Understanding the Relationships between Market Price and Fishery Yields in the Golfo de Santa Clara

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MAS Marine Biodiversity and Conservation
Capstone Project

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\textbf{ABSTRACT}

The Golfo de Santa Clara is a remote town in the Upper Gulf of California, where 50\%-80\% of the community is actively involved in the small-scale fishing industry. The relationship between market price and fishery yields is crucial to understand because it dictates the revenue for the local fishermen. In this study we examined each fishery dynamics and the relationship between market price and cumulative capture for Blue shrimp (\textit{Litopenaeua stylirostris}), Gulf corvina (\textit{Cynoscion othonopterus}), Bigeye croaker (\textit{Micropogonias megalops}), and Spanish mackerel (\textit{Scomberomorus spp.}). We discovered unique fishery dynamics and interactions between market price and capture for each fishery. Blue shrimp had a positive linear relationship between market price and cumulative capture. Gulf corvina had a negative logistic relationship between market price and cumulative capture, where the market price dropped off at the end of lent. Bigeye croaker had a positive logistic relationship between market price and cumulative capture, while for the two different seasons analyzed Spanish mackerel had two different relationships (positive logistic & quadratic) between market price and cumulative capture. A system wide evaluation, which incorporated dynamics of all four fisheries, showed that the system was made up of three distinct components, the Blue shrimp, Spanish mackerel, and then the combination of the Gulf corvina and Bigeye croaker. The Blue shrimp component had a significant impact on all of the other fisheries’ market prices. This study shows the importance of evaluating fisheries from a multi-species system perspective rather than a single species perspective. By taking into consideration the interactions between fisheries management can better aim to set regulations that have a positive impact on all fisheries, rather than regulating a single species at the expense of sustainable practices of other fisheries.

\textbf{1. Introduction}

The Gulf of California alone produces more than half of Mexico’s total annual fisheries production. The Upper Gulf of California (UGC) consists of some of the most productive small-scale fisheries within the region (Erisman et al. 2015). The Upper Gulf’s economy relies heavily on these small-scale fishing communities and a collapse of the major fisheries in the area would have a catastrophic impact on the communities’ wellbeing as well as a significant effect on the Mexican fishing industry (Cisneros-Mata, 2010).

The UGC is a difficult place to inhabit due to its remote nature. It was not until the 1970s that the UGC grew to become some of the most productive national artisanal fisheries in the Gulf of California. In the early 1900s the UGC communities relied on the fisheries for personal consumption and local trades. In 1924 the first trade route ran through the UGC, which brought resources to the town that preserve capture. The ability to place the fish on ice increased the time from capture to sale, which allowed the communities to increase their production since they
could then sell the capture to buyers who would take the fish to other markets. However, the main growth of the small-scale fisheries did not occur until the 1970s. During the 1970s Mexico aimed to improve the national fisheries and invested in industrial fishing fleets, along with thousands of artisanal vessels (Cisneros-Montemayor and Vincent 2016). The investment into the fisheries by the Mexican government provided jobs and increased the economies of the small remote communities along the UGC.

One specific community in the UGC, the Golfo de Santa Clara, economically relies entirely on its local fisheries. The Golfo de Santa Clara is located in Sonora, at the mouth of the Colorado River Delta, surrounded by the Sonoran Desert containing very few road networks (CONANP, 2007). The Golfo de Santa Clara’s fisheries consist of multiple fishermen working on one boat, and then compiling their capture from multiple boats into a truck, which transfers the capture to the buyer (Figure 1). About 50%-80% of the people in the community are actively involved in this fishing system, which produces about 10.4 million USD each year for the community (Ávila-Forcada et al., 2012; Vázquez León et al., 2012).

The UGC has a long history of fisheries management struggles due to the presence of endangered species: the vaquita porpoise (*Phocoena sinus*) and the totoaba (*Totoaba macdonaldi*) (Table 1). In 1993 President Salinas decreed a biosphere reserve to put in place boundaries to protect the vaquita (Cisneros-Montemayor and Vincent 2016). The establishment of the reserve segregated the UGC into no-take zones, buffer zones, and the Vaquita refuge zone, all of which have had major impacts on the fishing communities (Figure 2, Erisman et al. 2015). Additionally, there are multiple fishing gear restrictions regulating different fisheries, such as the mesh size for gillnets or the type of fishing gear allowed. Most recently, management implemented a gillnet ban within the UGC (Table 1). This management strategy has a drastic effect on the fishing in the UGC since the majority of the fisheries use gillnets.

Table 1: Timeline of Upper Gulf of California’s Important Regulations and Events

<table>
<thead>
<tr>
<th>Year</th>
<th>Management Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>Colorado Delta Biosphere Reserve created (CONANP, 2007)</td>
</tr>
<tr>
<td>2005</td>
<td>Vaquita Refuge Established, limiting fishing activities within its boundaries (DOF, 2005)</td>
</tr>
<tr>
<td>2007</td>
<td>Implementation of “Programa de Acción para la Conservación de la Especie: Vaquita (Phocoena sinus) (PACE-Vaquita)” (Semarnat, 2008)</td>
</tr>
<tr>
<td>2012</td>
<td>First quota set for Gulf corvina (DOF, 2011)</td>
</tr>
<tr>
<td>2013</td>
<td>Announcement of the phase-out of the shrimp gillnets over next three years (DOF, 2013)</td>
</tr>
<tr>
<td>2015</td>
<td>No-gillnet polygon (i.e. gillnet ban on everything except corvina) (DOF, 2015)</td>
</tr>
</tbody>
</table>

![Figure 1: The workflow for the fisheries in the Golfo de Santa Clara. Around 3-4 men fish in one boat, then compile their capture with multiple other boats into one truck. This truck then takes the capture to local buyer to sell.](image)
In the Golfo de Santa Clara there are 20 fisheries, but the four main commercial fisheries, based on capture and revenue, are Blue shrimp (*Litopenaeu stenotrostris*), Gulf corvina (*Cynoscion othonopterus*), Bigeye croaker (*Micropogonias megalops*), and Spanish mackerel (*Scomberomorus spp.*). These fisheries differ in the length of their respective seasons, predictability, and economic yield, which makes management strategies difficult because it is tough to understand the unique and complex dynamics of each fishery.

The Blue shrimp fishery is primarily exported to US and Asian markets, where the price is set at an international level (Vinuya 2007). This fishery is only allowed during daylight hours and is regulated by a legal norm, NOM-002-PESC, which prohibits targeted fishing during the spawning season, which is from March to August (DOF, 2013). Furthermore, in 2013 the norm was modified to include a gear phase out from gillnets to trawlers (Table 1).

Gulf corvina fishing occurs during the spring tides preceding the new and full moons. This creates a cycle of short, intense fishing periods (~5 days) followed by longer periods (~10 days) of no fishing within the fishing season. The Gulf corvina is targeted during spring tides because it is when the corvina form huge spawning aggregations, which makes it easy to capture a large amount at one time. Consequently, the fishermen flood the national market until demand drops and market prices plunge until there is an excess of catch that is discarded (C. Lopéz-Sagátegui pers. comms., Paredes et al. 2010). The variability in capture and market price makes it difficult to predict the catch and prices within the season but also, for the following year’s
fishing seasons (Johnson et al. 2015). In order to combat this erratic fishing practice, there are multiple regulations in place for the Gulf corvina (DOF, 2007, Erisman et al. 2012). The fishery is closed at night and also from May 1st to August 31st each year. Furthermore, there is a yearly catch quota in an attempt to prevent overfishing of the stock. Although there are many different forms of regulations for the Gulf corvina, the erratic nature of the fishery, the subsequent catch-price relationship and the ecological nature of the fishery there are still threats of collapse for this lucrative artisanal fishery (Erisman et al. 2015).

The Bigeye croaker is a relatively new fishery to the UGC and its only regulation is the limit to how many fishing permits are issued for finfish. All of the catch is exported to Asian markets. Similar to Bigeye croaker with respect to regulations is the Spanish mackerel fishery. Spanish mackerel is targeted at nighttime and the main capture is sent to markets in Mexico City. The Gulf corvina, Bigeye croaker, and Spanish mackerel fisheries each have a total of 405 permits, while the Blue shrimp fishery allocates 423 permits (Erisman et al. 2015).

In a traditional fishery market, one expects that as the quantity supplied increases (i.e. catch present in the market) the price will decrease in response. Likewise, it is projected that as the quantity supplied decreases the price will increase (Keohane & Sheila, 2007). In a competitive market with multiple buyers and sellers, the buyers have relatively little control over the market quantity or price, but simply their individual quantity contributed (Keohane & Sheila, 2007). The Golfo de Santa Clara has few buyers, with one buyer dominating the market at any given time. This sets up for a monopsony market, where the buyer holds the power over the market and can dictate the price for which the fishermen sell their catch. This dynamic can lead to an increased price gap between the fishermen's $/kg price versus the buyer’s $/kg price in the higher markets if the buyer sets lower selling prices. This monopsony market leaves the fishermen with essentially no power and the buyer with full control over the local market. The remote nature of the Golfo de Santa Clara also means that this monopsony market is persistent because there is not a lot of other competition for the buyer, since very few buyers are capable of transferring the catch via the few road networks to larger markets.

Considering the diverse complexities of the Golfo de Santa Clara, it is crucial to understand the fishery dynamics and the relationships between the fishery yields and market price, which dictate the fishermen’s yearly revenue. The work presented herein aims to provide insight for management about the fishery yields and price dynamics in the Golfo de Santa Clara and investigate how the fisheries interact with one another. This information will be useful because it provides management with a novel view of the communities as the target for regulation rather than each individual fishery as a separate view.

2. Methods and Materials

2.1 Data Set

We obtained artisanal fisheries data from a buyer in the Golfo de Santa Clara, for the period March 2006 to February 2015, which includes 114,927 records. We used all data from January 2006 to March 2015, for Blue shrimp, Gulf corvina, Bigeye croaker, and Spanish mackerel.

The data includes multiple capture records per day, detailing each individual purchase (kg of capture) made by the buyer, with the price information beginning in 2012. A single recorded landing is an accumulation of one or several boats compiling their catch into one truck
to bring to the buyer. Due to the inconsistency in reporting for the earlier years of the data, only the most complete data were used when analyzing the behavior of the separate fisheries.

2.2 Fishery Descriptions

All fish captures were recorded as the sum of the records for each day, and reported as daily totals. Revenue was calculated by multiplying the daily capture by the average daily price for each species. All means are reported ± standard deviations.

The dates of the full and new moon were used to segregate the data by individual tides rather than a daily resolution because it accounts for variation between years of when the fish resource is present in the UGC. Leading up to and including each full moon was considered an individual tidal cycle, and likewise for new moons. Full and new moon data were based off the Gregorian calendar.

2.3 Market Price vs. Cumulative Capture

To examine the relationship between market price and catch we evaluated average daily price against cumulative capture. We used cumulative capture because it includes a time component of the capture, which is useful because it accounts for the total capture presented to the market over the entire season. We used regression analysis to evaluate the relationships between market price and cumulative capture by season for each species. Each regression included data from 2013 and 2014, but also the 2012 and 2015 data for the Blue shrimp regression. The regressions ran were based off of the trend in the market price data. Multiple different model shapes were tested for each fishing season for each species and the best fitting models selected for each.

2.4 System Wide Evaluation

We aimed to evaluate the interactions of the four fisheries of the Golfo de Santa Clara by examining all four fisheries together as a complete system. To look at the interactions within the system we performed a Pearson principle component analysis (PCA) for years 2013 and 2014, segregated by tidal cycle. We segregated by tidal cycle because the fisheries are targeted around the tides. We summed the cumulative capture for each species for each tidal cycle. We then used the PCA to determine how the fisheries influence each other based on cumulative capture.

To look at the impact of the presence of different fisheries on market price we ran a principle coordinates analysis using the PCA matrix coordinates, from the previous PCA, against the average price for each tidal cycle per species.

3. Results

3.1 Fisheries Descriptions

Targeted fisheries by the artisanal fishing fleet in the Golfo de Santa Clara, Mexico, occur at different times of the year. Starting in February, when Gulf corvina is usually present for its spring spawning aggregations, it is fished heavily approximately on every spring tide and then closed due to regulation on May 1st. The Bigeye croaker fishery begins during the Gulf corvina season and is caught leading into summer months, July and August, when the water is warmer and there is lower primary productivity (Thunell et al. 1996). The Spanish mackerel fishery begins when the fish are present in the spring months, around March and April. Similar to
Bigeye croaker the mackerel fishery is open leading into the summer months. Lastly, beginning in September when the fishery is officially opened, the Blue shrimp fishery is targeted heavily. During the Blue shrimp fishery season, September through February, there are small amounts (<100 tonnes per month) of Gulf corvina, Bigeye croaker, and Spanish mackerel caught as bycatch. The Blue shrimp season closes on March 1st, and the targeted fishery switches to Gulf corvina (DOF, 2013). There is no recorded capture during the month of August of any of the study species, as it is the hottest month in the Upper Gulf of California, and local fishermen do not fish and buyers temporarily close their processing plants.

Figure 3: Daily total capture (tonnes) for 2014, by month and species in the Golfo de Santa Clara, Mexico.
Figure 4: Trends in the capture (tonnes) and price (USD $/kg) for the Blue shrimp (*Litopenaeus stylirostris*) in the Golfo de Santa Clara, Mexico (nb: the 2014-2015 season data is not complete, and does not detail the captures and prices for February and March 2015).

The Blue shrimp fishery in the Upper Gulf of California is open from September to February, and closed for the spawning season March-August (Erisman et al 2015). Between 2012-2015 the mean seasonal catch for the fishery was 327 tonnes (±36 tonnes). The maximum monthly catch recorded for Blue shrimp was 123 tonnes in October 2012. Although, the maximum catch documented in a single recorded landing was 693kg in September of 2013, the mean catch per recorded landing between 2012 and 2015 was 18.3kg (±25kg).

The mean starting price for Blue shrimp between 2012-2015 was $167.40/kg (± $69.4). The price for Blue shrimp is highest at the end of the season, peaking each year in February and March. The highest price, $315/kg, was recorded in January of 2015, while the mean price for 2012-2015 was $198/kg (±$65.2).
The Gulf corvina fishery is dictated by the spring tides. The fishing occurs in cycles preceding the new and full moons, shown in the cyclical catch trends between February and April (Figure 5). The mean annual catch for Gulf corvina between 2006-2014 was 1004 tonnes (± 411tonnes), with a maximum of 1,534 tonnes in 2014. Interestingly, the maximum annual catch occurred in 2014 even though there was a catch quota implemented in 2012 (Table 1). The maximum monthly catch recorded for Gulf corvina was 663 tonnes in April 2013. The maximum catch documented in a single recorded landing was 4,458kg in April of 2011 and the mean catch per recorded landing between 2006-2014 was only 557kg (±529kg). The Gulf corvina season closes on May 1st each year, but in the following months there are small amounts of catch recorded as bycatch from other fisheries (DOF, 2007).
Due to the lack of price recording for the Gulf corvina, there was only pricing data starting in June of 2012, when systematic monitoring began as a result of the quota being implemented. The mean starting price for Gulf corvina between 2013-2014 was $16.24/kg (± $1.4). The price for Gulf corvina is highest in the beginning of the season and drops off ± 10 days from Easter. The highest price, $18/kg, was recorded in March and April of 2013, while the lowest price is seen in the later months (October and November) when it is caught as bycatch, selling for a price as low as $4/kg.

![Graph](image)

Figure 7: Trends in the capture (tonnes) and price (USD$/kg) for the Bigeye croaker (*Micropogonias megalops*) in the Golfo de Santa Clara, Mexico (nb: 2013-2014 is used for the above example).

Based on data from 2011-2014, the Bigeye croaker fishery in the Upper Gulf of California begins between late February and early March. The main season for Bigeye croaker ends in July, but in September-December, there are small amounts of landings caught as bycatch of other fisheries. Between 2011-2014 the mean annual catch for the fishery was 1033 tonnes (±517 tonnes). The maximum monthly catch recorded for Bigeye croaker was 663 tonnes in April 2013. Although, the maximum catch documented in a single recorded landing was 3,884 kg in April of 2011, the mean catch per recorded landing between 2011-2014 was only 213.17 kg (±247 kg).

The mean starting price for Bigeye croaker between 2013-2014 was $10.59/kg (± $0.83). The price for Bigeye croaker is highest in the middle of the season, 4-7 weeks after the first recorded catch and stays completely constant for 8-9 weeks. The highest price, $19/kg, was recorded in June of 2012, while the lowest price is seen in the later months when it is caught as bycatch, selling for a price as low as $4/kg (November of 2014).

Specifically, years 2013 and 2014 were selected for visualization because they contained a more thorough set of data, whereas years such as 2012 did not include pricing for the beginning of the season.
Based on data from 2012-2014, the Spanish mackerel fishery in the Upper Gulf of California begins in April and ends in July. From September and October there are small amounts of landings caught as bycatch from other fisheries. Between 2011-2014 the mean annual catch for the fishery was 857 tonnes (±335 tonnes). The maximum monthly catch recorded for Spanish mackerel was 663 tonnes in April 2013. Although, the maximum catch documented in a single recorded landing was 2,297kg in May of 2013, the mean catch per recorded landing between 2011-2014 was only 163.31kg (±222.67kg).

The mean starting price for Spanish mackerel between 2013-2014 was $15.67/kg (± $0.88). The highest price, $20/kg, was recorded in June/July 2012, and September of 2014. The lowest price was seen in the later months when it was caught as bycatch, selling for a price as low as $4/kg (November of 2014).

Only 2012-2014 were selected for visualization because they contained price data which was not recorded during 2011. Note that 2012 did not contain pricing data for the beginning of the season (April-May 2012).

Figure 8: Trends in the capture (tonnes) and price (USD$/kg) for the Spanish mackerel (*Scomberomorus spp.*) in the Golfo de Santa Clara, Mexico (only 2012-2014 used for the above example).
Between 2013 and 2014, the mean annual revenue for the Golfo de Santa Clara was 129.5 million dollars (±5.3 million). The revenue for the Golfo de Santa Clara fluctuates throughout the year, with a mean monthly revenue of 11.8 million dollars and a standard deviation of 7.1 million dollars. The maximum monthly revenue, $23.2 million, was recorded in October of 2014. The mean revenue per landing record between 2013-2014 was $3,727.7 (±$5,680). For both 2013 and 2014, the revenue from June, July, and August was below the 1st standard deviation. Both 2013 and 2014 had zero revenue for the month of August. The Blue shrimp fishery had the highest revenue, with a mean seasonal revenue of 65.2 million dollars (±23 million), and for 2013, this fishery made up 58% of the revenue and 59% for 2014. The second highest revenue-producing fishery was the Gulf corvina, but it only represented 17% of the revenue for both 2013 and 2014. The Bigeye croaker made up 12% of the revenue for both 2013 and 2014. Similarly, the Spanish mackerel made up 14% of the revenue in 2013 and 13% of the revenue in 2014.
3.2 Market Price vs. Cumulative Capture

Figure 10: The relationship between market price and cumulative capture in the Golfo de Santa Clara, Mexico, between 2013-2014 for (A) Blue shrimp, (B) Gulf corvina, (C) Bigeye croaker, and (D) Spanish mackerel by season (nb: shrimp includes years 2012 through 2015 data). All plotted lines are significant (P <0.05).
Table 2: Statistics for the regressions shown in Figure 10 analyzing the relationship between market price and cumulative capture in the Golfo de Santa Clara, Mexico.

<table>
<thead>
<tr>
<th>Species</th>
<th>Season</th>
<th>Degrees of Freedom</th>
<th>F statistic</th>
<th>p-value</th>
<th>Adjusted R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue shrimp</td>
<td>Season 0</td>
<td>144</td>
<td>737.6</td>
<td>&lt;0.01</td>
<td>0.8355</td>
</tr>
<tr>
<td></td>
<td>Season 1</td>
<td>160</td>
<td>525.1</td>
<td>&lt;0.01</td>
<td>0.765</td>
</tr>
<tr>
<td></td>
<td>Season 2</td>
<td>127</td>
<td>974.7</td>
<td>&lt;0.01</td>
<td>0.8838</td>
</tr>
<tr>
<td>Gulf Corvina</td>
<td>Season 1</td>
<td>31</td>
<td>12.43</td>
<td>&lt;0.05</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Season 2</td>
<td>90</td>
<td>5.41</td>
<td>&lt;0.05</td>
<td>-</td>
</tr>
<tr>
<td>Bigeye Croaker</td>
<td>Season 1</td>
<td>106</td>
<td>15.99</td>
<td>&lt;0.05</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Season 2</td>
<td>131</td>
<td>6.69</td>
<td>&lt;0.05</td>
<td>-</td>
</tr>
<tr>
<td>Spanish Mackerel</td>
<td>Season 1</td>
<td>82</td>
<td>4.32</td>
<td>&lt;0.05</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Season 2</td>
<td>87</td>
<td>156</td>
<td>&lt;0.05</td>
<td>-</td>
</tr>
</tbody>
</table>

Blue shrimp showed a significant positive linear relationship between market price and cumulative capture for all seasons. The market price increased for each season between 2012 and 2015. The Gulf corvina showed a significant negative logistic relationship between market price and cumulative capture for both seasons, with the price dropping off steeply at the end of the season. The steep drop to around 4USD/kg can be accounted for by corvina that was caught as bycatch out of season. The Bigeye croaker had a positive logistic relationship between market price and cumulative capture for both seasons. Once Bigeye croaker capture reached around 200-400 tonnes, the market price was constant for the majority of the rest of the season, only showing steep declines at the end of the season when it is later caught as by catch in the Blue shrimp fishery. Lastly, the Spanish mackerel fishery showed two unique significant relationships between market price and cumulative capture for the different seasons. Season 1 showed a significant positive logistic relationship, which follows a similar trend as Bigeye croaker. Season 2 had an extremely different relationship, following a significant, negative quadratic trend, where the prices were the lowest in the middle of the season (see Table 2 for all statistics relationships between the cumulative capture and market price for each species).
### 3.3 System Wide Evaluation

**Figure 11:** Principal component analysis (PCA) plot for the Golfo de Santa Clara fisheries for various tidal cycles during 2013 and 2014. Each point represents the cumulative capture during one tidal cycle.

**Table 3:** Pearson correlation matrix for the PCA. Values in bold are different from 0 with a significance level alpha=0.05.

<table>
<thead>
<tr>
<th>Fisheries</th>
<th>Gulf corvina</th>
<th>Blue shrimp</th>
<th>Bigeye croaker</th>
<th>Spanish mackerel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf corvina</td>
<td>1</td>
<td>-0.472</td>
<td>0.868</td>
<td>0.183</td>
</tr>
<tr>
<td>Blue shrimp</td>
<td>-0.472</td>
<td>1</td>
<td>-0.568</td>
<td>-0.553</td>
</tr>
<tr>
<td>Bigeye croaker</td>
<td>0.868</td>
<td>-0.568</td>
<td>1</td>
<td>0.322</td>
</tr>
<tr>
<td>Spanish mackerel</td>
<td>0.183</td>
<td>-0.553</td>
<td>0.322</td>
<td>1</td>
</tr>
</tbody>
</table>

The principal component analysis of the Golfo de Santa Clara’s fisheries shows that the fishery system contains three distinct components based on the biomass of their capture. These distinct components were separated by capture from the Blue shrimp, Spanish mackerel, and Bigeye croaker combined with Gulf corvina fisheries. It is important to note in Figure 11 that the distance between each component represents how different each component is from one another.
Table 4: Table showing how the presence of each fishery component impacts the market price of each species in the Golfo de Santa Clara, Mexico.

<table>
<thead>
<tr>
<th></th>
<th>Blue shrimp</th>
<th>Gulf corvina &amp; Bigeye croaker</th>
<th>Spanish mackerel</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ Blue shrimp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ Gulf corvina</td>
<td>Higher*</td>
<td></td>
<td>Lower*</td>
</tr>
<tr>
<td>$ Bigeye croaker</td>
<td>Lower*</td>
<td></td>
<td>Lower*</td>
</tr>
<tr>
<td>$ Spanish mackerel</td>
<td>Lower*</td>
<td>Higher</td>
<td></td>
</tr>
</tbody>
</table>

*significant relationship based off of correlation matrix

The Blue shrimp fishery market price is not influenced by any other fishery component. The Gulf corvina prices are higher when Blue shrimp is in the system, and the prices are lower when the Spanish mackerel fishing component is active. The Bigeye croaker market price is lower when the Blue shrimp fishing component is active, and also lower when there is Spanish mackerel is in the system. The Spanish mackerel prices are lower when Blue shrimp is being landed, but the prices are higher with then Gulf corvina and the Bigeye croaker component is active.

4. Discussion

Our results show the complex nature of the fisheries in the Golfo de Santa Clara. When examined closely, it is obvious that each fishery has a unique set of dynamics regarding how market price and cumulative capture interact. Within the community of the Golfo de Santa Clara, the town transitions between fisheries depending on the time of year and presence of the resource. No one fishery stands alone, as each overlaps with at least one other either in the beginning or end of their respective seasons. By analyzing the Golfo de Santa Clara fisheries as one system, it is possible to differentiate between the behavior of distinct components that dictate the patterns within the whole system. We found that the Blue shrimp fishery and the Spanish mackerel fishery are distinct components within the system and that the Bigeye croaker and Gulf corvina fishery combine to create the third distinct component. This is essential to understand when interpreting the results because it shows that a change in Blue shrimp or Spanish mackerel will have a greater effect on the stability of system as a whole, whereas a shift in the Bigeye croaker or Gulf corvina will have less of an effect because they can compensate for one another.

Specifically, the Blue shrimp fishery is the largest revenue fishery for the Golfo de Santa Clara. At the start of the season the prices are the lowest, and the price increases as the season progresses. The significant statistical linear relationship we see with market price and cumulative catch makes sense because Blue shrimp is in high demand in the international market. As the Blue shrimp season progresses and the demand stays steady, the resource becomes less available and the price increases. This large international demand makes the market price easier to predict because there is greater competition, which stabilizes the price. Furthermore, as the season progresses the size of the shrimp increases and therefore the price for the shrimp also rises. This creates an inverse relationship with time of season and market price. This dynamic is what one expects to see in a competitive market, that as the resource becomes less available and the
demand remains constant or increases, then the price increases. The market price for the shrimp has increased between the seasons from 2012 to 2015. This may be due to a greater influence of the international market demand, or greater transparency of the international market price in the Golfo de Santa Clara, forcing the buyer to agree to pay fishermen a higher price. The Blue shrimp fishery is consistent and predictable due to the significant positive linear relationship that is seen between 2012 and 2015. This consistency is crucial for the complex community of the Golfo de Santa Clara, as it is a reliable source of revenue for the town.

In contrast to the Blue shrimp fishery, the Gulf corvina fishery is highly variable and difficult to predict. The logistic relationship of corvina market price against cumulative capture is a more difficult trend to follow and predict than the simple linear relationship seen with Blue shrimp. The market price of the corvina dramatically drops off in the middle of the season, which is most likely due to the timing of lent. During lent, there is a higher demand for fish, and Gulf corvina is readily available to be fished and sent out to Mexican markets. Therefore, the timing of the Easter holiday has a great impact on the market price of the corvina. Fishermen are inclined to maximize their profits by catching as many Gulf corvina as possible in the beginning of the season when the prices are high and the demand is high due to lent.

Toward the end of the Gulf corvina fishery season, the Bigeye croaker fishery is at its peak with its captures and prices at the highest. During this time, the Gulf corvina fishery prices are dropping off, but the Bigeye croaker prices are steady. Interestingly, the Bigeye croaker is seen as a very low quality fish in the Mexican markets. It is a relatively new fishery, which began in 1991, when the Asian markets expressed an interest in the species. All of the capture is currently exported internationally. This international influence on the fishery may be the reason for the positive relationship between cumulative capture and market price because there may be a bigger more consistent market demand throughout the season. Furthermore, the potential large, steady international demand may perhaps be the explanation for the consistent pricing toward the middle/end of the season. If these hypotheses are correct, then it would suggest that international influence possibly allows for more consistency and predictability in the market price, which determines the capture effort of the fisheries.

The last component in the Golfo de Santa Clara’s fishery system is the Spanish mackerel, which is inconsistent between 2013 and 2014. The market price for the species shows two distinctive relationships with the cumulative capture between 2013 and 2014. These unique price differences show how the market price shifts trends between seasons. The distinct interactions of market price are a key example of the immense influence the buyer has on the market. The buyer is able to dictate the price on a daily, even hourly basis. Without predictability of the market price, such as in competitive markets, it is difficult to determine when the monopsony factor is the key to the dramatic price differences or other unknown factors are at play, such as the availability of the resource and the consequent effort required to extract the resource.

Throughout the year the fisheries revenue in the Golfo de Santa Clara varies significantly. The question is whether or not these revenues dip below the first standard deviation, when the revenue is the lowest, are compensated for with peaks above the standard deviation, so that the average revenue on a yearly span is consistent. Furthermore, the power of the monopsony buyer on the town potentially increases the monthly or even daily variation in price for each species throughout the year. Since there is not a competitive market in the Golfo de Santa Clara, the buyer has the ability to shift the prices for fish without any repercussions. This sets up for small changes in the fisheries to have an aggregated effect on the revenue stream.
As the most economically important fishery, Blue shrimp has a significant impact on the system as a whole, influencing the market prices of the other species. Blue shrimp in the system does not have a consistent effect on each fishery. The Blue shrimp positively impacts the market price of the Gulf corvina, which could also be due to the time of the Gulf corvina season. Contrary to Gulf corvina, when Blue shrimp is being caught, the Bigeye croaker and Spanish mackerel prices are lower. These unique relations show the complexities of the Golfo de Santa Clara fisheries system, detailing how when there are landings from one fishery component, there is potential for the market price of the other fisheries to be influenced. Overall, Blue shrimp dominates the system, by influencing the market price of all other fisheries. From the fishermen’s perspective, they will always prefer to target the Blue shrimp over the other fisheries as long as the price stays high for shrimp because otherwise they will have to fish for longer to accumulate enough capture to compensate for the lesser market price of the other species.

The Upper Gulf of California is a politically complicated area with multiple endangered species, which adds to the complexities of managing the fisheries. When setting regulations, it is typical for management to take a single species approach. By examining the fishery dynamics in the Golfo de Santa Clara it is clear that single species based management is not ideal. In an effort to conserve the vaquita in the UGC, there was a gillnet ban implemented in 2015 where the fishermen were compensated for the restrictions on gear (DOF, 2015). The subsidy expenditure made it exceptionally difficult to predict how their revenue stream would transition and if the fishermen would target other fisheries to compensate for the fishing ban. The impact of regulations on one fishery can greatly influence the market price for the others. For example, when Blue shrimp is being caught, the Gulf corvina market price is higher. It is impossible to precisely say how the ban of shrimp fishing will ultimately impact the market price of the Gulf corvina, but potentially a loss of the shrimp capture in the UGC will result in lower Gulf corvina prices. Therefore, if the Gulf corvina prices are lower, then the fishermen might target the Gulf corvina fishery even harder to compensate for the loss in revenue from the lower corvina prices. This is one hypothetical interaction that could occur from the 2015 gillnet ban, which shows how the fisheries are linked and shifts in one fishery can negatively impact another.

It is essential for fisheries management in the UGC to consider the interactions between fisheries when setting regulations. Rather than focusing on a single species view, management must take a multi-species approach to set regulations that will have a positive impact on all of the fisheries. While, the single species management promotes sustainable practices for one fishery it can negatively impact another if the fishermen target other fisheries to compensate for the loss of revenue in the regulated fishery. Therefore, all complex interactions between fisheries in the fishing community must be considered when setting regulations. Furthermore, the market price greatly influences the earnings of the fishermen, so it is important to recognize how the market price is set and to understand the capture and market price relationships within and between seasons. Additionally, this method of multi-species evaluation could be helpful for conservationist dealing with issues in the Upper Gulf of California. There is potential for adverse effects for the endangered species if the fishermen increase their fishing efforts due to higher regulations on another species. Therefore, when managing the endangered species issues in the UGC, it is vital to understand the entire system in order to set regulations that take into consideration potential fishery interactions.

Overall, it is essential for management to shift their views from single species evaluations to multi-species evaluations, so that all of the fisheries are more sustainable. Furthermore, management must take into consideration the livelihoods of the fishermen in the community by
understanding how fishermen’s revenues shift across seasons and species. By understanding the shifts in yearly revenue for the fishermen, it is easier to predict how the fishermen will react to regulations in order to sustain a more constant stream of earnings.

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Diario Oficial de la Federación. 2011. ACUERDO por el que se establece la cuota de captura para el aprovechamiento de curvina golfina (Cynoscion othonopterus), en aguas de jurisdicción federal del Alto Golfo de California y Delta del Río Colorado para la temporada 2011-2012. Mexico, D.F., 10 de octubre de 2011


Diario Oficial de la Federación. 2015. ACUERDO por el que se suspende temporalmente la pesca comercial mediante el uso de redes de enmalle, cimbras y/o palangres operadas con embarcaciones menores, en el Norte del Golfo de California. Mexico, D.F., 10 de abril de 2015


