Project (Proyecto de Modernizacion de Embarcaciones Menores) which subsidized up to 40% of the cost of the acquisition of new motors, new hulls, more selective fishing gear, coolers to better preserve catch, and GPS units. Some state governments were also involved, contributing an additional 30% of costs. These rates also apply to the substitution of old motors for more fuel efficient motors, known as the Ecological Motors subsidy. In 2013, the federal government subsidized the purchase of ecological motors (fuel efficient motors) with $29 million pesos in the state of Sonora ($15 million additional subsidy by the state) and roughly $3 million in Baja California ($2 million additional subsidy by the state). Finally, there is also a national-level subsidy to reduce the size of the industrial fleet, offering permit holder $1.3 million pesos (roughly $1 million USD) to retire their permits and boats. (CONAPESCA, 2015)

2.5 Key Commercial Species

In the Upper Gulf, artisanal fisheries target numerous species throughout the year. Most important amongst these in terms of value of catch are shrimp, corvina, shark, finfish, and benthic (bottom-dwelling) species. These species are fished over the course of the year during different open fishing seasons. As a result of the seasonal closures, most fishermen target more than one species, enabling them to fish throughout the year and have a regular source of income.

Table 2.2: Key Commercial Species and Fishing Seasons in San Felipe, Baja California

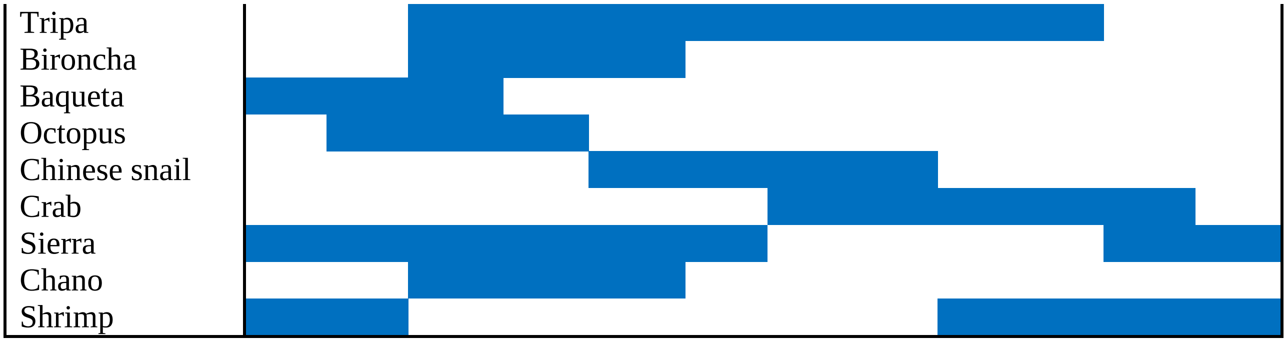
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Corvina		■	■	■								
Manta Arenera	■	■	■									■
Manta Mariposa	■	■	■	■	■	■						■
Guitar fish				■	■	■						
Tripa			■	■	■	■	■	■	■	■		
Broncha			■	■	■							
Baqueta	■	■	■									
Octopus		■	■	■								
Crab							■	■	■	■	■	
Sierra	■	■	■	■	■	■					■	■
Chano			■	■	■							
Shrimp	■	■							■	■	■	■

Source: CEDO

* Shaded square indicates open fishing season for species

Table 2.3: Key Commercial Species and Fishing Seasons in Golfo de Santa Clara and Puerto Peñasco, Sonora

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Corvina		■	■	■								
Manta Arenera	■	■	■									■
Manta Mariposa	■	■	■	■	■	■						■
Guitar fish				■	■	■						
Angel fish					■	■					■	■



Source: CEDO

* Shaded square indicates open fishing season for species

2.5.1 Shrimp

The Upper Gulf of California shrimp fishery is the region's highest value fishery and is driven by demand for exports. Seasonal catch is in the range of 700 metric tons with an approximate value of $10 million annually (Barlow, et al, 2010). It is estimated that 80% of shrimp caught in the Upper Gulf is exported to the United States and large U.S. seafood companies have a presence in the Upper Gulf to purchase, process, and export the shrimp (Ardjosoediro & Bourns, 2009). The fishery targets two species of shrimp, blue shrimp (*Penaeus stylirostris*) and brown shrimp (*Penaeus californiensis*). 90% of shrimp capture in the UGC is blue shrimp (Rodriguez-Quiroz, 2009). Shrimp fishing began in the Upper Gulf in the 1930s and scaled up in the 1940s and 1950s with the decline of the totoaba. The artisanal fleet became active in the shrimp fishery in the 1970s. In the late 1980s and early 1990s, there was a drastic decrease in the shrimp population, provoking economic crisis for the Upper Gulf communities (Cudney-Bueno & Turk-Boyer, 1998). The collapse was caused by overfishing and increases in the fishing effort. Catch per unit effort fell and fishing enterprises suffered financially. The establishment of the Biosphere Reserve in the 1990s and the limitations that placed on fishing, as well as a movement towards more small-scale fishing in place of industrial-scale fishing contributed to help the shrimp fishery recover (Brusca & Bryner, 2004).

The artisanal fleet fishes shrimp from all three Upper Gulf communities and industrial trawling is based in San Felipe and Puerto Peñasco. Industrial scale fishing does not occur in Golfo de Santa Clara because the community and its fishing grounds fall entirely within the Biosphere Reserve. There are roughly 150 industrial shrimp trawlers in Upper Gulf communities (Ardjosoediro & Bourns, 2009).

Upper Gulf shrimp is marketed for export, for domestic consumption, and for local consumption. Shrimp prices are affected by global markets. One major factor that affects the market for shrimp is aquaculture production, which has placed downward pressure on shrimp prices (Meltzer & Chang, 2006). Mexico’s shrimp aquaculture industry has grown exponentially, from less than 10,000 tons annually in 1990 to 120,000 tons of production in 2008. Within the Gulf of California, Sonora has the largest shrimp aquaculture industry. The shrimp aquaculture industry is also driven by demand for exports to the United States, which is expected to grow to 750,000 tons of annual production by 2020 (Aragon-Noriega, 2011). Shrimp aquaculture often uses coastal mangrove habitat for construction of aquaculture ponds. The ponds are constructed with levees between them to regulate the flow of water and freshwater is used to regulate the salinity of the ponds. Drainage is sent to the ocean, introducing water with high levels of waste and chemicals into the marine environment. The environmental impacts of the habitat destruction and dumping of effluent into the sea are major concerns stemming from the growth of this industry. In the Upper Gulf, there are few, if any, ongoing aquiculture projects. Development of aquaculture in the region is constrained by lack of fresh water.

2.5.2 Gulf Corvina

The Gulf Corvina (*Cynoscion othonopterus*) is a finfish that migrates from lower in the Gulf of California to the mouth of the Colorado River Delta in the spring timed with the moon cycles during a series of tides between February and April to aggregate and spawn. The fishery is seasonal and exclusively targets the fish during their large spawning aggregations, which happen to coincide with Lent when there is a high demand for fresh fish in Mexico's largest urban areas (Cudney-Bueno & Turk-Boyer, 1998; Moreno-Baez, et al, 2012). Gulf corvina are targeted primarily by fishermen from Golfo de Santa Clara, the Cucupá fishing camp of El Zanjon, and San Felipe. Gulf corvina arrive with a series of tides, during which time there is a frenzy of fishing activity and markets are flooded with the product. Gulf corvina were fished until they stopped migrating to the Delta in 1960s and disappeared for 30 years, reemerging in the 1990s (IAES, 2014). It is hypothesized that their spawning migration stopped after Colorado River flows ceased with the filling of Glenn Canyon Dam in the 1960s, as well as due to the practice of leaving the eviscerating fish remains in the water during the fishing season (Cudney-Bueno & Turk-Boyer, 1998). In the early 1990s, the corvina began to migrate to the Delta again, and the fishery resumed. It is suggested that the high river flows in the 1980s may have prompted their return to the Delta.

The demand for Gulf corvina is driven by two factors – the demand for their flesh in Mexico's major urban centers during Lent, and Asian demand for corvina swim bladder. During the corvina season, roughly 40% of corvina flesh is shipped to the Nueva Viga market in Mexico City, around 15% is shipped to Guadalajara, and the remainder is sent to other major cities in Mexico (CapLog Group, 2012). The timing of Lent can affect the market price for Gulf corvina, as can the timing of fishing effort. In the past, the rush to fish has flooded the markets with corvina after the first tide. Efforts to space fishing out more evenly across the tides have resulted in more stable prices over the corvina season (CapLog Group, 2014). It is reported that fishermen have generally cooperated with the catch restrictions and even started fishing more strategically, waiting for later in the season with the expectation that prices would be higher later.

A recent emerging trend in the corvina fishery is Asian demand for corvina swim bladder. In the Upper Gulf, there is a history of Asian demand for totoaba swim bladder dating back 100 years. Overfishing, however, drove totoaba to the brink of extinction and the totoaba fishery was officially closed in 1975. Today the totoaba is listed as "critically endangered" (CapLog Group, 2012). Despite protections put in place, there is a thriving black market for totoaba swim bladder, which can fetch up to $14,000 USD for a single dried swim bladder (Diaz, 2014). In recent years, demand has been increasing for corvina swim bladder and prices have increased by a factor of 24 since 2005 (CapLog Group, 2014).

In 2005, CONAPESCA issued a fisheries closure for corvina from May 1st and August 31st, starting in 2006 onward (IAES, 2014). Concerns over the sustainability of the gulf corvina fishery have led to efforts by the Environmental Defense Fund (EDF) to implement a total allowable catch (TAC) pilot program in Golfo de Santa Clara in 2012 in conjunction with a number of local partners (EDF, 2013). Agreements were brokered between fishermen, buyers, and local fisheries leaders to limit the amount of catch overall and per panga in an effort to boost ex-vessel prices, stabilize ex-vessel prices through the season by avoiding the mad rush to fish all within the first few tides, and to ensure a more sustainable catch level for the fishery. The monitoring program is managed by EDF, the government of the State of Sonora, and CONAPESCA. In 2013, individual fishing permits were introduced (CapLog Group, 2014) and the TAC and monitoring efforts have started to be effective in stabilizing prices. While catch has exceeded TAC in Golfo de Santa Clara, it has only been by a few percentage points in recent years. Fishermen reported that the TAC system allows them to free up time to pursue other species once they met their quota, generating greater revenues for their fishing operations (CapLog Group, 2013). Pangas operating illegally during the corvina season continue to be a concern and reported catch may have further exceeded TAC due to this activity. In 2013, the estimated number of illegal pangas was between 20 and 65, and in 2014 the number was between 60 to 80, beyond the roughly 400 boats operating under permits in Golfo de Santa Clara (CapLog Group, 2014). At one point towards the beginning of the monitoring efforts, the presence of monitors in El Golfo de Santa Clara forced individuals from outside the community and illegal fishermen, and consequently buyers, into El Zanjon, a Cucupá community easily accessible and lacking in enforcement (IAES, 2014).

In 2014, a quota was implemented for Baja California on the capture of gulf corvina. It limits catch to 5.728 tons of corvina per panga and an overall quota of 3,620 tons, of which San Felipe is entitled to 18% and Alto Golfo (El Zanjon, etc.) is entitled to 24% of the state's entitlement to gulf corvina (Olivares Bañuelos, 2014). The 2015 TAC issued for the gulf corvina fishery limits the catch for the Upper Gulf communities to 3,790 metric tons of gutted fish and 80 tons of buche, which translates to a maximum catch per panga of 5.1 metric tons (DOF, 2015).

The corvina fishery is estimated to have revenues between $2 to $3 million USD over the past decade and annual landings of between 2,000 and 6,000 tons (Moreno-Baez, et al, 2012). The market price for corvina has fluctuated over time and depends upon the timing of Lent and the supply of corvina in the market. The price of buche, however, has consistently increased since 2005. In 2013, corvina meat generated 80% of ex-vessel revenue, while buche accounted for 20%. Increases in revenue are recently driven by increases in the price of buche (CapLog Group, 2013). In 2014, corvina buche represented 35% of fleet revenue (CapLog Group, 2014). CapLog bases their reports off of data collected through the corvina monitoring in Golfo de Santa Clara through the Environmental Defense Fund and the Instituto de Acuacultura del Estado Sonora (IAES).

2.5.3 Shark and Finfish

Shark and finfish represent other important commercial species in the Upper Gulf, though declines in the shark population have resulted in lower catch levels and less overall commercial importance. Finfish is a general category of fish that typically includes lisa (*Mugil cephalus*), lenguado (*Paralichthys aestuarius*), big eye croaker (*Micropogonias megalops*), Spanish mackerel (*Scomberomorus sierra*), red groupers (*Epinephelus acanthistius*), and extranjero (*Paralabrax auroguttatus*). Depending upon the species, these fish are caught using gillnets or longlines (Cudney-Bueno & Turk-Boyer, 1998). Finfish generate an estimated $5.7 million USD in revenues per year (Afflerbach, et al, 2013).

2.5.4 Benthic Species

Benthic species are of particular importance in Puerto Peñasco, and are harvested as well in San Felipe. Pangas are equipped with compressors and an air tube and mask, known as a “hooka”. Fishermen dive to collect species, including snails, oysters, scallops, octopus, and a siphon clam called geoduck. The crab fishery is also a significant fishery, especially in Puerto Peñaso. Crabs are caught using traps. Many of these species are destined for Asian markets. Snails, including *caracol chino* (“chinese snail”, or black murex snail) and *caracol rosa* (“pink snail”) are frequently exported to Korea and Japan. Geoduck, a large siphon clam, is typically exported to China, Hong Kong, and Taiwan (over 90% of production) (CapLog Group, 2013). Mexico is a relatively new entrant into the geoduck market, though all geoduck is produced in North America. CONAPESCA has 89 permitted geoduck harvesting areas. In 2012, top grade geoduck is sold at $220 to $330 USD per kilogram in China, while average quality product sold for between $60 and $80 USD per kilo. Mexican geoduck is exported to Asia through Los Angeles International Airport as the product is fragile and must be transported live.

2.5.5 Totoaba

Though no longer a legal commercial species due to its status as critically endangered, the totoaba (*Totoaba macdonaldi*) is targeted in a lucrative black market. Totoaba swim bladder (buche) is highly sought after in Asian markets, China in particular, for its culinary and medicinal properties. It is reported that in some restaurants in Asia, clients will pay over $25,000 for soup containing totoaba buche. Buyers pay between $7,000 USD and $14,000 USD for a single swim bladder, with a preference for buches over 1 kilogram. The swim bladders of female totoabas are preferred, putting significant pressure on the species' ability to reproduce. Fishermen go out at night to fish the totoaba, remove the swim bladder, and discard the remains in the water. The swim bladders, once dried, are low weight and high in value. Organized crime and narco-traffickers have become involved in the lucrative totoaba buche trade. A shipment of 70 swim bladders represents around $1 million USD in value. The product is taken to Chinese buyers in Southern California where it is then exported to Asia (Diaz, 2014).

2.6 Conservation of threatened and endangered species

In 1993, the Upper Gulf of California and Colorado River Delta Biosphere Reserve (Reserva de la Biosfera Alto Golfo de California y Delta del Río Colorado) was created to protect the region's biodiversity and cultural heritage. In 2005, the Reserve was designated as a UNESCO Natural World Heritage Site. It was created in response to a number of threats to the region, including dramatic reductions in flows from the Colorado River impacting the Colorado River Delta ecoystem, protection of the critically endangered totoaba, protection of the vaquita, the most critically endangered porpoise in the world, and unsustainable fishing practices. Despite protective measures put in place, fishing is still permitted in the Upper Gulf's Marine Protected Areas (MPAs), in fact, within the Upper Gulf, roughly 62% of catch occurs within marine protected areas (Rodriguez-Quiroz, 2012). As such, fisheries and conservation must continue to work together to provide solutions to issues affecting the health and sustainability of the region's ecosystem.

Perhaps the most acute of these issues at this time is protection of the vaquita porpoise (*Phocoena sinus*). The vaquita is a small porpoise endemic to the Upper Gulf of California weighing up to 120 pounds. The species has suffered huge population declines as a result of gillnet bycatch mortality. In 2005, SEMARNAT established the Vaquita Refuge, a 1,264 square kilometer polygon, 80% of which falls within the Biosphere Reserve, consisting of known vaquita habitat. This refuge, however, has failed to reduce the bycatch problem as a significant portion of vaquita sightings occur outside of the refuge and enforcement of the ban on gillnet fishing in the refuge has been lax. Since efforts to save the vaquita started in 1993, the Mexican federal government has spent at least $30 million USD on conservation efforts. In 2006, the PACE-Vaquita program provided $1 million USD to the states of Baja California and Sonora to implement the vaquita refuge and fund a voluntary buyout program that would provide financial assistance to fishermen to help them transition from gillnets to other fishing equipment. The program had minimal impact and was revised to provide a fishing permit buyout option which offered $40,000 USD to $60,000 USD to fishermen to retire their permits and exit fisheries as an occupation (Afflerbach, et al, 2013). Estimated willingness to accept for a buyout was US$29,700, $24,200, and $35,200 for San Felipe, Santa Clara, and Puerto Peñasco, respectively (Barlow, et al, 2010).

Despite these efforts and federal spending, the population of the vaquita has continued to decline to perilously low levels. A 2014 report by CIRVA (Comite Internacional para la Recuperacion de la Vaquita) estimates that fewer than 100 vaquita remain as of 2014, of which only around 25 are females of reproductive age (CIRVA, 2014). At the current rate of decline of -18.5%, vaquita are project to become extinct by as early as 2018. The report states that the government's buyout effort did not succeed at reducing the fishing effort in the Upper Gulf, and emerging trends such as illegal totoaba fishing using gillnets are increasing the risk of further bycatch. CIRVA recommends an immediate ban on gillnets for all of the known vaquita range.

On April 10th, 2015, a two-year fisheries closure for the Upper Gulf was put into place in response to mounting pressure to protect the vaquita (SAGARPA, 2015). The measure bans fishing in the Upper Gulf for two years, with the exception of gulf corvina, sport fishing, and those fishermen who participated in the gear reconversion program through CIRVA vaquita now using the "chango ecologico" to fish shrimp. The ban is accompanied by an economic compensation program for all affected permit holders, as well as their crews. The compensation is reported to cost 541 million pesos, or roughly 35.6 million US dollars per year (El Economista, 2015). It's estimated this would amount to around $7,000 pesos or $460 per month in compensation (Dibble, 2015). In field interviews, some fishermen communicated that the economic compensation accompanying their gear switch-out will cease with the new compensation program, and that shrimp fishing with the new gear but no subsidy will become unprofitable (see Appendix C).

Other major marine conservation activities in the Upper Gulf include work by the Environmental Defense Fund (EDF) and Noroeste Sustentable (NOS) to implement corvina catch shares in Golfo de Santa Clara, as well as monitor the corvina season to ensure compliance, and work by CEDO to implement Environmental Impact Analyses (Manifestacion de Impacto Ambiental, or MIA) for the Upper Gulf fisheries. The MIA process is an accounting of the environmental impact of commercial activities or projects overseen by SEMARNAT.

Table 2.4: Conservation Organization Involvement in Upper Gulf and Biosphere Reserve

Organization / Entity	***Activity***
World Wildlife Fund (WWF)	Vaquita conservation and bycatch reduction; protection of other species including sharks, whales, and turtles
Environmental Defense Fund (EDF)	Corvina catch shares and monitoring; Colorado River Delta restoration and Pulse Flow; DeltaWater Trust
Noroeste Sustentable	Corvina catch shares and monitoring
Alto Golfo Sustantable	Community development activities
Sonoran Institute	Colorado River Delta restoration and Pulse Flow monitoring; Colorado River Delta Water Trust
Pronatura Noroeste	Colorado River Delta restoration; Delta Water Trust
CEDO	MIA process for Upper Gulf fisheries; fisheries monitoring and education
Walton Foundation	Fisheries Improvement Partnership Fund, part of the Clinton Global Initiative Commitment to Action
The Nature Conservancy	Baja Marine Initiative; protection of mangrove habitat
SEMARNAT	Federal government's wing dedicated to conservation of species and natural resources
CONAPESCA	Federal government's National Commission on Fisheries – involved in permitting and regulations regarding gear and species closures
INAPESCA	Federal government's wing dedicated to research on fisheries and aquaculture
COFEPRIS	Federal government's environmental protection wing dedicated to enforcement; federal programs to protect the totoaba and vaquita; biosphere reserve
David & Lucile Packard Foundation	Fund projects related to sustainable fisheries management
Sustainable Fisheries Partnership	Gulf of California Shrimp Supplier Roundtable

Another important effort related to research and conservation in the Upper Gulf was the PANGAS project. Starting in 2005, the project was a collaborative effort between universities (University of Arizona, CICESE, University of California, Santa Cruz) and conservation organizations (CEDO, Pronatura Noroeste, COBI) to develop a body of research around artisanal fisheries in the Upper Gulf. Part of this project included surveys to catalogue and systematize local knowledge around fishing in order to assess the impacts of policy, regulations, and conservation measures on local communities and the environment (Moreno-Báez, et al, 2010; Moreno-Báez, et al, 2012).

2.7 Economic impact of conservation measures on fisheries

Most valuation of the Upper Gulf of California fisheries has been linked to calculating economic compensation related to conservation actions such as the creation of the Biosphere Reserve and conservation of the vaquita. Rodriguez-Quiroz, et al (2009) assess the importance of the Upper Gulf of California Biosphere Reserve and the Vaquita Refuge as shrimp fishing grounds for the Upper Gulf artisanal fleet using catch reports and interviews. They found that shrimp fishing in the MPAs (marine protected areas) represents an average of $6 million USD per year in income from 1996 to 2007, around 58% of total gross income in the MPAs, and an average fishery profit of around $1.9 million USD, a return rate on value of catch of 32%. In a later study, Rodriguez-Quiroz, et al (2010) performed a study to identify the portion of fishing grounds that fell within the Biosphere Reserve and Vaquita Refuge MPAs by community to assess the impact that these MPAs would have on fisheries income. He found that for Puerto Peñasco, 75% of fishing activity occurred in the Biosphere Reserve and 20% in the vaquita refuge; for Golfo de Santa Clara, 100% of activity occurred in the Biosphere Reserve and around 50% occurred in the vaquita refuge; finally, for San Felipe, 70% of fishing activity occurred in the Biosphere Reserve and 100% occurred in the vaquita refuge. The Upper Gulf fishery, with profits valued at $5.897

million USD per year, depends heavily upon the marine protected areas, clearly demonstrating the potential for conflict between conservation and economic interests in the region.

A 2004 World Wildlife Fund report performs a similar analysis, utilizing GIS analysis to identify the percentage of fishing grounds that lie within the Vaquita Refuge by community and species, and then applying those proportions to a calculation of revenues minus cost, calculates the net loss to the Upper Gulf communities. The authors find that fishing areas were diminished by 53% for San Felipe, 30% for El Golfo de Santa Clara, and 8% for Puerto Peñasco. This translates to an annual cost of 11.5 million pesos in lost primary production (WWF, 2004). San Felipe, in general, suffers the greatest reduction in utility as a result of having the largest share of its fishing grounds closed. Rodriguez-Quiroz, et al (2012) estimate the opportunity cost for artisanal fishers giving up their activities in the vaquita refuge at roughly $1.7 million USD per year.

The World Wildlife Fund (2006) presents a compensation calculation framework for Upper Gulf fishermen in exchange for transitioning to alternative fishing gear and alternative livelihoods. It estimates annual fisheries profits from gillnet fishing in the Upper Gulf at $30,219,913 pesos annually, based upon a GIS analysis of fishing grounds, catch, and overlap with vaquita habitat. If gillnet fishing were only restricted in the vaquita refuge, the net income lost as a result of prohibiting gillnet fishing would be $17 million pesos. According to surveys carried for the report, the top cited economic alternatives in the region beyond fishing are working as merchants or working in the tourism sector. Despite these alternatives, most fishermen surveyed stated that if the gillnet fishery were closed, they would apply for permits for a different species, apply for economic compensation, or could continue fishing, though illegally. (WWF, 2006)

Other studies have measured changes in socioeconomic well-being before and after the creation of the Biosphere Reserve. Vasquez-Leon & Ferman-Almada (2010) measure changes in economic and social benefits of fishermen in San Felipe between 1994 and 2002, between which time the Biosphere Reserve was implemented. They found that though fishermen believed that the Biosphere Reserve would lead to an increase in their incomes, incomes actually declined over the study period. Between the two survey years, the authors found no significant socioeconomic changes in the fishermen, suggesting that the Biosphere Reserve has not led to positive changes in the well-being of fishermen.

Vasquez-Leon, et al (2012) analyze income inequality between 1994 and 2002 in the Upper Gulf communities before and after the implementation of the Biosphere reserve. They use a Gini coefficient measure of income distribution to assess income inequality using catch reports, reported prices, and costs information. The results show that there was not a significant change in income inequality for San Felipe or Puerto Peñasco. There was, however, an increase in income inequality in Golfo de Santa Clara, the community most heavily dependent upon fisheries (Vasquez-Leon, et al, 2012).

A number of authors have examined the clash of economic and conservation interests in an effort to identify policies that find an optimal solution given the competing objectives. Lercari and Sanchez (2009) use an Ecosim model to simulate tradeoffs between social, economic, and ecological interests in the Northern Gulf of California. The model includes trophic level functional groups, including endangered species like the vaquita and totoaba. Trophic levels measure where an organism ranks within the food chain and functional groups are organisms that are alike based upon their behavior and other characteristics, and that play similar roles within the trophic system. Economic interests were represented by net profits and social criteria were measured by jobs per landed value. Their results point to a 35-60% reduction in the industrial shrimp trawling fleet, a 52-57% reduction in the gillnet fishing fleet, and an increase in the artisanal shrimp fleet of 63-222%. They conclude that though social and ecological interests are inherently in conflict, economic and ecological interests can be positively correlated.

Afflerbach, et al (2013) also use a bioeconomic tradeoff model to prescribe potential policy scenarios that could aid in the recovery of the vaquita. They find that fisheries revenues must be sacrificed in order to obtain positive growth rates in the vaquita population. Their recommendations included restricting gillnet fishing completely, increasing the size of the vaquita refuge, increasing compliance through enforcement, and implementing an alternative fishing technology referred to as an artisanal trawl, similar to an industrial shrimp trawl that scours the bottom of the marine habitat to catch shrimp, versus a net which would entrap the shrimp closer to the surface, but adapted for smaller fishing vessels.

Navarro, et al (2013) look at how catch limits on corvina have affected the Cucupá. Located in the center of the Biosphere Reserve, the Cucupá have come into conflict with the federal government regarding recognition of their fishing rights. The Cucupá hold that the legislation creating the Biosphere Reserve did not take into consideration the economic impact it would have upon the tribe. They argue that there is a distinction between commercial fishing and indigenous fishing, and the current policy of fisheries management through issuing permits forces the resolution of conflicts through compensation, whereas as an indigenous people they should have their rights to fish recognized. According to the study, catch limits on corvina would allow for roughly 19,000 pesos in annual revenue, not net of fishing costs, while it costs an estimated 1,583 pesos per month to sustain a family.

While most studies calculating economic losses resulting from conservation efforts and other policy changes estimate losses or compensation as the loss in profits or rents resulting from the change, some studies neglect to take into consideration the costs of fishing when calculating losses. A recent proposal to eliminate gillnet fishing in the entire range of the vaquita calculates economic losses as simply the average annual catch multiplied by average price (CONFEMER, 2014). The study does, however, consider potential losses to the regional fisheries value chain, in addition to the foregone revenues.

Table 2.5: Summary of Economic Impact & Value Studies of Upper Gulf Fisheries

Study	Motivation of Study	Economic Value / Impact Findings
WWF (2006)	Compensation framework for Upper Gulf fishermen in exchange for transitioning to alternative fishing gear and alternative livelihoods	• Annual Upper Gulf gillnet fisheries profits estimated at MXN $30,219,913 • Lost net income from banning gillnet fishing in vaquita refuge MXN $17 million
WWF (2004)	Calculation of net loss due to fishing restrictions in the vaquita refuge	• Fishing areas were diminished by 53% for San Felipe, 30% for El Golfo de Santa Clara, and 8% for Puerto Peñasco • Annual net loss of MXN 411.5 million in primary production
Rodriguez-Quiroz, et al (2012)	Estimate of the opportunity cost for artisanal fishers giving up their activities in	• Opportunity cost of USD $1.7 million per year

	the vaquita refuge	
Rodriguez-Quiroz, et al (2009)	Importance of Upper Gulf of California Biosphere Reserve and the Vaquita Refuge as shrimp fishing grounds for the Upper Gulf artisanal fleet	• Annual average of USD $6 million in artisanal fleet income from shrimp fishing in Upper Gulf MPAs (1996-2007) • 58% of total gross income came from MPAs, representing USD $1.9 million, 32% return rate
Rodriguez-Quiroz, et al (2010)	Identification of share of each community's fishing ground that falls within the Biosphere Reserve and vaquita refuge	• Upper Gulf fisheries profits valued at USD $5.897 million per year • Shares of fishing in MPAs (Biosphere Reserve/Vaquita refuge): - Puerto Peñasco – (75%/20%) - Golfo de Santa Clara – (100%/50%) - San Felipe – (70%/100%)

2.8 Biological Impact of River Flows on Key Commercial Species

Of the many economic sectors that depend upon the Colorado River, artisanal fishing in the Upper Gulf of California is one whose connection to the river is not often considered in decisions regarding water allocation. Species of finfish and shrimp have shown to be correlated with freshwater flows into the Gulf as the brackish water in the Delta provides prime spawning and nursery ground for their young (Aragon & Calderon, 2000; Rowell, et al, 2005) . Furthermore, fresh water flows into the Gulf bring nutrients, sediment, and detritus which serve as inputs into the fisheries (NOAA, 2012; Rowell, 2005). These correlations in yield are experienced in the three main Upper Gulf fishing communities, San Felipe, Baja California, El Golfo de Santa Clara, Sonora, and Puerto Peñasco, Sonora. Anecdotally, fishermen report observing lagged increases in fisheries yields for a number of species after high river flow years. The most important commercial species that exhibit population responses to freshwater inflows are shrimp and gulf corvina.

A number of authors have examined the relationship between fisheries yields and freshwater input into the Upper Gulf of California from the Colorado River. Perhaps the most cited amongst these studies is by Manuel Galindo-Bect and Edward Glenn (2000). The authors correlate shrimp landings in San Felipe, Baja California with freshwater discharge into the Gulf from the Colorado River. The authors found that shrimp landings were positively correlated with the log of river flows lagged by 1 year ($r = 0.67$, $p < 0.001$) and were most highly correlated with the interaction of the number of trawlers and the log of river flows lagged by 1 year, roughly the life cycle of shrimp ($r = 0.80$, $p < 0.001$). Aragon and Calderon (2000) also found a strong positive correlation between fresh water flows from the Colorado and the abundance of postlarvae blue shrimp in the Upper Gulf, observing a statistical correlation with river flow of $r = 0.8815$ ($p < 0.05$).

Calderon and Flessa (2009) present an analysis of the catch of key commercial species in the Upper Gulf and their correlation and time lag associated with Colorado River flows. Shrimp ($r = 0.23$) were associated with a 1 year time lag in flows, and gulf corvina ($r = 0.31$) with a 4 year time lag. An oxygen isotope analyses of gulf corvina remains confirms that they use the Colorado River Delta as a spawning and nursery ground (Rowell, et al, 2005), and lack of freshwater flows into the Delta has been cited as one of the factors behind past declines in the fishery. The population of totoaba, an endangered species of finfish dependent upon Colorado River Delta estuary, has a strong correlation with freshwater river discharge, exhibiting a linear relationship between population and river discharge lagged by two years with an R^2 of 0.92 (Lercari & Chavez, 2007). Though not a legal commercial species, the lucrative black market for totoaba swim bladder in Asia represents a commercial value. Rowell, et al (2008) also found that pre-dam totoaba matured faster, grew larger, and had higher lifetime fecundity as a result of earlier maturation compared to post-dam totoaba. Additionally, reductions in the size and quality of the Colorado River Delta estuary likely had impacts on recruitment for totoaba after the construction of the dams. For purposes of this analysis, because the totoaba is an endangered and protected species, it will not be taken into consideration in the economic impact calculation, however, it is important to note that given the impact of river flows on the species fecundity and recruitment, under future scenarios, it is possible to assume that if the fishery were to make a comeback, the species might again have legal commercial value.

Perez-Arvizu, et al (2008) present a model of shrimp catch in the Upper Gulf of California as it relates to the discharge of fresh water from the Colorado River into the delta. They examine the relationship in Golfo de Santa Clara, were the authors hold that the relationship is most pronounced. They found that for years when river flow was in excess of 80 cubic meters per second, the abundance of shrimp was relatively high and for years under 80 cubic meters per second, it was relatively low. A linear regression of CPUE on river flows produced an R^2 of 0.4686 and a polynomial model produced an R^2 of 0.793. They state that the shrimp population benefits from increased river flows as a result of improved habitat and food availability from nutrients delivered by the fresh water inflows. (Perez-Arvizu, et al, 2008).

Castro-Ortiz and Lluch-Belda (2008) present an analysis of offshore shrimp harvests occurring further south in the Gulf of California for the ports of Guaymas, Sonora and Mazatlan, Sinaloa, two of the largest industrial shrimp hubs in Mexico, as a function of environmental factors including rainfall, river discharge, Pacific Decadal Oscillation (PDO), and the MEI-ENSO index. Their analysis splits the year into two shrimp harvest seasons and examines catch and catch per unit effort (CPUE). Their regression analyses found catch in both ports to be positively correlated with PDO and MEI-ENSO. The study found a negative relationship between precipitation and water flows in some regression models, though in other models catch was positively correlated with rainfall. They found that environmental conditions during the cold season (first half of year) were effective predictors of blue shrimp catch during the subsequent fishing season. (Castro-Ortiz & Lluch-Belda, 2008)

Other studies have examined the relationship between Colorado River flows and the prevalence of other, non-commercial species and life cycle in order to reconstruct the historical river flow or population data. Rodriguez, et al (2001) look at the prevalence of the Colorado Delta clam (*Mulinia coloradoensis*) using an oxygen isotope analysis of old shells found in the Delta in order to reconstruct historical river flows. The clam is known to prefer fresh water environments and is in greater abundance closer to the mouth of the delta. The results of their analysis show that prior to the 1935 damming of the Colorado with the construction of the Hoover Dam, river flow was between 16 billion and 18 billion cubic meters of water per year. After the construction of the dams, the prevalence of the clam fell significantly. Today, the river delta receives on average only 0.7 billion cubic meters of water per year (Rodriguez, et al, 2001).

Table 2.6: Summary of Existing Research on Colorado River Flows Relationship to Fisheries Productivity

Author(s), Year	Species	Location	Relationship
Galindo-Bect & Glenn, 2000	Shrimp	San Felipe, Baja California	• Landings positively correlated with log of river flows, with 1 year lag ($r = 0.67$, $p < 0.001$) • Landings positively correlated with number of trawlers and log of river flows, with 1 year lag ($r = 0.80$, $p < 0.001$)
Aragon & Calderon, 2000	Blue shrimp post-larvae	Upper Gulf	• Postlarvae abundance positively correlated with river flows ($r = 0.8815$, $p < 0.05$)
Calderon & Flessa	Shrimp; Gulf Corvina	Upper Gulf	• Landings of shrimp associated with a 1 year time lag ($r=0.23$) • Landings of gulf corvina associated with a 4 year time lag ($r=0.31$)
Lercari & Chavez, 2007	Totoaba	Upper Gulf	• Population associated with a two-year time lag ($R^2 = 0.92$)
Perez-Arvizu, et al, 2008	Shrimp	Golfo de Santa Clara, Sonora	• CPUE positively correlated with river flows in linear model ($R^2 = 0.4686$) • CPUE positively correlated with river flows in a polynomial model ($R^2 = 0.793$)

2.9 Upper Gulf fisheries value chain and markets

Upper Gulf of California fishermen commercialize their products locally, domestically, and internationally. Fishing enterprises in the Upper Gulf of California vary considerably in terms of size, legal status, and level of vertical integration. Some fishermen operate independently while others belong to fishing cooperatives. Fishing cooperatives are legally constituted entities that serve as businesses, managing administrative and financial activities for the fishing enterprise. While some cooperatives are large and complex, most are family enterprises. There are 85 cooperatives in Golfo de Santa Clara, 20 in Puerto Peñasco, and 15 in San Felipe (MIA, N/D;

personal communication). Costs and profits are split amongst cooperative members as agreed by the members. In some cases, cooperative members cover their own costs and contribute a portion of their profit to the cooperative to cover administrative costs. In other cases, the members of the cooperative function as a sole enterprise and share expenses. Some fishing cooperatives do the fishing themselves, while others hire fishermen to work under their permits. In some cooperatives it is mixed and some members fish themselves while others choose to hire fishermen to work for them. Some cooperatives solely engage in fishing while others have integrated vertically to take on processing, transport, marketing, financing, and other commercialization activities.

Once pangas have arrived at the beach with their catch, buyers purchase the product. Sometimes there will be agreement between fishermen and buyers to sell catch at pre-agreed prices. This can be in return for financing the purchase of equipment, lending capital to finance operating expenses, or to ensure a predictable buyer-seller relationship. Larger cooperatives may have their own processing facilities and there is no commercial transaction at the beach. The benefit of this arrangement is that there are fewer intermediary transactions and more of the value of the final product can be retained by the cooperative. Some buyers work as intermediaries, maintaining relationships with processors and distributors, while other fishermen or cooperatives sell directly to the processors.

Upper Gulf of California fisheries are influenced heavily by export markets. It is estimated that roughly 80% of shrimp from the Upper Gulf is destined for export to the US, and as the most important species in terms of commercial value, regional value chains are in place to support export activity (Ardjosoediro & Bourns, 2009). In the Upper Gulf, there are 3 processors in Golfo de Santa Clara, 5 in Puerto Peñasco, and 3 in San Felipe (Ardjosoediro & Bourns, 2009). These processors work for the major buyers, preparing, packing, and freezing shrimp for export.

Major buyers in the region that export to the United States include Ocean Garden Products, Ofi Markesa, and Eastern Fish. Ocean Gardens is a company with a long history in Mexico. Once a government-owned enterprise, the company went through a series of transitions between public and private ownership, and now is a private company based in San Diego, California. Ocean Gardens is considered to be the largest US imported of Mexican shrimp, at one time thought to be responsible for 60-80% of US imports of Mexican shrimp (Meltzer & Chang, 2006; Ardjosoediro & Bourns, 2009). Ocean Gardens is reported to be involved in providing financing to fishermen, and has also been involved to some level in conservation efforts in the Upper Gulf (Meltzer & Chang, 2006). Ofi Markesa is a Los Angeles, California based seafood company, and Eastern Fish is based in New Jersey (Ardjosoediro & Bourns, 2009). The buyers exercise considerable control over prices paid to fishermen within the Upper Gulf due to the volume of their purchases.

Guillermina Garcia Guzman and Golsomax are the largest buyers of corvina in Golfo de Santa Clara. Gulf corvina is destined primarily for national markets (CapLog Group, 2013), with the exception of the swim bladders which are exported to Asia. Asian buyers have a strong presence in the Upper Gulf, inspecting product before making purchases, and working with local staff to manage day-to-day operations. They are involved primarily in the corvina buche trade, as well as geoduck, snail and other benthic species, and some finfish species. For products destined for export to Asia, much of the value chain leads to Ensenada, Baja California, or major cities in Southern California like San Diego and Los Angeles.

It is of interest to note a shift in recent years in regional export value chains. There has been a decline in small regional buyers that service nearby markets and metropolitan areas such as Southern and Central Arizona, as well as Southern California. Small and medium sized seafood markets and seafood distributors have direct relationships with buyers in the Upper Gulf who provide regular deliveries to these companies, who in turn supply to upscale restaurants, and other customers. This used to be a more common business model. However, recently, there has been a decline in these small to medium sized regional distributors and a shift towards larger more centralized and industrial processors, most of whom operate out of Southern California with branches in major metro areas. Some businesses report that health regulations on seafood crossing the border make it prohibitive for smaller operations, and this has driven the movement towards channeling product through larger enterprises.

At the fishing enterprise level, the availability of credit and financing for operating expenses and investment in fishing gear is an important component to the fisheries value chain. Financing is provided by buyers, cooperatives, and, though not as commonly, financial institutions (Ardjosoediro & Bourns, 2009). Some initiatives exist in the region to provide microfinancing for fishermen. Finally, fishing gear dealers are another key component of the fisheries value chain. Most are companies that have a presence throughout the Upper Gulf in larger fishing ports. Equipesca is one example. Fishing gear dealers oftentimes have business relationships with buyers who provide financing to fishermen and sell them equipment, which in turn is provided to the fishermen. Some buyers even provide free equipment to fishermen in exchange for verbal contracts to sell at a pre-determined price. This applies to both fishing and diving operations.

CHAPTER THREE: CONCEPTUAL MODEL LITERATURE REVIEW

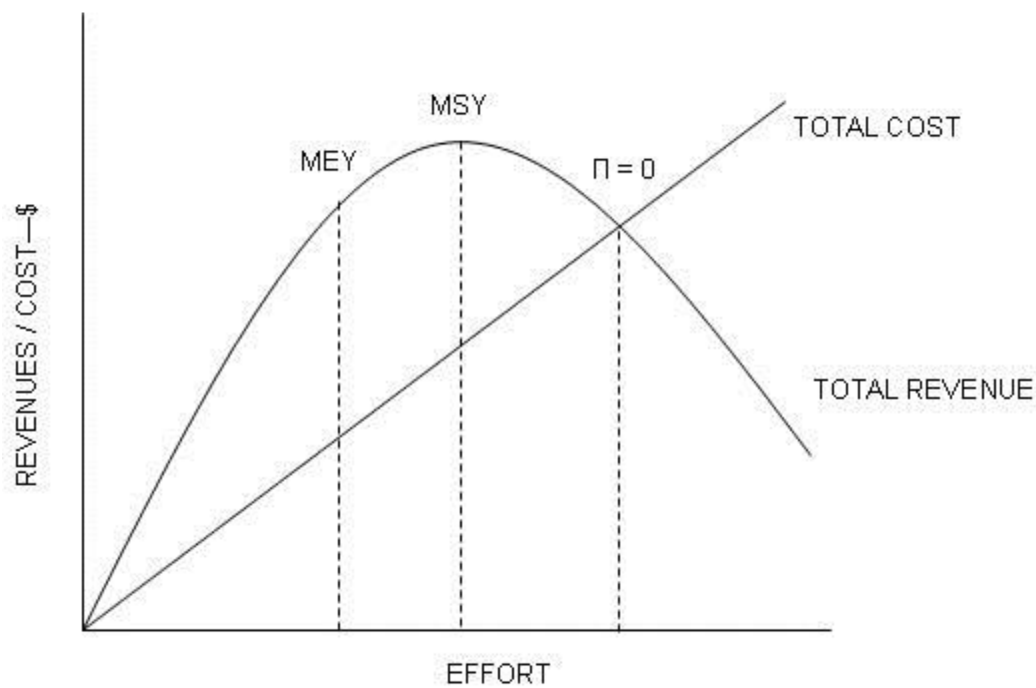
This chapter provides a literature review for the conceptual model underlying my analysis. I present a review of basic fisheries economics concepts and theory to frame the subsequent fisheries models. A review of fisheries and water tradeoff analyses in the Colorado River Delta region is presented. I examine past bioeconomic models used for the Upper Gulf which incorporate environmental variables into the production function, followed by enterprise-level objective functions. I review past studies valuing the Upper Gulf of California fisheries, and finally, I provide background of input-output analysis, presenting a selection of input-output models created for and applied to fisheries.

3.1 Fisheries economics key concepts and key policies

Fisheries are a classic example of an open-access *common-pool resource*. Accessible to all, fisheries attract entrants who are seeking *rent*, profit obtained by harvesting a resource. When exploited at sustainable levels, each fisherman can share in the rent obtained through the fishery. However, if rents in fishing are high enough to justify incurring entry costs (acquiring gear, permits, etc.), then the fishery will attract additional individuals to enter the market, pushing profits down to zero, and leading to non-optimal harvest rates (Tietenberg, 2004). Fisheries experience two types of externalities – *contemporaneous* and *intergenerational* externalities. Contemporaneous externalities arise due to the incentive to overfish when livelihoods depend upon catch and incentives created by open access – the fact that if one fisherman does not catch the fish, someone else does. Each fisherman, acting rationally, will overfish, and if all actors act rationally, the resource will eventually become overexploited or depleted. Intergenerational externalities occur when current fishing practices have adverse impacts on the stock and catch for future generations. The cost of current practices is not internalized by current fishermen, but rather is borne by future generations (Tietenberg, 2004). This arises from *time preferences* in the context of intertemporal choice, the tendency to place a higher value on consumption in the present than consumption in the future.

A *sustainable yield* for a fishery is considered to be one in which the growth rate of the species is equal to the level of catch. Following from that, *maximum sustainable yield* (MSY) is the highest level of sustainable yield that can be achieved on an ongoing basis, balancing catch and population. Maximum economic yield is the profit maximizing

Fig. 3.1: Illustration of Maximum Sustainable and Maximum Economic Yield Levels



Maximum economic yield (the greatest profit possible of being sustainably achieved) usually occurs below MSY and occurs at the point where the difference between revenue from catch and costs is the greatest. This is contrasted with the point at which profits are driven to zero from additional entrants into the fisheries, typically in excess of MSY. This illustrates the constant tendency to overfish – so long as profits, though small, can still be achieved within the fishery, people will be attracted to enter.

Further complicating the picture, fisheries are an *interactive* resource, which is to say that a variety of factors comingle to determine population levels, including human and natural influences such as weather, climate, and other species. Absent human influences on the marine population, the *natural equilibrium* is the population that would be sustained. *Carrying capacity* is the greatest population level that can occur without the species beginning to decline due to outmigration or mortality due to lack of food resources. In the case of overexploited fisheries, the *minimum viable population* is the smallest population which can be sustained without negative growth rate from mortality and out-migration. The influence of humans on marine populations through fisheries not only includes reductions in populations through direct catch. *By-catch* occurs when species besides the target species are caught. Oftentimes, bycatch is discarded if it is of relatively low value or if the species accidentally caught are legally protected (Tietenberg, 2004). Bycatch is a serious issue within the Upper Gulf of California, particularly in regards to the vaquita which is caught as bycatch in gillnets, though it is also a problem commonly associated with shrimp trawling.

In order to address the inherent drive to push fisheries beyond their maximum sustainable yield, fisheries management policies are developed, recognizing the need for coordinated efforts to achieve efficient outcomes. Fisheries can be managed with different types of restrictions. Spatial restrictions limit fishing within certain areas, typically critical habitat or ecologically sensitive areas. Temporal restrictions put limits on specific fishing seasons, allowing populations to rebound during times of the year or protecting species during their spawning seasons. Gear restrictions prohibit the use of specific types of fishing equipment that are destructive to marine habitat or that are associated with bycatch of protected or endangered species. Effort restrictions place limits on the number, size, and capacity of vessels operating in a fishery, though this does not limit the amount each vessel can catch. Catch restrictions limit the amount of catch that can occur within a season, by placing a total allowable catch (TAC) on the fishery or issuing individual transferable quotas (ITQs), entitling the holder of that license the right to harvest a specific amount. Finally, there can be restrictions on harvesting a species based upon its size or life stage restrictions, typically focusing on protecting juveniles and reproductively mature females. These various strategies can be used in conjunction with each other. For example, an effort restriction limiting the number of boats operating can be coupled with a total allowable catch. A gear restriction can be coupled with a spatial restriction, prohibiting the use of specific gear types within designated areas (FAO, 2002). Finally, restrictions may be placed on individual species if those species are protected or endangered.

Table 3.1: Fishing Restriction Types

Fishing Restriction	Description
Spatial Restrictions	Limits fishing within (or to) specific locations or areas
Temporal Restrictions	Defines open and closed seasons for fisheries during the course of the year

Gear Restrictions	Designates or limits which fishing equipment can be used, or puts limits on size, capacity, selectivity, or other variables
Effort Restrictions	Puts limits on the number of vessels operating or number of active permits
Catch Restrictions	Definition of a total allowable catch (TAC) for the fishery as a whole or a TAC per vessel or permit; often adjusted by season based upon measures of health of population
Species Restrictions	Restricts the harvest of particular species which might be protected or endangered

All of these types of restrictions are currently used for fisheries management in the Upper Gulf, though enforcement is reported to be lacking. Blue shrimp harvests in the Upper Gulf of California are believed to be at MSY levels (Monterey Bay Aquarium Seafood Watch, 2013). Concerns over pushing the corvina fishery beyond MSY levels were the motivation behind the implementation of the TAC in Golfo de Santa Clara and San Felipe, as well as a desire to move towards MEY by limiting catch, thereby supply, in order to command higher market prices.

3.2 Tradeoff analysis functions for the Upper Gulf

In assessing fisheries and environmental policy in the Upper Gulf as a whole, we can consider an objective function at the regional scale, that is, a function that captures key variables that influence a particular stakeholder's productivity or utility – a stakeholder might include the regional agricultural sector or the regional fisheries sector. In most cases, the aim is to find efficient and, if possible, Pareto improvements for all interests, including the possibility of compensation included to convert losses to gains. Efficient outcomes are ones in which one interest cannot be made better off without that improvement coming at the expense of the other interest, giving an initial allocation between the two interests. The objective function is designed to capture measures of well-being (or utility) to different interests, for example, fisheries, endangered species, agriculture, or urban areas. For most tradeoff studies of the Upper Gulf, the well-being of the fisheries economy is measured in profits or revenues from catch. The well-being of other interests, for example endangered species might be measured by their population or their population growth rate. Different authors have examined tradeoff models using objective functions for the Upper Gulf region, taking into consideration different combinations of economic, social, and environmental interests.

Afflerbach, et al (2013) utilize a tradeoff analysis to assess a variety of potential policy scenarios, including spatial closures, species closures, buyout programs, alternative fishing equipment, and different levels of compliance, weighing the competing interests of fisheries and conservation of the vaquita in the Upper Gulf of California. Their model measures the objective function of the Upper Gulf fisheries as net revenue, value of catch minus cost of catch. This is then indexed to the current (2013) policy conditions for the fisheries. The impacts of fisheries on the vaquita were modeled using spatial fishing grounds with varying degrees of fishing intensity and their degree of overlap with the population density of the vaquita. This provided an estimate of the impact that various fisheries policies would have on the vaquita population growth rate. The outcomes of these two competing interests were then plotted, yielding an efficiency frontier. While some policies yielded a population growth rate of zero (versus negative) at minimal cost to the fisheries relative to the current policy, achieving positive population growth rates almost exclusively comes at the expense of fisheries net revenues. Their analysis found that essentially all Pareto improvements still yielded a negative growth rate. The current policy of the spatial restrictions associated with the vaquita refuge were estimated as not having the ability to achieve positive growth rates. Finfish closures and a combination of finfish and shrimp closures were both modeled as having the ability to achieve positive vaquita population growth rates (Afflerbach, et al, 2013). This model provided a framework for the tradeoff analysis in this project which looks at the impacts of different tradeoffs on two competing interests.

Lercari and Sanchez (2009) incorporate three competing interests into a tradeoff model in order to assess potential policy changes for the Northern Gulf of California. They weigh economic interests, social interests, and ecological interests using an Ecopath with Ecosim model, developed at the University of British Columbia’s Fishery Centre. They measured ecological interests using a trophic level model which includes protected species, economic interests were measured as net profit in the fisheries, and social interests were represented by jobs per landed value. Their results suggest reducing the industrial shrimp trawl fleet, increasing the artisanal fleet, and reducing fishing using gillnets. Their model runs simulated the impacts of pursuing the maximum rebuilding of endangered species populations, maximum social benefits, maximum economic benefits, maximum ecosystem benefits, and a variety of strategies deemed viable for the region on the industrial shrimp fleet, artisanal shrimp fleet, and artisanal gillnet fleet in the three Upper Gulf communities (Lercari & Sanchez, 2009). The results of their model runs indicate that though ecological and economic interests are positively correlated with each other, social and ecological interests will always be at odds in the region. This study provides an important perspective on the impacts of policy on economic development by separating economic and social interests. Increases in profitability of an industry do not always translate to increases in the well-being of a community, considering that increases in profitability may come at the expense of jobs.

Medellín-Azuara, et al (2007) present a different type of tradeoff analysis using an economic engineering model to calculate the opportunity cost of dedicating water flows to the environment in the Colorado River Delta region. The model considers a range of future scenarios for agricultural demand in the Mexicali Valley, urban demand in Mexicali and San Luis Rio Colorado, and potential environmental flow scenarios to restore the Colorado River Delta. They use a system model, called CALVIN, representing the water demand and supply network, to estimate willingness to pay by different users in order to reveal the shadow price of water for the environment. The study finds that the marginal cost of water from the Mexicali Valley is $50 USD per thousand cubic meters at flow levels recommended by experts for restoration of the Delta. This marginal cost rises to $80 USD per thousand cubic meters at double that level. The margin cost of water foregone in US agriculture is much lower at $24 USD and $35 USD per thousand cubic meters, respectively. The authors note that their analysis does not take consumer surplus and economic welfare measures into consideration, only agricultural producer surplus (Medellín-Azuara, et al, 2007). The study provides a means of weighing the tradeoffs of different water uses in the Delta region, and a model such as this might be expanded to include the value of freshwater to fisheries productivity in the Upper Gulf in assessing the value of water for the environment.

3.3 Fisheries production function for the Upper Gulf

Bioeconomic models are used to analyze the intersection between biological ecosystems and human economic activities, such as fisheries. In basic bioeconomic models, such as one presented by Gordon (1954), fisheries population, landings, and fishing costs are functions of each other, as well as fishing effort. In an unregulated fishery, costs are equal to the value of landings, in other words, profits are driven to zero. Prices are assumed to be constant. Assuming sole ownership of the fishery, the objective function of the fishery is to maximize profits, and the fishery's optimal level of effort and landings is achieved by a monopoly solution. A third potential objective is to achieve maximum sustainable yield for the fishery. The work of Gordon, in conjunction with Schaefer (1954), led to what is referred to as the Gordon-Schaefer model (FAO, 1998), considered to be a foundational model in fisheries bioeconomics. This model, however, does not incorporate factors beyond effort and landings in determining the population of the fishery (FAO, 1998). More nuanced models incorporate additional factors such as mortality, recruitment, and other factors into the calculation of population dynamics.

These models can be used to look at fisheries at the macro scale in order to inform fisheries policy, such as the optimal effort level or maximum sustainable yield. De Anda-Montañez and Seijo (1999) applied a bioeconomic model to the sardine fishery in the Gulf of California, integrating mortality, recruitment, age group, and time lags into the model. Their results show that minimum size restrictions on catch were the most effective strategy at increasing measures of fisheries health. Barbier and Strand (1997) use a bioeconomic model to estimate the impact of mangroves on the productivity of shrimp fisheries in Campeche, Mexico. The authors model the effect of mangroves on the carrying capacity and productivity of the fishery using a discrete time model of stock. They incorporate mangrove area into the biological growth function, noting the positive influence of mangrove area on shrimp population as a breeding and nursery ground. They use a Schaefer-Gordon production function to calculate the fishery's equilibrium under "open-access" conditions, and then in turn compute comparative statics. A reduction in the area of mangroves results in reduced harvest and reduced revenues to the fishery. The authors apply their empirical model to Campeche and found that a square kilometer reduction in mangrove area lead to 14.39 metric tons less of shrimp harvest per year, with an estimated value of $139,352 USD (Barbier & Strand, 1997). This result varied depending upon the prevailing fisheries management strategy at the time. Garcia-Juarez, et al (2009) apply a Schaefer biomass dynamic model to assess the use of catch quotas for blue shrimp in the Upper Gulf of California as a fishery management strategy. Using CONAPESCA fishery office data from 1987 to 2007, they estimate maximum sustainable yield for the fishery at 6,325 tons, or 59% of biomass. They calculate that a seasonal catch quota should not exceed 2,400 tons in order for the population to remain steady, and should be lower in order for it to increase (Garcia-Juarez, 2009). 2,400 tons represents the harvest of a comparatively low year, given harvest levels over the last 30 years. The econometric models estimated in this thesis draw primarily upon the work of Barbier and Strand (1997) to estimate catch as a function of environmental variables.

Other authors have applied more sophisticated trophic level models to the Upper Gulf of California to model the interaction between natural and anthropogenic forces, such as fisheries or climate change. Building upon the work of Morales-Zarate, et al (2004), Lozano (2006) applies the Ecopath with Ecosim (EwE) model to the Upper Gulf to describe the influence of changes in fresh water inflows from the Colorado River on the marine ecosystem. The EwE model is a trophic structure model with separate functional groups which models ecosystem nutrient inputs, food webs, and predation, as well as commercial fishing (Morales-Zarate, et al, 2004). Lozano applies EwE with 50 functional groups. He notes the importance of detritus in the ecosystem's productivity, explained by the delivery of nutrients and detritus by the Colorado River. The model was most sensitive to trophic system functional groups at the top and bottom of the trophic system, and detritus was one of the groups that yielded the greatest model sensitivity. Modeling the removal of detritus from the system over 20 years, blue shrimp were reduced to 50% of their original biomass, and corvina to roughly 40%. In a counterfactual case, using modeled undepleted Colorado River flows into the Upper Gulf yielded a 220% increase in biomass in the Upper Gulf ecosystem and allowing just 1% of river flows to reach the Upper Gulf led to a roughly 10% increase in biomass (Lozano, 2006).

Another bioeconomic model specifically calibrated to the Northern Gulf of California is the Atlantis model. It is spatial trophic level model that models biomass and integrates fishing effort, gear, and spatial restrictions of fishing. Ainsworth, et al (2012) use the Atlantis model to predict changes in fisheries revenue under a series of policy scenarios, including seasonal and spatial closures, gear restrictions, elimination of poaching, PACE-Vaquita buyout and switch-out programs, and all of these scenarios combined. Fisheries revenues decline as a result of reduced effort. Full enforcement is estimated to cost $230 million USD in reduced revenues compared to the status quo. (Ainsworth, et al, 2012)

The Atlantis model has been applied to the Clarence River Estuary in Australia to model the impact of freshwater river discharge on the productivity of marine environments, specifically the concentration of zooplankton, phytoplankton, and other plankton and bacteria (Condie, et al, 2012). The freshwater flows contribute to marine productivity through provision of nutrients, sediments, and detritus, as well as providing other water quality impacts important to estuarine habitat. The model yielded outcomes that were consistent with past data on the estuary. The model produced a high correlation between modeled zooplankton and prawn catch, which feed on zooplankton. The relationship between biomass and river flows did not show as strong of a correlation ($R^2 = 0.07$) (Condie, et al, 2012). This thesis applies the Atlantis model to the Upper Gulf of California in order to model the effects of freshwater inflows into the marine ecosystem.

3.4 Fishing enterprise objective function

Economists can also consider fishery objective functions on the micro-level, looking at the behavior of the representative fishing enterprise. Almendarez (2013) created a model for representative industrial shrimping boats to analyze their economic performance under a variety of policy and future climate scenarios. He modeled Gulf of California fleets representative of Mazatlan, Guaymas, and Salina Cruz. The model is based on MexSim, developed from Texas A&M's Farm Level Income and Policy Simulation Model, and incorporates macroeconomic forecasts, future climate change scenarios through the IPCC, and data on representative fishing units derived from panel interviews with fishermen. The model used a Cobb-Douglass production function. Economic performance of the representative enterprises was assessed under different public policy and climate change scenarios. The model results revealed differences between the fleets in terms of profitability. Important factors influencing profitability included the marine diesel subsidy (elimination thereof), type of shrimp harvested by region, and climate change. The model indicates that elimination of the marine diesel subsidy significantly increases the chance of incurring losses. Those areas that harvest the most desirable species of shrimp with the highest price per unit had the highest profitability. Finally, climate change further reduced profitability, especially in the case of elimination of diesel subsidies, holding true for all three communities. Losses due to climate change exhibited significant variance from one year to the next. (Almendarez, 2013)

Within the context of vaquita conservation in the Upper Gulf, Avila-Forcada, et al (2012) use a Random Utility Model (RUM) based on a multinomial logit model to predict enterprise (fisherman) level choice of whether or not to participate in the PACE-Vaquita fisheries buyout program. The PACE-Vaquita program includes options to buy-out fishing permits from fishermen permanently, offering one-time compensation, a switch-out program to change fishing gear to a vaquita-safe technology, and a rent-out in which fishermen agree to temporarily suspend gillnet fishing in the Vaquita Refuge in exchange for compensation.   The model uses survey data from artisanal fishermen randomly selected from within all three communities on socioeconomic characteristics, attitudes, alternative livelihood skills, and the type of fishing enterprise the fishermen belonged to and their position within that enterprise. Model results showed that fishermen's attitudes on conservation did not have a significant impact on their propensity to opt to enroll in the conservation program. Having alternative income potential had a positive marginal effect on propensity to enroll in the program. The wealth of fishermen had an influence on their likelihood to enroll in the rent-out program, but not in the buyout program. Cooperative owners were more likely to enroll in the programs. The least profitable fishermen were not necessarily the most likely to enroll in the program, with the exception of the gear switch out program.   Profitability took into account financial obligations of the fishermen such as loans and was calculated as net present value using a discount rate of 10% and ending at age 86, what is considered to the "end of career". Results found that older fishermen were more likely to prefer the buy-out program.

This analysis extends the enterprise-level model to a representative single-panga enterprise in the Upper Gulf in order to estimate the potential influence of river flows on enterprise profitability.

3.5 Valuation of marine ecosystem services in Upper Gulf

The productivity of marine fisheries is linked to the health of coastal ecosystems, such as coastal wetlands, marches, and estuaries. According to the Millennium Ecosystem Assessment, "ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth" (Millennium Ecosystem Assessment, 2003). Fisheries, commercial or otherwise, are examples of an ecosystem service provided to humans. Insofar as coastal ecosystems affect the productivity and profitability of fisheries, they too provide ecosystem services, though they might be considered "intermediate" services, versus the direct, "final" services provided by fisheries themselves (Fisher, et al, 2009).

A variety of strategies for valuing ecosystem services exist, including contingent valuation (willingness to pay or willingness to accept), direct observed behavior methods (market prices, etc.), revealed preference methods such as travel cost method, and, in the case of regulating services, replacement cost in the case of damages avoided (Millennium Ecosystem Assessment, 2003). Aburto-Oropeza, et al (2008) estimate an ecosystem services value for coastal mangrove ecosystems in the Gulf of California (further south within the Gulf including the coasts of

Sonora, Sinaloa, Nayarit, and Baja California Sur) using the relationship between fishery yield and the proximity of mangroves in Gulf of California fisheries. 13 fishing regions were included in the analysis, all within 50 km of mangrove habitat. Only local economic benefits were considered in estimating the value of ecosystem services, excluding existence and other values. The study used fisheries landings data from CONAPESCA and converted those landings into economic values using prices paid locally by fishing cooperatives to the fishermen. The authors found that a positive relationship between fisheries landings and total mangrove area ($r^2 = 0.70$, $P = 0.0002$), as well as a positive relationship between the length of the fringe of the mangrove area and fisheries landings ($r^2 = 0.76$, $p = 0.00004$). Using this correlation, the authors estimate that per one kilometer of mangrove fringe, the annual value of ecosystems provided to fisheries in the study area was $25,149 USD on average. When calculated in terms of area corresponding to each kilometer of fringe, each fringe kilometer provides a median of $37,500 USD of ecosystem services to fisheries (Aburto-Oropeza, et al, 2008). Though the Upper Gulf of California does not have mangrove ecosystems, marshes and estuaries would play a similar role to mangroves in this case, providing a protected habitat for the spawning and recruitment of commercial species.

Camacho-Valdez, et al (2013) perform an analysis of ecosystem services of coastal wetlands in southern Sinaloa, Mexico using the value transfer method and a meta-analysis of existing estimates of the value of ecosystem services. Their study area included 120 km of coastline from Mazatlan to Teacapan and spans marches, mangroves, lagoons, and estuaries. GIS was used to categorize the wetlands by type and the value of ecosystem services was estimated regionally and by location applying the results of the meta-analysis by unit area for the study region. The ecosystem services definition used by the authors follows that of the Millennial Ecosystem Assessment, and included flood control and storm buffering, water supply, water quality improvements, commercial fishing and hunting, recreation fishing, recreational hunting, harvesting of natural materials, fuel wood, non-consumptive recreational activities, and biodiversity. 152 value observations from 58 studies were used in the meta-analysis and only those types of wetlands present in the study area were used. Other value transfer studies were not used in the analysis. Values were standardized accounting for currency exchange rates and inflation, purchasing power parity, and GDP per capita. Commercial fishing was a service provided by coastal lagoons and saltmarshes (includes mangroves), with 97 study observations. Using mean per hectare values of coastal wetlands by wetland type applied to the study area, a total value of $1.07 billion USD in 2003 was obtained as the total value of ecosystem services provided by coastal wetlands in the region. Commercial fishing and hunting represented a value of $3,386 USD (2003) per hectare per year in ecosystem services for saltmarsh/forested mangrove and $459 USD (2003) for saltmarsh/unconsolidated bottom. (Camacho-Valdez, et al, 2013)

These studies provide a means of estimating the economic value of environmental preservation and maintaining undisrupted coastal habitat which might otherwise have been developed for economic uses like housing or tourism. This thesis applies this concept to the topic of allocation of water for environmental purposes. Instead of land area, the resource being valued is quantity of in-stream river flows which might have otherwise been applied to alternative economic uses, such as agriculture or municipal or industrial use.

3.6 Input-output models for fisheries

Input-output (I/O) analysis has its foundations in the work of Leontief (Leontief, 1966) who developed the technique in the context of post-WWII economic planning. The method uses estimates of inter- and intra- industry sales and purchases of goods and services to estimate the economic activity stimulated by a specific shock to a regional economy, capturing the initial shock, and subsequent rounds of economic activity that result, ad infinitum.

Input-output analysis has been applied to fisheries extensively within the United States. Seung and Waters (2006) review fisheries input-output models that have been used in the U.S. since the late 1980s. They note that static I/O models dominate the literature. While simple to employ, conventional I/O models do not take into account the variability of prices over time given fisheries management decisions, nor do they consider the equity of the distribution of economic impacts. To address this shortcoming of conventional I/O, other models have been used, including social accounting matrices (SAM), computed general equilibrium models (CGE), and econometric input-output models (EC I/O) (Seung & Waters, 2006). They note that EC I/O models overcome a number of shortcomings of conventional I/O models: the integration of econometric models can account for changes over time in the conditions of the fishery and the use of regional or local data in the development of the econometric model and help reduce any bias resulting from disaggregation / regionalization of matrices to the regional or local level (Seung & Water, 2006).

Norman-Lopez and Pascoe (2011) use input-output analysis to assess the impacts of achieving maximum economic yield (MEY), a level of yield that maximizes profits in the fishery, as compared to achieving maximum sustainable yield, MSY, in four Australian fisheries that experienced similar adjustments as a result of the *Securing our Fishing Future* program. Some critics of MEY as a fisheries management policy suggest that maximizing profits can lead to negative social consequences such as reduced fleet size, labor, and income for the fisheries. MEY is not achieved only through a specific level of catch, but also through corresponding levels of effort and biomass, though maximum profit is achieved at the point of greatest distance between revenues and cost (Norman-Lopez & Pascoe, 2011). While achieving MEY maximizes profits, it also generally reduces the demand for goods and services along the fisheries value chain in the short term, such as processing, transport, and so on. Eventually, however, as stock increases, catch per unit effort may also increase, and offset some of any negative economic impact resulting from the reduced fishing effort and value chain activities. The authors used a national I/O table for Australia, aggregating other sectors and disaggregating fisheries by species. The authors found that the two primary impacts of shifts to MEY include fleet reductions and changes in revenue, and changes in revenue varied over time depending on responses in the fish stock to reduced efforts over time. They also found that the benefits to society outweighed any losses in the case the MEY catch levels were at least equal to pre-adjustment levels in the case of Australia. They pinpoint the tradeoff as reduced short-term economic activity versus increases in long-term economic activity and greater resiliency of the fishery in the long-term (Norman-Lopez & Pascoe, 2011). This is an issue confronting Upper Gulf fisheries. Conservation measures are aimed at reducing effort which can have negative effects on employment, while concurrently producing a positive effect on fisheries profitability.

Recent applied examples of fisheries I/O models developed within the United States include the National Marine Fisheries Service Commercial Fishing & Seafood Industry Input-Output Model (CFSI I/O) (Kirkley, 2009). The CFSI I/O model was developed using IMPLAN in order to measure the economic impact of fisheries through their value chain from producers to final consumers, providing estimates of the impact to processers and dealers, wholesalers and distributors, seafood retailers, and restaurants (Kirkley, 2009). The model estimates economic impact by output, employment, and personal income. Impacts can further be broken down by state and by species harvested. The impact model relies on revenue and cost data for business along the seafood value chain. The Pacific Coast Fisheries Input-Output Model (IO-PAC) (Leonard and Watson, 2011) is an I/O model developed to estimate the economic impacts of factors influencing fisheries productivity. Fisheries are divided into sectors and species, and impacts can be obtained by industry, commodity, state, and port. IO-PAC is also built using IMPLAN, PacFIN data, and Northwest Fisheries Science Center survey data on earnings and cost. Each fishery was assigned a specific production function and cost structure developed through survey data to most accurately estimate the economic impact by species and fleet. Application of this method may be a good opportunity for future research on the Upper Gulf fisheries economy. Regionalization of I/O matrices and aggregation of sectors can remove some of the nuances of the artisanal fisheries, and this method could produce better measures of the specific impact of artisanal fisheries versus fisheries in general.

The application of I/O to fisheries in Mexico is limited to date. Mexico's federal statistics agency (INEGI) produces national-level input-output matrices by industry, sector, and sub-sector. At the state level, only one Mexican state, Jalisco, has a state-level matrix generated by the survey method. The region of Colima, Jalisco, Michoacán, and Nayarit also has a matrix developed via the survey method (Chapa-Cantu, et al 2009). Other state matrices have been estimated using the national matrix and disaggregation methods, such as Coahuila which used the Flegg method (Davila, 2002) and Baja California using a partial survey method and RAS (Fuentes, 2005). Fuentes has estimated matrices for northern border states (Baja California, Sonora, Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas) for 1993 (Fuentes, 2002), a state-level matrix for Baja California Sur using a partial-survey method (Cortes-Ortiz, et al, 2006), as well as a municipal level matrix for the regional of Mexicali, Baja California (Sosa-Gordillo & Sanchez-Lopez, 2007). Cortes-Ortiz, et al (2006) estimate output and employment multipliers for fisheries in Baja California Sur, building upon Fuentes' work disaggregating from the national level. They found that fisheries had an output multiplier of 1.56, an income multiplier of 1.5, and an employment multiplier of 1.31 (Cortes-Ortiz, et al, 2006). Though Baja California, contiguous to Baja California Sur, has a larger and more diverse economy compared to Baja California Sur, these multipliers provide a point of reference for comparison for calculations in this analysis. These matrices provide a means of comparison for estimating regionalized matrices using more recent base-years.

Input-output analysis has been used to the Colorado River Delta region in an analysis of the socioeconomic effects of the lining of the All-American Canal in the Mexicali Valley (Sosa-Gordillo & Sanchez-Lopez, 2007). The All-American Canal, stretching from Imperial Dam on the Colorado River north of Yuma, Arizona west along the US-Mexico border to west of Calexico, Mexico, used to leak 113 million cubic meters of water per year into the ground, which was recuperated by groundwater pumping in Mexico. In an effort to reduce losses and increase water available to Southern California, the canal was lined, and Mexico lost an estimated 83.5 million cubic meters of water. Sosa-Gordillo and Sanchez-Lopez (2007) convert this water loss into an estimation of crop area that cannot be planted, roughly 7,640 hectares. The economic impact was estimated with an input-output model using an estimated decrease in net profit by crop for 2003 as a base year, integrating production costs and fixed costs, labor, and estimated reductions in crop productivity due to increases in salinity. This yields an estimated loss in production of $2.3 billion pesos over 20 years, and a negative economic impact of$2.382 billion pesos in the agricultural sector and $2.592 billion pesos for the municipality as a whole. The inclusion of production costs in addition to profits is critical in calculations of economic impacts in order to capture the impacts to regional value chains. In terms of jobs and wages, there would be an estimated job loss of 15,425 employees in the agricultural sector and 16,940 for the whole economy, taking with them $539.8 million pesos in agricultural wages and $592.8 million pesos in total wages for the economy over 20 years. The job losses and productivity losses were phased-in over time, implying that the full impact of the reduction in water available for pumping occurred gradually (Sosa-Gordillo & Sanchez-Lopez, 2007).

CHAPTER FOUR: CONCEPTUAL MODEL

This chapter presents the theoretical model that frames my analysis of Upper Gulf of California fisheries. It presents a general functional relationship between fisheries catch and environmental and market variables, known as a bioeconomic model. It also presents the concept of a tradeoff analysis which, in subsequent chapters, will draw upon the results of the bioeconomic model to weight possible strategies for making water available for the environment against each other.

4.1 Bioeconomic Model

Fisheries are dynamic resources that change over time as a result of fluctuations in environmental and economic variables. A conceptual model of fisheries productivity in the Upper Gulf of California can be presented as a time series model. Barbier and Strand's characterization of the relationship between shrimp yields and an environmental variable, mangrove area, defines changes in fisheries yields as a system of equations (Barbier & Strand, 1997). The biological growth function, F, is a function of fisheries stock, X_t, and mangrove area, M_t. Harvest, h, is a function of fisheries stock and effort, E_t.

$$X_{t+1} - X_t = F(X_t, M_t) - h(X_t, E_t)$$

where $F_X \leq 0$ and $F_M > 0$ and $\frac{\partial F}{\partial M} = F_m > 0$

Harvest is specifically defined as the product of stock and effort, as well as a ‘catchability’ coefficient for the species, “q”.

$$h_t = qX_tE_t$$

The authors represent the growth function, F, as a logistic growth function, yielding

$$X_{t+1} - X_t = [r(K(M_t) - X_t) - qE_t]X_t$$

where $K_M > 0$

K represents the environmental carrying capacity of the fishery, and is a function of mangrove area. R designates the intrinsic growth rate of the shrimp population in each period. They assume an open access fishery, where fishing effort is motivated by prices. Changes in effort are motivated by the fishing firm’s objective function, revenues minus costs, or in this case, price multiplied by harvest minus costs multiplied by effort.

$$E_{t+1} - E_t = \varphi[ph(X_t, E_t) - cE_t]$$

In order to perform comparative statics, they compute an equilibrium assuming $E_{t+1} = E_t = E$ and $X_{t+1} = X_t = X$. This yields

$$X = \frac{c}{pq}$$

and

$$E = \frac{r(K(M) - X)}{q}$$

The authors assume a proportional relationship between the area of mangrove in the ecosystem and its carrying capacity for shrimp, assuming that the function $K(M) = \alpha M$ where $\alpha > 0$. To assess effect on effort of mangrove area, they take the total derivative of the function:

$$r[\alpha dM - dX^A] - qdE^A = 0$$

This can be rewritten as

$$\frac{dE^A}{dM} = \frac{\alpha r}{q} > 0$$

As such, a reduction in mangrove area will reduce the equilibrium level of fishing effort. Using the equation for harvest and taking its total derivative, the authors obtain:

$$dh^A = qX^A dE^A = \alpha r X^A dM = \frac{\alpha rc}{pq} dM > 0$$

Using this result, the change in revenue to the fishery can be calculated:

$$pdh^A = \frac{\alpha rc}{q} dM > 0$$

A positive change in mangrove area will result in a positive change in fisheries revenue, and similarly, a negative change in mangrove area will lead to a negative impact on revenues. The authors go on to perform an empirical analysis, estimating the relationship between mangrove area and fisheries revenues (Barbier & Strand, 1997).

This conceptual model captures the junction of human (economic), biological, and environmental factors at play in determining the productivity and profitability of a fishery. To test this model empirically would require time series data on fisheries stock, catch, fishing costs, and estimates of environmental carrying capacity, catchability, and intrinsic species growth rate. In fact, Barbier and Strand do not test the entire system of equations but rather assume catch to be at equilibrium, and estimate coefficients for the following equation:

$$h = qEK(M) - \frac{q^2}{r} E^2$$

which can be expressed as

$$h = q\alpha EM - \frac{q^2}{r} E^2$$

They estimate the coefficients on the interaction between effort and mangrove area and on effort squared. Following from those estimates, they go on to calculate comparative static effects of changes in mangrove area on the fisheries. Data on effort in the Upper Gulf is a challenge to estimate. The number of pangas operating by community is available over a window of time, while the number of industrial trawlers operating over time is more difficult to obtain. Estimating this model with available data yields a model with extremely low explanatory power and no statistically significant variable coefficients.

The model for the present study of Upper Gulf of California fisheries must be adapted to accommodate the available data. Furthermore, some of the assumptions of the Barbier model do not hold completely, for example, the fishery is not open access. There are a permitted number of vessels operating, though those vessels are entitled to unlimited catch for shrimp, for corvina there are some recent limits on total catch. The time series data available for the model include catch data for shrimp and corvina, river flows, the MEI-ENSO index as a means of measuring environmental variables, effort, and the prices of shrimp, corvina, and corvina swim bladder. Cost estimates are available based upon surveys performed in specific years. Given available cost data, we can assume a fixed cost per unit effort of harvest.

In this case, fisheries stock is an unobserved variable. Our dependent variable, the change in stock from one time period to another, no longer holds, and therefore we need to change the function to be in terms of harvest, as Barbier and Strand did. The change in harvest is a function of effort and the unobserved variable, stock, which in turn is a function of a vector of environmental variables, including river flows, some of which are time lagged. Applied to the available data, the function will vary by species. Furthermore, different models need to be created to accommodate the data as it is available.

At its most simple, we can model catch in period t (h_t) as a function (γ) of past river flows (f_{t-a}). The delay or lag in the correlation between river flow and catch (a) will vary by species based upon the life cycle of the species. Shrimp, for example, reach maturity in roughly a year. Corvina reach maturity in about 3 to 4 years.

$$h_t = \gamma(f_{t-a}) \qquad (1)$$

The functional form of f could take a number of different forms, linear or nonlinear, or perhaps even a threshold function. Perez-Arvizu, et al (2008) relate catch, CPUE, and post-larval abundance of shrimp in Golfo de Santa Clara to river flows. They found that a linear relationship of flows to CPUE yielded an R^2 of 0.4686 while a polynomial relationship produced an R^2 of 0.793. They also found that for years where river flow was in excess of 80 cubic meters per second, relative abundance of postlarval shrimp was positive, while under the threshold of 80 cubic meters per second, relative abundance was negative. Relative abundance was measured using normalized values and comparing relative to the sample average.

Expanding upon the simple catch to river flow relationship, additional environmental variables can be introduced. Factors beyond freshwater flows and nutrients affect species' growth and recruitment. Sea surface temperature, air temperature, precipitation, and other factors can have an influence on the ecosystem's productivity. A vector of other environmental variables can be introduced to capture these additional influences.

$$h_t = \gamma(f_{t-a}, \bar{V}) \qquad (2)$$

We know, however, that the harvest of a given species is the result of many other factors beyond environmental variables. It is the comingling influence of the environment, anthropogenic influences on the environment, market variables such as prices, and regulations affecting the level of effort and harvest in the fishery. We can introduce price received for fish into the model, either in the current time period, or lagged to account for the expectation of price by the fishermen.

$$h_t = \gamma(f_{t-a}, \bar{V}, \bar{P}) \qquad (3)$$

Effort, in terms of number of boats, has held relatively constant in recent years, with the exception of small changes due to buyout programs. The data on effort doesn't, however, account for additional effort through illegal fishing. We can also introduce effort into the equation, though the data available for effort is simply number of boats.

$$h_t = \gamma(f_{t-a}, \bar{V}, \bar{P}, E_t) \qquad (4)$$

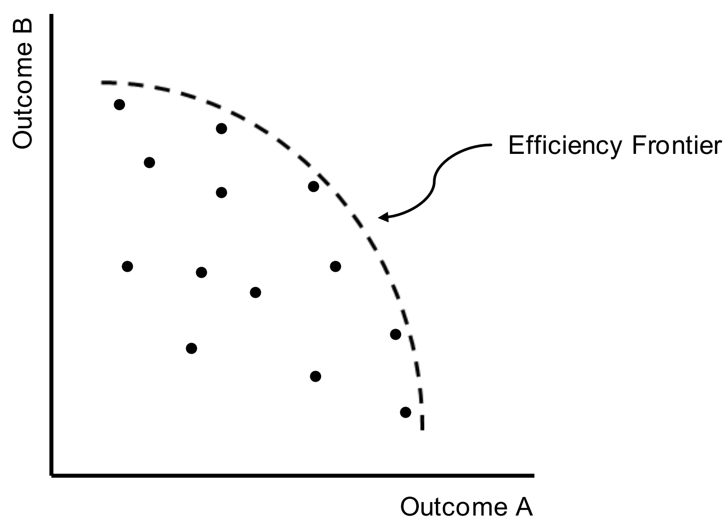
Finally, in the case of corvina, there is a total allowable catch (TAC) that was introduced in 2011. We can introduce regulation as a variable into the econometric model.

$$h_t = \gamma(f_{t-a}, \bar{V}, \bar{P}, E_t, D_t^{TAC}) \qquad (5)$$

4.2 Tradeoff Analysis

Tradeoff analyses are rooted in the ideas of Pareto improvements and Pareto optimality. Given an initial allocation of two goods between two individuals, those individuals can make an exchange of goods based upon their preferences, for an arrangement that is desirable to both of them, increasing each of their levels of utility. This is known as a Pareto improvement. If those individuals keep trading until neither individual can be made better off without making one of the individuals worse off, this is known as Pareto optimality. The many different allocations of the two goods between the two individuals can be plotted, and in some cases will yield an "efficiency frontier", a convex curve that maps all optimized solutions.

Fig. 4.1: Efficiency Frontier



Similar to the policy tradeoff analysis by Afflerback, et al (2014), we can present a series of policy options in terms of river flow scenarios and plot those relative to the fisheries yields they are able to achieve versus other outcomes, for example, the opportunity costs of dedicating the water to environmental purposes. We can also incorporate cost data to provide an estimate of the fisheries profits in place of yields. By plotting multiple scenarios, we will be left with a series of outcomes, and some of those outcomes will be efficient outcomes, that is to say, given the outcome to one competing interest, the other competing interest cannot be made better off. The results of the Atlantis model runs provide the river policy scenarios and modeled fisheries outcomes. Estimates of per hectare productivity in the agricultural sector can provide a means of estimating the impact of reduced agricultural production on the regional economy due to movement of water out of agriculture and to environmental uses. We can associate costs with the acquisition of the water for environmental purposes, and even extend those policy tradeoffs to compute potential net economic impacts of the tradeoffs. It is possible that there might be no solutions that improve overall utility without coming at the expense of one of the parties, underlining the intractability of the issue and the need for compensation in making changes to allocations of resources.

CHAPTER FIVE: DATA & METHODOLOGY

5.1 Data

This economic analysis relies primarily on data obtained through government sources, both from Mexico and the United States. The largest challenges associated with data for the Upper Gulf fisheries was lack of data, inconsistencies between different data sources, gaps in data, and lack of historical baselines for comparison. Any instances where data assumptions were made have been noted.

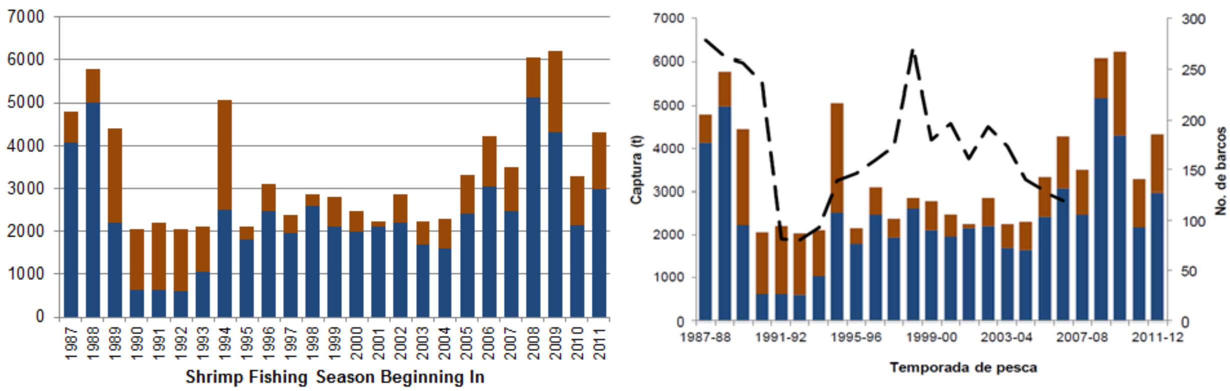
5.1.1 Fisheries Data

Catch data for Mexico's fisheries is tracked by the Comisión Nacional de Acuacultura y Pesca (CONAPESCA) (National Commission for Aquaculture and Fishing), under the auspices of the Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA) (Secretary of Agriculture, Livestock, Rural Development, Fishing, and Food). CONAPESCA has fisheries offices throughout the country in major fishing ports. Within the Upper Gulf, there are fisheries offices located in all three Upper Gulf communities, Puerto Peñasco, San Felipe, and Golfo de Santa Clara. Additionally, they have an office in Mexicali which captures catch registered in the Cucupa community of El Zanjon and other small fishing camps within the municipality of Mexicali. Catch data is aggregated by community. Fishermen, upon landing, are required to submit an "Aviso de Arribo" or "notice of arrival", which provides information to CONAPESCA on the species caught, the weight of the catch, the location of the catch, the permit number that the catch was made under, the boat registration information, and the duration of the fishing trip, among other details. CONAPESCA compiles and publishes these fisheries statistics in an online portal, as well as through annual fisheries reports, “Anuarios estadísticos”. The data available in the Anuarios varies year by year in terms of level of aggregation, making it difficult to obtain a continuous time series. The data available through their web portal starts in 2001 and continues through 2014. The data available through their online interface has been compiled and entered into an interactive, user-friendly format by the DataMares project (www.datamares.org), a project aimed at making data on Gulf of California marine ecosystems readily available to researchers, and housed by the University of California, San Diego (UCSD) (Giron-Nava, et al, 2014).

Fisheries office data is available through a variety of other sources, including the MIA reports (Manifestación de Impacto Ambiental) for the Upper Gulf fisheries (CEDO, N/D), as well as through published academic articles. Most sources vary from each other, at times significantly so. This is due to the use of different estimation techniques to account for missing data. There have been inconsistencies over time as to how data was reported, or the level of aggregation or disaggregation by species. Corvina, for example, in the past is at times reported under a general corvina or finfish category in certain communities. Other communities do not report species as a result of lack or regulation around certain species during different times (Molina-Ocampo, 2015).

Data on shrimp catch was available through a variety of sources, but not continuously for more than 10 to 15 years from one single source. In the cases where there was overlap in dates between different sources, typically there were significant inconsistencies between the data, making it difficult to piece the data together. The data was available, however, in graphical form from 1987/1988 to 2011/2012 within a report from INAPESCA (Garcia-Juarez, et al, 2014) and is based off of CONAPESCA catch reports. The data was carefully estimated from the graph, including the breakout between blue and brown shrimp.   Included below is a side-by-side comparison of the estimated data graphed and the original graphical data it is based upon for purposes of comparison.

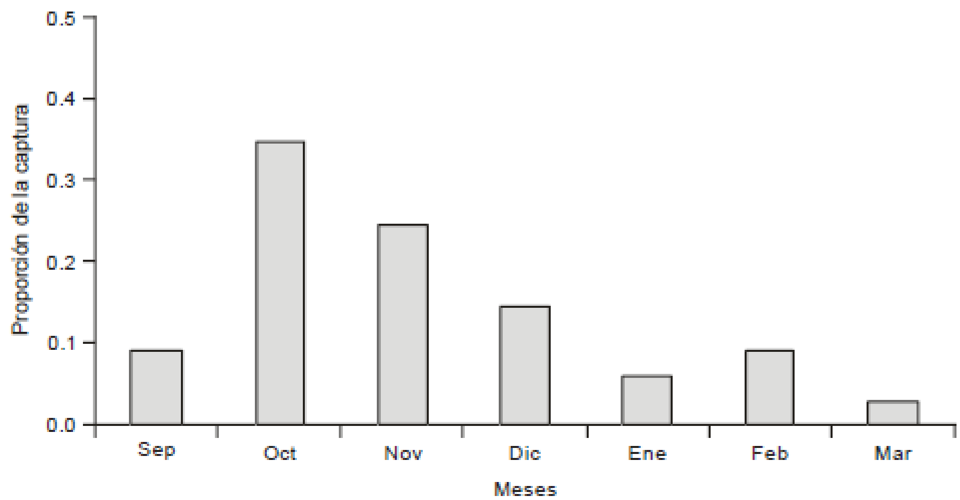
Fig. 5.1: Comparison of Estimated Data vs. Original Data Graphic



Source: Author estimation (left); INAPESCA (Garcia-Juarez, et al, 2014) (right)

The last two years of shrimp catch were added using DataMares data (Olivares- Bañuelos, 2014) which is also based off of CONAPESCA catch reports. There is a small inconsistency in these two years of additional data in that it is reported by calendar year versus fishing season. The shrimp season in the Upper Gulf runs from September through February, with the large majority of catch occurring before January.

Fig. 5.2: Distribution of Upper Gulf Shrimp Catch by Month



Source: INAPESCA (Garcia-Juarez, et al, 2014)

While completing the time series using the DataMares data is an imperfect solution, it should provide a reasonably good estimate of the seasonal data since roughly 80% of catch is accounted for before the new year and each year will include the tail end of the previous season at the beginning of the calendar year to offset the end of the season in the subsequent calendar year.

Table 5.1: Shrimp catch by species and fishing season

Year	Blue Shrimp	Brown Shrimp	Total Shrimp
1987/88	4,080	720	4,800
1988/89	4,995	795	5,790
1989/90	2,200	2,200	4,400
1990/91	630	1,420	2,050
1991/92	630	1,570	2,200
1992/93	620	1,430	2,050
1993/94	1,050	1,050	2,100
1994/95	2,500	2,550	5,050
1995/96	1,800	320	2,120

1996/97	2,480	620	3,100
1997/98	1,950	425	2,375
1998/99	2,600	280	2,880
1999/00	2,100	700	2,800
2000/01	1,980	495	2,475
2001/02	2,120	105	2,225
2002/03	2,200	680	2,880
2003/04	1,700	530	2,230
2004/05	1,600	700	2,300
2005/06	2,400	920	3,320
2006/07	3,050	1,180	4,230
2007/08	2,475	1,025	3,500
2008/09	5,130	920	6,050
2009/10	4,300	1,900	6,200
2010/11	2,150	1,150	3,300
2011/12	2,980	1,320	4,300
2012			2,588*
2013			2,189*

Source: CONAPESCA – data estimated from graphic

* Source: DataMares (Olivares- Bañuelos, 2014), based on CONAPESCA catch reports

Data on corvina catch was provided by CONAPESCA-SAGARPA for the communities of Golfo de Santa Clara, San Felipe, and small Alto Golfo communities including El Zanjon. This data excludes Puerto Peñasco. The remainder of the data not provided by CONAPESCA was accessed through Olivares- Bañuelos (2014). According to Olivares-Bañuelos (2014), for recent years, gulf corvina represented 82% of corvina caught in San Felipe and 99.7% of corvina captured in the Alto Golfo region of Baja California (Mexicali office) which includes El Zanjon. Other species of corvina include yellow fin corvina, white corvina, blue corvina, and striped corvina, among others. Given that interannual variation in the proportion of corvina catch represented by gulf corvina is not available over the full 2006 to 2014 period, the full values were used. This assumes that the slight overreporting of gulf corvina will offset any gulf corvina caught in Puerto Peñasco, not a major harvester of gulf corvina, and not included in the data. For 2005, the data for San Felipe and Bajo Rio is missing, in which the data was interpolated by calculating the average nominal growth of harvest by community over the range of available data and applying the average annual nominal growth to the previous year to obtain the missing value.

Table. 5.2: Catch of Gulf Corvina in Upper Gulf of California, in metric tons

Year	**El Golfo de Santa Clara (SON)**	**Bajo Río Colorado (BC)**	**San Felipe (BC)**	**TOTAL**
1987	0.1			0.1
1988	1.7			1.7
1989	2.1			2.1
1990	1.1			1.1
1991	0.9			0.9
1992	3.9			3.9
1993	31.7			31.7
1994	177		43	220
1995	561		61	623
1996	1,278		122	1,400
1997	2,150	8	277	2,435
1998	2,567	19	303	2,889
1999	3,312	57	220	3,588
2000	2,669	154	816	3,638
2001	2,604	468	643	3,715
2002	4,357	656	918	5,931
2003	2,214	250	268	2,731
2004	1,597	342	357	2,295
2005	1,576	368[1]	392[1]	2,214
2006	2,406	430[2]	148[2]	2,984
2007	3,000	913[2]	307[2]	4,220
2008	3,155	939[2]	309[2]	4,403
2009	3,899	1,096[2]	322[2]	5,317
2010	2,850	754[2]	454[2]	4,058
2011	3,530	217[2]	371[2]	4,118
2012	1,848	850[2]	479[2]	3,177
2013	2,222	547[2]	1,232[2]	4,001
2014	2,437	445[2]	748[2]	3,630

Source: CONAPESCA-SAGARPA

[1] Source: Interpolated using overall growth rate by community over period of available data

[2] Source: Olivares- Bañuelos (2014), based upon CONAPESCA catch reports

5.1.2 Cost Data

Fisheries cost data is available through a number of studies, typically gathered through surveys. Costs are presented as total cost of catch for the fishery as a whole, or broken down to cost per season or trip per panga. These costs are sometimes even further broken down into individual expenses such as labor, gasoline, and other gear and supplies. The MIA report for the west coast of the Upper Gulf (CEDO, N/D) presents a breakdown of the costs associated with fishing in the Upper Gulf, with cost estimates by community and the number of pangas making the investment each year (Fig. 5.3). They also present operating costs for pangas involved in the MIA project.

*Table 5.3. Initial capital investment by Upper Gulf of California communities (MXN**)*

Item	San Felipe	Golfo de Santa Clara	Puerto Peñasco*
Motor	$131,778	$119,644	$3,513,000
Panga	$54,778	$59,568	$1,156,000
Shrimp net	$20,422	$25,589	$60,000
Corvina net	$35,000	$10,909	$20,000
Sierra net	$78,293	$48,045	$70,000
Guitarra net	$20,933	$23,578	$232,000
Chano net			$12,000
Lenguado net			$104,000
Longline	$7,581		$146,000
Hooka	$15,000		
Traps	$30,000		$483,600
Auxiliary Equipment	$8,156	$6,356	$120,215

Source: MIA (N/D)

* Costs are for industrial boats

** No date associated with data for conversion to 2014 pesos

Table 5.4. Seasonal Operating Costs, 2004 (2014 MXN)

Item	San Felipe	Golfo de Santa Clara	Puerto Peñasco
Number of Trips per Season	279	209	76
Gasoline per Trip	$890.46	$1,322.92	$937.01
Motor oil per Trip	$112.62	$207.22	$277.80
Food per Trip	$225.24	$270.29	$285.31
Average Cost per Trip	$1,228.32	$1,665.29	$1,500.11
Nets per Season	$97,408.86	$82,034.51	$74,248.84
Total Cost per Season	$440,109.79	$430,079.69	$188,257.24

Source: Rodriguez & Bracamonte (2008), author calculations

Other cost estimates based upon field interviews are presented below:

Table 5.5: Miscellaneous Costs

Item	Cost (Pesos)	Useful Life
Panga (used)	15,000 – 40,000	15 years
Panga (new)	75,000 – 100,000	
Used panga repair	17,000 – 100,000	
Motor	270,000	5-8 years
Motor maintenance	1000	10 x per year
Ecological motor (with subsidies)	175,000 – 189,000	
Nets	20,000 – 30,000	1 – 2 years
Gasoline	500 – 1,200	Per trip

Source: Interviews in Puerto Peñasco, June 2014

5.1.3 Effort

Fishing effort can be measured in a number of ways, including number of vessels, number of permits, and days or hours of fishing per season. For this analysis, a number of proxies for effort were considered, including marine gasoline sales and high-wind days per year, however, this data was not available on the spatial or temporal scales needed. The number of permits per year is not well-documented for the Upper Gulf fisheries, and thus the number of vessels operating is the most complete effort data available.

The number of pangas operating in the Upper Gulf has fluctuated over time. From the mid-nineties to the mid-2000s, the number increased substantially; however, programs aimed at reducing the level of effort, including the PACE-Vaquita buyout program, have reduced the numbers since.

Table 5.6: Number of artisanal boats operating in the Upper Gulf

Year	***Total***	***SF***	***PP***	***GSC***
1995	635	30	390	215
1996	848	233	390	225
1997	1269	294	550	425
1998	1160	205	550	405
1999	1308	333	550	425
2000	1388	288	550	550
2001	1466	366	550	550
2002	1465	238	670	557
2003	2070	840	673	557
2004	2070	840	673	557
2005	2070	840	673	557
2006		ND	673	557
2007		ND	673	557

Source: Federación de Sociedades Cooperativas de Producción Pesquera Ribereña del Puerto de San Felipe. (N/D). Manifestación de Impacto Ambiental modalidad regional. Pesca ribereña multiespecifica.

Currently, there are an estimated 806 pangas operating legally out of San Felipe with a total of 1,354 fishing licenses (Johnson, 2015) and roughly 435 operating out of Golfo de Santa Clara (personal communication). There are 8 industrial shrimp trawlers operating out of San Felipe (personal communication) and 103 operating out of Puerto Peñasco (Ainsworth, et al, 2011). No industrial boats are based out of Golfo de Santa Clara because they fall completely within the biosphere reserve where only artisanal fishing with pangas is permitted.

5.1.4 Output Prices

Mexico's federal government tracks market prices for a variety of commodities, including seafood, through the Secretary of Economy's National System for Information and Market Integration (Sistema Nacional de Información e Integración de Mercados, SNIIM). Historical and current seafood market prices are available for the largest seafood markets across the country, including Nueva Viga in Mexico City and Mercado del Mar in Guadalajara. While some gaps exist in the data, there is sufficient information to calculate average annual market prices for different presentations of shrimp and corvina. The average annual shrimp prices were calculated at the average of six types of shrimp: small, medium, and large shrimp, with and without heads.

Table 5.7. Corvina Market Prices, in Pesos per Kilo (2014 MXN)

	Nueva Viga, Mexico City	Mercado del Mar, Guadalajara
2000	N/A	$33.36
2001	N/A	$38.22
2002	N/A	$36.16
2003	N/A	$36.90

2004	N/A	$37.45
2005	N/A	$39.59
2006	N/A	$37.85
2007	N/A	$37.26
2008	N/A	$36.97
2009	N/A	$35.27
2010	$61.03	$38.67
2011	N/A	$38.20
2012	N/A	$36.97
2013	N/A	$36.64
2014	N/A	$32.07
2015	N/A	$33.36

Source: Secretaria de Economia, SNIIM

Fig. 5.3. Average Annual Market Price for Corvina, Guadalajara, Jalisco (Mercado del Mar) (2014 MXN / kilo)

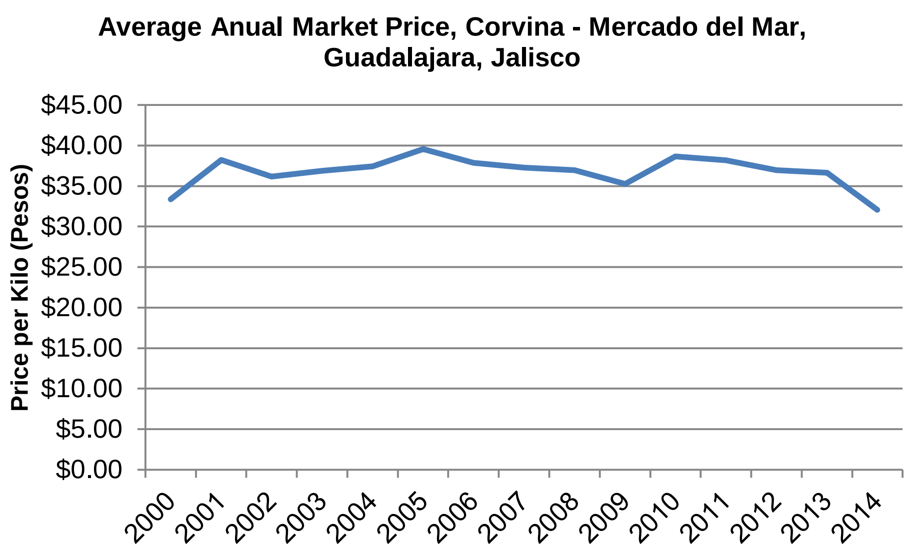


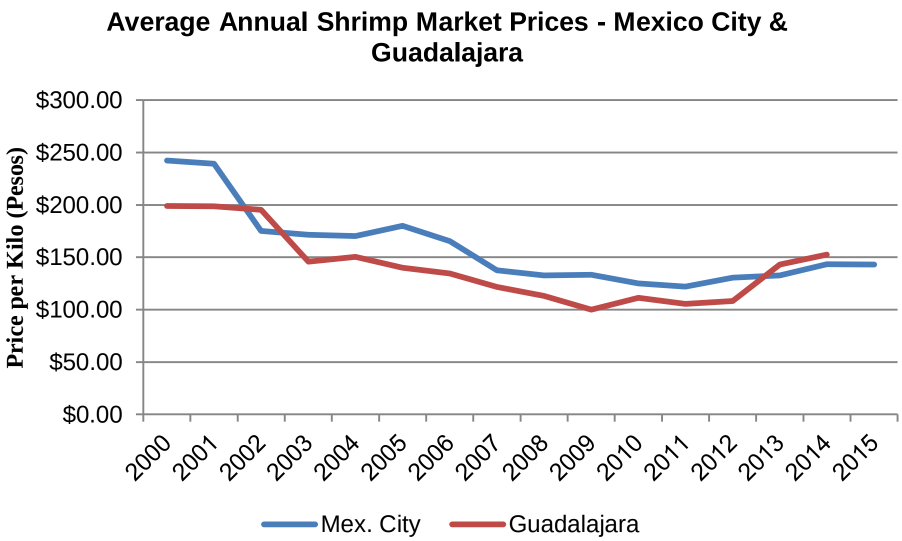
Table 5.8: Shrimp Market Prices (2014 MXN / kilo)

	Nueva Viga, Mexico City	Mercado del Mar, Guadalajara
2000	$242.46	$199.11
2001	$239.29	$198.80
2002	$175.04	$195.40
2003	$171.44	$145.95

2004	$170.37	$150.35
2005	$180.08	$139.95
2006	$165.28	$134.61
2007	$137.49	$121.81
2008	$132.60	$113.28
2009	$133.38	$99.88
2010	$125.12	$111.20
2011	$121.92	$105.58
2012	$130.65	$108.36
2013	$132.71	$143.19
2014	$143.32	$152.68
2015	$143.00	N/A

Source: Secretaria de Economia, SNIIM

Fig. 5.4: Average Annual Shrimp Market Prices – Mexico City (La Nueva Viga) and Guadalajara (Mercado del Mar) (2-14 MXN / kilo)



Prices can also be inferred through CONAPESCA's interactive system which provides data on live weight of catch. These are the prices paid to fishermen as reported on their catch reports submitted to CONAPESCA and are likely to reflect either the beach price, or the price paid by processors to larger cooperatives.

Table 5.9. Average Annual Price per Kilo for Shrimp Catch by Community, All Species (2014 MXN / kilo)

Year	Golfo de Santa Clara	Puerto Peñasco	San Felipe
2011	$110.98	$68.39	$79.59
2012	$112.03	$69.45	$86.37
2013	$109.45	$64.27	$71.86

Source: CONAPESCA

Table 5.10. Average Annual Price for Gulf Corvina Catch by Community, All Species (2014 MXN / kilo)*

Year	Golfo de Santa Clara	Puerto Peñasco	San Felipe
2011	$12.16	$9.95	$10.27
2012	$11.76	$6.87	$15.11
2013	$14.41	$9.89	$12.40

Source: CONAPESCA

* Includes some catch reported generally as "corvina", not as "gulf corvina"

Prices for corvina are also available through monitoring programs. The Environmental Defense Fund (EDF), in their work focused on promoting sustainable fisheries practices for the gulf corvina fishery, have funded annual studies summarizing each gulf corvina fishing season in Golfo de Santa Clara, Sonora (CapLog Group, 2012; CapLog Group, 2013; CapLog Group, 2014). The reports track ex-vessel (beach) prices and market prices in Mexico City's Nueva Viga market. They also provide separate price data on corvina swim bladder ("buche"). These prices correspond roughly with what can be calculated through the CONAPESCA data. Data is also available in recent years from the monitoring efforts by the Instituto de Acuacultura del Estado Sonora (IAES) who track individual catch by panga, recording the weight of catch and price received from the buyer, working in conjunction with the EDF, CONAPESCA, and

SEMARNAT on the monitoring program (IAES, 2014). This effort tracks the prices of gutted fish and swim bladder, and also includes other catches by species observed during monitoring.

Table 5.11: Average Ex-Vessel and Market Corvina Prices, Golfo de Santa Clara & Nueva Viga, 2011-2014 (2014 MXN / kilo)

	2011	2012	2013	2014
Ex-Vessel Price	$12.03	$20.13	$16.36	$14.75
Market Price	$26.26	$31.05	$26.34	$43.22

Source: CapLog Group (2014), calculations by author

Table 5.12: Historic Corvina Market Prices – In Season (March-May) (2014 MXN / kilo)

Year	Price
2007	$29.28
2008	$25.52
2009	$31.93
2010	$30.58
2011	$26.26
2012	$31.05
2013	$26.34
2014	$43.22

Source: CapLog Group (2014), calculations by author

Table 5.13: Historic Corvina Buche Prices in Golfo de Santa Clara (2014 MXN / kilo)

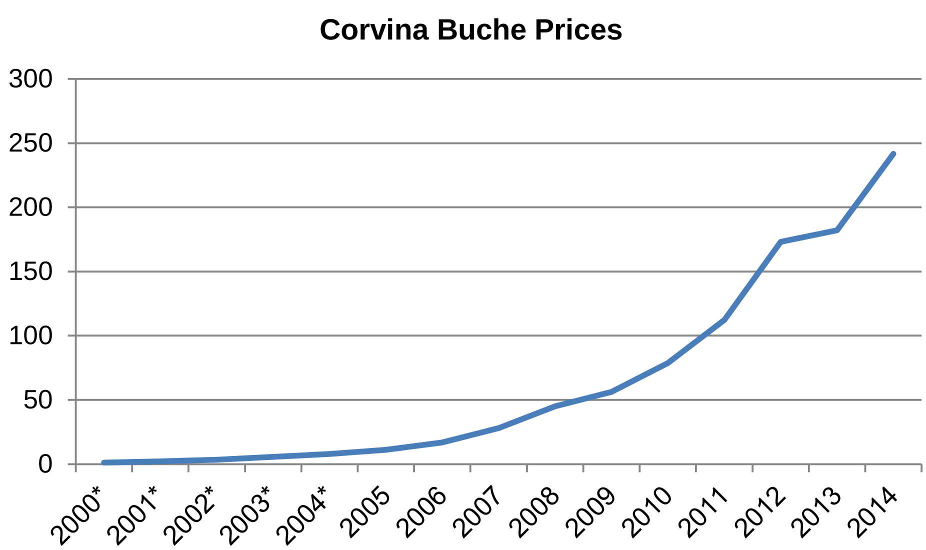
Year	Price
2005*	$11.24
2006*	$16.86
2007*	$28.10
2008*	$44.97
2009*	$56.21
2010*	$78.69
2011*	$112.42
2012	$173.12
2013	$182.12
2014	$241.70

Source: CapLog Group (2014), CapLog Group (2012), author calculations

* estimated (CapLog Group)

According to anecdotal information from a processor in Golfo de Santa Clara, the corvina buche industry first emerged in the late 1990s and prices were in the 5-10 pesos per kilo range (CapLog Group, 2012). I have extrapolated prices beyond the range of data provided by CapLog to begin in 2000 at roughly 1 peso per kilo and growing at a trend consistent with the remainder of the price data.

Fig. 5.5: Corvina Buche Prices Used in Analysis, 2000-2014 (2014 MXN / kilo)

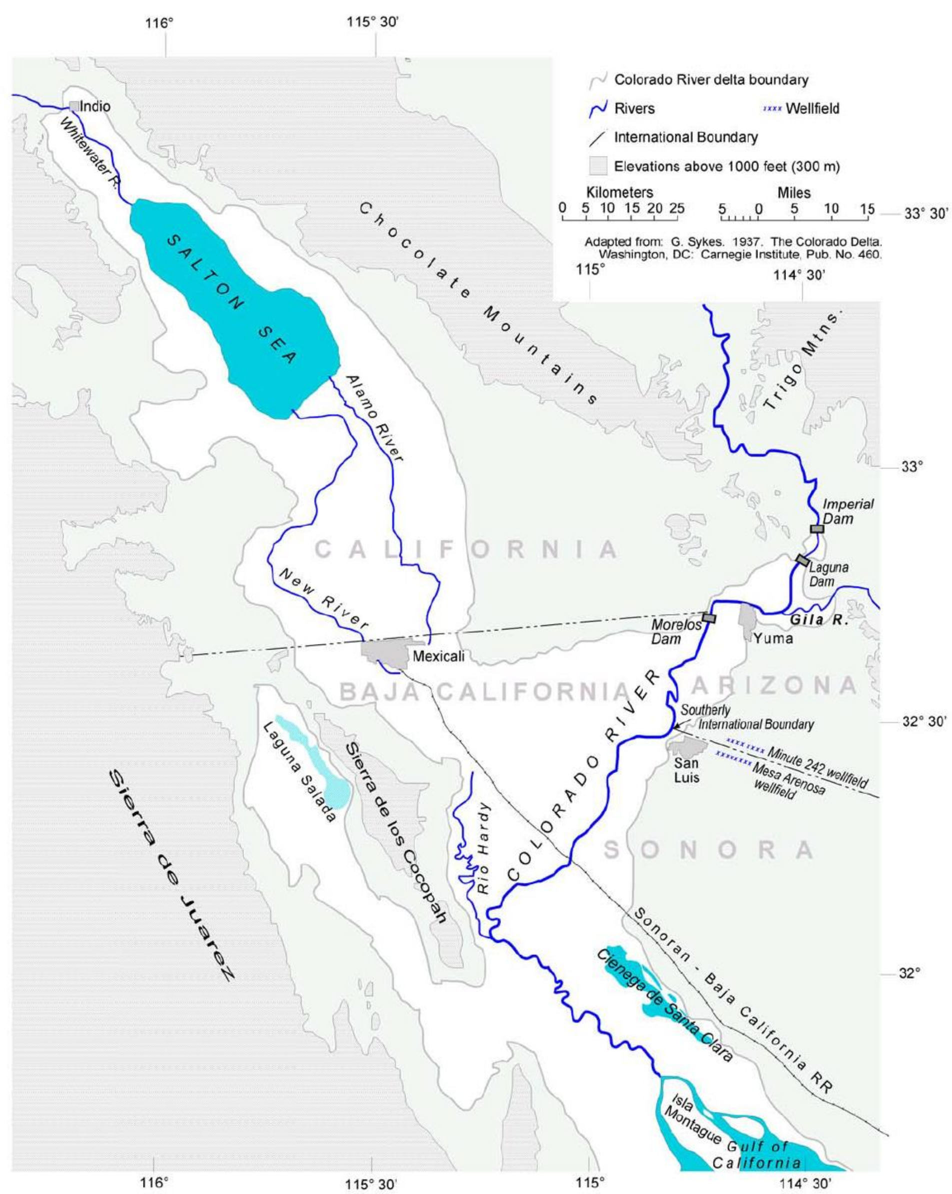


5.1.5 Colorado River Flow Data

Colorado River flows are tracked at various points along the river's course by a number of agencies. Data on the flows of the Colorado River into the Upper Gulf of California, however, are not available. Today, the southernmost location where river flows are tracked is the Southern

International Boundary (SIB), the southernmost point along Arizona's western border, defined by the Colorado River, near San Luis, Sonora. Data on Colorado River flows at the SIB are available through the International Boundary Water Commission (IBWC), the U.S. Bureau of Reclamation (USBR), and Mexico's Comisión Nacional de Agua (CONAGUA).

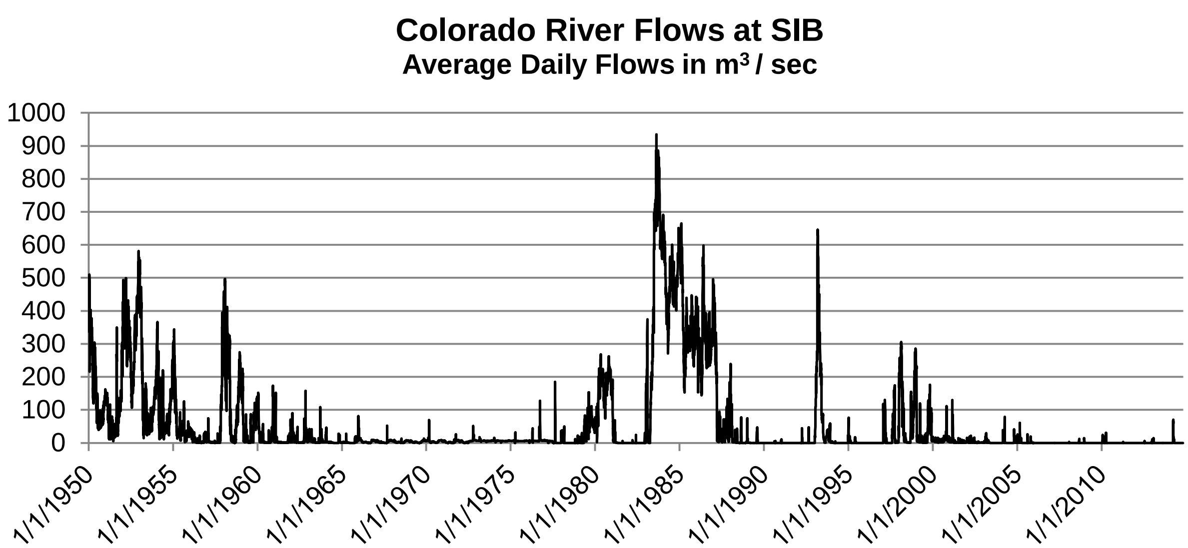
Fig. 5.6. Colorado River Delta Region



Source: Cohen & Henges-Jeck 2001

The IBWC provides data on daily average flows at a number of points in the Colorado River Delta region from Yuma to the SIB in cubic meters per second. Data on river flows at the SIB obtained for this analysis begins in 1950 (Fig. 5.7). Note the small spike in 2014, at which point the Minute 319 pulse flows were registered.

Fig. 5.7. Colorado River Flows at Southern International Boundary in Cubic Meters per Second. 1950-2014.



Source: IBWC (2014); Personal communication

Historically, two river flow gauges were located south of the Southern International Boundary (the M.C. Rodriguez and El Maritimo stations), however, they have been removed from operation as their values are unreliable, registering the tides of the Sea of Cortez and not river flows due to the lack of water (Cohen & Henges-Jeck 2001). The SIB gauge is located 75 miles north of the mouth of the Colorado River, however, due to lack of data on inflows into the gulf, most literature uses the SIB data (Cohen & Henges-Jeck 2001). Cohen and Henges-Jeck (2001) present two linear regressions that estimate river flows at the historical river gauges for 1960 (a flood-year) and 1964 (a non-flood year).

Table 5.14: Correlation of Mean Daily Discharge at SIB and Downstream Stations

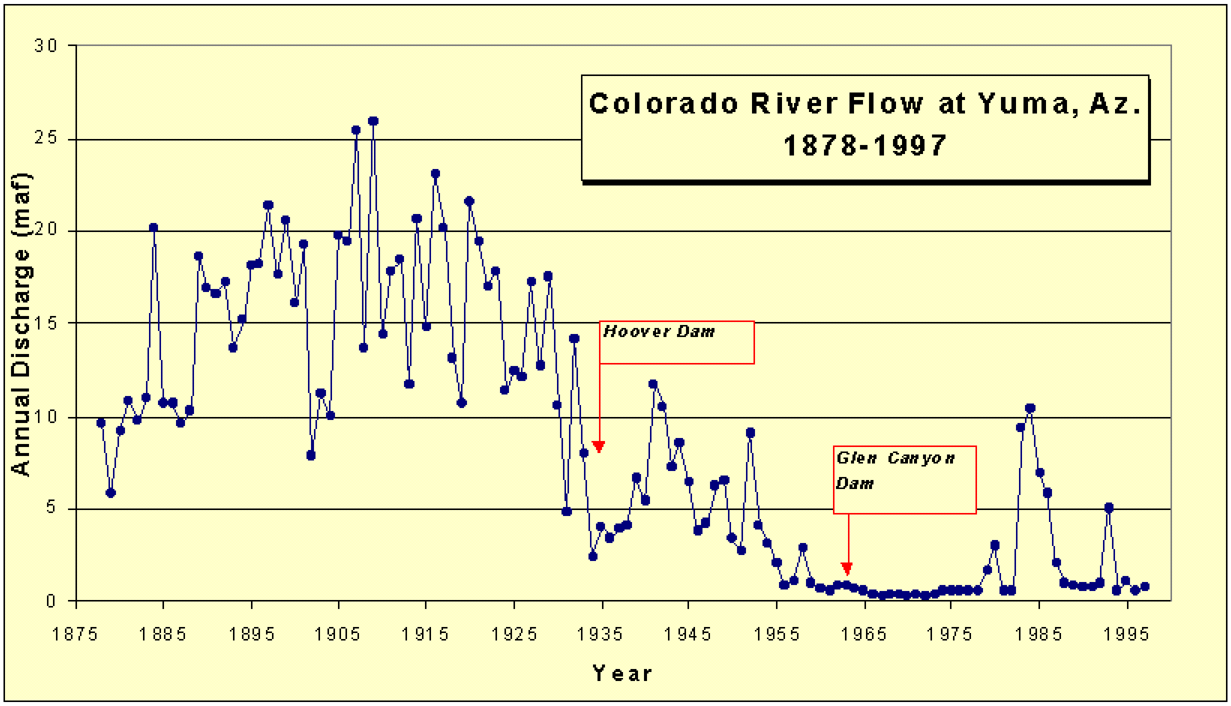
		1960		1964	
Station	***Lag***	R^2	***Regression equations***	R^2	***Regression equations***
M.C. Rodriguez	1 day	0.967	y = 0.959x + 25.2 cfs (0.71 m^3/sec)	0.873	y = 0.893x + 7.24 cfs (0.21 m^3/sec)
El Maritimo	2 days	0.944	y = 0.834x + 50.0 cfs (1.42 m^3/sec)	0.696	y = 0.694x + 69.9 cfs (1.98 m^3/sec)

Source: Cohen and Henges-Jeck (2001)

Potential changes in hydrology, groundwater levels, and vegetation in the delta, however, make these correlations unreliable for use in estimating water reaching the Upper Gulf. Correlations are therefore estimated using Southern International Boundary data, or in other cases, a threshold function that registers flows in excess of specific levels.

Pre-dam river flow information (prior to the 1930s) provides an opportunity to estimate fisheries productivity prior to the construction of the three major upstream dams.

Fig. 5.8: Colorado River Flows at Yuma, 1878-1997



Source: Flessa, et al (2001)

Based loosely off of the pre-dam river flows and the average flow at the SIB for 1993, roughly 130 m^3/sec, the following average flow scenarios were created, assuming reductions in river flows due to riparian and other consumptive use in the Delta between the SIB and the Upper Gulf:

Table 5.15: 1993 and Pre-Dam Flow Scenarios

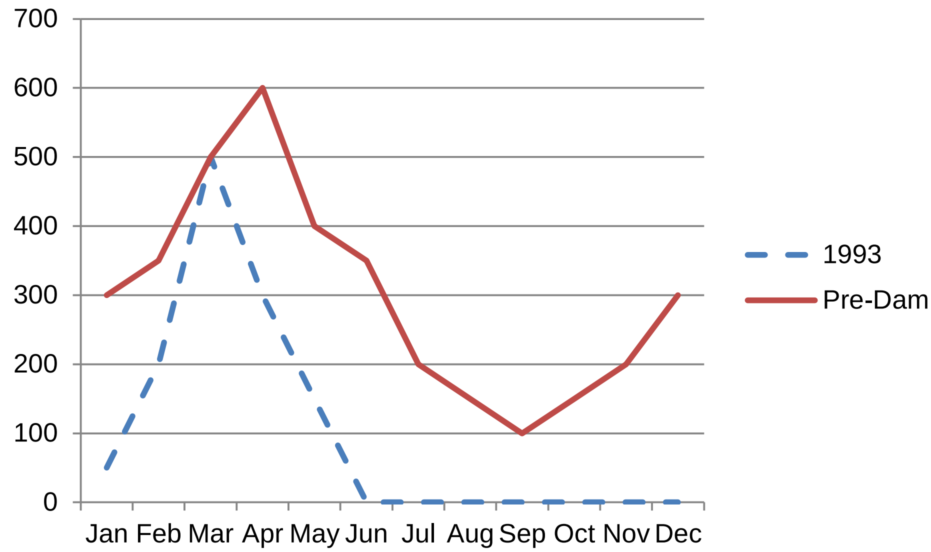
Scenario	Est. Annual Flows at Yuma (MAF)	Est. Flows at SIB (m^3/sec)	Est. Flows into UGC (m^3/sec)
1993	5	130	100
Pre-Dam	15	390	300

These flows were then allocated over the year mimicking the pattern of average monthly flows during 1993, and mimicking a spring pulse flow and regular base flows over the course of the year for the pre-dam scenario.

Table 5.16: River Flow Inputs to Atlantis Model in Cubic Meters Per Second

Month	1993	Pre-Dam
Jan	50	300
Feb	200	350
Mar	500	500
Apr	300	600
May	150	400
Jun	0	350
Jul	0	200
Aug	0	150
Sep	0	100
Oct	0	150
Nov	0	200
Dec	0	300
Ave	**100**	**300**

Fig: 5.9: Annual Flow Pattern by Scenario



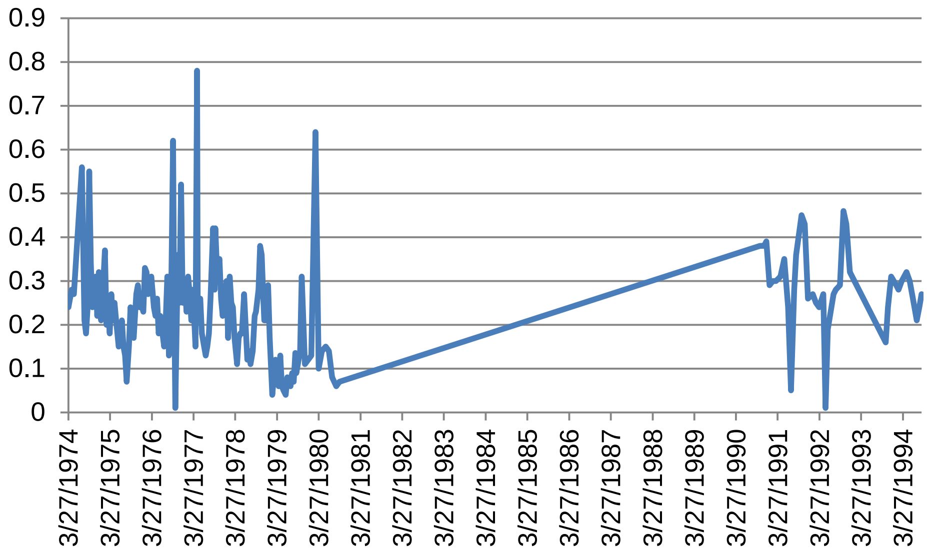
For the 1993 scenario, this flow pattern was run once every 10 years over 30 years. For the pre-dam scenario, the scenario was run as a repeating yearly pattern over 30 years.

5.1.6 Water Quality and Nutrient Data

Information on Colorado River water was required for nutrient inputs into the Atlantis model, including water temperature and nutrient, detritus, and sediment loads. The US Geological Survey (USGS) provides water quality data for the Colorado at different locations through its National Water Information System (NWIS) (USGS, 2015). There are, however, notable gaps in the data. The southernmost point with water quality data available was the USGS station #09522000, Colorado River at the Northern International Boundary (NIB), above Morelos Dam, Arizona. Morelos Dam is the point at which water is diverted from the Colorado to the Mexicali Valley for agricultural irrigation (see Fig. 5.6).

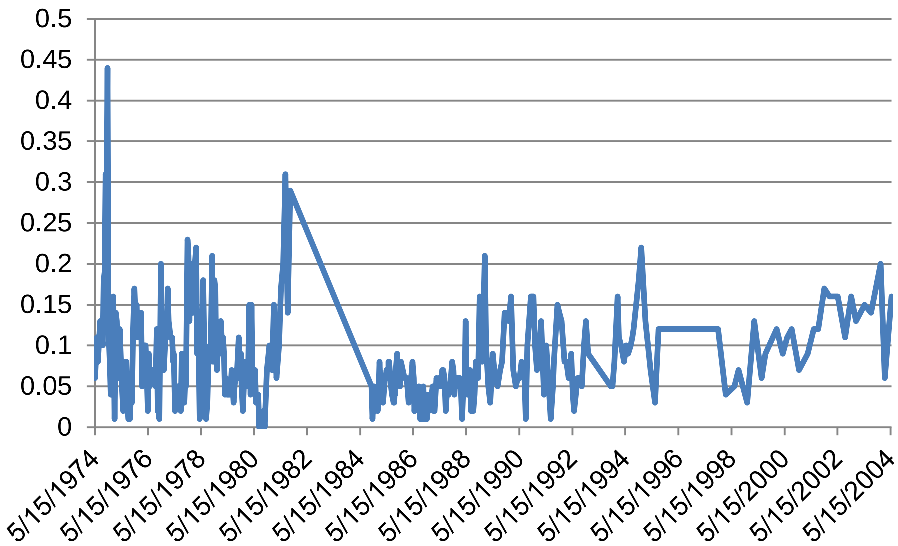
Nitrate levels were calculated as the average over the period of 1974 to 1994, the full range of available data above Morelos Dam (0.238460674 mg / L). There is a large gap in the data between 1980 and 1990, which displays as a straight line in the graph (see Fig. 5.10, below).

Fig. 5.10: Nitrate, water, unfiltered, milligrams per liter as nitrogen at USGS gauge station #09522000, Colorado River at the Northern International Boundary above Morelos Dam



Ammonia was calculated similarly, however, given that the data was more complete for recent years, the value was calculated as the average over the 10 most recent years available, 1994-2004, yielding an average of 0.1135 mg / L. There are two main gaps in the data which display in the graph as straight lines.

Fig. 5.11: Ammonia, water, unfiltered, milligrams per liter as nitrogen. USGS gauge station #09522000, Colorado River at the Northern International Boundary above Morelos Dam



Source: USGS

Average river water temperature was calculated using mean monthly temperature data from 1964 to 2014 at the Northern International Boundary (NIB) above Morelos Dam.

Table 5.17: Monthly Average Water Temperature at Northern International Boundary (NIB), in Degrees Celsius

Month	Ave. Temp
Jan	12.50
Feb	13.94
Mar	17.40
Apr	20.03
May	23.56
Jun	26.28
Jul	28.17
Aug	28.41
Sep	25.97
Oct	21.80

Nov	16.29
Dec	13.28

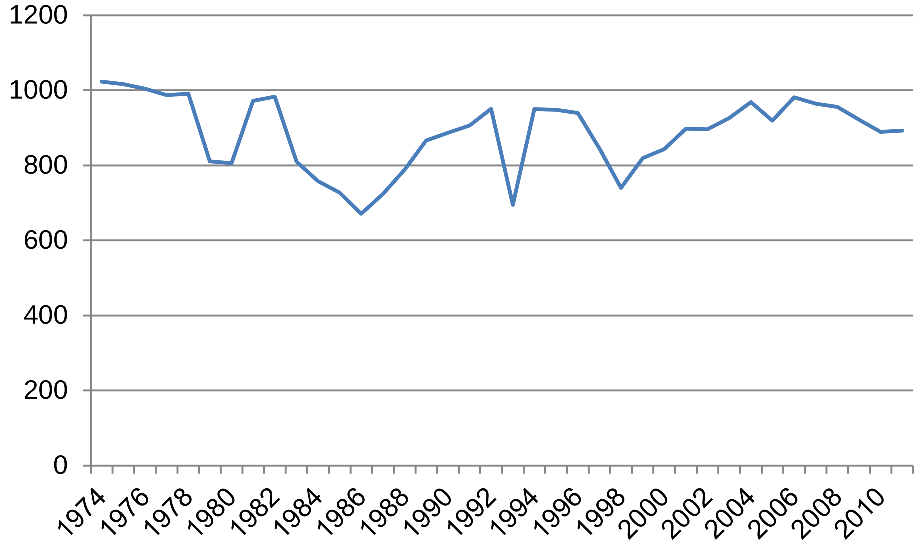
Source: USGS, Average Monthly Temp

at Gauge Station 09522000 Colorado

River at NIB, Above Morelos Dam, 1964-2014

Salinity data was retrieved from the Mexican side of the IBWC, known as CILA (Comisión Internacional de Límites y Agua) and was calculated based on a 10 year average salinity at Morelos Dam from 2002 to 2011 (most recently reported data) (CILA, 2015). The 10 year average was 932 ppm (parts per million), which for purposes of scenario creation, was designated at the low salinity level. The high salinity level was assigned as double the 10 year average, 932 ppm. Salinity data is not available below Morelos Dam, therefore the high and low scenarios were assumed considering that river water is likely to become more saline as it approaches the Upper Gulf due to high levels of evaporation and flows of agricultural runoff into the Delta ecosystem.

Fig. 5.12: Colorado River Salinity at Morelos Dam in Parts per Million, 1974-2011



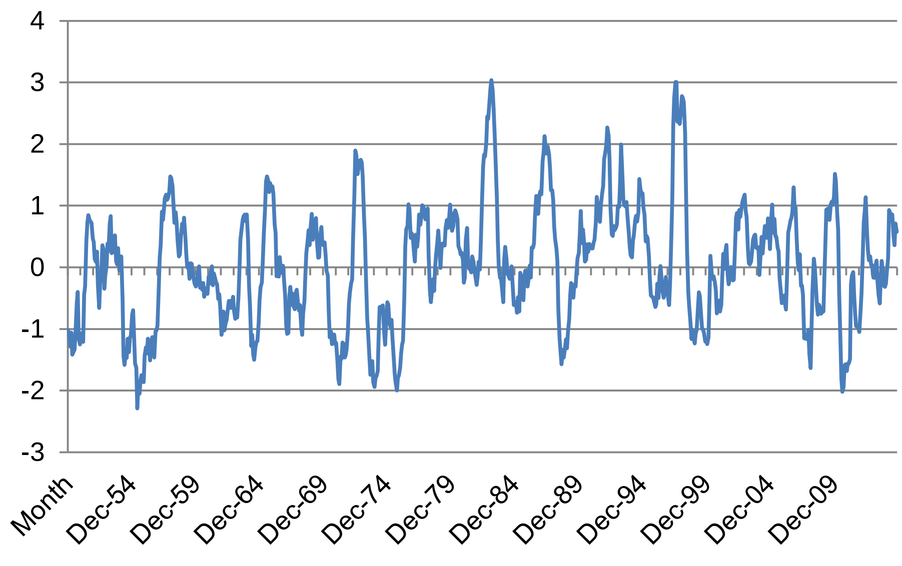
Source: CILA / IBWC

5.1.7 ENSO index data

Other climatic and oceanographic variables beyond freshwater river input into the Upper Gulf have influence on the environment and marine fisheries productivity. The El Niño Southern Oscillation (ENSO) index measures a number of climatic variables. Positive values indicate warm conditions associated with El Niño and negative values indicate cold conditions associated with La Niña. Lluch-Cota, et al (2007) note that ENSO is associated with temperature and sea-surface temperature anomalies, as well as the relative abundance of phytoplankton biomass, a key component of marine ecosystem productivity. Though the full relationship between ENSO and oceanic and fisheries behavior has yet to be fully documented for the Gulf of California, it captures important information about that climate that could impact fisheries productivity.

NASA's Global Change Master Directory publishes the Monthly Multivariate ENSO Index (MEI) (NASA, 2015). For purposes of this analysis, in order to accord with annual fisheries data, the monthly MEI-ENSO index values have been averaged over each calendar year and are introduced into the model as lagged variables, similar to river flow data, to account for environmental factors beyond river flow that might influence fisheries productivity.

Fig. 5.13: MEI-ENSO Index, 1950-2014



Source: NASA (2015)

5.1.8 Value / Opportunity Cost / Shadow Price of Water in the Delta

Economic valuation of water in the Colorado River Delta has occurred through a tradeoff analysis by Medellin-Azuara, et al (2007) and by Schuster, et al (2012) examining agricultural net returns to water (NRTW). This provides a baseline from which we can examine the tradeoffs of moving water from current uses to other uses such as environmental flows.

Table 5.18: Studies of Value of Water in Mexicali Valley and Colorado River Delta

Author(s), Year	Water Use	Value
Medellín-Azuara, et al (2007)	Water for the environment	Marginal cost of water from the Mexicali Valley: • $50 USD per thousand cubic meters (40 MCM/year base flow and 320MCM pulse flow every 4 years) • $80 USD per thousand cubic meters (double above level) The margin cost of water from the United States: • $24 USD (40 MCM/year base flow and 320MCM pulse flow every 4 years) • $35 USD per thousand cubic meters (double above level)
Schuster, et al (2012)	Net returns to water in agriculture	• $1,060.68 pesos ($111.78 USD) per thousand cubic meters of water per hectare for durum wheat • $194.79 pesos ($20.53 USD) per thousand cubic meters of water per hectare for cotton

5.1.9 Input-Output Data

In addition to the national level input-output matrix obtained through INEGI's national accounts, information on gross state product by sector and wages by state and sector were required to disaggregate the national level matrix and estimate state matrices which included households and labor.

Table 5.19: 2008 National & State GDP (in thousands, MXN) & Location Quotients by Sector

NAICS Code	Sector	GDP Mexico	GDP Baja California	GDP Sonora	LQ Baja California	LQ Sonora
11	Agriculture, Forestry, Fishing & Hunting	$18,649,362	$1,010,294	$5,252,314	2.101407	10.48759

21	Mining	$1,298,541,536	$229,835	$22,738,127	0.006866	0.65206
22	Utilities	$517,445,773	$33,824,992	$21,220,547	2.535708	1.527146
23	Construction	$405,388,143	$17,462,247	$14,003,531	1.670919	1.286339
31	Manufacturing	$4,876,999,255	$137,047,964	$158,762,593	1.09005	1.212228
43	Wholesale & Retail Trade	$471,905,392	$14,725,180	$13,215,470	1.210409	1.042837
46	Transportation & Warehousing	$601,102,378	$20,966,071	$17,447,179	1.352991	1.080851
48	Information	$425,694,006	$6,995,426	$6,031,566	0.637445	0.52762
51	Finance & Insurance	$448,716,273	$13,419,227	$11,148,860	1.160064	0.925225
52	Real Estate Rental & Leasing	$657,641,766	$1,052,331	$661,890	0.062071	0.037479
53	Professional, Scientific, & Technical Services	$90,928,887	$3,009,486	$2,344,287	1.283858	0.960059
54	Management of Companies & Enterprises	$167,616,404	$5,797,703	$2,600,922	1.341732	0.57783
55	Administrative and Support and Waste Management and Remediation Services	$113,674,427	$624,314	$0	0.213043	0
56	Education Services	$240,639,795	$5,120,384	$4,238,254	0.825394	0.655856
61	Health Care & Social Assistance	$103,361,529	$2,581,473	$2,057,653	0.968802	0.741314
62	Arts, Entertainment, and Recreation	$75,447,601	$2,977,122	$2,095,538	1.530656	1.034282
71	Accommodation and Food Services	$47,930,678	$2,502,237	$1,584,866	2.025076	1.231311
72	Other Services (except Public Administration)	$283,696,042	$10,029,959	$6,219,014	1.371426	0.816314
81	Public Administration	$153,047,210	$4,157,114	$3,730,543	1.053642	0.907686
	Total	$10,998,426,457	$283,533,359	$295,353,154		

Source: INEGI, 2009; Calculations by author

Table 5.20: Remunerations by Sector, 2008 Economic Census (in thousands $MXN)

NAICS Code	Activity	National	Baja California	Sonora
11	Agriculture, Forestry, Fishing & Hunting	$1,463,773	$111,428	$363,740
21	Mining	$33,185,351	$25,420	$478,949
22	Utilities	$47,242,840	$2,575,641	$1,851,819
23	Construction	$40,711,944	$1,668,195	$1,594,802
31	Manufacturing	$367,792,848	$29,406,525	$13,344,833
43	Wholesale & Retail Trade	$67,764,528	$2,261,444	$2,004,649
46	Transportation & Warehousing	$87,205,461	$3,779,942	$3,329,371

48	Information	$75,697,911	$1,270,377	$1,150,805
51	Finance & Insurance	$47,819,014	$1,400,724	$1,218,845
52	Real Estate Rental & Leasing	$64,093,011	$160,506	$134,145
53	Professional, Scientific, & Technical Services	$7,718,292	$462,918	$228,259
54	Management of Companies & Enterprises	$39,186,043	$897,770	$756,479
55	Administrative and Support and Waste Management and Remediation Services	$7,657,406	$0	$0
56	Education Services	$113,926,340	$2,215,416	$1,923,517
61	Health Care & Social Assistance	$44,789,125	$1,204,669	$892,051
62	Arts, Entertainment, and Recreation	$15,763,429	$655,689	$500,136
71	Accommodation and Food Services	$8,000,824	$730,041	$515,474
72	Other Services (except Public Administration)	$35,547,602	$1,647,283	$1,033,053
81	Public Administration	$23,334,979	$810,931	$763,926
	Total	$1,128,900,721	$51,284,919	$32,084,853

Source: INEGI

INEGI also produces a matrix of technical coefficients derived from the national inter-industry transaction table. This is available at the subsector level which includes 79 subsects, of which Fishing, Hunting and Capture are one. This provides the opportunity to look at technical coefficients and multipliers at the national level to assess impacts, as well as inputs to production for fisheries, though it does not reflect the specific conditions of artisanal fisheries versus industrial fisheries.

Table 5.21: 15 Largest Technical Coefficients for Fishing, Hunting, and Capture Sub-Sector (NAICS 114)

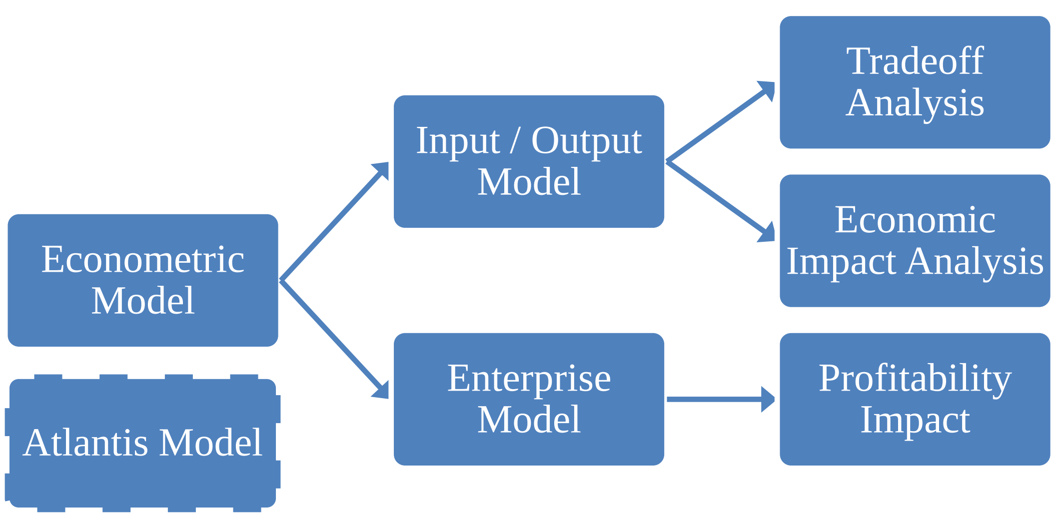
NAICS	Sub-Sector	Technical Coefficient
324	Manufacture of petroleum and carbon based products	0.212493
431	Commerce	0.040699
312	Beverages and tobacco	0.038686

488	Transport related services	0.033875
561	Business support services	0.022698
722	Food and beverage preparation services	0.019067
222	Supply of water and gas via ducts to final consumer	0.016355
532	Equipment rental services	0.015449
114	Fishing, hunting, and capture	0.010765
212	Mining of metallic and non-metallic minerals, except oil and gas	0.009227
484	Cargo transport by auto	0.006655
522	Credit and financial intermediation institutions and financing	0.006169
221	Generation, transmission, and distribution of electric energy	0.005929
325	Chemical industry	0.005794
517	Other telecommunications services	0.003247

5.2 Methodology

The following flowchart provides a schematic of the methodologies employed in this analysis and how the information obtained from each model feeds into subsequent models and, ultimately, final analyses.

Fig. 5.14: Flowchart of Models and Methods



5.2.1 Econometric Model

Catch was modeled as a function of river flows, as well as additional control variables that may influence fisheries productivity, including climate variability, and price. Given the limitations of available time series data for many of the variables, and the constraints of operating with a small number of observations, a series of models were estimated, some with fewer explanatory variables and more observations, and others with more explanatory variables and fewer observations. The models were estimated using ordinary least-squares regressions using SAS® software version 9.3.

For each level of model, a series of permutations combining different variables and transformations of the variables were run in order to identify the models with the best fits for each species. The transformations included using the log and square root of shrimp, corvina catch, and river flows. To adjust for zero values in river flow data, a value of one was added to all river flow data, enabling us to take the log. The various functional forms of the models tested also included linear, quadratic, and cubic river flow terms.

The regression models were assessed for their explanatory power (R^2), the statistical significance of their coefficients, and the overall significance of the models using an F statistic. A full table of models and estimated coefficients is presented in Appendix A.

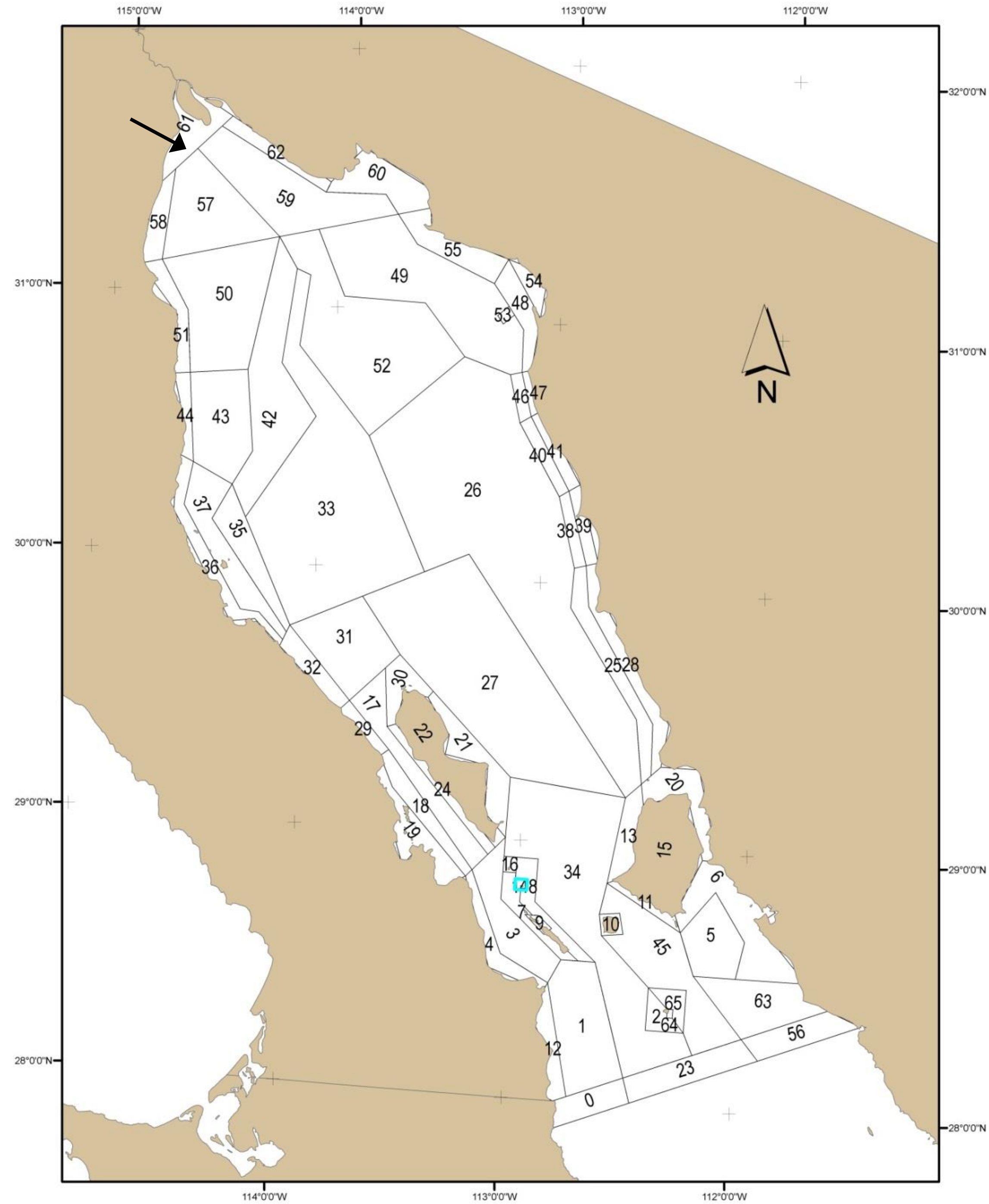
5.2.2 Atlantis Analysis

Assessing the impact of Colorado River flow on Upper Gulf of California fisheries is a complicated question, in part due to the lack of data at an appropriate spatial level in the pre-dam period. Furthermore, other variables have changed over time, including fishing effort, relative prevalence of artisanal fishing versus industrial fishing, and the information available to quantify these changes is limited. That is to say, a baseline for comparison is not easily established. For that reason, it can be helpful to use simulation methods to assess the influence of human and environmental variables on fisheries productivity.

This analysis applies the Atlantis model to the Upper Gulf of California. The Atlantis model is a bioeconomic model based on trophic level relationships between species (Ainsworth, et al, 2012). It integrates the spatial flux of nutrients and biomass in the environment between polygons within the model, as well as the influence of humans on the fisheries, taking into account fishing effort, fishing gear, and spatial and temporal regulations. It is calibrated to the Upper Gulf of California using data collected through the PANGAS project and has been used by Ainsworth, et al (2012) to assess the tradeoffs between conservation efforts to protect the vaquita porpoise and the economic and social interests of Upper Gulf fishing communities.

The Atlantis model allows for the input of freshwater into any given polygon. In this case, the freshwater input was introduced at the northernmost point of the Upper Gulf, the mouth of the Colorado River delta, indicated by the arrow on polygon 61 in Fig. 5.14.

Fig. 5.15: Atlantis Model Polygons for Upper Gulf of California



The objective of the model runs is to isolate the effects of freshwater river inflows into the Gulf and the nutrients that they bring to the ecosystem, biomass, and economic productivity of the fisheries. Therefore, all other variables were held constant, including fishing effort, levels of illegal fishing, fishing gear restrictions, and spatial and temporal fishing closures. The model assumptions reflect the status of the fisheries in 2014, prior to any restrictions currently being debated or implemented related to conservation of the vaquita.

The model takes inputs in time steps. In this case, a monthly time step was used. Nutrient inputs were calculated as a function of the water inflow rate, and were assumed to be at a constant concentration in the water within each individual scenario. The primary functions of the freshwater inputs within the context of the model are influencing water salinity levels and provision of nutrient inputs that drive biological productivity of the ecosystem.

The river flow scenarios were created based off of conservation goals and historic river flow levels. In their Delta Plan of Action (2011), the Sonoran Institute states a goal of achieving a base flow of 50,000 acre feet per year and a pulse flow of 250,000 acre feet every four years by 2022 for the delta. This translates to an average of roughly 2 cubic meters per second in base flows over the course of a year, and roughly 115 cubic meters per second in pulse flow every four years, assuming the pulse flow occurs over one month. As observed in the 2014 pulse flow, the pulse flow lasted for longer than a month, and thus the average daily flow rate of the conservation goal would likely be lower. 130 million cubic meters of water was released over 8 weeks, which translates to an average of roughly 27 cubic meters per second of flows, ignoring the fact that the rate of release was highest at the beginning and declined over the duration of the pulse. If the same quantity of water were released over 4 weeks, it would be equivalent to around 54 cubic meters per second in river flow.

Basing the scenarios loosely off of these conservation goals, the model flow levels entering the Upper Gulf of California were defined as follows:

Table 5.22: Model Flow Scenarios

Flow Component	Flow Level
Low Base Flow	2 m^3 / sec
High Base Flow	5 m^3 / sec
Pulse Flow	15 m^3 / sec every 4 years for month of April

Base flows levels reflect the amount of water reaching the Upper Gulf as surface flows. Though the numbers may appear high relative to the conservation goals (they assume that no water is lost between the US-Mexico border and the Upper Gulf) they also do not take into account water reaching the ocean through subterraneous channels. Evidence supports that subsurface water flows sustain riparian habitat within lower reaches of the delta, though the hydrology of the region is still not fully documented (Dr. Edward Glenn, University of Arizona; personal communication). It is reasonable to assume that there are sub-surface freshwater flows reaching the Upper Gulf, though the magnitude is at present undefined.

The base flow components were then combined in different permutations, including a baseline of zero inflows into the Upper Gulf, base flows alone, pulse flows alone, and a combination of base and pulse flows. These combinations also included varying levels of water salinity, to produce the following flow scenarios. As mentioned, nutrient concentrations were assumed to be constant, and the varying rates of nutrient inflows result from the varying rates of water inflows.

Table 5.23: Flow and Nutrient Scenarios Input into Atlantis Model

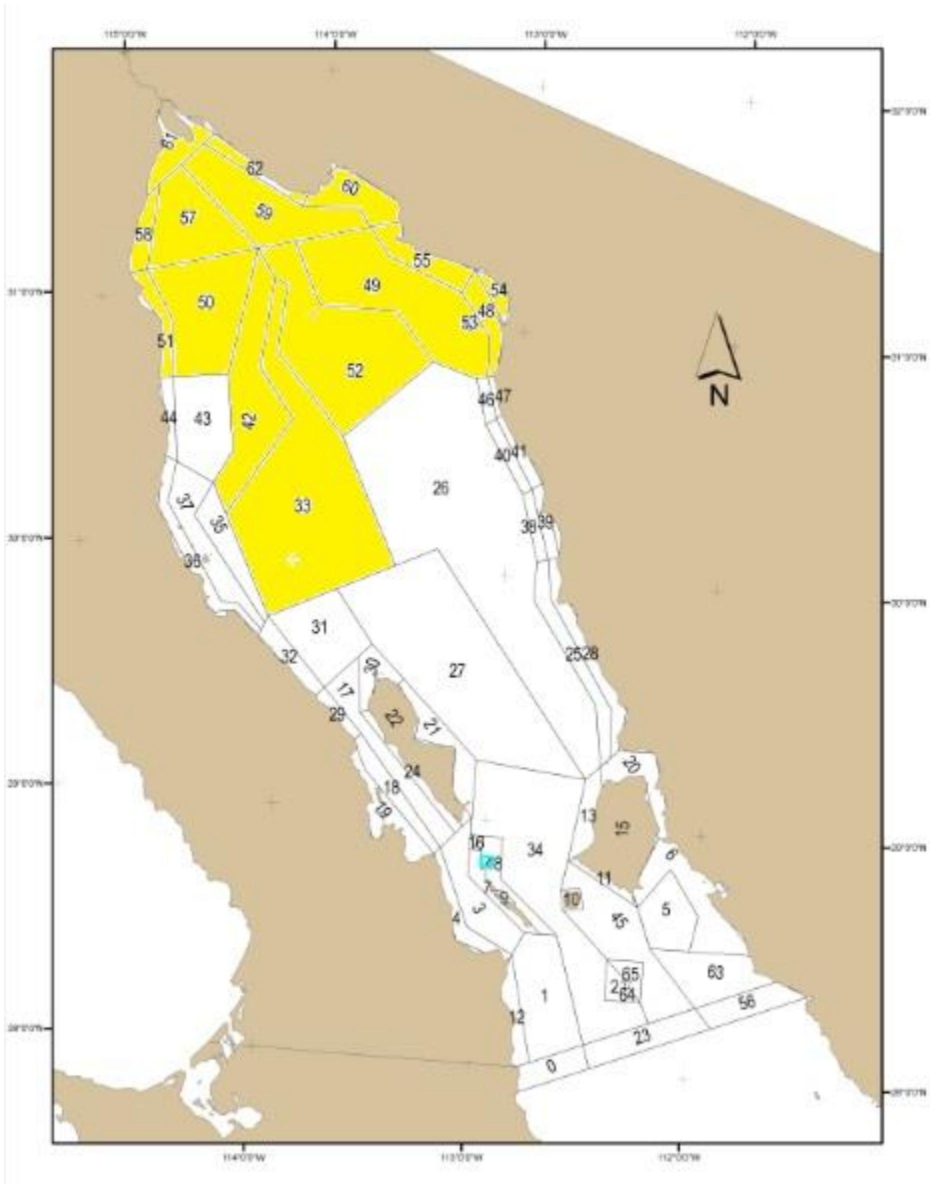
	Scenario	Flows	Salinity	Nutrients
A	Baseline	0 flows reaching Upper Gulf	N/A (0 ppt)	Ammonia: 0 mg/s Nitrate: 0 mg/s Detritus: N/A (0 mg/s) Silica: N/A (0 mg/s)
B	Low Base Flow Alone – Low Salinity	2 m^3 / sec (Sonoran Institute goal)	932 ppm (0.932 ppt)	Ammonia: 227 mg/s base Nitrate: 476.921 mg/s base Detritus: N/A (0 mg/s) Silica: N/A (0 mg/s)
C	High Base Flow Alone – Low Salinity	5 m^3 / sec	932 ppm (0.932 ppt)	Ammonia: 567.5 mg/s base Nitrate: 1,192.3 mg/s base Detritus: N/A (0 mg/s) Silica: N/A (0 mg/s)
D	Pulse Flow Alone – Low Salinity	15 m^3 / sec for month of April once every 4 years	932 ppm (0.932 ppt)	Ammonia: 1,702.5 mg/s pulse Nitrate: 3,576.91 mg/s pulse Detritus: N/A (0 mg/s) Silica: N/A (0 mg/s)
E	Pulse Flow Alone – High Salinity	15 m^3 / sec for month of April once every 4 years	1,864 ppm (1.864 ppt)	Ammonia: 1,702.5 mg/s pulse Nitrate: 3,576.91 mg/s pulse Detritus: N/A (0 mg/s) Silica: N/A (0 mg/s)
F	Low Base Flow & Pulse Flow – Low Salinity	2 m^3 / sec and 15 m^3 / sec for month of April once every 4 years	932 ppm (0.932 ppt)	Ammonia: 227 mg/s base, 1,702.5 mg/s pulse Nitrate: 476.921 mg/s base, 3,576.91 mg/s pulse Detritus: N/A (0 mg/s) Silica: N/A (0 mg/s)
G	Low Base Flow & Pulse Flow – High Salinity	2 m^3 / sec and 15 m^3 / sec for month of April once every 4 years	1,864 ppm (1.864 ppt)	Ammonia: 227 mg/s base, 1,702.5 mg/s pulse Nitrate: 476.921 mg/s base, 3,576.91 mg/s pulse Detritus: N/A (0 mg/s) Silica: N/A (0 mg/s)
H	High Base Flow & Pulse Flow – Low Salinity	5 m^3 / sec and 15 m^3 / sec for month of April once every 4 years	932 ppm (0.932 ppt)	Ammonia: 567.5 mg/s base, 1,702.5 mg/s pulse Nitrate: 1,192.3 mg/s base, 3,576.91 mg/s pulse Detritus: N/A (0 mg/s) Silica: N/A (0 mg/s)
I	High Base Flow & Pulse Flow – High Salinity	5 m^3 / sec and 15 m^3 / sec for month of April once every 4 years	1,864 ppm (1.864 ppt)	Ammonia: 567.5 mg/s base, 1,702.5 mg/s pulse Nitrate: 1,192.3 mg/s base, 3,576.91 mg/s pulse Detritus: N/A (0 mg/s) Silica: N/A (0 mg/s)

J	1993 Scenario – Low Salinity	100 m^3 / sec average for 1 year every 10 years	932 ppm (0.932 ppt)	Ammonia: 11,350 mg/s average during flow years; 0 mg/s during non-flow years Nitrate: 23,846 mg/s average during flow years; 0 mg/s during non-flow years Detritus: N/A (0 mg/s) Silica: N/A (0 mg/s)
K	Pre-Dam Scenario – Low Salinity	300 m^3 / sec average per year	932 ppm (0.932 ppt)	Ammonia: 34,050 mg/s average Nitrate: 71,538 mg/s average Detritus: N/A (0 mg/s) Silica: N/A (0 mg/s)

The output of this model is in terms of fisheries biomass, catch, and net benefits. When compared to the baseline scenario of zero freshwater inflows from the Colorado River, changes in harvest resulting from river flows are estimated. It captures total biomass and catch for major species groups, by specific fishing fleet, and by spatial polygon.

The model was run to include catch in only those polygons that represent fishing zones for the Upper Gulf communities, as pictured below.

Fig. 5.16: Polygons Used in Atlantis Catch Calculations



The Atlantis model does not separate corvina out from other similar species, but rather the catch of corvina can be measured as the share of drums and croakers catch attributable to the gillnet fleet. Shrimp is its own separate group. Though these are the two primary commercial species in question for this analysis, it can be useful to examine other species along different trophic levels as increases in biomass may or may not translate to increases in catch due to increased predation by other species.

5.2.3 Tradeoff Analysis

To analyze the tradeoffs between water for the environment, specifically sufficient river flows to reach the Upper Gulf of California and influence the estuarine environment and fisheries, and other uses of water in the Delta, we can assess the net economic productivity gains or losses of the various river flow scenarios, aiming to identify potential optimal solutions. Impacts on catch of river flow scenarios are estimated using a series of econometric models, and then translated into economic impact using an input-output model.

To calculate foregone production that would occur as a result of fallowing fields to avail the water for environmental restoration, data on acreage planted and water applied per acre can be used to estimate the number of acres that would need to be fallowed in order to provide the target level of environmental flows. According to SAGARPA-SIAP, in 2013, there were a total of 160,988.87 hectares planted and 158,565.37 hectares harvested in the Mexicali Valley, representing a production value of MXN $5,543,054,700. The three primary crops grown in the Mexicali Valley are wheat, cotton, and alfalfa.

Table 5.24: Agricultural Production by Crop in Mexicali Valley, 2013 (2014 MXN)

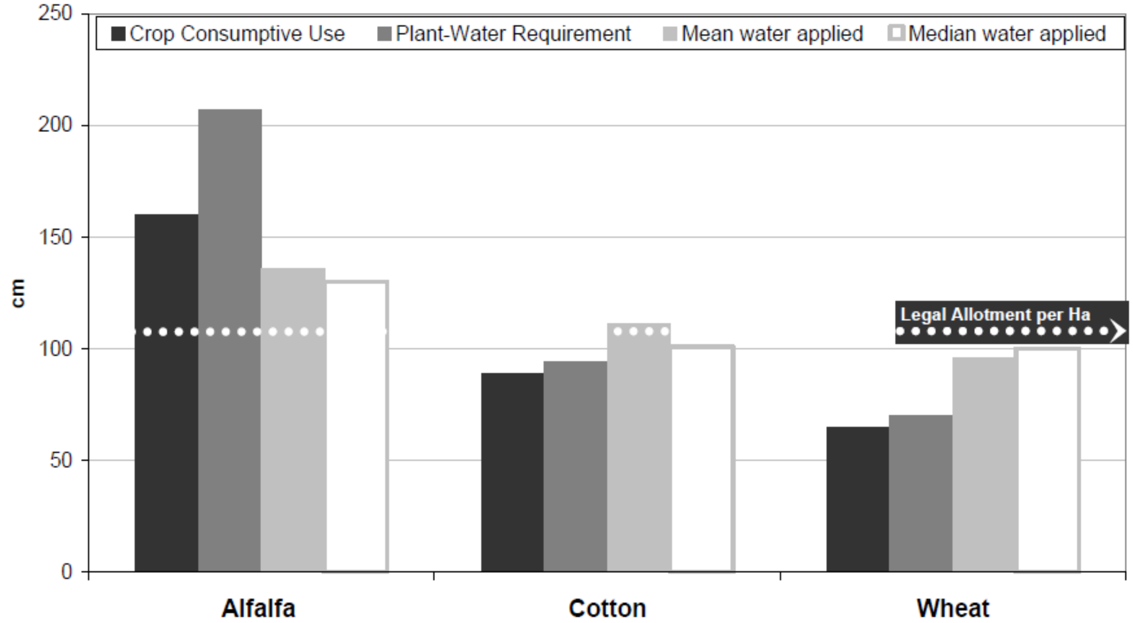
Crop	Area Planted (Ha)	Area Harvested (Ha)	Production (Ton)	Yield (Ton/Ha)	Ave Price ($/Ton)	Production Value (Thous Pesos)
Cotton	22,173.50	21,961.50	106,990.05	4.87	8,505.76	910,031.52
Alfalfa	27,091.00	25,677.00	2,024,882.70	78.86	449.11	909,404.15
Wheat	83,147.00	83,015.00	514,180.48	6.19	3,757.68	1,932,127.65

Source: SAGARPA (2015), Servicio de Información Agroalimentaria y Pesquera

These statistics on acreage planted by crop can be used as a baseline to compare potential changes in acreage planted through fallowing to make that water available for the environment.

For water applied per hectare of crop, there are two potential approaches. The first is to use the legal entitlement in the Mexicali valley, 10,108.8 cubic meters per year per hectare (Carrillo-Guerrero, 2009), or rounded to 10,000.0 cubic meters per year to account for conveyance losses (Francisco Zamora, personal communication). The second would be to use values for crop consumptive use. Finally, mean water application by crop could also be used to determine the number of hectares that would need to be fallowed to make water available for transfer. Applying all three assumptions permits us to obtain a range of potential values for each crop (Dr. Edward Glenn, personal communication).

Fig. 5.17: Crop consumptive use, plant water requirement, mean & median water applied by crop in the Mexicali Valley



Source: Carrillo-Guerrero (2009)

Fig. 5.18: Water application and plant water requirement by crop in Mexicali Valley

	P.Morelos	C.Revolucion	AgWells
Salinity of the irrigation water (dS/m)	1.49	1.65	2.27
Wheat (N=336) (CU=650 mm)	n= 190	n= 81	n= 65
Plant-water requirement (PWR)**(mm)	686 (106% CU)	690 (106% CU)	708 (109% CU)
Water applied (mean) (mm)	959 (104%PWR)	**980 (142% PWR)**	960 (136% PWR)
Alfalfa (N=101) (CU=1,600 mm)	n= 62	n= 20	n= 19
Plant-water requirement (PWR)** (mm)	1,956 (122% CU)	1,991 (124% CU)	2,265 (141% CU)
Water applied (mean) (mm)	1,322 (68% PWR)	1,454 (73% PWR)	1,442 (64% PWR)
Cotton (N=43) (CU=890 mm)	n= 12	n= 7	n= 24
Plant-water requirement (PWR)** (mm)	927 (104% CU)	932 (105% CU)	949 (107% CU)
Water applied (mean) (mm)	**1,158 (125% PWR)**	1,092 (117% PWR)	1,082 (114% PWR)

Source: Carrillo-Guerrero (2009)

Given these values of average water applied, I took the average for the three different irrigation water sources for each crop over the three water sources with different salinities (Morelos Dam, Revolution Canal, and Ag Wells per Carrillo-Guerrero, 2009) (Fig. 5.15), and got average water applied per hectare per crop. Adding the legal allotment per hectare for the Mexicali Valley and average crop consumptive use per hectare estimates, we can obtain a range of values to estimate decreases in crop production due to fallowing associated with shifting water allocation from farming to in-stream flows.

Table 5.25: Crop Water Use Estimates

Crop	Average Water Applied Per Hectare	Crop Consumptive Use per Hectare	Legal Allotment
Wheat	9,663 m^3	6,500 m^3	10,108.8 m^3
Cotton	11,106 m^3	8,900 m^3	10,108.8 m^3
Alfalfa	14,060 m^3	16,000 m^3	10,108.8 m^3

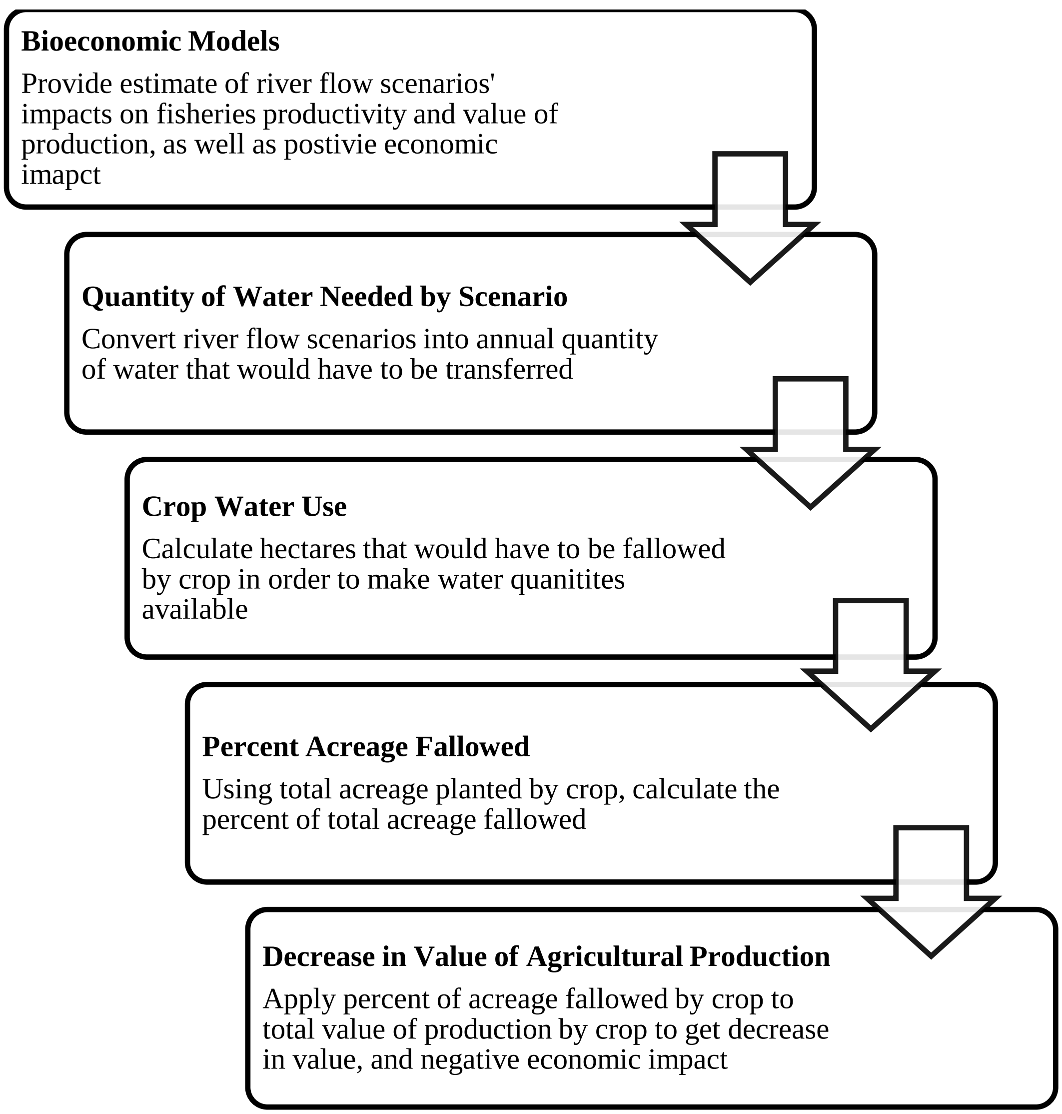
In the case that the cost of acquiring the water is necessary, we can use the shadow value (opportunity cost to other users) of water for the environment, or net returns to water, as a rough proxy of the lower bound of farmers' willingness to accept for water. Farmers, at minimum, week to be compensated for net crop revenues foregone in order to voluntarily refrain from applying water.

Table 5.26: Water Value Estimates

Author(s), Year	Water Use	Value
Medellín-Azuara, et al (2007)	Water for the environment	Marginal cost of water from the Mexicali Valley: • $50 USD per thousand cubic meters (40 MCM/year base flow and 320MCM pulse flow every 4 years)

		• $80 USD per thousand cubic meters (double above level) The margin cost of water from the United States: • $24 USD (40 MCM/year base flow and 320MCM pulse flow every 4 years) • $35 USD per thousand cubic meters (double above level)
Schuster, et al (2012)	Net returns to water in agriculture	• $1,060.68 pesos ($111.78 USD) per thousand cubic meters of water per hectare for durum wheat • $194.79 pesos ($20.53 USD) per thousand cubic meters of water per hectare for cotton

Fig. 5.19: Tradeoff Analysis Process



5.2.4 Input-output analysis

Mexico's Instituto Nacional de Estadistica y Geografia (INEGI) (National institute for Statistics and Geography) produces a national input-output matrix as part of the country's national accounts every five years. The matrices are available by sector, subsector, and industry. The sector matrix includes 19 sectors as well as household consumption and labor earnings, value added, imports and exports, and government expenditures. As mentioned in Chapter 3, state level IO tables are only available through government or academic sources for a handful of states. In order to estimate a regional economic impact, it is necessary to disaggregate the national level matrix to the state level for the two states that encompass the Upper Gulf of California region, Baja California (Norte) and Sonora.

For this analysis, I use the cross industry location quotient method (CILQ) (Flegg, et al, 1995) to disaggregate the national matrix to the state level. The CILQ method was developed in response to systematic inaccuracies in using a simple location quotient (LQ) method to disaggregate IO matrices. Simple LQ methods tend to overestimate multipliers as they do not appropriately account of interregional trade, noting that there is a greater propensity to import at the regional level as compared to the national level (Flegg, et al, 1995). The simple LQ method simply applies the following rule to national technical coefficients (multipliers) to adjust for relative concentrations of economic activity by industry at the regional level:

$$a_{ij}^{local} = \begin{cases} a_{ij}^{national} \; if \; LQ_{ij}^{local} \geq 1 \\ a_{ij}^{national} * LQ_{ij}^{local} \; if \; LQ_{ij}^{local} < 1 \end{cases}$$

CILQ is applied similarly:

$$a_{ij}^{local} = \begin{cases} a_{ij}^{national} \; if \; CILQ_{ij}^{local} \geq 1 \\ a_{ij}^{national} * CILQ_{ij}^{local} \; if \; CILQ_{ij}^{local} < 1 \end{cases}$$

however, the CILQ is obtained with the ratio of location quotients of industries i and j at the local level:

$$CILQ_{ij}^{local} = \frac{LQ_i^{local}}{LQ_j^{local}}$$

While there is still some error associated with this estimation, it provides an improvement over the LQ method (Flegg, et al, 1995).

The 2008 national input-output matrix was used (INEGI, 2008) to estimate the state level matrices for Baja California and Sonora. The 2008 matrix was used because the most recent economic census data available with data on state GDP by sector is the 2009 Economic Census (INEGI, 2009), consisting of data from 2008. The GDP by state data was used to calculate location quotients for the 19 industries, which in turn were used to calculate cross industry location quotients and then estimate the direct requirement matrices. In the case of Sonora, there was one location quotient of zero for Business Support and Waste Remediation Services, in which case I applied the simple location quotients for all input sectors to Business Support and Waste Remediation Services.

The national level matrix includes wages paid to labor as well as household consumption by sector, however, information on household consumption by sector at the state level is not available. Considering that this analysis is focused on estimating the impact of river flows on livelihoods and economic development for the region, it is important to find a way to estimate the household and labor components of the input-output system. For purposes of comparison, I use three different I/O matrices for each state:

1) Open I/O matrix not including influence of households and wages paid to labor
2) Closed I/O matrix assuming equal proportions of household spending by sector at national and state levels; labor as input to production calculated using total gross production by state and remuneration by sector by state data (INEGI, 2009)
3) Closed I/O matrix using location quotients to adjust national level household consumption by sector values; labor as input to production calculated by using total gross production by state and remuneration by sector by state data

The adjustment used in the third I/O matrix multiplies the technical coefficient for household consumption by the local location quotient for the state. These values are then summed over all sectors to insure that the value is equal to one. In the case that it is not, the difference between 1 and the sum of the coefficients is split proportionally amongst the sectors. There are 19 sectors, and the 20th sector represents household consumption and wages paid to labor.

$$\widehat{a_{i,20}^{local}} = LQ_i * a_{i,20}^{national} - \left\{ \left(LQ_i * a_{i,20}^{national} \right) * \left| 1 - \sum_{i=1}^{20} LQ_i * a_{i,20}^{national} \right| \right\}$$

These methods for approximating the state level closed I/O matrices, though imperfect, allow us to estimate the full impact of changes in fisheries productivity on the region. One important shortfall to mention is that this method treats Baja California and Sonora separately, not taking into consideration interstate trade and the feedback effects of rounds of impacts due to demand for goods and services between the two states. As such, the impacts will be more conservative than if we were to have created a multiregional input output (MRIO) system.

Also of interest to regional economic impact analyses are the multipliers contained in the technical coefficient and Leontif inverse matrices. For example, output multipliers measure the amount of output required from each industry i in order to produce one dollar or peso of output in a given industry j. This is also known as total backward linkages, the direct and indirect inputs from other industries that industry j depends on and indirectly creates through an increase in demend. Summing over all industries providing inputs, we can obtain the total output from the economy induced by a change in demand from industry j. In a closed model that includes households, households are excluded from the summation calculating the multiplier.

$$O_j = TBL_j = \sum_{i=1}^{n} b_{ij}$$

Another piece of useful information is contained in the technical coefficient matrix. Each element a_{ij} of the matrix provides the proportion of input supplied by each industry i for one peso or dollar of output in industry j. The technical coefficient matrix therefore can provide information on the cost structure of the fisheries and the direct impact on suppliers along the fisheries value chain.

CHAPTER SIX: MODELS & RESULTS

6.1 Econometric Model

The objective of developing econometric models for this project is to create a model capturing the relationship between river flows and fisheries productivity. Metric tons of catch for shrimp and corvina were regressed against river flows, introducing a variety of control variables. 1-year lagged catch was introduced into the models to control for autocorrelation in the catch data. The combinations of variables included in the models followed this general pattern:

1) Flow (linear, quadratic, and cubic) lagged according to literature on species' biologic response to river flows, and 1-year lagged catch
2) Flow (as above), 1-year lagged catch, MEI ENSO index lagged at same interval as river flows
3) Flow (as above), 1-year lagged catch, MEI ENSO index (as above), price (shrimp, corvina, corvina buche) or price interaction term for corvina

Diagnostics were run on all regressions to detect problems of heteroskedasticity and collinearity. There issues were not present in the data. First-order autocorrelation, however, was present in the catch data and was addressed by introducing a1-year lagged catch term into the models.

For shrimp, the models with the greatest overall statistical significance and explanatory power were those models that included only lagged catch and river flows, both linear and quadratic (p-values in parentheses):

Model 1

$$Shrimp_t = 1508 + 14.6 * flow_{t-1} + 0.45 * Shrimp_{t-1}$$

(0.024) (0.031) (0.014)

$R^2 = 0.333$, $p > F = 0.009$

Model 2

$$Shrimp_t = 1520 + 0.136 * flow_{t-1}^2 + 0.46 * Shrimp_{t-1}$$

(0.020) (0.019) (0.011)

$R^2 = 0.359$, $p > F = 0.006$

Both models indicate a positive correlation between catch and 1-year lagged flows. It's important to note that the functional form of the model has a major influence on the magnitude of estimated influence on catch. Additional model runs and results can be found in Appendix A. In most models tested, the models that used the square and cube of river flow had greater explanatory power than those that used linear river flows. The square and cubed functional forms operate in a matter that amplifies the difference between zero and non-zero flow years and those years with high flows. In fact, this may in effect account for the fact that only those years with especially high flows would have water reaching the Upper Gulf. Log-log transformation of the models also yielded models with statistically significant coefficients, however, their adjusted R^2 values were lower than the non-transformed models. In the corvina data, log-log models produced very high R^2 values, however, in these models only lagged catch showed to be statistically significant.

Estimating the influence of river flows on the corvina fishery presents a number of challenges due to the re-emergence of the fishery in the early 1990s. The fishery disappeared in the 1960s and then reemerged in the 1990s from zero catch to thousands of metric tons of catch by the early 2000s. This reemergence cannot be explained with available data and there is not a consensus among scientists on what caused the reemergence. As such, it is difficult to account for the dramatic increase in corvina catch in the 1990s within the model and considering the small number of observations available on corvina catch, it is not possible to simply ignore earlier period data. There is a high degree of autocorrelation in corvina catch data. The model with greatest explanatory power and statistical significance (aside from the simple autoregressive model) included river flows, lagged catch, MEI ENSO index, and an interaction term between the price of corvina and the price of buche (p-values in parentheses):

Model 21

$$Corvina_t = 1877 + 0.207 * flow_{t-4}^2 + 0.35 * Corvina_{t-4} + 940.5 * ENSO_{t-4} + 0.117 * PriceCorvina_t * PriceBuche_t$$

(0.049) (0.064) (0.129) (0.025) (0.161)

$R^2 = 0.654$, $p > F = 0.033$

For the corvina model, in order to address potential issues of endogeneity with the price variable, a lagged price interaction term was also included, however, there was a high level of collinearity between the two price terms and it was deemed preferable to exclude the lagged price term from the model. Endogeneity and excluded variable bias are potential issues in all models, however, lack of available data makes it infeasible to control for these problems.

In addition to linear regressions, a series of models with transformed dependent and explanatory variables were run including log-log models and the square root of catch. These models generally did not outperform the models with linear dependent variables. Chow tests were also run on flow data against catch data to test for structural breaks that might suggest that a threshold function would be the best fit for the data. In theory the possibility of structural breaks or threshold functions of flow versus catch fit well with the context of the research question and data, considering that the flows at the Southern International Boundary do not represent the quantity of water that reaches the Upper Gulf and only a certain proportion of flows would reach the sea after passing through the Delta. The Chow tests, however, did not indicate any structural break in the data and thus it was concluded that threshold functions were not the appropriate model for the data. Finally, first difference models were run, measuring the difference in the variables from one year to the next. These models generally did not outperform the other models and using first difference eliminated one degree of freedom in the models.

Based on the regression results, I created a spreadsheet model which uses the estimated models and coefficients. The spreadsheet model is then applied to modify the values of the variables in order to assess the value of predicted catch.

Fig. 6.1: Catch Projection Model

Model	Catch Variable		Lag Catch		Flow Lag1 (m3/s)			Flow Lag4 (m3/s)			ENSO				Price/kg (assumes MXN)			Other	Intercept	Func Value	Est Catch (met. Tons)	Change Catch (met tons)	Catch Change Kilos	Catch Change Value
	S	C	Shrimp	Corvina	Lin.	Quad.	Cub.	Lin.	Quad.	Cub.	lag1	lag2	lag3	lag4	Shr.	Cor.	Buche							
2	X		0.45831			0.13622													1519.95	3052.82	3052.82	13.622000	13622.00	$1,634,640
1	X		0.45038		14.56526														1508.00	3146.62	3146.62	145.652600	145652.60	$17,478,312
21		X		0.34699					0.21					940.48		0.12	int		1876.89	3226.81	3226.81	20.678000	20678.00	$769,174

	1	2	3	4		
lagshrimp	3314.9	1	1	1	1.15	138000
lagcorvin	2940	1	1	1		
flow	10	10	10	10		
enso	0.0305	0.0305	0.03054	0.0305		
priceshri	120					
pricecor	37.198					
pricebuc	64.378					

Assessing all control variables aside from flow (MEI ENSO, prices) at their averages (average over available data for prices, average over 1950-2014 for MEI ENSO, average over sample period for lagged catches) and then varying flow at different levels, I obtained the following trajectories of the value fisheries catch by freshwater inflow levels, assuming that increased catch does not influence price received per unit of catch. These scenarios also do not account for effort. The projected change in value of catch assumes a price of $120 pesos per kilo for shrimp, $37 pesos per kilo for corvina, and $64 pesos per kilo for corvina buche. $120 pesos per kilo for shrimp reflects a combination of recent market prices in major metropolitan markets, as well as beach prices reported by fishermen in field work which varied considerable depending upon size, species, and time of season. $37 pesos per kilo for corvina falls between the $38 pesos per kilo market price at Nueva Viga in 2014 and $13 pesos per kilo ex-vessel price as reported by CapLog Group (CapLog, 2014), however, assuming a price higher than ex-vessel price is appropriate to account for the value of buche obtained from the corvina. According to CapLog Group (CapLog, 2014), buche accounted for 35% of fleet revenue in 2014. A price of $64 pesos per kilo for corvina buche is a very conservative number considering that fishermen reported receiving prices in excess of $400 pesos per kilo in recent field interviews during the 2015 season (see Appendix C).

Using the results of the regression models, confidence intervals were estimated around the predicted catch values by assessing the variance of the predicted model at the selected flow levels of 0, 1, 2, 5, and 10 cubic meters per second:

Model 1:

$$Var\ [\widehat{Shrimp}_t] = Var[1508 + 14.6 * flow_{t-1} + 0.45 * Shrimp_{t-1}]$$

Model 2:

$$Var[\widehat{Shrimp}_t] = Var[1520 + 0.136 * flow_{t-1}^2 + 0.46 * Shrimp_{t-1}]$$

For the corvina model's predicted catch, the estimated variance was negative, likely due to the small number of observations in the corvina model. Therefore confidence intervals about the corvina catch estimates were not estimated. Also complicating the variance is the fact that the calculated confidence intervals for shrimp decreases in size with increasing flow levels. Therefore in calculating the change in flow estimated through the high and low confidence intervals, the high and low scenarios at times flipped with the high model predicting the low change in catch and the low model predicting the high change in catch. The calculated confidence intervals were used to create high and low scenarios around the estimates of catch and change in catch.

Fig. 6.2: Estimated Shrimp Catch by Model & Flow Level

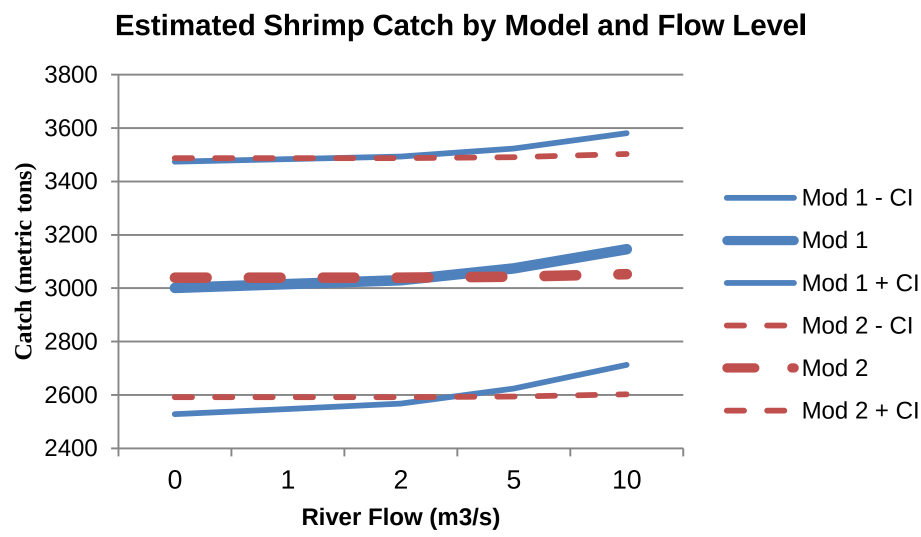
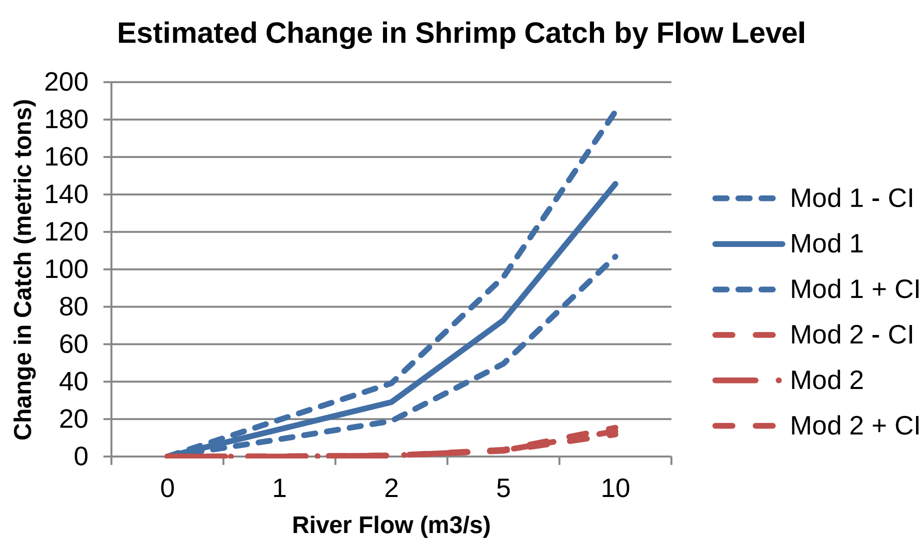


Fig. 6.3: Estimated Change in Shrimp Catch by Flow Level



It is particularly evident in this graph (Fig. 6.3) the substantial difference that the models' functional forms (linear versus quadratic flow term) make in the estimation of the impacts on catch. This trend was consistent across estimated models – linear models estimated a much larger effect of freshwater on fisheries catch than quadratic or cubic models. The scientific literature on relationships between flows, biomass, and catch does not suggest one functional form over another. Most literature uses simple linear correlations between catch and flows to estimate correlation coefficients (Aragon & Calderon (2000); Calderon and Flessa (2009); Lercari & Chavez (2007)). Perez-Arvizu, et al (2008) find that a polynomial equation produces the best fit between CPUE and river flows, and Galindo-Bect & Glenn (2000) find that a function using the log of river flows produces the best fit.

Fig. 6.4: Estimated Corvina Catch by Flow Level

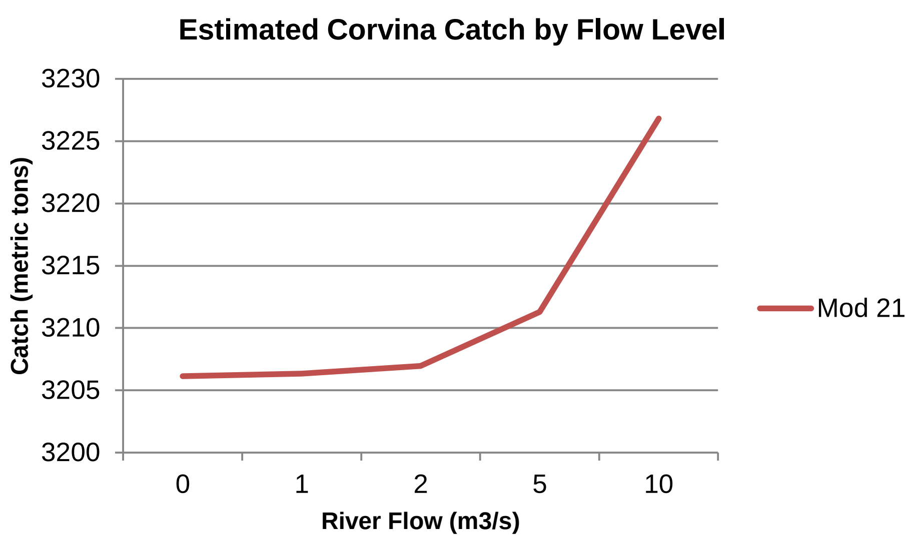


Fig. 6.5: Estimated Change in Corvina Catch by Flow Level

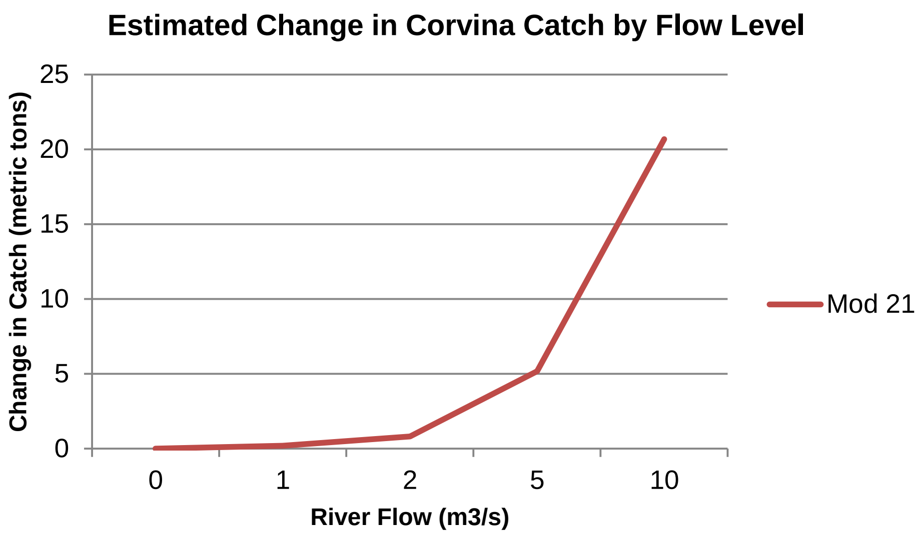


Table 6.1: Modeled Change in Value of Catch for Shrimp & Corvina by Flow Level

Model 1 - Shrimp			
	Mod 1 + CI	**Mod 1**	**Mod 1 - CI**
0	$0	$0	$0
1	$2,372,655	$1,747,831	$1,123,007
2	$4,712,358	$3,495,662	$2,278,966
5	$11,523,218	$8,739,156	$5,955,094
10	$22,121,981	$17,478,312	$12,834,643
Model 2 - Shrimp			
	Mod 2 + CI	**Mod 2**	**Mod 2 – CI**
0	$0	$0	$0
1	$20,791	$16,346	$11,902
2	$68,795	$65,386	$61,976
5	$375,390	$408,660	$441,930
10	$1,419,055	$1,634,640	$1,850,225
Model 21 - Corvina			
	N/A	**Mod 21**	**N/A**
0		$0	

1		$7,692	
2		$30,767	
5		$192,294	
10		$769,174	

6.2 Atlantis Model

The Atlantis model was run for 11 flow scenarios, encompassing a Baseline scenario of zero freshwater flows into the Upper Gulf, a variety of target conservation base flow and pulse flow levels, a scenario mimicking the 1993 floods, and a pre-dam flow level scenario. The model produces outputs in terms of biomass, relative biomass, catch, relative catch, and net benefits of the fisheries, by species, and at different spatial levels. The model assumes spatial restrictions and fishing effort level (both legal and illegal) prior to any recent or proposed changes in the Upper Gulf fisheries. The nutrient inputs do not include detritus or silica, but do however include nitrogen and ammonia.

Initial results show a very small response in biomass to the river flows. However, catch does not exhibit a corresponding increase. There is not enough of a response in the model at present to decipher a functional form for the change in biomass or catch resulting from changes in river flows, though an initial examination of the response of biomass to the two base flow scenarios (Scenario B with 2 cubic meters per second in base flow and Scenario C with 5 cubic meters per second in base flows) suggests there may be decreasing marginal gains in fisheries productivity from freshwater flows into the Upper Gulf. One exception is the highest flow scenario, the pre-dam scenario, where very modest increases in catch are observed. One suspected explanation for the lack of response in the model is the fact that detritus values for Colorado River flows were not included as an input due to having no reliable estimate of detritus levels in the water. Detritus is a key food source for shrimp and other bottom-dwelling creatures and plays an important role in the foodchain. Opportunities for future research include refining the inputs for this model to better capture the effects of freshwater on the ecosystem.

Table 6.5 presents the predicted change in biomass and catch of shrimp by the Atlantis model. Despite very small predicted increases in biomass for the Upper Gulf, catch, and consequently net benefits to fisheries, are negative. This could possibly be explained due to increased predation in the ecosystem, leading to a net decrease in catch by fisheries. The only exception is the pre-dam scenario (Scenario K), also the highest flow scenario. The pre-dam scenario still predicts a relative small increase in biomass, but the change is large in relation to the other flow scenarios. It also yields a net positive change in shrimp catch.

Table 6.2: Atlantis Results

Scenario	Change in Biomass	Change in Catch
A – Baseline	N/A	N/A
B	0.016%	-0.001%
C	0.039%	-0.004%
D	0.004%	-0.001%
E	0.004%	-0.001%
F	0.018%	-0.002%
G	0.018%	-0.002%
H	0.040%	-0.004%
I	0.040%	-0.004%
J	0.008%	-0.004%
K	0.477%	0.011%

Not all species were modeled as experiencing negative changes in catch. Overall though, there was a predicted negative change in net benefits to fisheries. These results must be interpreted with caution as additional work will be needed to better quantify nutrient and food-source inputs into the marine environment from the Colorado River.

6.3 Economic Impact Analysis

To assess the economic impact of potential flow scenarios, the modeled changes in value of catch from the econometric analysis, representing economic shocks, will be introduced into the input-output models for Sonora and Baja California. The total change in value of catch (revenue) will be use as opposed to profits because the input-output model takes change in production as the economic shock and were we to use profits net of expenses, it would be as if we were ignoring the impact of all inputs to production.

The share of change in value of catch must be split appropriately between the two states. The proportion of catch by state was calculated using DataMares data from 2001-2013 which is broken down by species and state. The breakdown is as follows:

Table 6.3: Breakdown of Catch by Species by States

Species	Baja California	Sonora
Shrimp	18%	82%
Corvina	14%	86%

Using these proportions, low, medium, and high estimates of change in value were created for each state and species and flow level. The model with the lowest projected change in catch for each species was designated as the 'low' scenario and the model with the highest projected change in catch for each species was designated as the 'high' scenario. The 'medium' scenario represents the average projected catch of all selected models for each species. These values represent the economic shocks that will be introduced into the input-output model.

Table 6.4: Estimated Economic Shocks by Model and Flow Level for Baja California

Model 1 Shrimp Change Baja California			
	Mod 1 – CI	**Mod 1**	**Mod 1 + CI**
0	$0	$0	$0
1	$427,078	$314,610	$202,141
2	$848,224	$629,219	$410,214
5	$2,074,179	$1,573,048	$1,071,917
10	$3,981,957	$3,146,096	$2,310,236
Model 2 Shrimp Change Baja California			
	Mod 2 – CI	**Mod 2**	**Mod 2 + CI**
0	$0	$0	$0
1	$3,742	$2,942	$2,142
2	$12,383	$11,769	$11,156
5	$67,570	$73,559	$79,547
10	$255,430	$294,235	$333,041
Model 21 Corvina Change Baja California			
	N/A	**Mod 21**	**N/A**
0		$0	
1		$1,077	
2		$4,307	
5		$26,921	
10		$107,684	

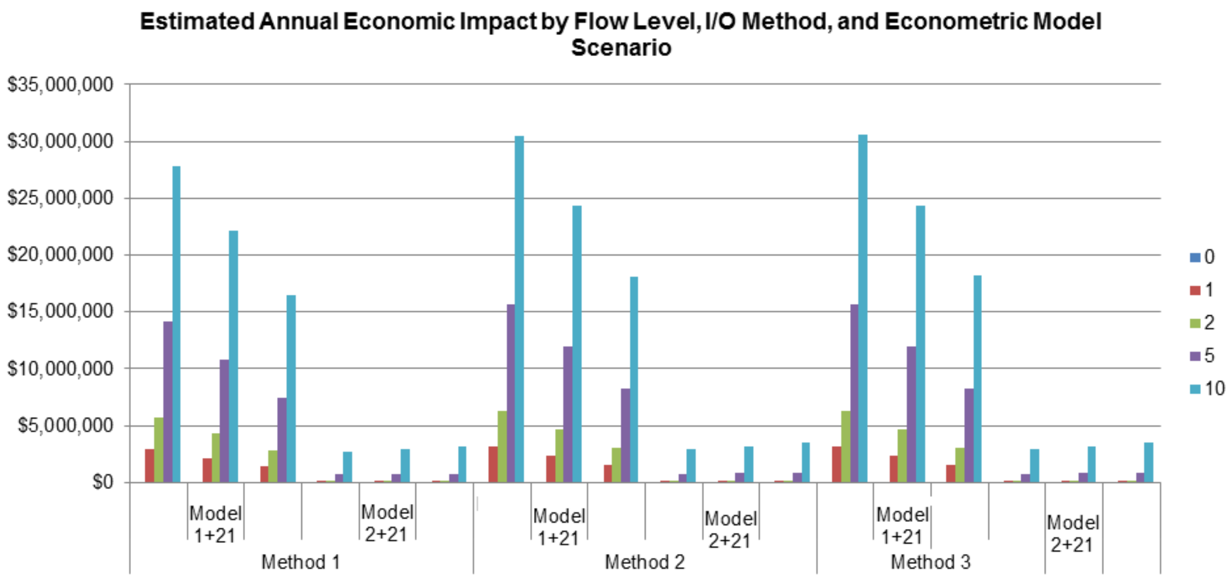
Table 6.5: Estimated Economic Shocks by Model and Flow Level for Sonora

Model 1 Shrimp Change Sonora			
	Mod 1 – CI	**Mod 1**	**Mod 1 + CI**
0	$0	$0	$0
1	$1,945,577	$1,433,222	$920,866

2	$3,864,134	$2,866,443	$1,868,753
5	$9,449,039	$7,166,108	$4,883,177
10	$18,140,024	$14,332,216	$10,524,408
Model 2 Shrimp Change Sonora			
	Mod 2 – CI	**Mod 2**	**Mod 2 + CI**
0	$0	$0	$0
1	$17,048	$13,404	$9,760
2	$56,412	$53,616	$50,820
5	$307,820	$335,101	$362,382
10	$1,163,625	$1,340,405	$1,517,185
Model 3 Corvina Change Sonora			
	N/A	**Mod 21**	**N/A**
0		$0	
1		$6,615	
2		$26,460	
5		$165,372	
10		$661,490	

Introduced into the input-output model, these shocks yield our estimated economic impacts. They are presented by method (Method 1: no labor or households; Method 2: including labor and households assuming national household spending by sector; Method 3: including labor and households with regionally adjusted household spending by sector). Due to a lack of confidence intervals for the corvina model, the same values were assumed for high, medium, and low scenarios. A full table of results is available in Appendix D.

Fig. 6.6: Annual Economic Impact by Scenario, Method, and Flow Level



Depending upon the model assumptions, method of I/O calculation, and flow level modeled, the economic impact to the region of changes in productivity could range from roughly $23,000 at the very lowest (Model 2+21, 1 cubic meter per second, I/O calculation methods not including households) to roughly $30 million pesos in increased economic output (Model 1+21, 10 cubic meters per second, I/O calculation including households with a regionalized consumption ratio). This corresponds to roughly $1,500 USD to $2 million USD in increased annual economic output.

Compared to existing studies valuing the Upper Gulf of California fisheries, these estimates of economic impact fit comfortably within the range of existing estimates. A change in primary productivity ranging from roughly $19,000 to $23 million, net of operating costs, fits well within the range of existing studies valuing the Upper Gulf fisheries. The World Wildlife Fund's 2006 study (WWF, 2006) estimates the value of profits from gillnet fisheries at $30,219,913 pesos annually, $42,109,905 in 2014 pesos. .

Of these estimated economic impacts, a high proportion of the impact falls within the Agriculture, Forestry, Fishing, and Hunting sector, followed by manufacturing, and finally, in the case of the calculations including labor and households, wages to labor. The proportion attributable to manufacturing is due in part to the heavy reliance on gasoline and diesel as an input to production. Labor represents only a small share of the impact, as the Upper Gulf of California fisheries are a predominantly extractive industry with few value-added activities taking place in the region. For the most part, catch is landed, in some cases processed and prepared for transport, and then shipped either internationally or to major urban markets domestically.

Table 6.6: Proportion of Economic Impact by Sector by I/O Method

Sector	Method 1 No Labor	Method 2 w/ Labor	Method 3 w/ Labor
Ag., Forestry, Fishing & Hunting	91.46%	79.16%	79.84%
Mining	0.15%	0.28%	0.29%
Utilities	0.59%	0.74%	0.81%
Construction	0.05%	0.05%	0.05%
Manufacturing	5.84%	8.90%	9.20%
Wholesale & Retail Trade	1.19%	2.01%	2.03%
Transportation & Warehousing	0.26%	0.84%	0.87%
Information	0.03%	0.28%	0.17%
Finance & Insurance	0.18%	0.48%	0.45%
Real Estate Rental & Leasing	0.01%	0.91%	0.05%
Prof. Sci., & Tech. Svcs	0.11%	0.25%	0.24%
Mgmt of Co's & Enterprises	0.03%	0.05%	0.05%
Admin. & Support & Waste Mgmt & Rem. Svcs	0.02%	0.05%	0.03%
Education Svcs	0.00%	0.09%	0.06%

Health Care & Social Assist.	0.00%	0.09%	0.06%
Arts, Entert, & Recr.'n	0.00%	0.05%	0.05%
Accom. & Food Serv.	0.03%	0.28%	0.35%
Other Svcs	0.04%	0.25%	0.23%
Public Admin.	0.00%	0.00%	0.00%
Labor	0.00%	5.24%	5.18%

Using the economic shocks and resulting economic output, an output multiplier can be inferred for fishing activities. It is estimated at roughly 1.35 using methods that include households and labor. This compares very closely with values obtained by Fuentes-Flores (2002) of 1.4182 for fisheries and hunting using the CILQ method, and an overall average of 1.3135 for fishing and hunting using multiple methods It is lower, though not far, from the estimation by Cortes-Ortiz, et al (2006) of the output multiplier for Baja California Sur of 1.56. It is important to note the high level of sectorial aggregation used in this analysis, which may account for the difference in estimated multipliers.

6.4 Tradeoff Analysis

A tradeoff analysis allows us to weight the net impacts of shifting water from one economic use to another. In this instance, a tradeoff analysis can be performed in terms of the impact on economic output of different tradeoff scenarios. The following section presents the results of the sequential steps required to assess the net impact of the tradeoff.

Step 1. Bioeconomic Models

Bioeconomic models provide an estimate of the river flow scenarios' impacts on fisheries productivity and the value of production, and can be extended to provide a measure of economic impact of changes in fisheries production by introducing those changes in production into the input-output model. The results of this analysis have been presented earlier in this chapter and the information will be integrated into subsequent steps.

Step 2. Quantity of Water Needed by Scenario

River flow scenarios must be converted into the annual quantity of water that would have to be shifted from one use to another.

Table 6.7: Annual Flow Volume by Flow Scenario

Average Flow (m3/s)	Annual Flow (thous. m3)
0	0
1	31,536
2	63,072
5	157,680
10	315,360

Step 3. Crop Water Use

To estimate in monetary terms the tradeoff between jobs and output in the fisheries and agricultural sectors, we calculate the number of hectares that would have to be fallowed per crop in order to make water quantities available. For the crop fallowing scenarios, it is assumed that the specified quantity of water would be made available through fallowing of that crop alone. In some situations, more acreage would have to be fallowed than currently exists in the Mexicali

Valley, yielding scenarios that were not feasible, indicated below. The crop shifting scenarios assume that a given quantity of acres of alfalfa would be shifted to cotton or wheat and the difference in water applied would be transferred to environmental flows. These values of acreage to be fallowed were calculated based upon three crop water use assumptions, described in section 5.2.3. They assume that the water was made available by fallowing only one crop, and not a combination of crops. In some cases, the area that must be fallowed is larger than the area planted as of 2013.

Table 6.8: Water Use Assumptions by Scenario, Crop, and Estimate Method

	Alfalfa			Cotton			Wheat		
Flow (m3/s)	Ave applied / Ha	Crop CU / Ha	Legal Allotment	Ave applied / Ha	Crop CU / Ha	Legal Allotment	Ave applied / Ha	Crop CU / Ha	Legal Allotment
0	0	0	0	0	0	0	0	0	0
1	2,243.0	1,971.0	3,119.7	2,839.5	3,543.4	3,119.7	3,263.6	4,851.7	3,119.7
2	4,485.9	3,942.0	6,239.3	5,679.1	7,086.7	6,239.3	6,527.2	9,703.4	6,239.3
5	11,214.8	9,855.0	15,598.3	14,197.7	17,716.9	15,598.3	16,317.9	24,258.5	15,598.3
10	22,429.6	19,710.0	31,196.6	28,395.5	35,433.7	31,196.6	32,635.8	48,516.9	31,196.6

* CU = Consumptive Use

Step 4. Percent Acreage Fallowed

Using total acreage planted by crop, we calculate the percent of total acreage that must fallowed, using numbers from Step 3. These percentages only apply to fallowing alone and not to crop shifting.

Table 6.9: Estimated Percentage of Planted Cropland to Be Fallowed

	Alfalfa			Cotton			Wheat		
Flow (m3/s)	Ave applied /	Crop CU / Ha	Legal Allotmen	Ave applied /	Crop CU / Ha	Legal Allotmen	Ave applied /	Crop CU / Ha	Legal Allotmen

	Ha		t	Ha		t	Ha		t
0	0	0	0	0	0	0	0	0	0
1	8.3%	7.3%	11.5%	12.8%	16.0%	14.1%	3.9%	5.8%	3.8%
2	16.6%	14.6%	23.0%	25.6%	32.0%	28.1%	7.9%	11.7%	7.5%
5	41.4%	36.4%	57.6%	64.0%	79.9%	70.3%	19.6%	29.2%	18.8%
10	82.8%	72.8%	*115.2%	*128.1%	*159.8%	*140.7%	39.3%	58.4%	37.5%

* Scenario not feasible

As mentioned in the previous step, it is important to note that for both cotton and alfalfa, in the 10 cubic meter per second flow scenarios, more acreage of the croup would have to be fallowed than was planted in the Mexicali Valley in 2013, depending upon which of the three alternative water use assumptions is employed.

Step 5. Decrease in Value of Agricultural Production

Applying the percentage of acreage fallowed by crop to the total value of production by crop to get a decrease in value of agricultural production, we can then estimate the negative economic impact of fallowing the crops. It needs to be noted that, in voluntary fallowing agreements, farmers would receive full compensation for net income sacrificed in return for the water provided by fallowing. These compensation payments would generate positive economic effects beyond the scope of this study to analyze.

Table 6.10: Decrease in Value of Production by Crop (Thous. 2014 MXN)

	Alfalfa			Cotton			Wheat		
flow (m3/s)	Ave applied / Ha	Crop CU / Ha	Legal Allotmen t	Ave applied / Ha	Crop CU / Ha	Legal Allotment	Ave applied / Ha	Crop CU / Ha	Legal Allotmen t
0	0	0	0	0	0	0	0	0	0
1	-$72,493	-$75,406	-$78,437	-$81,589	-$84,867	-$88,278	-$91,825	-$95,515	-$99,354
2	-$144,986	-$150,812	-$156,873	-$163,177	-$169,735	-$176,556	-$183,651	-$191,031	-$198,708

5	-$362,465	-$377,031	-$392,183	-$407,943	-$424,337	-$441,389	-$459,127	-$477,577	-$496,769
10	-$724,930	-$754,062	-$784,365	-$815,886	-$848,673	-$882,778	-$918,254	-$955,155	-$993,539

For simplicity of calculation, all agricultural productivity changes were assumed to occur in Baja California. Shifting a small portion of the productivity to Sonora for purposes of the input-output calculation would only yield a very small change in the value.

Table 6.11: Economic Impact of Reduction in Value of Production (Thous. 2014 MXN)

	Alfalfa			Cotton			Wheat		
flow (m3/s)	Ave applied / Ha	Crop CU / Ha	Legal Allotment	Ave applied / Ha	Crop CU / Ha	Legal Allotment	Ave applied / Ha	Crop CU / Ha	Legal Allotment
0	0	0	0	0	0	0	0	0	0
1	-$113,226	-$117,776	-$122,509	-$127,432	-$132,553	-$137,880	-$143,420	-$149,184	-$155,179
2	-$226,451	-$235,551	-$245,017	-$254,864	-$265,106	-$275,759	-$286,841	-$298,368	-$310,358
5	-$566,128	-$588,879	-$612,543	-$637,159	-$662,764	-$689,398	-$717,102	-$745,920	-$775,896
10	-$1,132,256	-$1,177,757	-$1,225,087	-$1,274,318	-$1,325,528	-$1,378,796	-$1,434,205	-$1,491,840	-$1,551,791

For purposes of the tradeoff analysis, I will use an average of the three site estimates of average water applied per hectare per crop provided by Carrillo-Guerrero (2009) for each crop and river scenario.

Also calculated was a scenario where in order to make the required volume of water available, one third of acres fallowed were alfalfa, one third cotton, and one third wheat.

Table 6.12: Average Economic Impact to Ag by Crop and Flow Scenario (Thous. 2014 MXN)

flow (m3/s)	Alfalfa Only	Cotton Only	Wheat Only	1/3 Alfalfa, 1/3 Cotton, & 1/3 Wheat
0	$0	$0	$0	$0

1	-$117,837	-$132,621	-$149,261	-$138,377
2	-$235,673	-$265,243	-$298,522	-$276,754
5	-$589,183	-$663,107	-$746,306	-$691,884
10	-$1,178,367	-$1,326,214	-$1,492,612	-$1,383,768

The 10 cubic meter per second scenario fallowing cotton was removed because the area of cotton that would have to fallowed is larger than what was planted in 2013.

Additional scenarios were added to the analysis to include crop shifting between instead of fallowing fields, trading acres of alfalfa, the highest per hectare water use crop, to either wheat or cotton, lower water use crops. This assumes there are not negative effects on productivity resulting from planting a larger quantity of the same crop. Shifting wheat for alfalfa, using the value of Average Water Applied per Hectare, would yield a reduction of 4.397 thousand cubic meters per hectare per year.

Table 6.13: Crop Shifting Requirements by Flow Scenario, Alfalfa to Wheat

Flow scenario	Water requirement (thous m3)	Crop shifting (Alfalfa to Wheat) requirement (ha)
0	0	0
1	31,536	7,172.16
2	63,072	14,344.33
5	157,680	35,860.81
10	315,360	71,721.63

The 5 and 10 cubic meter per second scenarios were removed because the area of alfalfa that would have to be fallowed is larger than what was planted in 2013.

The same tradeoff can be made between alfalfa and cotton. Roughly 3 thousand cubic meters of water are made available for transfer in shifting one hectare of alfalfa for cotton. Once again, the 5 and 10 cubic meter per second scenarios were removed from consideration as they would require more alfalfa be fallowed than was planted in 2013.

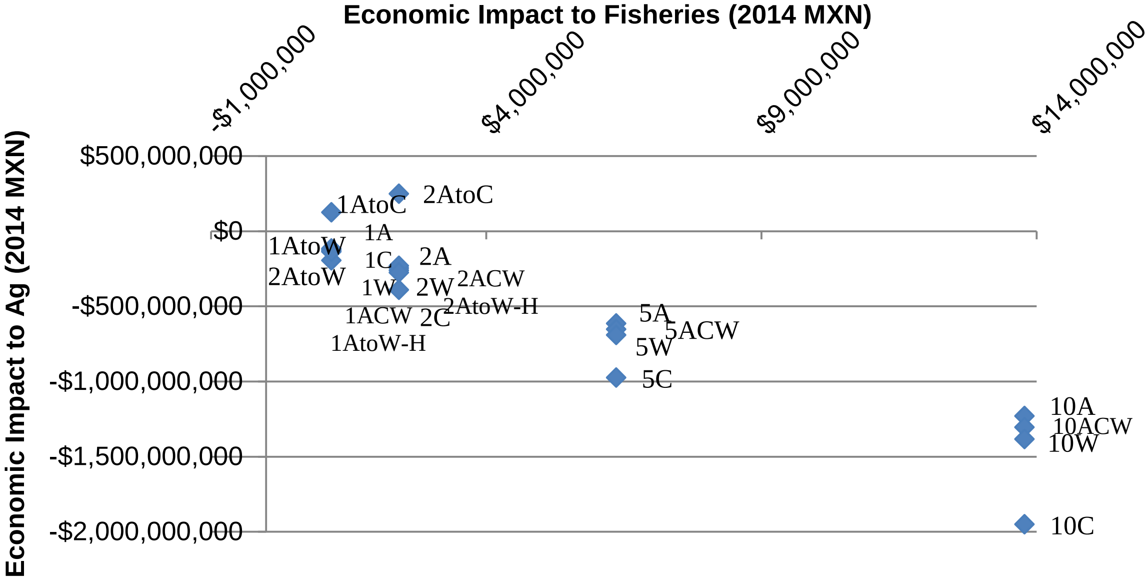
Table 6.14: Crop Shifting Requirements by Flow Scenario, Alfalfa to Cotton

Flow scenario	**Water requirement (thous m3)**	**Crop shifting (Alfalfa to Cotton) requirement (ha)**
0	0	0
1	31,536	10,675.69
2	63,072	21,351.39
5	157,680	53,378.47
10	315,360	10,6756.9

Using these final values of economic impact of fallowing crops, we can plot the outcomes of the modeled flow scenarios with economic impact resulting from changes in productivity in fisheries versus economic impact resulting from reductions in production in agriculture. The economic impact from fisheries was calculated as the average of Model 1 and Model 2 plus the corvina catch estimate from Model 21 and then run through the regionalized household consumption I/O model, Method 3.

As illustrated in Fig. 6.5, almost all scenarios yield a net loss in total economic output, with the exception of shifting alfalfa acreage to cotton production. In this case, there is a small net increase in economic output from agriculture, while freeing up enough water to also yield a small productivity gain for fisheries. This combination of crop shifting yields net increases due to the high price of cotton, and average applied water differential between the two crops. It is important to mention, however, that this analysis assumes the highest case of fisheries output per river input, and in almost all cases, any benefit to fisheries is far outweighed by its cost to agriculture.

Fig. 6.7: Tradeoff Analysis of Flow Scenarios



Legend: 1A = 1 cubic meter per second, fallowing Alfalfa; C = cotton; W = wheat; AtoW = shifting Alfalfa to Wheat; AtoC = shifting Alfalfa to Cotton; ACW = fallowing alfalfa, cotton, and wheat

6.5 Panga Enterprise Model

On the micro level, we can examine the influence of river flows on the profitability of the single-panga as an enterprise.   While most cooperatives have multiple pangas, for simplicity of the model, it will be assumed that the enterprise consists of only one boat. The objective of the enterprise is to maximize profits as revenues from catch minus fishing costs:

$$\pi = p * h - c_v * e - c_f$$

where profit is equal to price received for catch times the harvest minus variable fishing cost times effort (trips per season), minus fixed costs. Variable costs include costs associated with each fishing trip, including gasoline, labor, and food for the crew. Fixed costs include the panga, motor, nets, maintenance of equipment, and administrative costs. The cost structure is as follows:

Table 6.15: Panga Enterprise Cost Structure

Item	**Cost**	**Useable Life (years)**	**Per Year Cost**
Panga	$75,000	15 years	$5,000
Motor	$175,000	8 years	$21,875
Nets (total / season, 1 shrimp, 1 corvina)	$50,000	2 years	$25,000
Motor maintenance (10x / year)	$10,000	N/A	$10,000
Gasoline (200 trips / year, 800 / trip)	$160,000	N/A	$160,000
Food (250 per trip, 200 trips per season)	$50,000	N/A	$50,000
Labor	Varies	N/A	Varies
TOTAL ANNUAL			$271,875 + labor

Source: Field interviews (Appendix C); Rodriguez-Bracamonte (2008)

Harvest is a function (g) of both effort and environmental variables, and in this case, we want to explore the influence of river flows on harvest.

$$h = h(f)$$

Assuming an average number of trips per panga, and thus an average cost per year, we can remove effort from the equation and simply use it in calculating the variable costs, summing variable and fixed costs together. Harvest will be calculated as an average per panga. We can also break out harvest by species into shrimp and corvina, the two species of interest for this analysis. This gives us a modified objective function:

$$\pi = p_c * h_c(f) + p_s * h_s(f) - (c_v + c_f)$$

The Upper Gulf shrimp catch numbers used in this analysis include industrial shrimp trawling, therefore effort numbers used to calculate average catch per panga must take this into consideration. Barbier and Strand (1997) assume one industrial trawler represents an effort equivalent to 5.5 pangas. I will use this same assumption in calculating effort level. The estimated 1,914 pangas operating in the Upper Gulf, plus 111 trawlers based out of Puerto Peñasco and San Felipe would equate to 2,525 pangas total based upon the 5.5 panga per industrial trawler assumption. Not every panga has a permit for shrimp or corvina though. Some boats are dedicated to diving to harvest benthic species. My assumption for shrimp is that 2,000 pangas in the Upper Gulf are harvesting shrimp. For corvina, the number of pangas in Golfo de Santa Clara and San Felipe combine to 1,241. Therefore, I will use 2,000 as the number of boats to compute average catch numbers.

The econometric models provide us with the estimated changes in production resulting from different river flow scenarios. For purposes of this analysis, the predicted catch of models 1 and 2 (shrimp) were averaged to account for the differences between the two models, and projected catch for corvina was added to those models to provide low, medium, and high scenarios for total revenue to the shrimp and corvina fishery.

Table 6.16: Predicted Fisheries Revenue by Model and Scenario

	Low	Med	High
0	$513,555,384	$568,813,645	$624,071,906
1	$514,765,419	$569,709,046	$624,652,673
2	$515,999,209	$570,647,417	$625,295,625
5	$519,837,489	$573,720,354	$627,603,218
10	$526,657,105	$579,701,324	$632,745,543

These values can in turn be converted to per-panga revenues.

Table 6.17: Predicted Per-Panga Revenue by Scenario & Flow Level (2014 MXN)

Flow	Low	Med	High
0	$256,777.69	$284,406.82	$312,035.95
1	$257,382.71	$284,854.52	$312,326.34
2	$257,999.60	$285,323.71	$312,647.81
5	$259,918.74	$286,860.18	$313,801.61
10	$263,328.55	$289,850.66	$316,372.77

The breakout of value of catch by species corresponds with roughly 75% of revenue coming from shrimp catch and 25% from corvina, which on average represents a reasonable assumption for the Upper Gulf, excluding other commercial species. For Golfo de Santa Clara alone, corvina would likely represent a higher percent of revenue. Barlow, et al (2010) estimate average per season revenue per panga for shrimp and finfish, which in 2014 pesos corresponds to roughly $255,000 pesos per year. This corresponds well with my estimated value of annual per panga revenue at zero river flows. In terms of profitability, however, by my calculations, costs (including fixed costs spread over the useful life of the equipment) exceed revenues. Excluding fixed costs, cost per year would be roughly $210,000 pesos plus labor. Assuming 25% of profit is paid to labor, the flow scenarios produce the following profit estimates:

Table 6.18: Estimated Per-Panga Profit by Scenario

Flow	Low	Med	High
0	$35,083	$55,805	$76,527
1	$35,537	$56,141	$76,745
2	$36,000	$56,493	$76,986
5	$37,439	$57,645	$77,851
10	$39,996	$59,888	$79,780

Over the baseline of zero flows, the increases in profits associated with the river flow scenarios are as follows:

Table 6.19: Estimated Change in Per-Panga Profit by Scenario

Flow	Low	Med	High
0	0.0%	0.0%	0.0%
1	1.3%	0.6%	0.3%
2	2.6%	1.2%	0.6%
5	6.7%	3.3%	1.7%
10	14.0%	7.3%	4.3%

The outcomes of modeled increases in profits depend heavily upon the functional forms of the models used for the different scenarios. It is important to mention a number of caveats regarding these estimates. Fisheries catch data represents officially reported catch and therefore does not account for illegal fishing. The assumption of a single-panga enterprise is not necessarily representative of the average fishing enterprise in the Upper Gulf. Scaling the results of this analysis from one boat to many may not be accurate as economies of scale may exist for multi-boat enterprises. In field interviews, fishermen report that one benefit of belonging to cooperatives and federations is that administrative costs can be split amongst many boats, indicating that there may be benefits associated with belonging to larger enterprises. The effort assumptions in calculating per-panga revenues are rough assumptions that consider that not all boats target shrimp and corvina. Finally, the cost structure estimates do not take into account any fuel subsidies. Based upon field work, artisanal fishermen interviewed did not report taking advantage of the "gasolina ribereña" subsidy, stating that the administrative cost of the subsidy outweighed the benefit. The cost structure does, however, assume that the fishermen take advantage of the ecological motor subsidy in which the federal government and state government cover part of the cost of the new fuel-efficient motors. Most fishermen reported utilizing the subsidy for the purchase of new motors.

CHAPTER SEVEN: DISCUSSION, CONCLUSION & RECOMMENDATIONS

With projected decreases in precipitation in the Colorado River Basin due to climate change, increasing population in the Southwest United States, and historic over-allocation of Colorado River flows, competing demand for water is almost certain to remain a critical challenge for the Colorado River Basin, and, especially, the Colorado River Delta, the "last in line" for river flows. Given scarcity, tradeoffs become necessary. This analysis highlights the influence of river flows on Upper Gulf of California fisheries and the regional fisheries economy. Increasing water flows to the Upper Gulf to support fisheries productivity, however, requires that other users forego consuming water, and there is a resulting foregone economic impact as well. Voluntary agreements with compensation would be needed in the case of transfers of water from existing users to environmental uses. In the case that this money came from outside the local economy, for example, from environmental NGOs or donors in the United States, such arrangements could provide a net positive stimulus to the regional economy. Recent work has been done to quantify the economic values of water for Mexicali Valley agriculture and for the environment in the Delta (Kerna, 2012; Schuster, 2012). This study builds upon that work to take into consideration the economic contributions to fisheries livelihoods, productivity, and the regional economy generated by the river flows. This body of work quantifying the values of water for the environment is building towards a better understanding of the tradeoffs made when determining water and environmental policy in the Lower Colorado.

Through the use of econometric techniques, this analysis has explored the relationship between Colorado River flows and both shrimp and gulf corvina catch in the Upper Gulf of California, showing positive relationships with river flows lagged in accordance with their life cycles. This result is consistent with existing literature correlating river flows with fisheries catch and abundance. This study quantifies the impacts on the two highest value commercial species, shrimp and gulf corvina. It does not assess impacts on lesser value commercial species, nor does it explore potential economic impacts of the river's influence on totoaba, an endangered species whose swim bladder is currently the focus of a lucrative black market. This study also does not consider the no-doubt large economic effect of funding being provided from outside the region for spending on its conservation efforts.

Using estimated catch from the econometric models, I extend those results to an input-output model to provide an estimate of the economic impacts of the fisheries productivity changes that might result from increases in freshwater flows into the Upper Gulf of California estuaries. My results suggest increases in river flows between 1 to 10 cubic meters per second in sustained base flows would have modest positive economic impacts on the region. Additional studies are necessary to account for negative economic productivity impacts that might result in other areas of the economy in order to make the water available for environmental flows, and the effects of compensation paid to those making the water available.

The tradeoff analysis assessing the potential for net gains in economic productivity through shifting water from agriculture to the environment suggests that there is potential for productivity gains in both sectors by shifting alfalfa production to cotton production. This however does not consider any negative productivity impacts or impacts on price that might result from the crop shift.

Though my tradeoff analysis suggests that the economic impact of freshwater-induced productivity increases in Upper Gulf fisheries are small in comparison to the economic impact derived from water applied in agriculture within the Delta, a tradeoff solely between agriculture and fisheries is not a fair comparison of benefits generated from environmental flows. For that water to reach the Upper Gulf estuaries, it must pass through the entire Delta, where other benefits, both economic and otherwise, are realized, including recreation benefits, ecological benefits, and cultural benefits, among others. In addition, under voluntary agreements, compensation would be paid and spending of compensation payments would have an economic impact as well. This analysis builds upon existing studies that quantify the values of environmental flows through the Colorado River Delta. Furthermore, this analysis only assumes that the tradeoff will occur between Mexicali Valley agriculture and fisheries, versus upstream users in the US. Medellin-Azuara, et al (2007) provide analysis showing that the marginal opportunity cost of water in the Mexicali Valley is substantially higher than in the US. A tradeoff analysis could be expanded to consider alternative sources for environmental flows, such as from reduced consumptive use in U.S. agriculture.

These findings point to a need to integrate the effects of Colorado River flows on fisheries into the larger context of value generated by water for the environment in the Delta, including recreation values, non-use values, and other non-economic values in order to develop a more comprehensive understanding of the tradeoffs that are being made in diverting river flows for consumptive use.

Policy options

Conservation efforts for environmental restoration of the Colorado River Delta set forth specific goals around the acquisition of water for environmental flows. Though the targeted base flow levels for the Delta (ranging from roughly 2 to 4 cubic meters per second in base flows) most likely would not have a major influence on the Upper Gulf fisheries productivity, pulse flows have been shown to reach the sea and could potentially play an important role in restoring critical habitat for commercially important species, as well as endangered species like the totoaba.

As is evident from the econometric analyses, there are many factors beyond the freshwater input from river flows that influence fisheries productivity and sustainability. For instance, if restoration of river flows succeeded in increasing fisheries productivity and profitability, this would provide incentives for increased effort in illegal fishing as well as legally permitted fishing. Environmental restoration in the Delta must therefore be coupled with fisheries management practices that encourage responsible enforcement of fishing regulations. Many efforts are already underway in the Upper Gulf communities such as the implementation of TACs for gulf corvina in Golfo de Santa Clara and San Felipe. Conservation efforts such as these are aimed at optimizing productivity of the fisheries. Other efforts like PACE-Vaquita require difficult tradeoffs themselves, and conservation of a critically endangered species like the vaquita necessarily involves tradeoffs with commercial fisheries productivity and livelihoods.

Finally, in order to be effective, socially and environmentally sustainable economic development must be pursued in parallel with conservation efforts to help reduce economic dependence on fisheries and help to cushion shocks that may occur, such as fisheries closures for conservation.

Past economic loss estimates and critique

As most studies have done for Upper Gulf fisheries, economic losses must take into account the costs of production when calculating economic rents of fisheries. Neglecting to deduct costs from fishing revenues would lead to recommending an over-compensation of fishermen because in the absence of the fishing activity, production costs would not be incurred. On the other hand, if wages to labor are considered as part of the enterprise's costs, calculating losses as simply lost profits neglects to consider those individuals employed by the permit holders and does not consider the loss of their jobs and income as an economic loss. This also applies to the fisheries-dependent value chains in the Upper Gulf. The complexity of cooperative structure and ownership of fishing enterprises is not reflected in the economic loss models. The introduction of an economic impact analysis enables us to estimate the losses to the regional economy, including those sectors that supply goods and services to the fisheries, based off of changes in fisheries primary productivity. This type of analysis could be helpful in structuring compensation programs in such a way as to help reduce the incentive to continue fishing in violation of conservation-motivated fisheries restrictions.

Future Research

Future opportunities may exist to assess river impacts on productivity of key commercial species, shrimp in particular, by locating data on shrimp larvae or biomass and studying the relationship between abundance and river flows. The benefit of this approach is that it does not involve the confounding effects of catch and effort data, including illegal catch and effort.

A potential extension of this research could include the development of a system, similar to the system model by Medellín-Azuara, et al (2007) of the Mexicali Valley that incorporates the lowest reaches of the Delta and Upper Gulf fisheries productivity into the system of economic sectors depending upon the Colorado River. It could be used to examine the economic productivity of water in sectors from municipal and industrial use to agriculture, and even capture the economic values of water for the environment. This in turn could be connected with an economic impact model in order to weigh the output and employment impacts of various policy tradeoffs including the economic effect of various types of compensation to those providing water for environmental flows and to those altering their fishing practices for conservation purposes. A tool such as this would be critical in integrating existing research and applying it to quantifying the social and economic value of water for the environment, such as conservation efforts being implemented through and connected to Minute 319.

Potential extensions of the input-output model might include developing matrices that capture the impacts of the timing of flows to test if the timing of flows to the Upper Gulf influences the impact to fisheries, or if the timing of providing water to agriculture would have a larger or smaller impact at different times of the year. Another extension would be to calculate job impacts between agriculture and fisheries and examine water tradeoffs in terms of their impacts on employment, as well as job and output effects of compensation programs and conservation spending.

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GLOSSARY

CEDO – Intercultural Center for the Study of Deserts and Oceans (Centro Intercultural para el Estudio de Desiertos y Océanos)

CIRVA – International Committee for the Recovery of the Vaquita (Comite Internacional para la Recuperacion de la Vaquita)

CONANP – National Commission for Protected Natural Areas

CONAPESCA – Comision Nacional de Acuacultura y Pesca (National Commission on Aquaculture and Fishing)

CPUE – Catch per Unit Effort

EDF – Environmental Defense Fund

Ex-Vessel Price – Also “Beach price”

INAPESCA – National Fisheries Institute

INEGI – National Institute for Statistics and Geography

MIA – Environmental Impact Statement

MPA – Marine Protected Area

NGC – Northern Gulf of California

Rent – Profit obtained through exploitation of a resource

SAGARPA – Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca, y Alimentacion (Secretary of Agriculture, Livestock, Rural Development, Fishing, and Food)

SEMARNAT – Secretary of the Environment and Natural Resources

TAC – Total Allowable Catch

UGC – Upper Gulf of California

WWF – World Wildlife Fund

APPENDICES

APPENDIX A – Regression Results

* Results with shaded model numbers included in fisheries catch projection calculation; Bolded p-values statistically significant at 95% confidence level

Model	Dep Var	Ind Var	Obs	Years	R^2	Adj R^2	F Stat	p > F	Lag Catch Co	Lag Catch P	Lag Catch Std Err	Flow Lag	Flow Co	Flow P	Flow Std Err	ENSO Lag	ENSO Co	ENSO P	ENSO Std Err	Price Co	Price P	Price Std Err	Intercept	Intercept P	Intercept Std Err	VIF	White Test	P > ChiSq
1	Shrimp	Lagcatch, Flowlag1	26	1987-2013	0.333	0.275	5.75	**0.009**	0.450	**0.014**	0.169	1	14.5653	**0.031**	6.335								1508.001	**0.024**	623.761	1.006	7.170	0.209
2	Shrimp	Lagcatch, Flowlag1sq	26	1987-2013	0.359	0.303	6.44	**0.006**	0.458	**0.011**	0.166	1	0.1362	**0.019**	0.054								1519.952	**0.020**	608.177	1.009	9.020	0.109
3	Shrimp	Lagcatch, Flowlag1cub	26	1987-2013	0.367	0.312	6.66	**0.005**	0.468	**0.009**	0.165	1	0.0012	**0.016**	0.000								1503.007	**0.021**	605.396	1.013	9.910	0.078
4	Shrimp	Lagcatch, Flowlag1, Ensolag1	26	1987-2013	0.340	0.250	3.78	**0.025**	0.428	**0.025**	0.178	1	16.1035	**0.036**	7.187	1	-173.432	0.634	358.923				1596.354	**0.024**	660.246	1.07760; 1.25194; 1.33789	9.280	0.412
5	Shrimp	Lagcatch, Flowlag1sq, Ensolag1	26	1987-2013	0.369	0.293	4.29	**0.016**	0.433	**0.021**	0.174	1	0.1522	**0.020**	0.061	1	-207.771	0.560	351.396				1630.244	**0.019**	644.544	1.07647, 1.25721; 1.34052	10.810	0.289

Model	Dep Var	Ind Var	Obs	Years	R^2	Adj R^2	F Stat	p > F	Lag Catch Co	Lag Catch P	Lag Catch Std Err	Flow Lag	Flow Co	Flow P	Flow Std Err	ENSO Lag	ENSO Co	ENSO P	ENSO Std Err	Price Co	Price P	Price Std Err	Intercept	Intercept P	Intercept Std Err	VIF	White Test	P > ChiSq
6	Shrimp	Lagcatch, Flowlag1cub , Ensolag1	26	1987-2013	0.374	0.289	4.39	**0.015**	0.447	**0.017**	0.173	1	0.0013	**0.018**	0.000	1	-179.575	0.607	344.193				1599.754	**0.021**	642.547	1.07537, 1.22176, 1.29705	14.230	0.114
7	Shrimp	Lagcatch, Flowlag1, ensolag1, priceshrimp	13	2000-2013	0.364	0.047	1.15	0.401	0.328	0.397	0.366	1	-265.5783	0.597	482.401	1	-1026.547	0.344	1020.476	9.791	0.808	38.910	1204.027	0.845	5957.462	1.64061; 10.09720; 1.71210; 11.02075	12.660	0.394
8	Shrimp	Lagcatch, Flowlag1sq, Ensolag1, Priceshrimp	13	2000-2013	0.392	0.087	1.29	0.352	0.402	0.317	0.376	1	-33.2035	0.436	40.465	1	-1205.827	0.269	1014.663	12.221	0.701	30.665	428.692	0.938	5328.129	1.80532; 6.05895; 1.76812; 7.15008	6.160	0.940
9	Shrimp	Lagcatch, Flowlag1cub , Ensolag1, Priceshrimp	13	2000-2013	0.397	0.080	1.26	0.360	0.406	0.319	0.381	1	-3.1035	0.459	3.990	1	-1142.815	0.281	988.899	8.841	0.762	28.195	863.033	0.869	5078.716	1.8416; 4.94957; 1.66625; 5.99708	6.490	0.926
10	Corvina	Lagcatch, Flowlag4	22	1992-2014	0.636	0.598	16.61	**<.0001**	0.719	**<.0001**	0.128	4	7.7244	0.235	6.298								872.357	0.059	433.845	1.000	3.030	0.695

Model	Dep Var	Ind Var	Obs	Years	R^2	Adj R^2	F Stat	p > F	Lag Catch Co	Lag Catch P	Lag Catch Std Err	Flow Lag	Flow Co	Flow P	Flow Std Err	ENSO Lag	ENSO Co	ENSO P	ENSO Std Err	Price Co	Price P	Price Std Err	Intercept	Intercept P	Intercept Std Err	VIF	White Test	P > ChiSq
11	Corvina	Lagcatch, Flowlag4sq	22	1992-2014	0.644	0.606	17.17	**<.0001**	0.738	**<.0001**	0.127	4	0.0728	0.180	0.052								835.497	0.069	433.119	1.011	3.020	0.697
12	Corvina	Lagcatch, Flowlag4cub	22	1992-2014	0.637	0.599	16.67	**<.0001**	0.743	**<.0001**	0.129	4	0.0005	0.228	0.000								837.000	0.072	439.697	1.023	2.690	0.748
13	Corvina	Lagcatch, Flowlag4, ensolag4	22	1992-2014	0.737	0.694	16.85	**<.0001**	0.831	**<.0001**	0.119	4	2.5568	0.667	5.838	4	816.723	**0.017**	310.207				415.454	0.332	416.600	1.14502; 1.12746; 1.27330	8.970	0.440
14	Corvina	Lagcatch, Flowlag4sq, ensolag4	22	1992-2014	0.741	0.698	17.17	**<.0001**	0.837	**<.0001**	0.118	4	0.0324	0.511	0.048	4	796.531	**0.018**	306.319				399.601	0.348	414.780	1.12944; 1.12769; 1.25912	9.270	0.413
15	Corvina	Lagcatch, Flowlag4cub , ensolag4	22	1992-2014	0.739	0.696	16.99	**<.0001**	0.840	**<.0001**	0.118	4	0.0002	0.585	0.000	4	810.786	**0.016**	305.611				396.477	0.355	417.534	1.13137; 1.12677; 1.24387	9.100	0.428

Model	Dep Var	Ind Var	Obs	Years	R^2	Adj R^2	F Stat	p > F	Lag Catch Co	Lag Catch P	Lag Catch Std Err	Flow Lag	Flow Co	Flow P	Flow Std Err	ENSO Lag	ENSO Co	ENSO P	ENSO Std Err	Price Co	Price P	Price Std Err	Intercept	Intercept P	Intercept Std Err	VIF	White Test	P > ChiSq
16	Corvina	Lagcatch, Flowlag4, ensolag4, pricecorvina	14	2000-2014	0.649	0.493	4.16	**0.035**	0.282	0.226	0.217	4	3.7227	0.691	9.056	4	840.975	**0.037**	343.748	-425.664	0.065	202.946	18498.000	**0.043**	7864.741	1.20679; 1.22127; 1.2125; 1.17388	13.660	0.475
17	Corvina	Lagcatch, Flowlag4sq, ensolag4, pricecorvina	14	2000-2014	0.693	0.557	5.09	**0.020**	0.281	0.196	0.201	4	0.1155	0.253	0.094	4	771.844	**0.039**	320.519	-374.573	0.084	192.540	16558.000	0.054	7464.967	1.18063; 1.23322; 1.20659; 1.20936	13.750	0.392
18	Corvina	Lagcatch, Flowlag4cub, ensolag4, pricecorvina	14	2000-2014	0.715	0.588	5.64	**0.015**	0.293	0.164	0.193	4	0.0015	0.166	0.001	4	752.676	**0.038**	308.859	-357.802	0.087	186.328	15883.000	0.056	7231.907	1.17578; 1.23409; 1,204; 1.2171	13.380	0.419
19	Corvina	Lagcatch, Flowlag4cub, ensolag4, intpricebuch epricecorvin a	14	2000-2014	0.680	0.538	4.79	**0.024**	0.367	0.097	0.198	4	0.0024	**0.043**	0.001	4	919.746	**0.024**	337.684	0.111	0.162	0.073	1832.398	**0.046**	792.249	1.10153; 1.14603; 1.28453; 1.17463	12.680	0.552
20	Corvina	, ensolag4, intpricebuch epricecorvin a, lagintpricebu	14	2000-2014	0.681	0.482	3.42	**0.060**	0.373	0.119	0.213	4	0.0024	0.057	0.001	4	905.466	**0.040**	368.531	.04621; 0.08276 (lag)	0.9135; 0.8767 (lag)	0.41236; 0.51641 (lag)	1817.987	**0.063**	843.767	1.14614; 1.3643; 33.51824;	13.440	0.492
21	Corvina	Lagcatch, Flowlag4sq, ensolag4, intpricebuch epricecorvin a	14	2000-2014	0.654	0.501	4.26	**0.033**	0.347	0.129	0.207	4	0.2068	0.064	0.098	4	940.476	**0.025**	350.382	0.117	0.161	0.077	1876.891	**0.049**	824.346	1.11877; 1.17660; 1.27851; 1.19914	13.410	0.417

Model	Dep Var	Ind Var	Obs	Years	R^2	Adj R^2	F Stat	p > F	Lag Catch Co	Lag Catch P	Lag Catch Std Err	Flow Lag	Flow Co	Flow P	Flow Std Err	ENSO Lag	ENSO Co	ENSO P	ENSO Std Err	Price Co	Price P	Price Std Err	Intercept	Intercept P	Intercept Std Err	VIF	White Test	P > ChiSq
22	Corvina	Lagcatch, Flowlag4cub	14	2000-2014	0.391	0.280	3.53	0.065	0.250	0.311	0.235	4	0.0028	**0.034**	0.001								2655.248	**0.015**	921.339	1.000	2.860	0.722
23	Log Shrimp	Log(lagcatc h), log(flowlag1 +1)	26	1987-2013	0.273	0.209	4.31	**0.026**	0.447	**0.019**	0.177	1	0.0742	0.080	0.041								4.323	**0.006**	1.439	1.018	8.050	0.154
24	Log Shrimp	Log(lagcatc h), log(flowlag1 sq+1)	26	1987-2013	0.273	0.210	4.31	**0.026**	0.440	**0.021**	0.177	1	0.0361	0.080	0.020								4.388	**0.006**	1.433	1.013	8.320	0.139
25	Log Shrimp	Log(lagcatc h), log(flowlag1 cub+1)	26	1987-2013	0.273	0.209	4.31	**0.026**	0.438	**0.021**	0.177	1	0.0238	0.080	0.013								4.041	**0.005**	1.431	1.012	8.410	0.135
26	Log Shrimp	Log(lagcatc h), log(flowlag1 +1), ensolag1	26	1987-2013	0.273	0.173	2.75	0.067	0.449	**0.026**	0.188	1	0.0737	0.106	0.044	1	0.003	0.974	0.099				4.310	**0.010**	1.528	1.09848; 1.1328; 1.22069	10.530	0.309

Model	Dep Var	Ind Var	Obs	Years	R^2	Adj R^2	F Stat	p > F	Lag Catch Co	Lag Catch P	Lag Catch Std Err	Flow Lag	Flow Co	Flow P	Flow Std Err	ENSO Lag	ENSO Co	ENSO P	ENSO Std Err	Price Co	Price P	Price Std Err	Intercept	Intercept P	Intercept Std Err	VIF	White Test	P > ChiSq
27	Log Shrimp	Log(lagcatch), log(flowlag1 sq+1), ensolag1	26	1987-2013	0.273	0.174	2.75	0.067	0.443	**0.028**	0.188	1	0.0358	0.105	0.021	1	0.004	0.968	0.099				4.370	**0.009**	1.526	1.09740; 1.12355; 1.21673	11.850	0.222
28	Log Shrimp	Log(lagcatch), log(flowlag1 cub+1), ensolag1	26	1987-2013	0.273	0.174	2.75	0.067	0.441	**0.029**	0.188	1	0.0236	0.106	0.014	1	0.005	0.963	0.099				4.388	**0.009**	1.525	1.09723; 1.11989; 1.21445	12.160	0.204
29	Logcorvina	Log(lagcorvina), log(flowlag4 +1)	22	1992-2014	0.959	0.955	223.65	**<.0001**	0.653	**<.0001**	0.314	4	0.0013	0.974	0.038								2.876	**<.0001**	0.235	1.038	6.520	0.259
30	Logcorvina	Log(lagcorvina), log(flowlag4 sq+1)	22	1992-2014	0.959	0.955	223.64	**<.0001**	0.653	**<.0001**	0.032	4	0.0002	0.992	0.018								2.877	**<.0001**	0.235	1.04179; 1.04179	6.640	0.248
31	Logcorvina	Log(lagcorvina), log(flowlag4 cub+1)	22	1992-2014	0.959	0.955	223.63	**<.0001**	0.653	**<.0001**	0.032	4	-0.0001	0.995	0.012								2.876	**<.0001**	0.235	1.04358; 1.04358	6.730	0.242

Model	Dep Var	Ind Var	Obs	Years	R^2	Adj R^2	F Stat	p > F	Lag Catch Co	Lag Catch P	Lag Catch Std Err	Flow Lag	Flow Co	Flow P	Flow Std Err	ENSO Lag	ENSO Co	ENSO P	ENSO Std Err	Price Co	Price P	Price Std Err	Intercept	Intercept P	Intercept Std Err	VIF	White Test	P > ChiSq
32	Logcorvina	Log(lagcorvina), log(flowlag4 +1), ensolag4	22	1992-2014	0.961	0.954	146.92	**<.0001**	0.636	**<.0001**	0.038	4	-0.0004	0.992	0.038	4	-0.082	0.416	0.098				3.018	**<.0001**	0.291	1.46340; 1.04045; 1.44191	8.490	0.488
33	Logcorvina	Log(lagcorvina), log(flowlag4 sq+1), ensolag4	22	1992-2014	0.961	0.954	146.93	**<.0001**	0.636	**<.0001**	0.038	4	-0.0008	0.968	0.018	4	-0.082	0.415	0.098				3.018	**<.0001**	0.291	1.46491; 1.04573; 1.44340	8.900	0.447
34	Logcorvina	Log(lagcorvina), log(flowlag4 cub+1), ensolag4	22	1992-2014	0.961	0.954	146.95	**<.0001**	0.636	**<.0001**	0.038	4	-0.0007	0.955	0.012	4	-0.082	0.415	0.098				3.018	**<.0001**	0.291	1.46643; 1.04748; 1.44333	8.880	0.449
35	Sqr Rt Shrimp	Lagcatch, flowlag1	26	1987-2013	0.333	0.275	5.74	**0.010**	0.004	**0.015**	0.001	1	0.1208	**0.030**	0.052								41.833	**<.0001**	4.121	1.006	6.870	0.230
36	Sqr Rt Shrimp	Lagcatch, flowlag1sq	26	1987-2013	0.357	0.301	6.37	**0.006**	0.004	**0.012**	0.001	1	0.0011	**0.018**	0.000								41.949	**<.0001**	5.000	1.009	8.540	0.129
37	Sqr Rt Shrimp	Lagcatch, flowlag1cub	26	1987-2013	0.364	0.309	6.59	**0.006**	0.004	**0.010**	0.001	1	0.0000	**0.016**	0.000								41.810	**<.0001**	4.978	1.013	7.410	0.192

Model	Dep Var	Ind Var	Obs	Years	R^2	Adj R^2	F Stat	p > F	Lag Catch Co	Lag Catch P	Lag Catch Std Err	Flow Lag	Flow Co	Flow P	Flow Std Err	ENSO Lag	ENSO Co	ENSO P	ENSO Std Err	Price Co	Price P	Price Std Err	Intercept	Intercept P	Intercept Std Err	VIF	White Test	P > ChiSq
38	Δshrimp	Δlagcatch, Δflowlag1	25	1987-2013	0.402	0.348	7.39	**0.004**	-0.201	0.247	0.169	1	16.9767	0.004	5.319								-94.386	0.687	231.420	1.081	2.670	0.751
39	Δshrimp	Δlagcatch, Δflowlag1cu b	25	1987-2013	0.413	0.360	7.74	**0.003**	-0.178	0.304	0.170	1	0.0012	0.003	0.000								-134.931	0.560	228.184	1.104	2.860	0.721
40	Δshrimp	Δlagcatch, Δflowlag1, Δensolag1	25	1987-2013	0.460	0.383	5.97	**0.004**	-0.235	0.173	0.166	1	19.0267	0.119	5.349	1	-412.723	0.147	274.225				-113.880	0.619	225.412	1.1; 1.5574; 1/11491	6.510	0.688
41	Δshrimp	Δlagcatch, Δflowlag1cu b, Δensolag1	25	1987-2013	0.432	0.351	5.32	**0.007**	-0.203	0.254	0.173	1	0.0012	0.003	0.000	1	-227.032	0.414	272.678				-150.295	0.522	230.531	1.13781; 1.10911; 1.04766	3.550	0.939
42	Δcorvina	Δlagcatch, Δflowlag4	22	1992-2014	0.215	0.133	2.61	0.100	-0.195	0.346	213.749	4	9.5095	0.059	4.739								206.472	0.346	213.749	1.005	3.630	0.603

Model	Dep Var	Ind Var	Obs	Years	R^2	Adj R^2	F Stat	p > F	Lag Catch Co	Lag Catch P	Lag Catch Std Err	Flow Lag	Flow Co	Flow P	Flow Std Err	ENSO Lag	ENSO Co	ENSO P	ENSO Std Err	Price Co	Price P	Price Std Err	Intercept	Intercept P	Intercept Std Err	VIF	White Test	P > ChiSq
43	Δcorvina	Δlagcatch, Δflowlag4cub	22	1992-2014	0.073	-0.025	0.75	0.487	-0.213	0.350	0.223	4	0.0002	0.493	0.000								202.624	0.394	232.377	1.004	9.560	0.089
44	Δcorvina	Δlagcatch, Δflowlag4, Δensolag4	22	1992-2014	0.264	0.141	2.15	0.130	-0.091	0.691	0.225	4	8.8484	0.079	4.756	4	337.754	0.292	311.203				185.347	0.397	213.644	1.22766; 1.02136; 1.24809	5.500	0.789
45	Δcorvina	Δlagcatch, Δflowlag4cub, Δensolag4	22	1992-2014	0.145	0.002	1.01	0.410	-0.085	0.730	0.243	4	0.0002	0.501	0.000	4	407.964	0.236	332.729				177.282	0.451	230.288	1.23059; 1.00424; 1.22798	14.320	0.111

APPENDIX B – Input Output Matrices (Leontif Inverse Matrices)

Baja California – Open I/O Matrix by Sector, 2008

		Ag., Forestry, Fishing & Hunting	Mining	Utilities	Construction	Manufacturing	Wholesale & Retail Trade	Transportation & Warehousing	Information	Finance & Insurance	Real Estate Rental & Leasing	Prof. Sci., & Tech. Services	Mgmt of Companies & Enterprises	Admin. & Support & Waste Mgmt & Rem. Serv.	Education Services	Health Care & Social Assistance	Arts, Entertainment, and Recreation	Accommodation & Food Services	Other Services	Public Administration
		11	21	22	23	31-33	43-46	48-49	51	52	53	54	55	56	61	62	71	72	81	93
11	Ag., Forestry, Fishing & Hunting	1.117	0.008	0.017	0.020	0.106	0.007	0.026	0.014	0.004	0.003	0.004	0.002	0.005	0.003	0.015	0.006	0.009	0.010	0.012
21	Mining	0.000	1.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	Utilities	0.023	0.012	1.015	0.012	0.031	0.022	0.017	0.018	0.010	0.013	0.015	0.004	0.015	0.025	0.036	0.040	0.059	0.026	0.031
23	Construction	0.002	0.004	0.002	1.069	0.001	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.013	0.002	0.001	0.001	0.004
31-33	Manufacturing	0.195	0.137	0.292	0.325	1.812	0.115	0.435	0.247	0.076	0.047	0.072	0.032	0.083	0.047	0.249	0.098	0.147	0.173	0.203
43-46	Wholesale & Retail Trade	0.044	0.025	0.051	0.065	0.118	1.022	0.068	0.044	0.015	0.008	0.014	0.005	0.015	0.009	0.053	0.018	0.027	0.035	0.039
48-49	Transportation & Warehousing	0.010	0.007	0.015	0.015	0.031	0.011	1.040	0.019	0.018	0.003	0.010	0.004	0.008	0.005	0.016	0.008	0.006	0.010	0.027
51	Information	0.001	0.002	0.002	0.005	0.004	0.005	0.006	1.037	0.046	0.005	0.011	0.007	0.014	0.011	0.009	0.008	0.003	0.006	0.019
52	Finance & Insurance	0.007	0.010	0.005	0.020	0.012	0.008	0.018	0.030	1.110	0.009	0.024	0.017	0.018	0.007	0.007	0.015	0.007	0.004	0.039
53	Real Estate Rental & Leasing	0.000	0.005	0.000	0.001	0.001	0.002	0.001	0.003	0.001	1.001	0.002	0.001	0.004	0.001	0.001	0.001	0.000	0.002	0.001
54	Prof. Sci., & Tech. Svcs	0.004	0.016	0.012	0.016	0.023	0.017	0.037	0.042	0.056	0.016	1.077	0.067	0.035	0.021	0.053	0.028	0.013	0.024	0.036
55	Mgmt of Co's & Enterprises	0.001	0.008	0.003	0.003	0.009	0.007	0.010	0.014	0.028	0.002	0.004	1.072	0.007	0.002	0.004	0.004	0.004	0.003	0.004
56	Admin. & Support & Waste Mgmt & Rem. Svcs	0.001	0.010	0.002	0.004	0.008	0.010	0.007	0.015	0.008	0.005	0.011	0.007	1.027	0.004	0.007	0.008	0.008	0.005	0.006
61	Education Svcs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
62	Health Care & Social Assist.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
71	Arts, Entert, & Recr.'n	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	1.002	0.000	0.000	0.001
72	Accom. & Food Serv.	0.001	0.002	0.002	0.005	0.004	0.003	0.007	0.007	0.006	0.001	0.003	0.004	0.007	0.005	0.008	0.004	1.002	0.004	0.028
81	Other Svcs	0.002	0.002	0.002	0.005	0.005	0.004	0.013	0.003	0.011	0.002	0.007	0.002	0.003	0.004	0.015	0.014	0.006	1.014	0.010
93	Public Admin.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

Baja California – Closed I/O Matrix by Sector, 2008; Assuming National Ratio of Household Consumption by Industry

		Ag., Forestry, Fishing & Hunting	Mining	Utilities	Construction	Manufacturing	Wholesale & Retail Trade	Transportation & Warehousing	Information	Finance & Insurance	Real Estate Rental & Leasing	Prof. Sci., & Tech. Svcs	Mgmt of Co's & Enterprises	Admin. & Support & Waste Mgmt & Rem. Svcs	Education Svcs	Health Care & Social Assist.	Arts, Entert, & Recr.'n	Accom. & Food Serv.	Other Svcs	Public Admin.	Household consumption
		11	21	22	23	31-33	43-46	48-49	51	52	53	54	55	56	61	62	71	72	81	93	
11	Ag., Forestry, Fishing & Hunting	1.12	0.01	0.02	0.03	0.12	0.02	0.04	0.03	0.02	0.00	0.02	0.01	0.05	0.06	0.06	0.02	0.02	0.03	0.06	0.07
21	Mining	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	Utilities	0.03	0.02	1.02	0.02	0.04	0.03	0.03	0.03	0.02	0.01	0.03	0.01	0.05	0.07	0.07	0.05	0.06	0.04	0.07	0.05
23	Construction	0.00	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
31-33	Manufacturing	0.26	0.20	0.35	0.49	1.93	0.23	0.61	0.42	0.25	0.07	0.23	0.13	0.56	0.73	0.72	0.21	0.23	0.37	0.79	0.85
43-46	Wholesale & Retail Trade	0.06	0.04	0.07	0.11	0.15	1.05	0.11	0.09	0.06	0.01	0.06	0.03	0.14	0.19	0.18	0.05	0.05	0.09	0.20	0.23
48-49	Transportation & Warehousing	0.02	0.02	0.03	0.04	0.05	0.03	1.07	0.05	0.05	0.01	0.04	0.02	0.09	0.12	0.09	0.03	0.02	0.04	0.12	0.14
51	Information	0.01	0.01	0.01	0.02	0.01	0.01	0.02	1.05	0.06	0.01	0.02	0.01	0.05	0.06	0.04	0.02	0.01	0.02	0.06	0.06
52	Finance & Insurance	0.01	0.01	0.01	0.04	0.02	0.02	0.03	0.05	1.12	0.01	0.04	0.02	0.06	0.07	0.05	0.02	0.02	0.02	0.09	0.07
53	Real Estate Rental & Leasing	0.02	0.02	0.02	0.04	0.03	0.03	0.04	0.04	0.04	1.01	0.04	0.02	0.12	0.17	0.11	0.03	0.02	0.05	0.14	0.20
54	Prof. Sci., & Tech. Svcs	0.01	0.02	0.01	0.02	0.03	0.02	0.04	0.05	0.06	0.02	1.08	0.07	0.06	0.05	0.07	0.03	0.02	0.03	0.06	0.04
55	Mgmt of Co's & Enterprises	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.00	0.01	1.07	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01
56	Admin. & Support & Waste Mgmt & Rem. Svcs	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	1.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
61	Education Svcs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1.02	0.01	0.00	0.00	0.00	0.01	0.02
62	Health Care & Social Assist.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	1.01	0.00	0.00	0.00	0.01	0.02
71	Arts, Entert, & Recr.'n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	1.00	0.00	0.00	0.01	0.01
72	Accom. & Food Serv.	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.00	0.01	0.01	0.04	0.05	0.04	0.01	1.01	0.02	0.07	0.06
81	Other Svcs	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.00	0.02	0.01	0.03	0.04	0.04	0.02	0.01	1.03	0.04	0.05
93	Public Admin.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
	Wages to Labor	0.09	0.09	0.09	0.23	0.17	0.17	0.24	0.24	0.24	0.03	0.23	0.13	0.67	0.95	0.66	0.16	0.12	0.27	0.82	1.18

Baja California – Closed I/O Matrix by Sector, 2008; Regionally Adjusted Ratio of Household Consumption by Industry

		Ag., Forestry, Fishing & Hunting	Mining	Utilities	Construction	Manufacturing	Wholesale & Retail Trade	Transportation & Warehousing	Information	Finance & Insurance	Real Estate Rental & Leasing	Prof. Sci., & Tech. Svcs	Mgmt of Co's & Enterprises	Admin. & Support & Waste Mgmt & Rem. Svcs	Education Svcs	Health Care & Social Assist.	Arts, Entert, & Recr.'n	Accom. & Food Serv.	Other Svcs	Public Admin.	Household Consumption
		11	21	22	23	31-33	43-46	48-49	51	52	53	54	55	56	61	62	71	72	81	93	
11	Ag., Forestry, Fishing & Hunting	1.12	0.02	0.02	0.04	0.12	0.02	0.05	0.04	0.03	0.01	0.02	0.01	0.06	0.09	0.07	0.02	0.02	0.03	0.08	0.10
21	Mining	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	Utilities	0.03	0.02	1.02	0.03	0.04	0.04	0.04	0.04	0.03	0.02	0.03	0.01	0.07	0.10	0.09	0.05	0.07	0.05	0.10	0.09
23	Construction	0.00	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00
31-33	Manufacturing	0.27	0.20	0.36	0.51	1.94	0.24	0.62	0.44	0.27	0.07	0.25	0.13	0.60	0.79	0.76	0.22	0.24	0.39	0.85	0.92
43-46	Wholesale & Retail Trade	0.06	0.04	0.07	0.12	0.16	1.06	0.12	0.10	0.07	0.02	0.06	0.03	0.16	0.22	0.20	0.05	0.05	0.10	0.22	0.26
48-49	Transportation & Warehousing	0.02	0.02	0.03	0.05	0.06	0.04	1.08	0.06	0.06	0.01	0.05	0.02	0.11	0.15	0.12	0.03	0.02	0.05	0.15	0.18
51	Information	0.00	0.01	0.00	0.01	0.01	0.01	0.01	1.05	0.05	0.01	0.02	0.01	0.04	0.04	0.03	0.01	0.01	0.02	0.05	0.04
52	Finance & Insurance	0.01	0.02	0.01	0.04	0.02	0.02	0.03	0.05	1.13	0.01	0.04	0.03	0.06	0.07	0.05	0.03	0.02	0.02	0.10	0.08
53	Real Estate Rental & Leasing	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	1.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01
54	Prof. Sci., & Tech. Svcs	0.01	0.02	0.01	0.02	0.03	0.02	0.05	0.05	0.06	0.02	1.08	0.07	0.06	0.05	0.07	0.03	0.02	0.03	0.06	0.04
55	Mgmt of Co's & Enterprises	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.00	0.01	1.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
56	Admin. & Support & Waste Mgmt & Rem. Svcs	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	1.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
61	Education Svcs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1.01	0.01	0.00	0.00	0.00	0.01	0.02
62	Health Care & Social Assist.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	1.01	0.00	0.00	0.00	0.01	0.02
71	Arts, Entert, & Recr.'n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	1.00	0.00	0.00	0.01	0.02
72	Accom. & Food Serv.	0.01	0.01	0.01	0.03	0.02	0.02	0.03	0.03	0.03	0.00	0.02	0.02	0.07	0.09	0.07	0.02	1.01	0.03	0.10	0.11
81	Other Svcs	0.01	0.01	0.01	0.02	0.01	0.01	0.03	0.02	0.02	0.00	0.02	0.01	0.04	0.06	0.05	0.02	0.01	1.03	0.06	0.06
93	Public Admin.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
	Wages to Labor	0.09	0.09	0.09	0.24	0.17	0.17	0.24	0.24	0.25	0.03	0.23	0.13	0.68	0.96	0.67	0.16	0.12	0.28	0.83	1.20

Sonora – Open I/O Matrix by Sector, 2008

		Ag., Forestry, Fishing & Hunting	Mining	Utilities	Construction	Manufacturing	Wholesale & Retail Trade	Transportation & Warehousing	Information	Finance & Insurance	Real Estate Rental & Leasing	Prof. Sci., & Tech. Svcs	Mgmt of Co's & Enterprises	Admin. & Support & Waste Mgmt & Rem. Svcs	Education Svcs	Health Care & Social Assist.	Arts, Entert, & Recr.'n	Accom. & Food Serv.	Other Svcs	Public Admin.
		11	21	22	23	31-33	43-46	48-49	51	52	53	54	55	56	61	62	71	72	81	93
11	Ag., Forestry, Fishing & Hunting	1.108	0.008	0.032	0.028	0.107	0.008	0.032	0.015	0.005	0.003	0.005	0.002	0.005	0.003	0.015	0.008	0.016	0.013	0.013
21	Mining	0.002	1.010	0.032	0.028	0.087	0.006	0.026	0.012	0.004	0.003	0.004	0.002	0.004	0.003	0.013	0.007	0.013	0.011	0.011
22	Utilities	0.004	0.011	1.019	0.014	0.030	0.022	0.018	0.017	0.010	0.013	0.015	0.004	0.014	0.025	0.035	0.041	0.061	0.027	0.031
23	Construction	0.000	0.004	0.003	1.069	0.001	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.013	0.002	0.001	0.001	0.004
31-33	Manufacturing	0.044	0.140	0.539	0.470	1.816	0.131	0.542	0.251	0.083	0.051	0.086	0.040	0.084	0.055	0.262	0.140	0.266	0.221	0.216
43-46	Wholesale & Retail Trade	0.008	0.024	0.076	0.075	0.102	1.022	0.073	0.042	0.015	0.008	0.014	0.006	0.014	0.009	0.052	0.023	0.039	0.039	0.038
48-49	Transportation & Warehousing	0.002	0.006	0.022	0.017	0.028	0.011	1.041	0.018	0.018	0.003	0.010	0.004	0.008	0.005	0.016	0.009	0.009	0.011	0.027
51	Information	0.000	0.002	0.002	0.005	0.003	0.004	0.006	1.031	0.047	0.005	0.012	0.012	0.008	0.011	0.009	0.009	0.004	0.008	0.018
52	Finance & Insurance	0.001	0.009	0.007	0.021	0.009	0.007	0.017	0.029	1.101	0.009	0.025	0.018	0.016	0.007	0.007	0.017	0.010	0.005	0.039
53	Real Estate Rental & Leasing	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.001	1.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.002	0.001
54	Prof. Sci., & Tech. Svcs	0.001	0.016	0.015	0.016	0.019	0.015	0.035	0.040	0.054	0.016	1.074	0.068	0.032	0.021	0.052	0.031	0.016	0.026	0.036
55	Mgmt of Co's & Enterprises	0.000	0.007	0.002	0.002	0.004	0.004	0.006	0.013	0.017	0.001	0.002	1.041	0.004	0.002	0.003	0.002	0.003	0.002	0.002
56	Admin. & Support & Waste Mgmt & Rem. Svcs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
61	Education Svcs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	1.000	0.000	0.001	0.000	0.000	0.000
62	Health Care & Social Assist.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
71	Arts, Entert, & Recr.'n	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	1.002	0.000	0.000	0.001
72	Accom. & Food Serv.	0.000	0.002	0.003	0.005	0.003	0.003	0.007	0.007	0.006	0.001	0.003	0.004	0.007	0.005	0.008	0.004	1.002	0.004	0.028
81	Other Svcs	0.000	0.002	0.002	0.004	0.003	0.003	0.010	0.003	0.010	0.002	0.006	0.002	0.002	0.003	0.014	0.012	0.006	1.012	0.009
93	Public Admin.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

Sonora – Closed I/O Matrix by Sector, 2008;
Assuming National Ratio of Household Consumption by Industry

		Ag., Forestry, Fishing & Hunting	Mining	Utilities	Construction	Manufacturing	Wholesale & Retail Trade	Transportation & Warehousing	Information	Finance & Insurance	Real Estate Rental & Leasing	Prof. Sci., & Tech. Svcs	Mgmt of Co's & Enterprises	Waste Mgmt & Rem. Svcs	Education Svcs	Health Care & Social Assist.	Arts, Entert, & Recr.'n	Accom. & Food Serv.	Other Svcs	Public Admin.	Household consumption
		11	21	22	23	31-33	43-46	48-49	51	52	53	54	55	56	61	62	71	72	81	93	
11	Ag., Forestry, Fishing & Hunting	1.11	0.01	0.04	0.04	0.12	0.02	0.05	0.03	0.02	0.00	0.02	0.01	0.20	0.06	0.06	0.02	0.02	0.04	0.07	0.08
21	Mining	0.00	1.01	0.04	0.04	0.09	0.01	0.03	0.02	0.01	0.00	0.01	0.01	0.11	0.04	0.04	0.01	0.02	0.02	0.04	0.04
22	Utilities	0.01	0.02	1.02	0.03	0.04	0.03	0.03	0.03	0.02	0.01	0.03	0.01	0.15	0.07	0.07	0.05	0.07	0.04	0.07	0.05
23	Construction	0.00	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00
31-33	Manufacturing	0.10	0.20	0.62	0.66	1.94	0.25	0.73	0.43	0.29	0.07	0.30	0.16	2.37	0.77	0.76	0.26	0.36	0.50	0.87	0.89
43-46	Wholesale & Retail Trade	0.02	0.04	0.10	0.12	0.13	1.05	0.12	0.09	0.07	0.01	0.07	0.04	0.59	0.19	0.18	0.05	0.06	0.11	0.20	0.22
48-49	Transportation & Warehousing	0.01	0.02	0.03	0.05	0.05	0.03	1.07	0.05	0.05	0.01	0.04	0.02	0.37	0.12	0.09	0.03	0.02	0.05	0.13	0.14
51	Information	0.00	0.01	0.01	0.02	0.01	0.01	0.02	1.04	0.06	0.01	0.03	0.02	0.16	0.06	0.04	0.02	0.01	0.03	0.06	0.06
52	Finance & Insurance	0.01	0.01	0.01	0.04	0.02	0.02	0.03	0.04	1.12	0.01	0.04	0.03	0.21	0.07	0.05	0.03	0.02	0.03	0.09	0.07
53	Real Estate Rental & Leasing	0.01	0.01	0.02	0.04	0.03	0.03	0.04	0.04	0.05	1.01	0.05	0.03	0.53	0.17	0.12	0.03	0.02	0.07	0.15	0.21
54	Prof. Sci., & Tech. Svcs	0.00	0.02	0.02	0.02	0.02	0.02	0.04	0.05	0.06	0.02	1.08	0.07	0.12	0.05	0.07	0.04	0.02	0.04	0.06	0.03
55	Mgmt of Co's & Enterprises	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.02	0.00	0.00	1.04	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01
56	Admin. & Support & Waste Mgmt & Rem. Svcs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	Education Svcs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.05	1.02	0.01	0.00	0.00	0.01	0.01	0.02
62	Health Care & Social Assist.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.02	1.01	0.00	0.00	0.01	0.01	0.02
71	Arts, Entert, & Recr.'n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.01	1.00	0.00	0.00	0.01	0.01
72	Accom. & Food Serv.	0.00	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.00	0.02	0.01	0.16	0.05	0.04	0.01	1.01	0.02	0.07	0.06
81	Other Svcs	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.00	0.02	0.01	0.13	0.04	0.04	0.02	0.01	1.03	0.04	0.05
93	Public Admin.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
	Wages to labor	0.07	0.08	0.11	0.25	0.16	0.16	0.25	0.24	0.28	0.03	0.28	0.17	3.07	0.96	0.67	0.16	0.13	0.37	0.87	1.20

Sonora – Closed I/O Matrix by Sector, 2008; Regionally Adjusted Ratio of Household Consumption by Industry

		Ag., Forestry, Fishing & Hunting 11	Mining 21	Utilities 22	Construction 23	Manufacturing 31-33	Wholesale & Retail Trade 43-46	Transportation & Warehousing 48-49	Information 51	Finance & Insurance 52	Real Estate Rental & Leasing 53	Prof. Sci., & Tech. Svcs 54	Mgmt of Co's & Enterprises 55	Admin. & Support & Waste Mgmt & Rem. Svcs 56	Education Svcs 61	Health Care & Social Assist. 62	Arts, Entert, & Recr.'n 71	Accom. & Food Serv. 72	Other Svcs 81	Public Admin. 93	Household consumption
11	Ag., Forestry, Fishing & Hunting	1.12	0.03	0.06	0.09	0.15	0.05	0.09	0.07	0.07	0.01	0.07	0.04	0.74	0.23	0.18	0.05	0.05	0.10	0.22	0.29
21	Mining	0.00	1.01	0.04	0.04	0.09	0.01	0.04	0.02	0.01	0.00	0.02	0.01	0.12	0.04	0.04	0.01	0.02	0.03	0.04	0.05
22	Utilities	0.01	0.02	1.02	0.03	0.04	0.03	0.03	0.03	0.02	0.01	0.03	0.01	0.17	0.08	0.07	0.05	0.07	0.05	0.08	0.06
23	Construction	0.00	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00
31-33	Manufacturing	0.10	0.21	0.63	0.67	1.95	0.26	0.74	0.44	0.30	0.08	0.31	0.17	2.54	0.83	0.79	0.27	0.37	0.52	0.92	0.96
43-46	Wholesale & Retail Trade	0.02	0.04	0.10	0.12	0.13	1.05	0.12	0.08	0.07	0.01	0.07	0.04	0.58	0.19	0.17	0.05	0.06	0.11	0.20	0.22
48-49	Transportation & Warehousing	0.01	0.02	0.03	0.05	0.05	0.03	1.07	0.05	0.05	0.01	0.04	0.02	0.37	0.12	0.09	0.03	0.02	0.05	0.13	0.14
51	Information	0.00	0.00	0.01	0.01	0.01	0.01	0.01	1.04	0.05	0.01	0.02	0.02	0.09	0.04	0.03	0.01	0.01	0.02	0.04	0.03
52	Finance & Insurance	0.00	0.01	0.01	0.03	0.02	0.02	0.03	0.04	1.12	0.01	0.04	0.03	0.18	0.06	0.04	0.03	0.02	0.02	0.08	0.06
53	Real Estate Rental & Leasing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01
54	Prof. Sci., & Tech. Svcs	0.00	0.02	0.02	0.02	0.02	0.02	0.04	0.05	0.06	0.02	1.08	0.07	0.11	0.04	0.07	0.03	0.02	0.03	0.06	0.03
55	Mgmt of Co's & Enterprises	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.02	0.00	0.00	1.04	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.00
56	Admin. & Support & Waste Mgmt & Rem. Svcs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	Education Svcs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	1.01	0.01	0.00	0.00	0.00	0.01	0.01
62	Health Care & Social Assist.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	1.01	0.00	0.00	0.00	0.01	0.01
71	Arts, Entert, & Recr.'n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.01	1.00	0.00	0.00	0.01	0.01
72	Accom. & Food Serv.	0.00	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.00	0.02	0.01	0.17	0.06	0.04	0.01	1.01	0.02	0.08	0.06
81	Other Svcs	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.00	0.01	0.01	0.10	0.03	0.03	0.02	0.01	1.02	0.04	0.04
93	Public Admin.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
	Wages to labor	0.07	0.08	0.11	0.24	0.16	0.16	0.24	0.23	0.27	0.03	0.28	0.16	3.02	0.95	0.65	0.16	0.13	0.36	0.86	1.17

APPENDIX C – Field Work Interviews

NOTE: ALL NAMES AND IDENTIFYING INFORMATION WERE REMOVED FROM THE INTERVIEW NOTES TO RESPECT THE ANONYMITY OF THOSE INTERVIEWED

General Summary Notes

- Most cooperatives are comprised of family members to reduce risk of competing interests. Some cooperative members are active fishing, others hire people to fish for them.
- Some cooperatives own processing plants, others do not. Some sell directly to distributors, others go through middlemen. The structure and financial models of the cooperatives are very diverse.
- Asian buyers have Mexicans working for them managing their businesses, protecting them. They seldom communicate directly with anyone. There is lots of resentment towards Asian buyers coming in and exploiting the resources of Mexico
- General agreement that fisheries closures are effective at maintaining sustainable populations, however, lack of enforcement by authorities is cited as the largest barrier to closures ("vedas") being effective
- Fishers in Peñasco express an understanding that freshwater inflows from the Colorado have an impact on local fisheries productivity for certain species, notably shrimp and corvina, but also other species as well

Notes by Species:

- Benthic (snails, geoduck, etc.)

- Snails exported to China from Puerto Peñasco to Vietnam, Japan, and China. It takes a month from ocean to market. They are transported via boat.
- The beach price of snails increases over the season as they become more scarce
- Geoduck price has been increasing and the markup in China is significant, from US$6 per kilo in Peñasco to US$14.50 per kilo in China, or US$5 per piece to US$30 per piece
- The clams take up to 30 hours to get to China and go as far as Hong Kong and Vietnam
- They take them to Hong Kong to avoid taxes
- From Hong Kong onward, the product is often mistreated and the clams die or suffer reductions in quality
- There are three tiers of geoduck in Mexico and the product is highly associated with the location where they are harvested, in fact, there is name recognition in China of the cities where they are harvested
  - Pacific – (abrupta) – US$50 per kilo
  - San Carlos – (globosa) – US$17-30 per kilo
  - Sonora
    - Peñasco – (globosa) – US$4-14.50 / kilo
    - Guaymas – (globosa) – US$4-5 / kilo
    - San Felipe – (globosa) – US$4-5 / kilo – the product from San Felipe is very similar to the product from Peñasco
- In Hong Kong, the geoduck is selling form as much as US$40 per kilo. Last year, geoduck sold for US$7-8 per kilo in Peñasco, and was selling for US$23 in China.

US$5 per piece in Peñasco, and US$13 per piece in China, as such the retail price in China is over 3x as much as the local market price.

- Shrimp
    - Processors store their frozen shrimp after the season is over so they can sell it at a higher price when shrimp cannot be legally harvested. Camaron "nueva" ("new" shrimp) is freshly caught shrimp during the fishery closure, implying that it was illegally caught
    - Beach price for shrimp is MXN$110/kilo
    - One cooperative owner in Puerto Peñasco thinks that up to 60% of shrimp caught there is illegal
    -

Cooperative Owner Interview 1

- Recently opened new facility, with plans to expand more in the future. Invested in freezer rooms and new compressors which came from a company in Mexicali.
- Facility processes and packages the product for transport and export.
- Contract with a transport company that has operations elsewhere in Mexico
- Has an exclusive relationship with one coop to buy their product. Coop has 12 pangas.

Cooperative Owner 2

- Cooperative has 8 members and operates 7 pangas
- Fish for lenguado, chano, corvina, snail, almeja, sierra, and shark
- They fish all year round and bring in roughly 8,000 to 10,000 pesos per trip

- Work with a local buyer who gives them fishing nets and equipment in return for buying their fish at a slightly lower price, for example 15 pesos per kilo instead of 18 pesos per kilo. He has strong relationships with local and regional gear dealers.
- Fishing nets cost between MXN$20,000 – 25,000 and last about 2 years
- Other pangas stealing fishing gear is a major problem in the area
- Used pangas cost about USD$3,000
- Repairs can cost around MXN$17,000, without labor the materials would be MXN$8,500
- Pangas earn about $MXN800-1000 on a good day, MXN$100-200 on a bad day, gasoline costs MXN$700-800 per trip
- Earnings are split amongst all boat members, losses are taken by owner
- The community has seen positive results due to people respecting closures on the manta and guitarra fisheries

Cooperative Owner 3

- Exports geoduck to Hong Kong via Ensenada
- Sell to one of the largest regional buyers
- Are working on an aquiculture project for geoduck
- Spend MXN$30,000 per month on electricity for their plant
- Cooperative has 10 members and 30 employees, all members are family members (most cooperatives are comprised of family members)
- Reports that Golfo de Santa Clara and San Felipe both receive financial support to not fish in the vaquita polygon (CONANP, CONAPESCA) and Puerto Peñasco does not

have this. They assumed that people from Puerto Peñasco were not fishing in the polygon

- Working on getting certifications for their plant (COFEPRIS, Espejo de agua, etc.) These certifications help them get a premium and can help in being able to export to US
- Work with a processor in Ensenada

Cooperative Owner 4

- The geoduck fishery was recently closed during the winter which is the best time to harvest them, when they have the greatest weight and are most visible and accessible
- His production has decreased significantly recently, he thinks it's due to climate change and El Niño
- Has traveled to Asia to participate in seafood trade fairs
- Heavy competition from Asian buyers to maintain their relationship with producers
- Baqueta and lenguado are exported to the US
- Crab is exported to the US. They clean them and then is exported through Texas
- Catarina scallops are exported to the US
- Callo de hacha is commercialized locally and in other parts of Mexico
- Snails commercialized locally and in Korea
- Chano (seabass) is commercialized locally, they want to expand to Chinese and Korean markets
- Recently scallop harvests are low due to overexploitation and lack of enforcement
- Many of the geoduck processors in Ensenada have permits for San Felipe and San Carlos

- The geoduck permit holders have been interested in trying to close the fishery for a period of time to see if they can put pressure on the Chinese buyers to increase prices, however, all it takes is one person to cheat and it breaks down
- Employs over 100 people in the company plant, but with declines in fishing he is having to cut jobs. They are going to sell part of their operation.
- Right now, they spend MXN$70,000-100,000 per month on electricity for their processing plant and MXN$40,000-45,000 per month on electricity for their laboratory
- Crabs are exported to Houston, TX
- Their cooperative owns their pangas, 5 members
- They own a panga factory which makes 3 types of pangas that cost MXN$85,000, MXN$90,000, and MXN$110,000
- He said that there is problem with so many resources being invested in the vaquita and so few resource being invested in monitoring and enforcement of fisheries, which would solve many of the problems
- Motor maintenance: MXN$1,000 x 10 per year. They perform service according to hours of operation. The ball-bearings on the trailers need to be replaced and maintained
- Divers earn MXN$1,000-3,000 per day in geoduck, MXN$300-500 per day for crab, MXN$100-200 / kilo and 10-15 kilos per day for callo de hacha
- The three fishermen on the boat all receive ¼ of earnings, and the final ¼ goes to the cooperative to cover costs
- Prices:
    - MXN$17 / kilo for crab last year
    - MXN$5 / kilo for snails last year

    - US$5-14 / piece for geoduck

- In San Carlos, 700,000 geoducks harvested last year, had 300 pangas, market was saturated
- In general, the Chinese market buys geoduck and other exotic species. The Korean market buys snail, and chano

Cooperative Owner 5

- They have 8 pangas and 8 members, 4 of which actively fish. They employ 6-9 fishermen. Their cooperative is comprised of family members.
- They work with a number of buyers:
    - Geoduck – 3 different buyers in Ensenada
    - Fish – local buyer
    - Crab – local buyer
- They are working on a project to build a processing plant, this would be 2 years in the future, but so far have not started on it
- Major costs include transportation of product to buyers, repairs to motors and boats, and gas
- The contracted fishermen are paid by catch, whatever is left over goes towards the costs of the coop
- In a week, a worker will earn between 1700 and 2500 pesos, this was for last year
- On their pangas, the number of people onboard depends upon the species and method:
    - Diving – 3 people
    - Crabs – 2 people

    - Fishing – 2-4 people
- He says 60-65% of fishers belong to cooperatives, 35-40% are independent
- Repairs to the boat range between MXN$50,000 to 100,000
- They change the off-board motor every 5 years. A Suzuki motor costs MXN$270,000 new (this corresponds to the price of an ecological motor)
- There is a federal subsidy for buying ecological motors, only the cooperatives can participate. MXN$80,000 comes from the fisherman, the remainder is covered by the state and federal government.
- Gas costs:
    - Crab – MXN$600 / day – 8-16 miles
    - Chano – MXN$1,200 / day – 20-30 miles
    - Clams – MXN$500 / day – 1-2 miles
    - Shrimp – 30-40 miles
- 50-60% of the price of crab represents the costs
- The price of geoduck has declined
- A used panga costs about MXN$15,000 in bad condition, MXN$30,000 in good condition and would measure about 28 feet long, 8 feet wide, and 4 feet deep
- A new panga would cost about MXN$100,000
- The military auctions off boats that were confiscated from drug traffickers, cost MXN$10,000, but require MXN$20,000-30,000 in modifications and repairs
- Crab traps cost MXN$20,000-40,000 every season
- Fishing nets cost MXN$20,000-30,000 and last 1-2 years

- Buyers are in contracts with distributors to provide a certain amount of crab each year. If they do not deliver, they get punished with fines. As a result, buyers put pressure on the fishers to be fishing. On days when they don't go out, they will ask them why they're not out fishing.
- Illegal fishing provides flexibility to fishers. Sometimes people just want to do their own thing. Also, it allows them to move from one area to the next, following the good harvests and maximizing their profits. They are not tied to one particular community or species.

Gear Dealer 1

- Shrimping net, 200 meters long, they would use 10 of these at once per season – MXN$808
- Lead weights – MXN$46 / kilo, 25 kilos / panga
- Rolls of rope – MXN$1500, 2 rolls
- Buoys, 450 @ MXN$8, last for two years
- 2 kilos of "piola" (thin rope) MXN$150 / kilo
- Net for corvina – 55m x 3m x 50m – MXN$1,038 – would use 8 of these
- Pangas – 25 feet long – MXN$78,000
- Mercury 75 motor (ecological) MXN$189,000
- For crab traps, a roll of mesh that makes 10-11 traps costs MXN$2000
- 25 pounds of gravel – MXN$1,400
- For diving: compressor motor MXN$16,000; 5 pound weight for diver MXN$134; regulator MXN$1,100; boots MXN$690; hood MXN$250

- Processors buy equipment and give it to fishers with the understanding that they will bring them the catch

Cooperative Owner 6

- Nutrients and low salinity from the Colorado River are important to spawning habitat
- Before 1993, shrimp was in crisis, afterwards it recuperated
- Corvina, sierra, chano, shark, and shrimp all benefit from the lower salinity
- A new ecological motor costs MXN$175,000 and a used ecological motor costs MXN$50,000
- A used panga costs MXN$30,000
- To catch white corvina, they use a net that is 170m long, mesh size 3, cost is MXN$10,000, 1 for each boat
- It costs MXN$1,500-2,000 to paint a panga
- They service the motors every 100 hours of operation – MXN$1,000 for oil and filter
- Their shrimp season is only 5-6 days long. Last season they caught 2 tons of shrimp in a 3 day season, this season they caught only 17 kilos. It varies greatly
- He used to fish in Upper Gulf, but has stopped going. He says the area is over saturated with fishers, and people have started using huge nets. The fact that they use huge nets is part of the problem because they are left out for long periods and species drown. He used to use a chinchorro de linea which was small and selective and would be brought in frequently, reducing the risk of drowning species like turtles and porpoises.
- They fish 7 months out of the year
- Earnings, minus costs, are split 60% to the fishermen, 40% to the cooperative

- For sierra, they catch about 200 kilos per panga at a price of MXN$12 per kilo – MXN$2,400 total, 500 for gas, 1,900 in profit, 60% of which goes to fishermen, 40% to coop
- Corvina – the catch was very low this past season because there was a spike in the sardine population and many of the sardine boats were fishing in the area, he suspects that many of the corvina were caught by the sardine boats as incidental catch. The price was MXN$12 per kilo
- Chano – 2 years ago, they were catching between 1 to 4 tons per day, last year it was less, and this year was a terrible season
- He says that in the past catches were less variable, now the spikes in population are very dramatic
- Another problem is substitute species in international markets, for example, Alaskan halibut saturates the market and reduces the price for "lisa"
- Beach price for "lenguado" is MXN$50-60 per kilo
- 60 liters of gas costs MXN$840
- Sierra is sent to Mexico, Chano is exported to China, shrimp is sold locally, though before they used to sell to one of the largest regional buyers.
- He says the price paid for shrimp by a major regional buyer has fallen since the company was privatized. The beach price is MXN$100-120 / kilo
- Illegal fishing is fueled by extraordinary seasons. The price of a panga and fishing gear can be recuperated in a few days, attracting illegal fishers to the market. Then, when that species is exhausted or the season closes, then they have to figure out what they're going to do next, and this leads to overexploitation of all species. They go from one thing to the

next. They could earn up to MXN$68,000 in one day, enough to recuperate investment very quickly.

- One of the largest problems facing the fisheries is corruption. People fish illegally, get caught, and then just pay people off.

Fisheries Specialist 1

- Fisheries collapses
    - 1970's – totoaba
    - 1980's – groupers, corvina, totoaba
    - 1990's – everything else
    - Ecological collapse (species, environmental, and ecological)
- Illegal fishing
    - About half of fleet was not permitted, based on his experience
    - Oftentimes, multiple pangas would be fishing under the same permits
- Oceanographic science
    - CICESE has developed fine scale oceanographic model of oceanic flows in Northern Gulf, used to model larval dispersion, and then validated using genetic testing. Shows that there is a gyre in the Upper Gulf, mixing the waters
    - Connectivity pathways in the Upper Gulf, marine connectivity for three species, including blue crab and rock scallop
    - NOA Atlantis Model
        - Functional groups of organisms
        - You can model enforcement of MPAs and biomass is one of the outputs

        - Built around vaquita
    - There are clusters of areas where ocean flows get trapped, you see genetic isolation in these, they would make good marine protected areas
- Governance
    - In Mexico fisheries plans are blanket national plans, not specific to local biology
    - According to new rules, all communities are to have fisheries ordinance plans (ordenamientos pesqueros)
    - Currently, about 3,000 pangas have been chipped in the Gulf of California, COBI was assigned this project; ¾ of all legal boats are chipped
    - The ordenamientos are not well defined in terms of the implementation phase
    - In some communities, informal regulations are being formalized
    - Concessions – in Ensenada, fishermen rotate through various activities, including doing their own enforcement – FEDECOP
    - Not many functional cooperatives remain and there are few independent fishermen
- Misc other points
    - Cabo Pulmo is an example of restoring after ecological collapse – rule of 5 – 5 years to recuperate invertebrates, 10 for larger fish, 15 for sharks
    - Vaquita and anchovy tend to be in the same areas, prime area is south of refuge
    - Not much premium for Marine Stewardship Council certification
    - Boats are lost by narcos, end up in hands of fishermen and used

    - Anecdotal data on freshwater flows, correlation with catch for shrimp and corvina and el niño years, we would expect to see an impact on blue crab, all shrimp except rock shrimp, and corvina
    - Best catch data is collected by non-profits and observers for artisanal fishing
    - Look at US-Mexico customs broker data, import records

Fisheries Specialist 2

- Bahia Adair, freshwater upwells, high larval productivity
- Sustainability certification doesn't seem to command much of a market premium
- San Felipe has divided into 2 federations
- In last corvina season with catch quotas, some fishers held out until the end to fish and did well price-wise
- Totoaba aquaculture being pursued through CICESE in Ensenada
- Sistema Producto is an initiative to increase value chain capacity, the blue crab fishery is organizing this way
- Integradoras – sharing costs for taking things to market, 10 cooperatives work this way

Cooperative Owner 7

- There are 59 cooperatives and 22 sole permit holders in one Golfo de Santa Clara federation, around 80% of the fishing community belongs to this cooperative
- There are 85 cooperatives total in Golfo

- Within Golfo, there are 410 finfish permits, 400 gulf corvina permits, and 436 shrimp permits
- Belonging to a federation requires that you enter into a legal contract
- Federations formed in order to have greater leverage with the federal government, it affords them greater power in negotiations and helps them in communicating more effectively with the government, presenting a more unified message
- Roughly 90% of fishermen in Golfo fish shrimp and finfish, including corvina
- There is now a per-boat quota on corvina, 5.1 metric tons per boat per season
- In terms of income, shrimp represents around 60%, corvina 20%, and finfish 20%
- Before 2005, they would throw away the buche, in other words, its price was effectively $0
- Now, buche prices this season are up to $400 / kilo, even as much as $470 / kilo – in the first tide of this season, it was at $220 / kilo
- Some fishermen store the buche during the season and wait to sell it until the price is higher
- Koreans / Chinese come into town to buy buche, sometimes work through intermediaries
- He believes that the Asian buyers work together in order to extract the most advantageous price from fishermen
- The buche market first emerged around 8 years ago
- Now the Asian buyers are starting to buy the corvina roe (eggs) for caviar, this just started last year. At first they were buying it at $5 pesos / kilo, this season the price is at $20 pesos / kilo
- They fish almost entirely for the whole year

- Shrimp: September to February
- Corvina: February to May 1st
- Chano: March
- Sierra: May
- Month of July is spent doing repairs, very low fishing activity, only may 40% of fishermen are out at all
- The “red de arrastre”, the new fishing gear intended to prevent entanglement of the vaquita, is less selective and is having an impact on biomass, high rates of bycatch and low rates of catch for the target species
- Compensation related to the change in nets is related to the changes in productivity due to the use of the nets, change in catch
- Now there is the vaquita agreement for 2 years, this week the announcement will come out, the fishing ban starts on April 29th – not only do they compensate the permit holder, they also compensate the contracted crew, and the production / value chain that depends upon the fisheries for their livelihoods
- Beach price for shrimp varies significantly, around $120 / kilo, but the people who sell on the beach is minimal, the price can be up to $140-$150, the price varies by tide and increases with the growth of the shrimp, which progresses with the tides
- Corvina goes directly to La Viga, roughly 80% goes to Mexico City (some to Guadalajara), the remainder goes to Ensenada, San Luis, Tijuana, etc.
- Buche is transported to Ensenada frozen for export to Asia

- Foreign influence in market is creating disorder and competition, introduction of demand without regards to or ownership of local environmental / ecological consequences of harvest
- For example, the jellyfish market in Asia – the locals had no use for or connection to jellyfish but fish it for Asian markets – young people involved in fishery are pulled into drugs in order to stay awake for multiple days to fish
- He says that the richness of the Upper Gulf depends upon the river
- People that used to fish in the area used to fish higher up in the mouth of the Delta in the estuary, now it is prohibited
- The abundance of species (shrimp) was impressive in 1993
- Ocean currents in the Upper Gulf attract the fish as well
- He believes the earthquake influenced the corvina because the depth of the river bed / sea floor has changed
- Says there are places where freshwater reaches the sea, springs in the ocean where the shrimp congregate
- Says that in the past, 2 tons of shrimp per boat per season was normal, now 1 ton per boat is rare
- “Last chance vaquita” is an organization involved in compiling information related to vaquita conservation and fisheries

Cooperative Owner 8

- There are 7 federations in Golfo

- He says that the quota has not benefited fishermen – any increase in price has not been enough to offset decreases in catch – he says that what is missing to make the quota successful is sufficiently high prices
- He thinks roughly 80% of fishermen respect the quota
- Believes that corvina season monitoring has not benefited the community, people find a way to circumvent / cheat the system
- Says that shrimp represents 40% of income and finfish / corvina represent 60%
- Shrimp sells for $240 / kilo, blue shrimp size 16 20-10 – they use a selective net that doesn't catch young shrimp
- The new shrimp net is very destructive – in order to protect one species, you're destroying others and the benthic habitat – high levels of bycatch
- Buche this year started at $240 pesos / kilo and is now at around $385 pesos / kilo
- They've only been selling buche for around 2-3 years now
- Asian buyers send intermediaries who are from the community, actual buyers are located in Ensenada
- In El Zanjon they are throwing away the corvina meat and just keeping the buche
- There are 100 corvina permits in El Zanjon, but there are 300-400 pangas fishing there, some of them come from the ejidos, others from Peñasco
- Gasoline is very expensive, they use about 100-150 liters per day for corvina, and 50-100 liters per day for shrimp
- With all the costs, the owner of the boat ends up earning about 30% of the total earnings from corvina, there are many others involved in the processing, etc.
- Shrimp and chano are exported, shrimp to US, chano to Asia

- His coop sells to a major processor, they have a price list with what they pay per species
- Pay $20-$22 USD per kilo for shrimp
- There's no negotiation
- He says the recuperation of the corvina can be attributed to the quota
- Corvina, shrimp, chano, all arrive to spawn when the water flows arrive
- Overall, shrimp and shark have both declined
- In 1993 there was a ton of shrimp
- He says in the past there was a lot of small shrimp in the past, it was fished high up in the estuary, lots of shrimp reproduction in that area
- He says there has been more recuperation in Baja California due to the pulse, it has a greater influence there compared to in Sonora
- He says that for the new vaquita conservation measure, the fisheries sector is protected
- With the new fishing gear for shrimp that protects the vaquita, one of the problems is the cost of using it, requires a lot of motor power and gasoline – new ecological motors do not last very long when they pull the new gear
- Corvina is spared from the new vaquita closure, will continue to be fished

Conservation Organization 1

- Are working in many areas, including community development, economic development, microenterprises, education, building capacity and human capital in the community – in essence, are an incubator for implementation of federal programs
- Has contact with all the federations

- Working on a virtual university program, so far there have been 8 graduates, afterwards they are asked to contribute to the community in return, are provided access to computers at offices, receive donations to support program
- Also has organized the “festival de la corvina” which is operating now as a microenterprise, run completely by women; aimed at creating community, driving tourism; 20-30 people have been involved in organizing it
- There is another microenterprise focused on processing shrimp head discards for export
- Efforts have been focused on breaking cycle of local fisheries problems leading to frustration, discord, and complaining; instead, trying to reinforce creating new solutions and opening dialogue so people listen to each other; notes that the attitude of the sector has been changing recently
- Promote litter removal campaigns on the beach, provides a month and a half of salary to 3 groups of 20 people during the fishing down-season
- Working on monitoring program for the upcoming shrimp fishing closure
- Has recycling facilities on site
- Lack of enforcement is what leads to drops in price during corvina season; corvina from El Zanjon affects the price, not by flooding the market, but because the product arrives in worse condition and generally leads to lower prices overall
- Golfo usually produces around 900 or 1000 tons of corvina per season. El Zanjon produces around 600 tons
- Some panga owners own their own trailers, others do not; it depends upon the number of boats they own whether or not it becomes worth it to buy one
- 2 processing plants in community

CONAPESCA

- From 2007-2010, 178 boats were retired and there were 45 “reconversiones tecnologicos”
- Today there are 435 pangas with shrimp permits; 410 have finfish permits; previously there were 610 boats total
- In the 80s there were only large boats, but over time that changed towards using pangas, especially with the biosphere reserve being established

Fisheries Specialist 3

- The fisheries in San Felipe will be closed, with the exception of chano using the new “ecological” net and shrimp using the new ecological net; geoduck fishing with dive gear will be permitted
- Only about 33 people voluntarily converted their permits to the new ecological net
- Now, when people go in to renew their fishing permits, the government is involuntarily converting them to the new fishing gear; people are very upset about this
- The fishermen prefer the compensation of the new program
- The 2 federations came to an agreement with the government about the new vaquita arrangement
- Right now, the community’s understanding is that the money has been acquired, people feel relatively comfortable with the compensation compared to past compensation that only compensates the permit holders – this will also compensate the crew members
- About 1-2% have sports fishing permits, they can also continue working

- There are 2 federations in San Felipe that are currently at war with each other, it's based off of a personal conflict – there used to be 1 federation, but the leader split off due to conflict and formed a new one; people tend to join federations based upon their friendships and social networks; the new federation is only about 2 years old
- Having 2 federations has affected the ability of the community to communicate with the government, it's more challenging to present a unified message
- Shrimp beach price started at 180 per kilo at beginning of season, ended at 320/330 per kilo – this applies to blue shrimp which is exported – brown shrimp sells for much less
- Corruption is a major problem
- Community distrusts the government – at times the government has used strategies that upset fishermen in making decisions and collecting information
- Everyone is extremely distrustful of each other and especially outsiders, given the history of deceit in the community – for this reason it can be very hard to get information from the community because they are fearful of how the information will be used

Cooperative Owner 9

- Their cooperative solely fishes for shrimp
- 16 members, they are all friends
- Each member pays their individual costs, each pay 5-10% of their earnings into the cooperative to cover administrative costs, including accounting, taxes, paperwork, etc.
- He has been fishing for 38 years
- He says no one gets permits anymore

- Says that most permit holders live in San Felipe, not like other communities where the owners often live elsewhere
- Buyers have monopoly, price of shrimp fluctuates depending upon value of peso relative to the dollar. The beach price of chano has been very steady for 3 years now, at ~14 pesos per kilo
- There are no intermediaries in the shrimp market, very few people sell at the beach, they receive according to the cooperative's negotiation with the regional buyer
- The buyers have price ceilings for what they're willing to pay, but often lower price when they have the opportunity
- Regional buyer has a price list
- He believes the buyers definitely take advantage of their monopoly position in the market
- For finfish, there are intermediaries that sell the product to large companies and to the Asian buyers
- Previously, using typical gear, on a normal day you might bet 30-40 kilos of shrimp, on some days up to 100-250 kilos of shrimp on a very good day
- They use about 60 liters of gasoline in the past; now, with the chango ecologico, they use 130-160 liters of gas during a day's trip
- The chango ecologico is less selective, catching more bycatch
- Local fishermen do not understand what influences the ups and downs of the shrimp population
- He doesn't believe the fishery is being overexploited, says there are usually 700-800 boats per season fishing

- Says there is a lot of illegal fishing activity from Sinaloa and Sonora, coming to fish totoaba
- There are people monitoring who are supposed to be enforcing but they do not act when they see someone in violation of the rules
- Says corruption is a major problem with enforcement
- The new compensation is not equitable and he believes people will not respect the fishing ban
- For people like him who accepted to convert to the new gear, the federal government decided not to pay them their compensation this year and they are also not eligible for compensation under the new rules because they can continue fishing, though it is not profitable without the compensation
- Feels that the federations are not on the side of the fishermen in the negotiations
- Says that the PACE-Vaquita program was implemented before they have proven whether or not the chango ecologico was profitable to fish with – it turns out that it isn't
- Does not know of freshwater upwells in the San Felipe area

CONANP

- 2 federations
- The federations negotiate directly with the federal government
- CONANP has retired 600 boats in the Upper Gulf

Capitania del Puerto

- There are 8 local industrial trawlers

- 4 additional trawlers come in from Guaymas and Peñasco
- There are many more in Peñasco compared to San Felipe

Cooperative Owner 10

- Fishes sierra, chano, and shrimp
- 14 members in the cooperative, including both family and friends (multi-generational)
- Each member contributes to the cooperative, expenses are covered by the cooperative (shared)
- They employ an additional 28 individuals, some of the members fish as well
- Shrimp represents ~70% of earnings, sierra 15%, chano 15%
- Using new nets, they use about 100 liters of gasoline per trip fishing for shrimp, this is with the ecological motors
- Production is reduced by about half with the new nets – with the old nets they'd get 100 kilos, now they get 10, 12, up to 20 kilos
- The river influences the fishery, all species
- He converted the whole coop to the chango ecological thinking it would be a way to contribute to saving the vaquita
- Now they are outside of the economic compensation program, thinks that the people who converted should be first in line
- Thinks the compensation program will help, but it won't be a complete solution
- Beach price for sierra is 16 pesos / kilo, for chano it is 15 pesos / kilo
- Has not noticed freshwater upwells around San Felipe

- Belonging to a federation is helpful for complying with administrative requirements, they provide administrative support
- He will continue to fish shrimp but will also be participating in a pilot program to try new experimental fishing gear for chano and extranjero
- He says the compensation provides for permit holders and crew members for sure, beyond that it's unclear

Seafood Distributor 1

- Hazard Analysis and Critical Control Point (HACCP) plan implemented by FDA for seafood importers / distributers, must be implemented for each species you import – whereas in the past you could buy directly from fishermen in Mexico, this regulation made it prohibitively expensive for the small fishermen to comply with paperwork requirements for importing, so now they have to work through large distributors, coops, or sell locally or nationally. Fishers are at the mercy of the coops. Many have stopped fishing.
- Used to be a major regional distributor and would receive large trucks of seafood from the Gulf for distribution to the Southwest and California/Los Angeles. Now that they do not move the same tonnage, the companies in California get their seafood directly from Mexico.
- Used to get seafood from Upper Gulf but now gets most of their seafood from the Guaymas area.

- There are very few processors in Arizona. The seafood distributors in the Phoenix metro are owned by large California companies. Processing is done in California. The product usually travels through Tijuana, to Los Angeles, and then to Phoenix.
- Supply local restaurants
- Many consumers do not want to pay the price for fresh wild caught seafood
- Mentioned that Chinese boats are fishing in Mexican waters and there is not enough enforcement to curb this
- Used to work with Asian buyers in California – the Asian buyers would play games such as suddenly lowering their price when the product was delivered or say that something was wrong with the product when it arrived, forcing the seller to accept a lower price. They have all the power in the negotiations because the product is perishable and cannot be returned, take advantage of having the upper hand in the negotiations.

Seafood Distributor 2

- Business is based off of personal connections with sellers from the Gulf.
- People he doesn't know show up at his business with truckloads of seafood trying to sell him product. Most of the time these people have import licenses but don't have enough product to sell to the big companies and are trying to sell it however they can
- Weather, holidays affect how much catch they bring in. Also, any border closures affect delivery of product
- In the 1990s there was a cattle crisis in Mexico due to drought and many of the ranchers got into fisheries at this time

- Right now there is inconsistent supply and quality. People do not arrive with the product when they say they are going to. Sometimes the product arrives spoiled.
- One of the last businesses working the “old fashioned” way, cutting the fish themselves. Most fish now days is pre-cut in California. Grocery stores sell less variety and no one is educated on how to cut fish.
- The prevalence of smartphones has been important for the business because buyers can photograph the product if it is damaged or spoiled and have proof of their claims about the quality of the product.
- Now days most fish goes through LA
- Oysters are now booming on Pacific side of the Baja
- In 1942, Tucson and Nogales were awash in fresh oysters, and then a virus hit. Now things are starting up again
- The underground business is a big deal, people bringing coolers full of seafood from the Upper Gulf
- There is a flat rate to cross the border, this makes it difficult to deliver small loads in the summer

APPENDIX D - Economic Impact Analysis Results

Model 1 & 2 – Shrimp

Model 21 – Corvina

Method 1: No Households or Wages to Labor

Model 1 Total EI			
	Low	Med	High
0	$0	$0	$0
1	$2,877,838	$2,119,978	$1,362,117
2	$5,715,709	$4,239,956	$2,764,202
5	$13,976,731	$10,599,889	$7,223,047
10	$26,832,172	$21,199,778	$15,567,384

Model 2 Total EI			**Shrimp**
	Low	Med	High
0	$0	$0	$0
1	$25,217	$19,827	$14,436
2	$83,443	$79,307	$75,172
5	$455,318	$495,672	$536,025
10	$1,721,199	$1,982,686	$2,244,173

Model 21 Total EI			**Corvina**

	Low	Med	High
0	N/A	$0	N/A
1	N/A	$9,256	N/A
2	N/A	$37,023	N/A
5	N/A	$231,393	N/A
10	N/A	$925,572	N/A

Method 2: Including Wages and Household Consumption using National Ratios

Model 1 Total EI			
	Low	Med	High
0	$0	$0	$0
1	$3,164,212	$2,330,936	$1,497,661
2	$6,284,478	$4,661,873	$3,039,267
5	$15,367,553	$11,654,682	$7,941,810
10	$29,502,236	$23,309,363	$17,116,491

Model 2 Total			**Shrimp**
	Low	Med	High
0	$0	$0	$0
1	$27,727	$21,800	$15,873
2	$91,746	$87,199	$82,652
5	$500,627	$544,996	$589,365

10	$1,892,475	$2,179,983	$2,467,491

Model 21 Total EI			
	Low	Med	High
0	N/A	$0	N/A
1	N/A	$10,175	N/A
2	N/A	$40,699	N/A
5	N/A	$254,372	N/A
10	N/A	$1,017,487	N/A

Method 3: Including Wages and Regionally Adjusted Household Consumption Ratios

Model 1 Total EI			
	Low	Med	High
0	$0	$0	$0
1	$3,168,939	$2,334,419	$1,499,899
2	$6,293,867	$4,668,837	$3,043,808
5	$15,390,511	$11,672,093	$7,953,675
10	$29,546,311	$23,344,186	$17,142,062

Model 2 Total EI			
	Low	Med	High
0	$0	$0	$0

1	$27,768	$21,832	$15,897
2	$91,883	$87,330	$82,776
5	$501,374	$545,810	$590,245
10	$1,895,302	$2,183,239	$2,471,177

Model 21 Total EI			
	Low	Med	High
0	N/A	$0	N/A
1	N/A	$10,188	N/A
2	N/A	$40,753	N/A
5	N/A	$254,706	N/A
10	N/A	$1,018,826	N/A