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BIO-ECONOMIC ASSESSMENT OF THE INDUSTRIAL POMADA SHRIMP FISHERY IN POSORJA (GUAYAS-ECUADOR) DURING THE PERIOD 2008-2014[1]

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Abstract

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In this paper we attempt to establish a baseline to understand the profitability of the Pomada fleet that operates in Posorja, province of Guayas in Ecuador, under different policy scenarios. For that purpose, we use primary and secondary data collected from 2008 to 2014. We estimate both the maximum sustainable yield (MSY) and the maximum economic yield (MEY) for the Pomada shrimp fishery. We found that the individual daily catch quota, which was established in 2013 by the same Pomaderos for the Pomada shrimp fishery, is likely to be beyond the sustainable limits by about 750 Kgs. We discuss how to implement fishery management policies using either MSY or MEY as references. We also simulate how alternative total allowable catch policies could affect the profitability and financial risk of the fishing fleet. Finally, some recommendations are provided to improve the process of data collection, as well as improvements to the methodology, to increase the accuracy, reliability and sophistication of the estimation of both MSY and MEY.

Keywords: *Sustainable yield, Fishing effort, Exclusionary zone*.

JEL: *C65, Q22, Q27.*

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[1] The views and opinions expressed in this article are those of the author only, and do not necessarily represent the views and opinions of the Interamerican Development Bank or any of their affiliates and employees.

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EVALUACIÓN BIOECONÓMICA DE LA PESCA INDUSTRIAL DEL CAMARON POMADA EN POSORJA (GUAYAS-ECUADOR) DURANTE EL PERÍODO 2008-2014

Resumen

En este documento intentamos establecer una línea de base para comprender la rentabilidad de la flota de Pomada que opera en Posorja, provincia de Guayas en Ecuador, bajo diferentes escenarios de políticas. Para ello, utilizamos datos primarios y secundarios recopilados de 2008 a 2014. Estimamos que tanto el rendimiento máximo sostenible (RMS) como el rendimiento económico máximo (REM) para la pesquería de camarón Pomada. Encontramos que la cuota de captura individual diaria, establecida en 2013 por los mismos Pomaderos para la pesquería de camarón Pomada, es probable que supere los límites sostenibles en unos 750 kg. Discutimos cómo implementar políticas de manejo de pesquerías usando RMS o REM como referencias. También simulamos cómo el total de alternativas de captura permisibles podrían afectar la rentabilidad y el riesgo financiero de la flota pesquera. Finalmente, se proporcionan algunas recomendaciones para mejorar el proceso de recopilación de datos, así como mejoras en la metodología, para aumentar la precisión, confiabilidad y sofisticación de la estimación de RMS y REM.

Keywords: *Rendimiento sustentable, esfuerzo de pesca, zona exclusive.*

JEL: *C65, Q22, Q2.*

1. Introduction

1.1. Description and Composition of the Pomada fleet

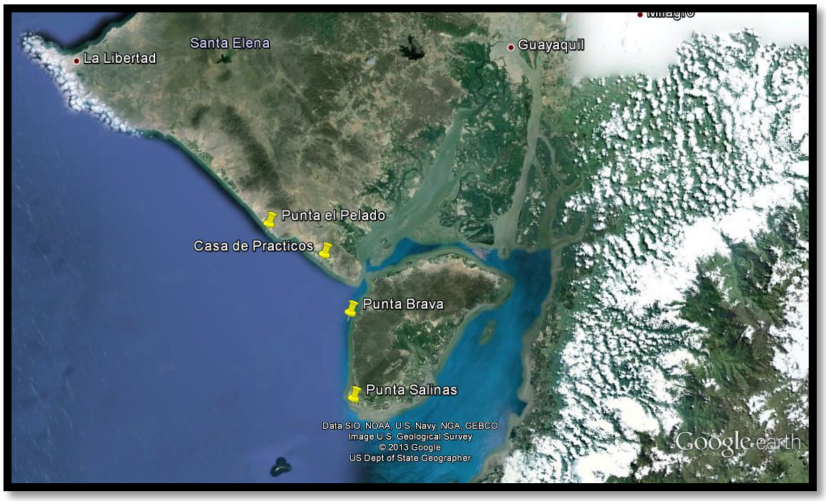
This research is focused on the Pomada Shrimp Fleet whose headquarters are located in the coastal city of Posorja in the Province of Guayas in Ecuador. The fishing activity of this fleet is highly concentrated into two fishing regions, laid out in established regulations (Acuerdo Ministerial 426-A from October of 2012). The first region has an extension of 10 miles in length and goes from Punta el Pelado to Casa de Practicos (Figure 1). The second region has an extension of 13 miles and goes from Punta Brava to Punta Salinas (Figure 1).

The Pomada fleet started its fishing activity with 5 boats in 1956. This number increased continuously until it reached a peak of 74 boats during the 1980's. Nowadays this fleet has decreased by 48.64% from its maximum size, to only 38 boats. A regulatory change that it is important to highlight is that the Pomada fleet was considered as an artisanal fleet until 2007. Since then, the Pomada fleet began to be considered as a semi-industrial fleet. By the time of writing, the Pomada Fishery fleet has a total of 330.41 Net Registered Tonnage (NRT) of displacement. All vessels have a wooden hull and are at least 23 years old. The average year of construction is 1971 with an average NRT of 18.2 tons. Their engine power ranges from 165 to 300 HP while their length ranges from 12 to 23 meters. These boats have also an average beam of 5.08 meters and an average depth of 2.46 meters. The average characteristics of the Pomada fleet are given in Table 1.

Table 1: Average characteristics of the Pomada shrimp fleet

Dimensions and capacity	Mean
Length(m)	18.54
Beam(m)	5.75
Height (m)	2.66
NRT (TM)	13.86
Power (HP)	284.00

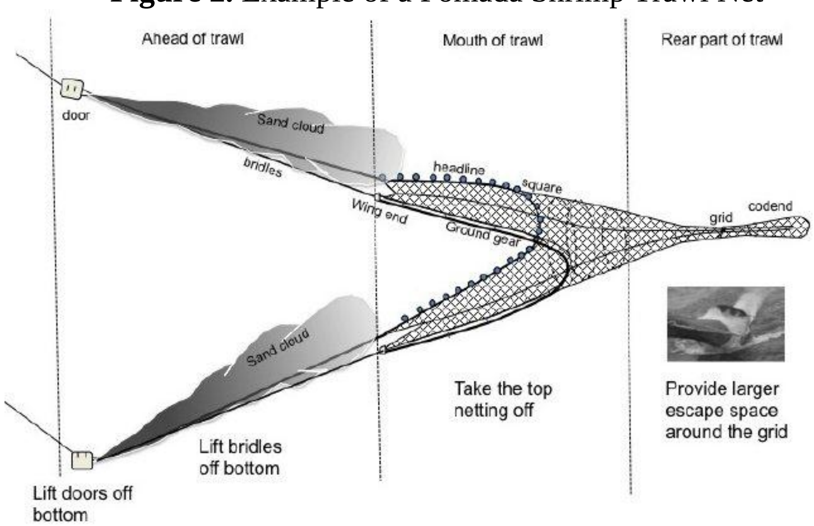
Figure 1: Permitted fishing areas for the Pomada Fleet



The gear used by the Pomada fleet is known as trawl net (Figure 2), which is a conical net composed of several sections: wings, sky, back, belly and head. The trawl net is attached to two ropes. An upper rope made of floats and a lower rope made of weights. For its optimal operation the trawl net is also rigged to two wooden gates of rectangular shape and these in turn are secured by drag lines to the beam of the boat. The trawl net has an average length that ranges between 14 and 17 meters and its mesh size goes from 1 ¼ to 1 ½ inches. It is required for the Pomada fleet that all their nets use Turtle Excluding Devices (TEDs) to operate and at the same time all ships must have GPS and two-way radios as part of their equipment.

On average, the crew for each fishing trip is composed of 6 people whose composition is as follows: one captain, one machine operator, one helmsman, one engine operator and two fishermen.

Figure 2. Example of a Pomada Shrimp Trawl Net



Source: He (2015)

1.2. Regulations

Until 2014 the Pomada fishery was managed exclusively by command and control policies, several of which were proposed by the "pomaderos" (i.e. people that participate in the Pomada fishery either as boat owner or fishermen). The policies that were used for the Pomada shrimp fishery until 2014 were:

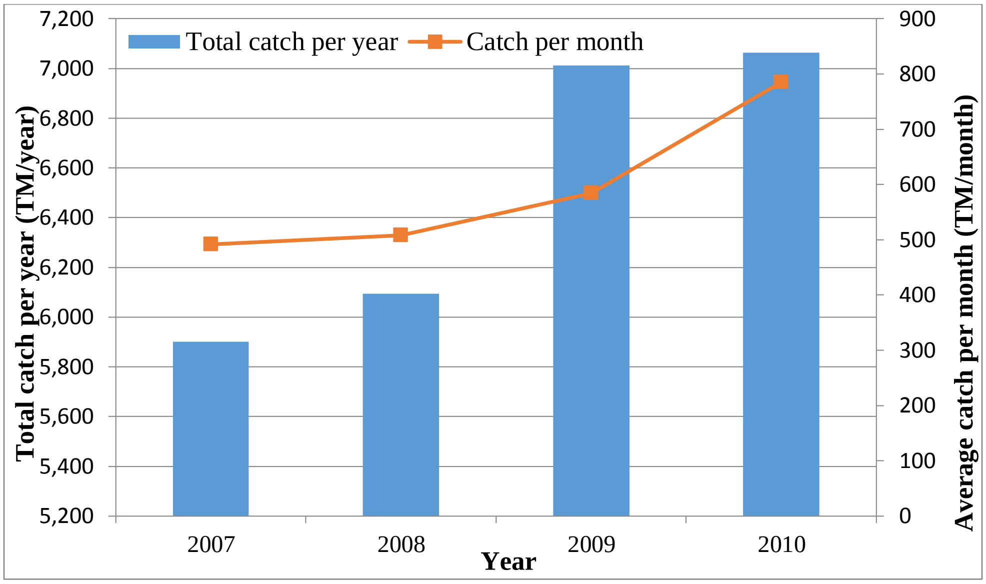
1. **Temporal Closures:** usually between two or three months per year, generally during the months of January, February, March and/or April.
2. **Fishing gear restrictions:** a maximum length of the net dragline of 50 meters and a minimum eye mesh size of 1 ¼ inches; as well as the adoption of Turtle Excluding Devices (TEDs) as a by-catch reduction device.
3. **Spatial closure:** Vessels are not allowed to fish within one mile from the shore, to protect spawning areas of marine species. In addition, trawler vessels are prohibited to fish in the area delimited between Punta el Pelado and Chanduy.
4. **Daily Quota:** Each vessel is not allowed to fish more than 2,267 Kg. per day (i.e. 2.27 MT per day or 5,000 pounds per day).

1.3. Historical Evolution of Landings

The total catch per year of Pomada shrimp has increased continuously from 2007 to 2009 (Figure 3). Then in 2010 the total catch stabilized at a level very similar to 2009. This may indicate that the expansion in the catch level stopped in 2010, except for the fact that in that year the season length was shortened from 12 months to 9 months. Hence, if we examine the average catch per month of Pomada shrimp, we find that the series show a positive trend which accelerates in 2010. The latter is because 2010 was a year in which the catch was the highest (but very similar to that in 2009) but with fewer months of activity (i.e. 9 months).

Hence, from Figure 3 it can be concluded that the catch of Pomada showed a positive trend which could reflect an increasing pressure on the resource. This justifies the need to further analyze whether the Pomada shrimp fishery is sustainable or not; and consequently, to determine which new management policies would favor the sustainability of that fishery.

Figure 3: Total catch per year and average catch per month of Pomada shrimp



Source: National Institute of Fishery (INP)

1.4. Behavior of the Price of Pomada Shrimp

The behavior of the Pomada shrimp price series show a particular pattern since the year in which the first closure for that fishery was established (2010). In Figure 4 we observe the following behavior: the price of a pound of Pomada shrimp ends at a high level just before the closure begins. Then, the closure is established and immediately when it is over, the season opens with a very low price that is maintained for approximately two or three months. Subsequently, there is a gradual recovery in the price until the end of the season when the price reaches its maximum (Table 2). At the end of the season a new closure is established, and the cycle described above starts again.

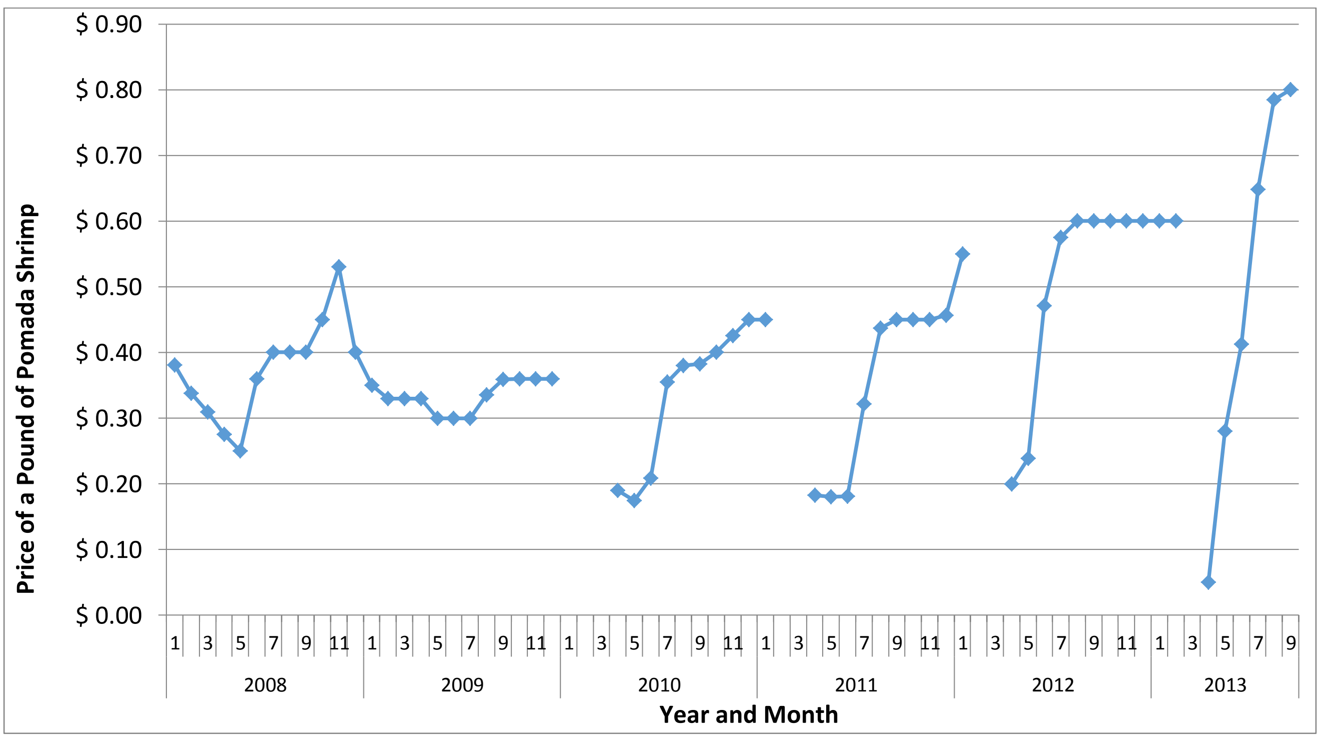
The latter price behavior for the years with closure in place may be related to the fact that the Pomada shrimp fishing season can be divided into a high and a low season. The high season begins immediately after the closure ends. The high season is characterized by abundance of product, and it is logical to expect that the prices during this part of the Pomada shrimp fishing season would be low. Then, as the months pass the abundance decreases until the low season begins. The latter is characterized by low abundance and, as expected, high prices.

Hence, from the beginning of the season a gradual decrease in the abundance is experienced, and this could be the reason behind the continuous increase of the Pomada shrimp price, which reaches its maximum at the end of the season just before the closure begins. Therefore, this price difference between the low and high season (Table 3) may be an indication that the law of supply and demand is operating on the Pomada shrimp market of Posorja.

It is important to emphasize that this difference between high and low season prices is not exclusive from those years with a closure in place. For instance, from Table 3 it may be verified that even in those years without a closure, there is a difference between the average prices of a pound of Pomada shrimp during the high season compared to those during the low season (i.e. specifically the price is higher in the low season than in the high season). The only dissimilarity is that the price spread between the low and the high season is more accentuated for those years with a closure in place than those years without closure; a phenomenon that could be translated as an additional effect operating over the price of the product derived from the closure itself.

In addition, if we examine the behavior of the price of Pomada shrimp in the international market (Figure 5) we observe that it is divorced from the behavior of that price in the Posorja local market. For instance, the maximum correlation between the local price and the international price of Pomada shrimp is 0.38 (a figure that is obtained when we compared the local price against to the international price of the Pomada shrimp classified in the category 201-300). The latter along with the previous finding that the price of the Pomada shrimp in Posorja is impacted by the local availability and/or abundance of the product (i.e. price difference in the low and high season), may be considered as relevant evidence that could lead us to conclude that the factors that affect the price of Pomada shrimp in this market (i.e. Posorja) are mostly local.

Figure 4: Average monthly price of a pound of Pomada shrimp in the period 2008-2013



Consequently, based on those findings we consider that the more profitable strategies for this fishery are those that focus mostly on controlling product quality, increasing activities to add value, as well as strategies focused on controlling the available quantity in the market. In other words, we consider that the best strategy for this fishery might be to change the current approach, in which Pomaderos try to maximize their profit through increasing their catch levels and therefore their effort, to a new approach focused on quality and better prices through limiting effort and quantity especially during the high season, and this is possible because the price of the product in this market is endogenous.

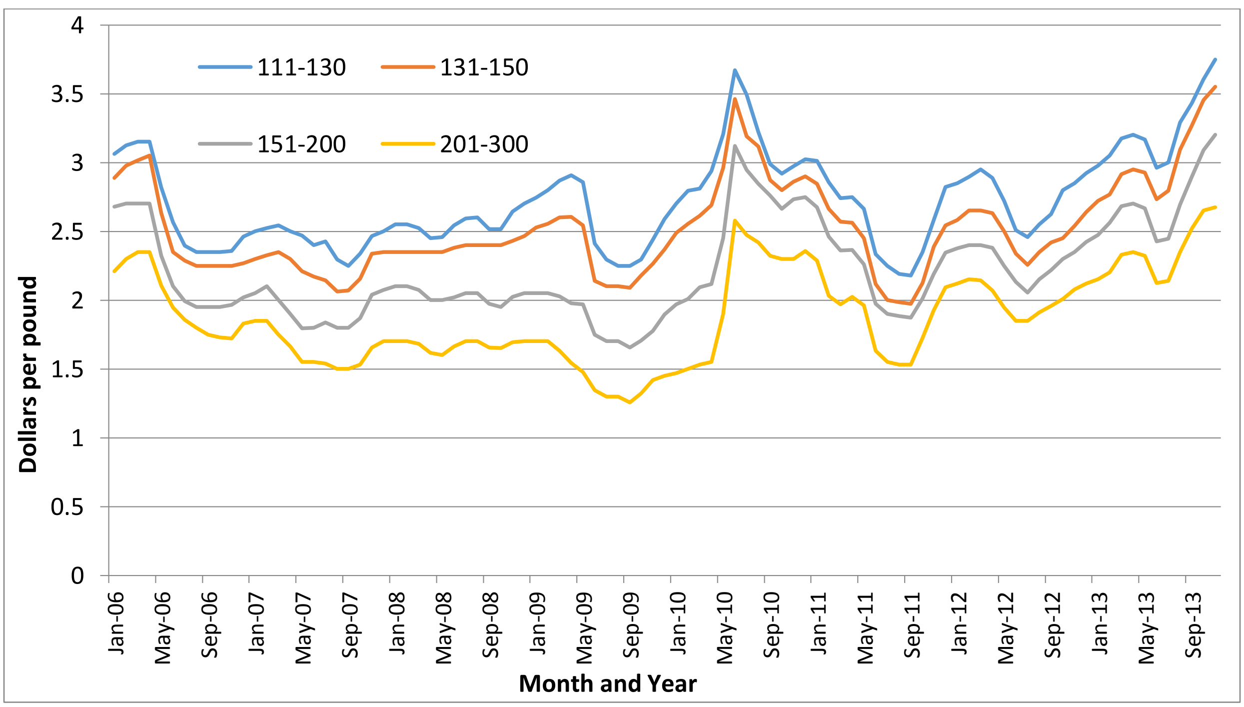
Table 2: Average price of a pound of Pomada shrimp at the beginning and at the end of the season for the years with closure in place.

Average Price	2010-2011	2011-2012	2012-2013	2013-2014
At the beginning of the season	$ 0.19	$ 0.18	$ 0.20	$ 0.05
At the end of the season	$ 0.45	$ 0.55	$ 0.60	$ 0.80
Differential (Finish vs Start of the season)	$ 0.26	$ 0.37	$ 0.40	$ 0.75

Table 3: Average price of a pound of Pomada shrimp calculated for different periods in a specific year for both those years without a closure in place (2008 and 2009) and those years with a closure in place (2010 – 2013)

Average Price	Years without a closure in place		Years with a closure in place			
	2008	2009	2010	2011	2012	2013
During the entire season	$ 0.37	$ 0.33	$ 0.33	$ 0.35	$ 0.50	$ 0.52
During the high season	$ 0.31	$ 0.32	$ 0.19	$ 0.18	$ 0.30	$ 0.34
During the low season	$ 0.42	$ 0.35	$ 0.40	$ 0.43	$ 0.59	$ 0.71
Differential (Low vs High)	$ 0.12	$ 0.03	$ 0.21	$ 0.25	$ 0.29	$ 0.37

Figure 5: International price of Pomada shrimp for different sizes expressed as the average number of individuals per pound



Source: Urner Barry

1.5. Size composition of the catch

From Table 4, data appears to suggest that the size of the product has been shrinking since 2006. However, the available data also show that product size varies monthly, in many instances data are not available for all months each year (Table 2.5). Taking the latter into account, the apparent shrinkage effect can be explained as a function of the months for which data are available (or not available) in different years, plus the enactment of a closure during 2010 covering precisely the months when catches of large shrimp are to be expected. In addition, 2010 was the only year with a season closure in place for the available dataset, therefore the lack of information for year 2011 and 2012 -the most recent years with a closure in place- makes it more difficult to assert that the size of the product has been decreasing.

Using the available data and categorizing it by monthly periods (Table 6) we tested the hypothesis that there is a relationship between the months and the size of the product. For this purpose, we applied an independence test from which it is found that the null hypothesis of independence between the month of capture and the size of the product is rejected ($P<0.0001$). Thus, from this result we can infer that the product during the low season is larger in size than that during the high season. The latter could be another factor that could explain the behavior of the local price of Pomada shrimp showed in Figure 4. Specifically, it is likely that there is a price premium for larger products which operates mostly during the low season, which is when the largest product is observed.

Table 4: Size distributions of Pomada shrimp surveyed during the period 2006 – 2010

	Number of Species Surveyed			Proportion from total Surveyed		
Year	Small	Medium	Large	Small	Medium	Large
2006	32	315	41	8.25%	81.19%	10.57%
2007	30	336	31	7.56%	84.63%	7.81%
2008	99	490	17	16.34%	80.86%	2.81%
2009	66	332	17	15.90%	80.00%	4.10%
2010	14	121	-	10.37%	89.63%	0.00%

Products whose size range between 4-5.90 cms are classified as small. If the product range between 6 -8.90 cms the product is classified otherwise if the product is larger than 8.90 cms is classified as large

Table 5: Number of months in which the INP survey product during the period 2006 – 2010

Year	Months	% Season	%High	%Low
2006	9	75.00%	67%	83%
2007	10	83.33%	83%	83%
2008	12	100.00%	100%	100%
2009	8	66.67%	83%	50%
2010	4	44.44%	67%	33%

Products whose size range between 4-5.90 cms are classified as small. If the product range between 6 -8.90 cms the product is classified otherwise if the product is larger than 8.90 cms is classified as large

Table 6: Size distributions of Pomada shrimp surveyed during the period 2006 – 2010 divided by periods.

	Number of Species Surveyed			Proportion from total Surveyed		
Period	Small	Medium	Large	Small	Medium	Large
Jan - Mar	36	221	20	13.00%	79.78%	7.22%
Apr - Jun	114	557	11	16.72%	81.67%	1.61%
Jul - Sep	40	423	26	8.18%	86.50%	5.32%
Oct - Dec	51	393	49	10.34%	79.72%	9.94%

Products whose size range between 4-5.90 cms are classified as small. If the product range between 6 -8.90 cms the product is classified otherwise if the product is larger than 8.90 cms is classified as large.

2. Data

The analysis conducted in this paper to assess the status of the industrial Pomada shrimp fishery relies on the following information:

1. Annual and monthly catch data: This information includes the total annual and monthly catch of Pomada shrimp measured in tons during the period 2008-2010. The available landing information is aggregated, whichdoes not allow us to identify the specific locations where the fishing was done. Also, this dataset lacks of a variable that allow to make a correspondence between catch and vessel. Hence the relationship between catch and effort would be limited to the aggregated level and to the active fleet.

It is important to emphasize that this data was obtained not based on direct observation of INP officials at the port and/or reporting of the vessel owners but through a sampling procedure. Specifically, the INP samples each month a set of vessels and their catch. Then, to obtain the monthly catch they extrapolate the catch of this sample to the entire fleet and the studied month using as assumption a predetermined and fixed number of active boats as well as days of activity per month (which generally are established as 20 for both parameters). The latter data collection procedure is highly likely to be affected by measurement error, but it was the only landing data available. For that reason, it is important to recognize its deficiencies and consequently we should highlight that the results and conclusions obtained from this data must be treated carefully.

2. Departure data: We obtained this information for the period 2008-2010 from the DIRNEA (Dirección Nacional de los Espacios Acuáticos). This information as in the case of the landings data was not gathered through observation and/or direct survey at the port but through self-reporting information obtained from vessel owners. To be more precise, vessel owners, in order to get a sailing permit for a specific period, must declare to the DIRNEA whether they will be active or not during a specific month and if they declare that they would be active, how many days they plan to be active during that month. Thus, from the DIRNEA database we get an approximation of how many boats decided to participate in a specific month and how many days these active boats were doing fishing activity during that month. This data therefore is subject to a great deal of measurement error in the days that a boat would be actively fishing. It is important to acknowledge the limitations of the latter dataset and consider those drawbacks when providing our conclusions. At the end this DIRNEA data will allow us to estimate the monthly fishing effort in the Pomada shrimp fishery defined as the number of days per boat that the active fleet has been fishing during a month.

To aggregate from the individual effort to the total effort per month of the entire fleet we should make an additional assumption; that is, that the boats that belong to the Pomada fleet (and their effort) are homogenous. Then it is not necessary to conduct a standardization procedure for the individual effort. The reason of this simplification is because there is no complete, detailed and updated information about the characteristics of each vessel of the fleet. Thus, to reduce measurement error and bias in this component of the data we assumed that the fleet is homogenous. The optimal course of action would have been to establish a standard vessel and then to standardize the effort of each boat based on the characteristic of this standard vessel. But this is not possible again due to the limitations of the available information.

3. Economic Data: we obtained the economic information from the following sources: 1) Observer program implemented in Posorja from June 20th, 2013 to October 1st, 2013 with the financial support of World Wildlife Fund (WWF); 2) private historical information obtained from the archives of an anonymous group of vessel owners, and 3) two socioeconomic surveys that were conducted first to 55% of the registered vessel owners and second to a sample of 46 fishermen. Both surveys were conducted one month before and during the duration of the observer program.

From the first source of information we obtained data related to the costs per trip. From the second source we obtained the historical price series of the product at the dock. And from the last source we obtained the average annual fixed costs of each boat. As in the previous cases and for simplification (given the limitation on previous variables) we assumed that the boats are homogenous and therefore we used the costs (fixed and variables) at the mean level. It is important to note that for this part we consider it cumbersome to make any distinction between vessels (and their characteristics) and consequently among their specific fixed and variable costs, because as we stated we do not have any mechanism to relate individual catch with individual effort per day in the available data.

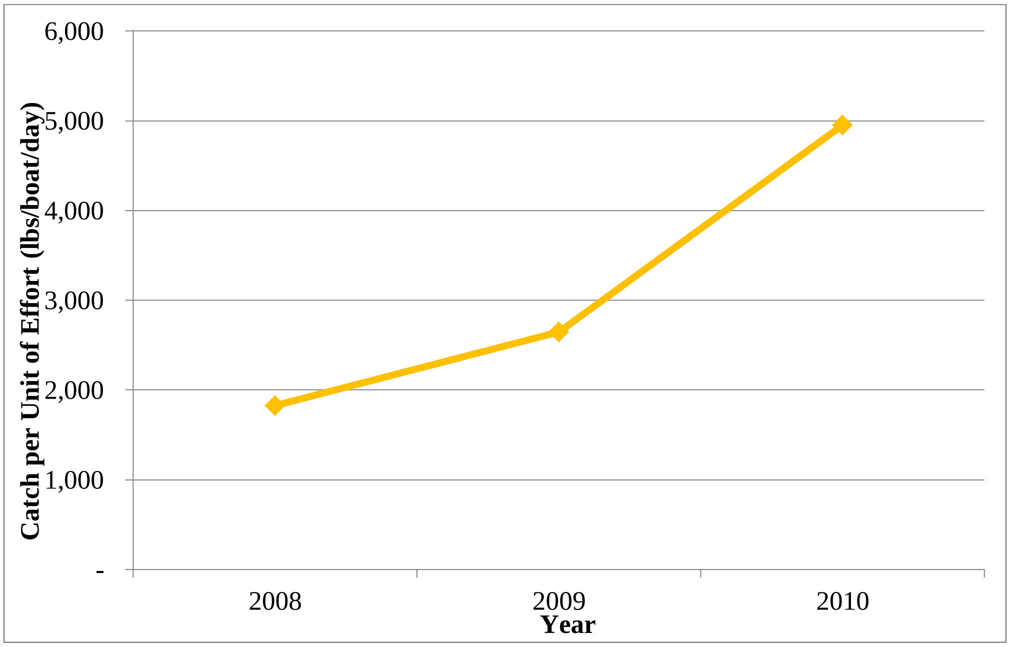
As we indicated, the data suffers from several limitations and/or deficiencies, consequently, we must keep in mind that the results provided along this paper can only offer a notion about the maximum sustainable yield (MSY) and the maximum economic yield (MEY) that could be obtained in equilibrium and under the assumption of homogeneity. Then readers should recognize the inherent limitations of the data and therefore any conclusion derived from them should be treated carefully.

3. Catch Per Unit of Effort

For the estimation of the “catch per unit of effort” (CPUE) we used the available information regardless of its problems. Specifically, we used the total annual and monthly catch of Pomada shrimp measured in tons provided by the INP and the landing information provided by the DIRNEA, both datasets for the period 2008-2010. We need to recall the limitations of both datasets. The first one (i.e. catch dataset) provides aggregate data that was not obtained through direct observation at the port and/or reporting of the vessel owners but through a sampling procedure and extrapolation of the sample to the entire fleet and the entire month. Meanwhile the second dataset was not gathered through observation at the port and/or direct survey but through self-reporting process from vessel owners about if they will participate in the fishery and how many days they will be active. Both pieces of information are imprecise and limit our ability to establish a relationship between individual effort and catch to produce an accurate measurement of the CPUE. There is a third piece of information that is related to the characteristics of the boats that are part of the fleet. This information does not provide the necessary detail and is not updated which would make difficult to standardize the effort. The latter is not a significant problem by itself because as we argued it is not possible to establish a correspondence between effort and catch then a standardization of the effort would be cumbersome given the previous deficiency. Therefore, it is valid to keep in this section and the next ones our assumption of homogeneity among the boats that belong to the fleet.

We estimated the CPUE whose results are shown in Figure 4.1. From that figure we can observe that during the analyzed period the CPUE was increasing which allows us to reject any argument of overexploitation during that period. However, given the limitations described previously, the results shown in Figure 4.1 should be treated carefully. In addition, it would have been optimal to have a more extended period of study but given the inexistence or impossibility of obtaining this data, this was not possible to do so, which reduces the reliability of our results. In the final section we will provide a set of recommendations to overcome the problems that we have faced during this research process as well as some advice about how to systematically calculate effort more accurately and consequently calculate CPUE for this fishery in such a way that it can be used as a policy tool.

Figure 6: Catch per unit of effort measured in pounds per boat per day during the period 2008 – 2010



4. Maximum Sustainable Yield

In this section we estimate the maximum sustainable yield (MSY) for the industrial Pomada shrimp fishery. For this purpose, we will use aggregate information on two variables, catch and effort, for the period 2008-2010.

4.1. Methodology

The information that we used for the estimation of both the production function of the system as well as the maximum sustainable yield (MSY) is the following: 1) the total monthly catch of Pomada shrimp for the industrial fleet of Posorja; and 2) the effort applied by that fleet to obtain that monthly total catch, measured as the total number of days per boat for each month. The methodology selected for this work considers the following with regard to the available information: 1) it is aggregated; and 2) it lacks the necessary detail to establish a correspondence between the effort applied for each boat and the catch level of the target specie (i.e. Pomada shrimp) derived from the application of that specific effort level.

In the case of the fishing effort the typical task at hand is to standardize the effort for the different type of boats that participated in the fishery. As we indicated in section 2, we assumed along all in this paper that the fleet is homogeneous; therefore, the total standardized effort per month (f) will be equal to the number of active boats in a month multiplied to the average number of days that those boats were fishing during that month. This measure is used along with the total catch of shrimp (Y) to obtain the MSY. Hence, for this purpose we defined the following:

1. $f_{(i)}$ is the standardized effort in time i, (i = 1, 2, ..., n)
2. $Y_{(i)}$ is the total catch in metric tons in time i, (i = 1, 2, ..., n)

3. Therefore $Y(i)/f(i)$ is equal to the catch per unit of standardized effort in time i, CPUE(i)

Our purpose was to relate the CPUE as a function of the total standardized effort through the model proposed by Schaefer (1957) which is assumed to be linear and therefore is easy to estimate. The Schaefer model can be defined as follows:

$$\frac{Y_{(i)}}{f_{(i)}} = a + bf_{(i)} \quad if \quad f_{(i)} \leq -{}^{a}/_{b} \qquad (1)$$

We expected the parameter that represents the slope (b) to be negative since it is theoretically assumed that the CPUE decreases as the effort grows. The intercept is the CPUE that could be obtained after the first boat departs to fish for the first time in a moment in which the resource has remained in virgin state. For this reason, the intercept must be positive. In the same way since a negative value of CPUE is absurd, the model only works for those efforts (f) whose value are lower than$-a/b$.

The final objective is not only to parameterize the production function of the shrimp fishery but also to get an estimate of MSY and with that to determine what level of effort (*f*) yields the estimated MSY. For this reason, we rewrote the Schaefer production function in such a way that the catch is expressed as a function of the effort; so, we obtain the following:

$$Y_{(i)} = af_{(i)} + bf_{(i)}^{2} \quad if \quad f_{(i)} \leq -{}^{a}/_{b} \qquad (2)$$

The Schaefer model is represented by a quadratic function, for which its maximum is equal to the MSY which is expressed as follows:

$$MSY = -0.25\frac{a^2}{b} \qquad (3)$$

As a result, the corresponding effort to reach MSY is equal to:

$$f_{MSY} = -0.5\frac{a}{b} \qquad (4)$$

We have chosen this method because is easy to apply and is ideal for cases in which the information is scarce and poor in quality. This is because this method:

1. Does not require calculating the catchability coefficient "q" to estimate MSY.
2. Does not require disaggregated information on catch and effort.
3. Does not require knowing the age and size structures of the species; and
4. Does assume independence; that is, it does not need to assume any biological or ecological interconnection with its ecosystem.

However, the model has some disadvantages, such as it:

1. Does not include environmental factors in its structure.
2. Does not incorporate trophic links between species.

3. Does assume that the actions have stabilized at the current rate of fishing (assumed equilibrium); and
4. Does not tell us anything about the mechanisms that affect the dynamics of the population.

4.2. Estimation Procedure

In order to estimate *Equation 2* we applied a Nonlinear Least Square (NLS) Estimation Procedure. NLS estimators minimize the sum of squared residuals, so for independent observations, the NLS estimator $\hat{\beta}$ minimizes:

$$Q(\beta) = \sum_{i=1}^{N} \{y_{(i)} - m(x_{(i)}, \beta)\}^2 \qquad (5)$$

where $m(x_{(i)}, \beta)$ is the specified functional form for the conditional mean of y given x, $E(y_i|x_i)$, that in our case would be equal to: $af_{(i)} + bf_{(i)}^2$. Then in our specific case y will be equal to the total catch per month *($C_{(i)}$)* and *x* will be equal to the standardized total effort applied to the fisheries *($f_{(i)}$)*.

We obtained the estimators of Equation 1 which are shown in Table 7. From those results we can conclude that the Schaefer functional form is adequate for our data, and moreover that the monthly standardized effort (based on the assumption on a homogeneous fleet) is an adequate variable to explain the level of monthly catch of Pomada shrimp during the study period.

Table 7: Estimation Results of Equation 2

Coefficient	Estimator	Bootstrap Std. Err.	Z	P-Value
A	3.748041	0.6165008	6.08	0.00000
B	-0.004974	0.0011567	-4.30	0.00000
	Number of Obs. =		28	
	R-Squared =		0.8057	
	Adj R-Squared =		0.7907	
	Root MSE =		309.7009	

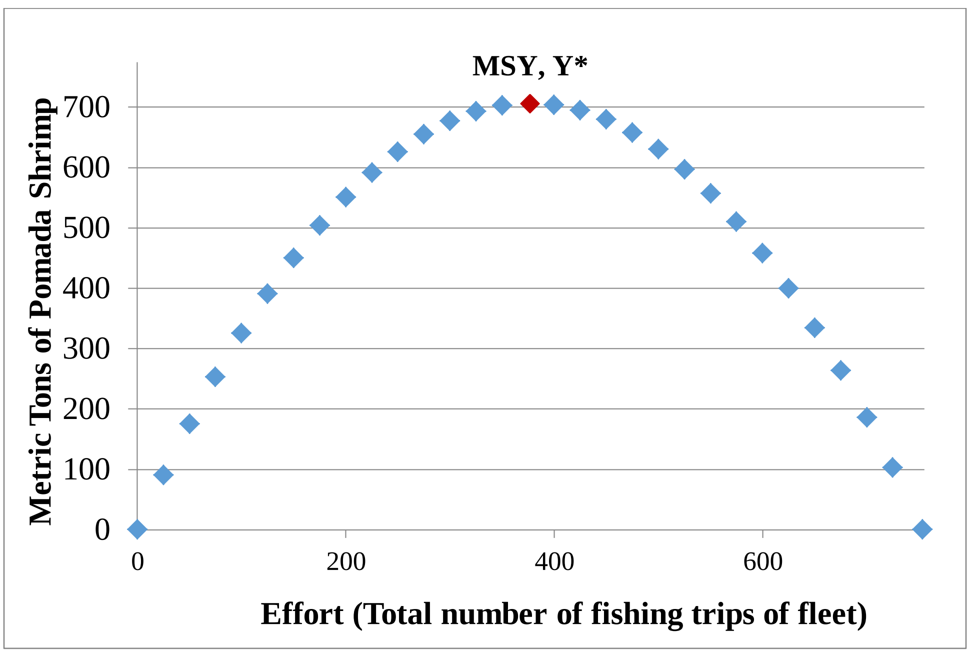
The dependent variable is the total catch per month measured in metric Tons, and the independent variable is equal to the number of active boats per month multiplied by the average number of fishing days for those boats

It can be observed in Table 7 that the estimators of both parameters, ***a*** and ***b***, are statistically significant and that they show the sign that we expected (i.e. a positive sign for ***a*** estimator and a negative sign for ***b*** estimator). We also found that the total fleet effort explains approximately 80% of the variation observed in the total monthly catch. In other words, we consider that the functional form proposed by *Equation 3* is statistically adequate and then we can make inferences based on the results from Table 7.

We sketched the function that relates effort and catch in Figure 7. We determine that the MSY of the system is equal to 706 MT per month (7,060 MT annually in a year with a two-months closure). If we use the INP assumptions that the average number of boats that participate per day is 20 and that the average number of days that an active boat participate during a month is also 20, we can determine that the MSY per day is approximately 1,527 Kg per boat; that is, a 1/3 lower than the current quota (i.e. 2,267 Kg). On the other hand, assuming an active fleet size of 20 boats we found that the optimal time that any boat should be fishing per month is 17 days. And if it is assumed that a total of 38 vessels (i.e. the current size of the authorized fleet) are all operating continuously each month, the optimal operation time would be 9 days per month per vessel.

Based on our results we determine that the current daily quota is off by approximately 741 Kg per boat. In other words, we found that the current daily quota is apparently too lax; something that is logical to expect given that the quota was established by the same "Pomaderos" to self-regulate their activity. Therefore, the main conclusion of this analysis is that it is very important to continue research efforts to assess the appropriateness of the regulations implemented for the Pomada shrimp fishery.

Figure 7: Relationship Effort vs. Catch



The previous model has several limitations especially because of the quality and quantity of data as we indicated previously in section 3. Given those restrictions the model obtained in this section can only provide a guide of the probable state of the Pomada fishery through a simple relationship between catch and effort.

Our model only looks at catch-effort relationship so can only be used to make recommendations on catch/effort restrictions. Further study might yield more fine-grained recommendations pertaining to biological characteristics of the species and spatial traits of the fishery, e.g. when/where to avoid fishing juveniles/spawning females. It is also important to note that the estimates derived from our model could be considered an average of the system, and therefore they are not good predictors for abnormal years (years of abundance and scarcity).

Finally, although this estimation of the MSY has many limitations, it is important to emphasize that this is the first attempt to examine this fishery technically and therefore our main aim is to get some ideas that allow us to establish the direction that should take the future studies on this fishery.

5. Maximum Economic Yield

For this part of the analysis we use the results obtained in the previous section; that is, the generated yield curve obtained in section 5 along with economic data obtained from: 1) the observer program established during 2013, 2) private financial information from a group of anonymous vessel owners and 3) information from the surveys applied to some Pomaderos and fishermen during 2013.

The maximum economic yield (MEY) is defined as the level of landings that would maximize profits to the harvesting sector. The latter occurs when the difference between total revenue and total costs is the greatest. The effort needed to harvest the MEY is labeled as E_{MEY}. Since the total cost curve is positively sloped, it is expected that E_{MEY} will be less than E_{MSY}.

Through this analysis it is also possible to estimate the open access equilibrium where landings are at OAY (open access yield) and effort is at E_{OAY}. In an open access fishery, when there are positive profits additional vessel owners will enter the fishery to capture these economic profits. The entry of additional vessels will increase effort, eventually to the point (i.e. long run) where TR equals TC (i.e., all economic profits have been captured and are thus zero), which occurs at E_{OAY} units of effort equivalent to landings equal to OAY.

5.1. Methodology

The equations used to calculate MEY, E_{MEY}, OAE, and E_{OAE} are derived as follows:

- ***Total revenue (TR)*** is equal to price/Ton (***p***) times tons of Pomada landed (***Y***); that is: $TR = pY$. It is important to specify that the net revenue that vessel owners receive in this fishery should account for the cost of labor which is a percentage of the total revenue generated per trip. Then the net revenue (***NR***) for vessel owners is equal to: $NR = spY$ where ***s*** is the percentage of the catch (or revenues) that vessel owners receive.

- ***The (non-labor) operative cost*** for this analysis is composed by fuel cost (***Fu***), lubricant cost (***Lu***), filter cost (***Fl***), ice cost (***Ic***), Food cost (***Fo***) and water cost (***Wa***). Thus, the total (non-labor) operative cost is defined as:

$$TC = Fu + Lu + Fl + Ic + Fo + Wa \qquad (6)$$

where $Fu = fu*f_{(i)}$; $Lu = lu*f_{(i)}$; $Fl = fl*f_{(i)}$; $Ic = ic*f_{(i)}$; $Fo = fo*f_{(i)}$; *and* $Wa = wa*f_{(i)}$.

Thus ***fu***, ***lu***, ***fl***, ***fo*** and ***wa*** are the different operative cost per unit of effort and $\boldsymbol{f_{(i)}}$ is the standardized unit of effort expressed in number of trips.

At the end the total operative cost can be expressed as follows:

$$TC = \mathrm{f}_{(\mathrm{i})} * (fu + lu + fl + fo + wa) = \mathrm{f}_{(\mathrm{i})} * c \qquad (7)$$

As we determined in the previous section the estimated yield curve is expressed by the following equation: $Y_{(i)} = af_{(i)} + bf_{(i)}^2 \quad if \quad f_{(i)} \leq -{}^{a}/_{b}$, where the values of ***a*** and ***b*** are fitted parameters associated with the estimated yield curve and which were estimated in the previous section (i.e. ***a*** = 3.748041 and ***b*** = -0.0049745).

Based on the previous information we determined the following relations:

$$E_{MEY} = \frac{c-asp}{2bps} \qquad (8)$$

$$MEY = aE_{MEY} + bE_{MEY}^2 \qquad (9)$$

$$E_{OAY} = \frac{c-asp}{bps} \qquad (10)$$

$$OAY = aE_{OAY} + bE_{OAY}^2 \qquad (11)$$

5.2. Results

The average price observed historically for a ton of Pomada is equal to $1,128 with a standard deviation of $443.01. It was also determined that 30% of the total revenue is used to pay labor costs. On the other hand, Table 8 shows the average (non-labor) operative cost per unit of effort obtained from the observer program.

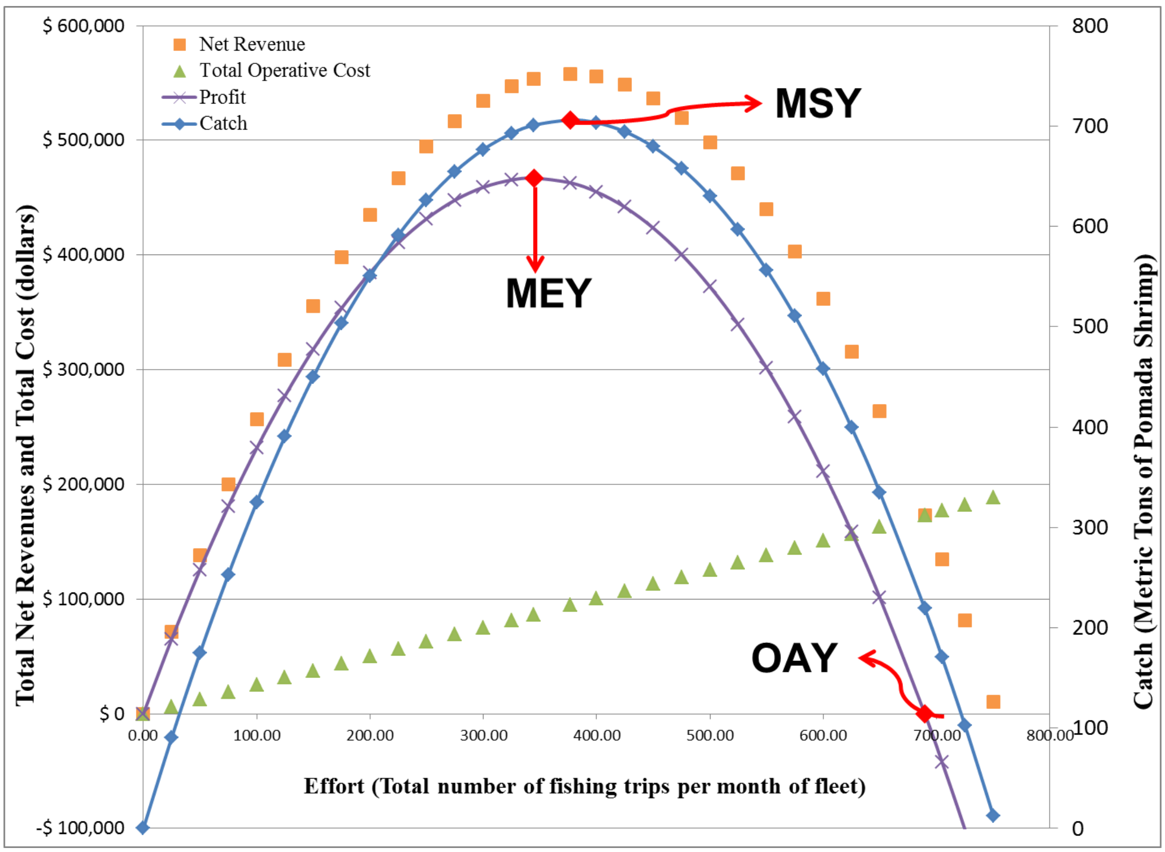
Table 8: Quantity and Unit Cost for calculating the (non-labor) operative costs per unit of effort

	Quantity consumed per trip		Unit Cost	
	Mean	Std Dev	Mean	Std Dev
Fuel	131.56	21.16	1.06	0.04
Lubricants	0.83	0.34	17.62	1.44
Ice	0.14	0.08	15.12	9.62
Food	16.86	6.31	1.76	0.41
Water	16.87	4.99	1.78	0.59

Based on this information it was determined that the MEY per month of the Pomada Fishery is equal to 701 tons (approx. 3 Tons less than the MSY) which is related to an effort (E_{MEY}) that is equal to 345 trips per month. In the case of the open access case we determined that open access effort (E_{OAY}) is approximately 690 trips per month which produced a yield (OAY) equal to 219 Tons per month.

Figure 8 shows the different relationships between effort and other variables such as catch, net revenues and profits as well as the different points of interest (e.g. MSY, E_{MSY}, MEY, E_{MEY}, OAY and E_{OAY}). In Figure 8 we can observe that MSY is very similar to the MEY. The reason for this is because the operative cost of the Pomada fishing activity is relatively low, which means that the difference between both values is small.

Figure 8: Relationship Effort vs. Catch, Net Revenues, Cost and Profit



6. Profitability Analysis of the Pomada Shrimp Fishery

6.1. Current situation or Business as Usual analysis (BAU) and calculation of the Breakeven Point (BEP) of the Industrial Pomada Fleet.

This analysis suggests that Pomaderos are not fishing at the MSY level, but they are fishing at a higher (unsustainable) level. In addition, the current daily quota is approximately 48% above the MSY estimated in this analysis and therefore affords no protection to the biological health of the target Pomada stock. We observe that in 2010, the total catch was 783 tons per month in average (i.e. 11% above the MSY). This generated that on average the annual net profit for each boat owner was approximately $109,000. The latter figure is aligned with what was estimated by Aguero et. al. (2011), specifically they estimated that the net annual profit of each boat owner is on average $119,000. However, we should emphasize that even though this profit is high this is derived from a non-sustainable fishing practice scenario (i.e. BAU) in which the capture is likely above both the MSY and MEY of the Pomada shrimp fishery.

In the case of the average break-even point (BEP) of the fleet, it was estimated that for any boat the BEP is 884 Kgs per trip on average. When comparing this BEP with the possibility of a daily catch quota determined by either the MSY or the MEY, we found that a daily quota established using the MSY (MEY) would be 72% (71%) higher than the BEP calculated per trip. That means it is possible to establish regulations using measures such as MSY and MEY, without affecting the financial sustainability of the fleet because largely the average BEP of each boat per trip is relatively low.

6.2. Simulation of Individual Annual Profits and its Relationship with Different Quota Scenarios

We first start defining the two daily quotas that will be the starting points for the scenarios analyzed in this part. We defined the first quota using the MSY and the other one using the MEY. The daily individual quota that was obtained using the MSY is equal to 1,527 Kg per boat and the daily quota that was obtained from the MEY is equal to 1,516 Kg per boat (which is very similar to the MSY quota). For both cases the daily quota is approximately ¾ of a ton less than the current daily quota established in the Pomada shrimp fishery (i.e. 2,267 Kg per boat per day).

For this section we also use information obtained from the vessel owners survey, from which we were able to determine that the annual fixed cost that those vessel owners must pay is approximately $50,000 per year in average with a standard deviation of $18,000. Based on the latter information as well as information from previous sections, we were able to determine that the annual profit of a boat owner when the quota is established using the MSY is $88,909 and when the quota is established using the MEY the annual net profit for a boat owner is $90,112.

We also conduct a Monte Carlo simulation, from which we obtained two probability distributions, showed in Figures 9 and 10, which are based on 1 million replications. From those probability distributions we determine that the probability that the annual individual net profit of any vessel owner should fall below zero when the daily quota is determined using the MSY (MEY) is equal to 5.66% (5.16%). On the other hand, if we assume that vessel owners required that the fishing activity generate them at least a monthly income of $2,000 (i.e. $24,000 annually) the probability that the net profit did not reach that threshold is 14.90% when the daily quota is determined using the MSY and 14.06% when the daily quota is determined using the MEY. This low probability could be considered as an indication that it is possible to establish a more stringent catch quota without affecting the economy of the vessel owners.

It is important to highlight that for both probability distributions the highest sensitivity is related to the price variable. The price elasticity of these two distributions is approximately 0.94.

An assumption embedded in this exercise is that we are implementing quotas that are lower than the actual quota and, given the current complaint that the current quota is very low, we are able to assume that fishermen will be able to attain these two proposed quotas imposed for this analysis (i.e. MSY and MEY quotas) and we disregard any variability in the catch level assuming that Pomaderos will reach those thresholds without problems.

Figure 9: Probability distribution of Individual Net Profits under the scenario of a catch quota equal to MSY

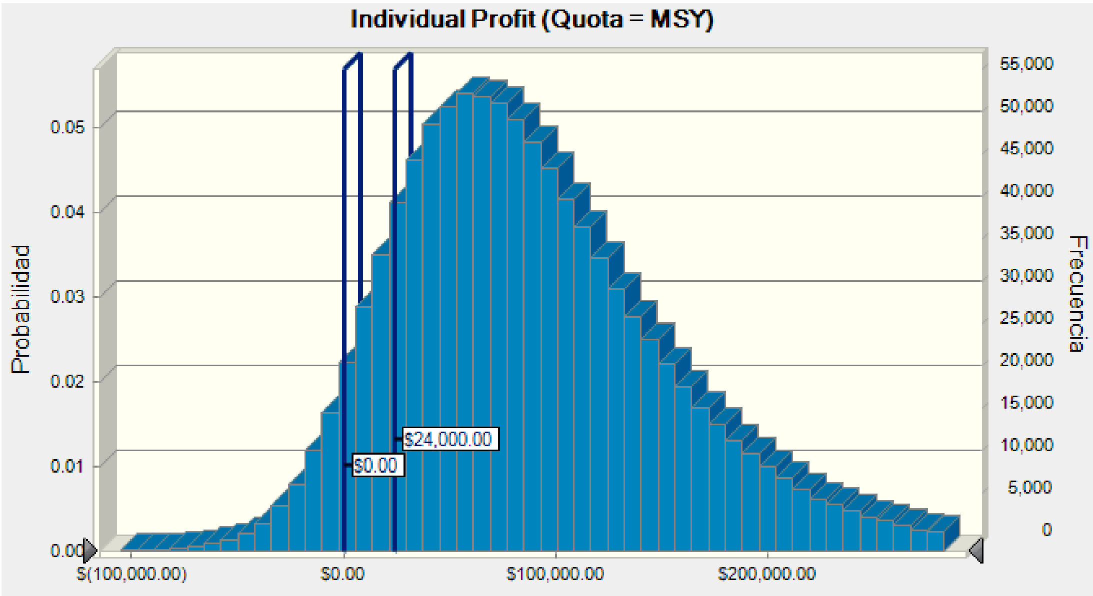
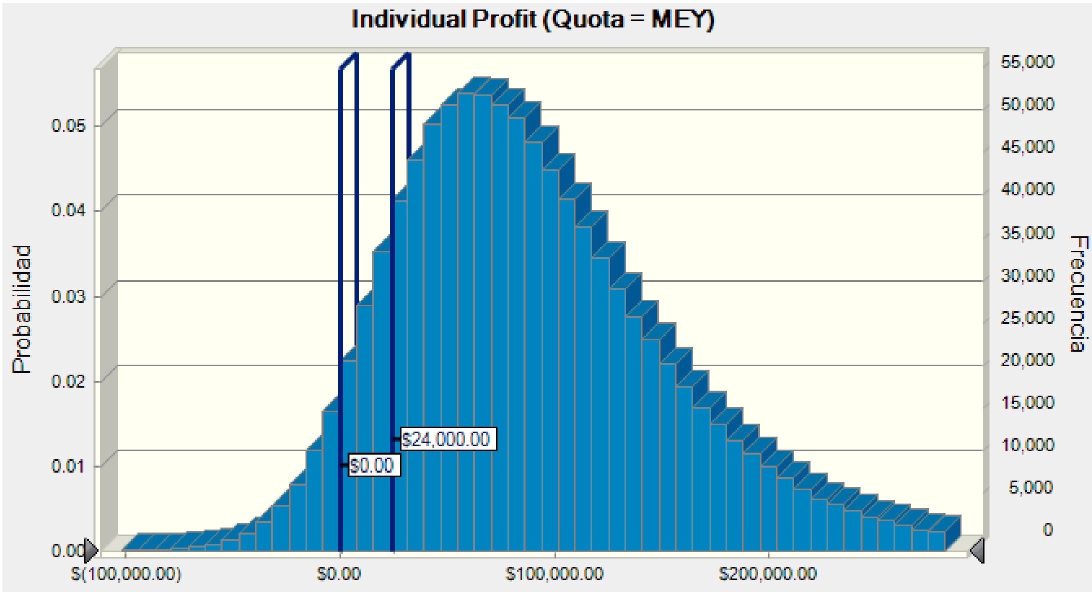


Figure 10: Probability distribution of Individual Net Profits under the scenario of a catch quota equal to MEY



6.3. Simulation of individual annual profits with a scenario of two quotas (i.e. Low season quota and high season quota)

We proceed to analyze what the effect on the individual annual profit of any boat owner would be if two different daily quotas are established based on the different characteristics of both the ***high season*** *(February to June)* and the ***low season*** *(July to January)*. We estimate *Equation 2* but including an additional variable (i.e. a dummy variable) that takes the value of 1 when the observation is related to the low season and 0 when is related to the high season.

Table 9: Estimation Results of Schaeffer Model with a dummy for low season months

Coefficient	Estimator	Bootstrap Std. Err.	Z	P-Value
A	4.307602	0.5691657	7.57	0.000
B	-0.0050605	0.0010101	-5.01	0.000
Low season dummy	-354.4168	117.3568	-3.02	0.006
Number of Obs. =			28	
R-Squared =			0.8576	
Adj R-Squared =			0.8405	
Root MSE =			270.35	

The dependent variable is the total catch per month measured in metric Tons, and the independent variable is equal to the number of active boats per month multiplied by the average number of fishing days for those boats

We obtain the estimators shown in Table 9 from which we conclude that the Schaefer functional form is still adequate for the data. Furthermore, we observe in Table 7 that the significance of the model increases by 5% because of the inclusion of the seasonal dummy.

Table 9 also shows that the estimators of the three parameters of the model (i.e. ***a, b***, and the ***Low season dummy***) are statistically significant and they show the sign that we expected; that is, a positive sign for the estimator of ***a***, a negative sign for the ***b*** estimator and a negative sign for the season dummy, which is congruent with our initial expectations because it is expected that the MSY be smaller for the low season. We also found that the total fleet effort with the season dummy explains approximately 85% of the variation observed in the total monthly catch. In other words, we consider that the functional form proposed is statistically correct and then we can make inferences based on the estimators from Table 6. Specifically, we were able to calculate the MSY for each season, which are 916.68 tons per month for the high season and 562.26 ton per month for the low season. This is equivalent to a quota of 2,294 Kg per trip per boat for the high season (~26 Kg above the current quota) and 1,140 Kg per trip per boat for the low season (~1,127Kg below the current quota). This system of seasonal quotas could be considered as something more in line with the seasonal variability of the catch.

We should recall that there are important differences in the price behavior of both seasons too as we showed in section 4. In the low season the average price is higher, specifically $1,394.75/ton with a standard deviation of $181.83/ton, meanwhile in the high season the average price is lower, specifically $709.76/ton with a standard deviation of $407.98/ton. Based on the latter difference as well as the difference obtained from the estimated parameters in Table 7 we calculated two different MEY values, one for each season. The MEY for the high season is 904.06 ton per month and for the low season is 549.64 ton per month. In addition, based on the previous information as well as the ones provided in previous sections, we were able to determine that when there are two daily quotas (i.e. one for each season) and these are established using as reference the estimated MSY, the expected annual net profit for each boat owner is equal to $73,271, and when the two quotas are established using the MEY, the expected annual net profit for a boat owner will be equal to $73,942.

We also conduct a Monte Carlo simulation from which we generate two probability distributions, showed in Figures 11 and 12, which are based on 1 million replications. From those probability distributions we determine that the probability that the annual net profit of any vessel owner should fall below zero when the two daily quotas (i.e. low and high season quotas) are determined using the MSY (MEY) is equal to 1.82% (1.58%). Conversely if we assume that vessel owners required that the fishing activity generate them at least a monthly income of $2,000 (i.e. $24,000 annually), the probability that the net profit did not reach that threshold is 6.70% when the two daily quotas are determined using the MSY and 6.15% when those two quotas are determined using the MEY.

It is important to note that even though the expected individual net profit is lower in the case of two quotas compared to the case of only one quota (i.e. previous section), in the case of two quotas it is less likely that negative profits will occur than in the case of one quota (approximately 3.7% less likely). Vessel owners are also less likely to see their annual profits fall below $24,000. This indicates that even though the return of a two-quota system is lower than that of a one-quota system, this is compensated by a lower probability of a negative profit. In other words, the axiom that any policy instruments that reduce the risk also reduce the expected return holds in this case. Therefore, we conclude that a two-quota system could potentially higher reduce the risk of vessel owners than a system in which only one quota exists.

Figure 11: Probability distribution of Individual Net Profits under the scenario of two quotas (one for each season) equal to MSY

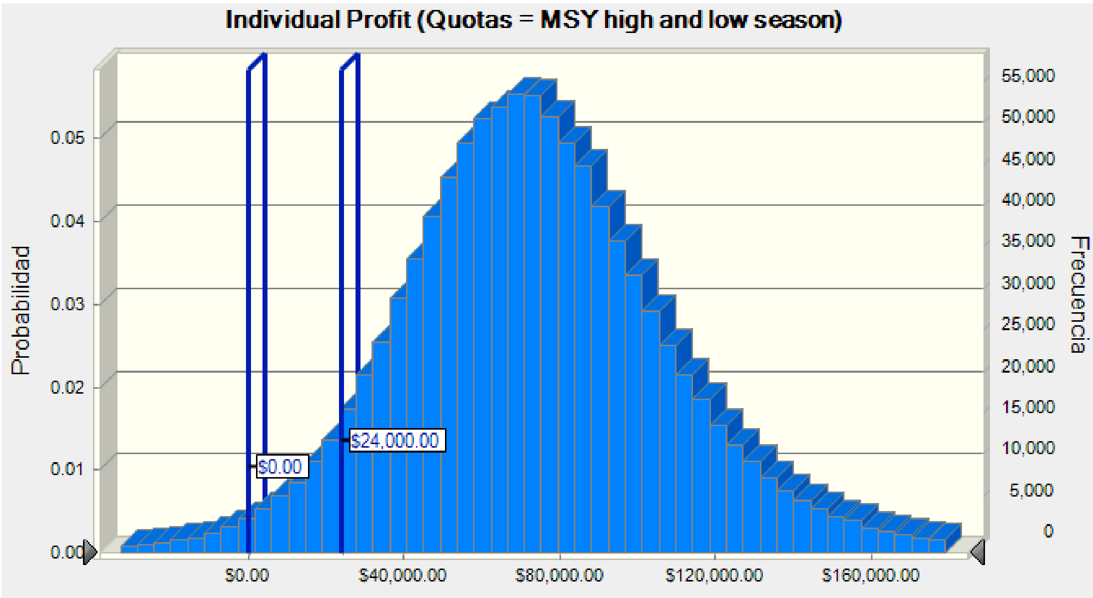
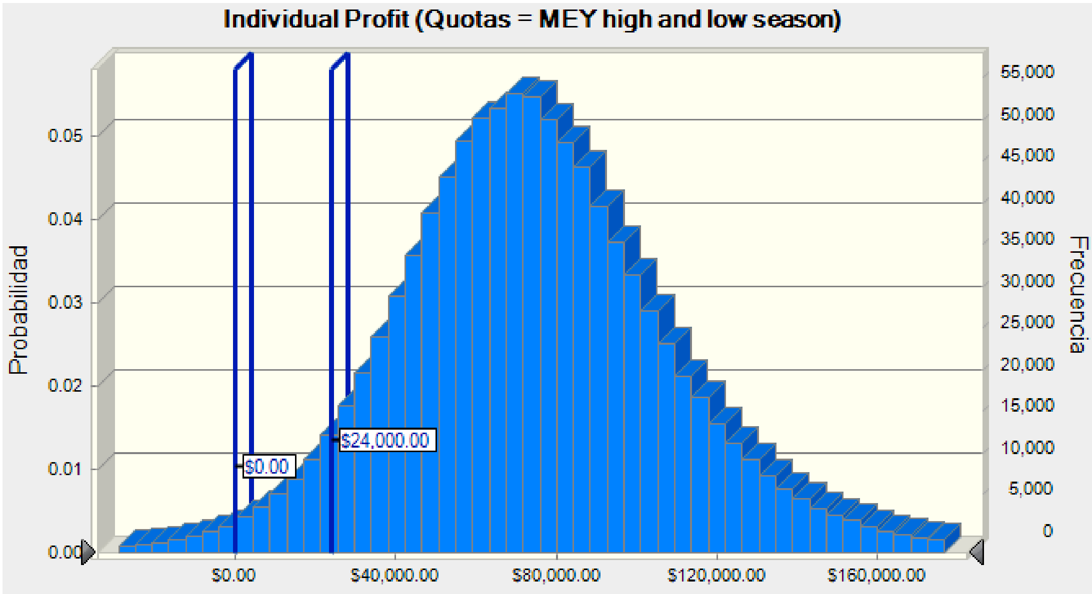


Figure 12: Probability distribution of Individual Net Profits under the scenario of two quotas (one for each season) equal to MEY



6.4. Summary of Results

In the previous sections we estimate the expected annual profit that vessel owners would receive under different scenarios. Initially we determined that under the BAU scenario the average annual net profit that vessel owners received in 2010 was $109,000, which may be considered as a profit of the current situation. The latter is a profit derived from an unsustainable fishing scenario (i.e. BAU) in which the capture is above both the MSY and MEY of the Pomada shrimp fishery. Consequently, we find that the average annual profits that vessel owners would receive under various sustainable scenarios are expected to be smaller (Table 10). It is important to emphasize that since the BAU scenario is unsustainable, we would expect to see declining annual profit in that scenario while in the sustainable scenarios we expect that profits would endure indefinitely during many years.

Table 10: Individual Annual Profit under different scenarios

SCENARIO		NET ANNUAL PROFIT FOR VESSEL OWNERS
UNSUSTAINABLE SCENARIO	BAU	$ 109,000
SUSTAINABLE SCENARIOS	One quota using MSY	$ 88,909
	One quota using MEY	$ 90,112
	Two quotas using MSY	$ 73,271
	Two quotas using MEY	$ 73,942

From Table 10 we observe that when only one quota is established the individual annual profit is on average 18% less than the current situation but when two quotas are established the individual annual profit is on average 32% less than the current situation. Hence, we reaffirm again that even though the short-term annual net profits of the sustainable scenarios are lower they can be guaranteed for a long term while the BAU profit will be declining for each year because of the systematic biological depletion of the Pomada shrimp.

Table 11: Probability of Negative or Insufficient Profits under different sustainable scenarios

SCENARIO		Probability (Profit < $0)	Probability (Profit <$24,000)
SUSTAINABLE SCENARIOS	ONE QUOTA USING MSY	5.66%	14.90%
	ONE QUOTA USING MEY	5.16%	14.06%
	TWO QUOTAS USING MSY	1.82%	6.70%
	TWO QUOTAS USING MEY	1.58%	6.15%

Based on results from Table 11 it could be affirmed that the optimal sustainable strategy is to establish one quota instead of two quotas. However, as we found in Table 9, even though the expected individual net profit is lower in the case of two quotas compared to the case of only one quota (i.e. previous section), in the case of two quotas it is less likely that negative profits will occur than in the case of one quota (approximately 3.7% less likely). This indicates that the two-quota system reduces the risk of a negative profit, but this reduction is at cost of a lower return (i.e. expected profit). Thus, as we indicated previously, the axiom that any policy instruments that reduce the risk also reduce the expected return holds in this case[3]; consequently, policy makers should consider this trade-off when making a choice decision among policies.

7. Conclusions

The objective of this paper is to establish a baseline understanding of the profitability in the Pomada fleet operating out of Posorja under different scenarios. We conduct an analysis that allows us to provide the following conclusions:

1. The price of Pomada shrimp in Posorja is determined endogenously (~80%) by factors of the local market mainly. The relative importance of the international price (or the international market) on the behavior of the price of Pomada shrimp in Posorja is very low.

[3] As we can observe in Tables 7.2 and 7.3 the axiom that says that a high return implies a high risk also holds when we compare policies that have been established using as reference the MSY with those that have been established using as reference the MEY. Specifically, we can observe in Tables 7.2 and 7.3 that MSY policies have a higher return but also a higher risk than MEY policies.

2. The main local factors that affect the behavior of the price of Pomada shrimp in Posorja are the abundance and the size of the product. This suggests that it is possible to change the current management strategy of the sector from a quantity-driven-strategy to a price-driven-strategy that focuses either on controlling the production of Pomada shrimp to raise its local price or, alternatively, on increasing the product's added-value to raise the price paid by local buyers (i.e. instead of selling the product raw to sell it peeled).

3. The estimated MSY of the Pomada shrimp fishery is equal to 706 MT/month while the estimated MEY is equal to 701 MT/month.

4. Using as a reference both the estimated MSY and the estimated MEY it was determined that the current individual daily catch quota, which was established by the same Pomaderos for the Pomada shrimp fishery, is likely to be beyond the sustainable limits by about 750 Kgs.

5. It was determined that if the MSY (MEY) is used as a reference to establish an individual daily catch quota this would generate a 5.66% (5.16%) probability that the annual net profit of any boat owner be negative.

6. It was also found that the probability of negative net profits is lower if instead of setting only one quota for all the season, two quotas (one for the low season and one for the high season) are established. Specifically, if the two quotas are established using as a reference the MSY (MEY) level this would generate a 1.82% (1.58%) probability that the individual annual net income of any owner is negative, a reduction of 3.84 (3.58) percentage points compared to the one quota scenario.

7. The downside of establishing a system of two quotas compared to a system of one quota is that the expected net individual profit per year is lower in the former case than in the latter in approximately 23%. This illustrates the axiom that when policy instruments reduce risk, they also reduce the expected rate of return, a tradeoff that policy makers should consider when deciding.

8. Compared to the BAU scenario, it is expected that sustainable scenarios modeled in this paper generate a decrease in short-term benefits (approximately 20% in average). However, it is also expected that as compensation for this loss in the short-term benefits, the different sustainable scenarios modeled in this paper are able to promote the protection of the activity in the long run.

8. Recommendations

As we indicated throughout this paper there were significant limitations for the analysis of the Pomada shrimp fishery that we conducted. The source of these limitations was the lack of information in some cases and the low quality of the available information in other cases.

In this part we will review the different information problems that we had to face during our research process. Most of the information problems that we found during this research can be solved immediately with a very low cost because in most of the cases it only requires an increase in the willingness to collaborate between different public institutions. On the other hand, private individuals (i.e. some vessel owners) were able to provide us very valuable information impossible to get from another means (e.g. the price series of the Pomada shrimp at port). However, we consider that information of this type should be gathered officially by a specific institution to be available to all the fishery participants as well as scientists interested in the Pomada shrimp fishery. For that purpose, in this section we will also provide some advice about how to systematize the recollection of this information by an official institution, maybe by the fishing cooperative "Primero de Mayo".

For the estimation of the MSY and the CPUE we faced the following problems:

1) The available landing information from the INP was limited in its accuracy because it was obtained not from direct observation but from a sampling and extrapolation procedure. Because of the previous procedure, only aggregated information about catch was available, which made impossible to establish an individual correspondence between the fishing effort from each boat and their individual catch. In addition, this information did not allow us to identify where and when (during a month) the fishing was done.

2) The departure data from the DIRNEA was faulty too by the same reason of the landing data; that is, because this data was not gathered through observational methods at port. Instead DIRNEA obtained the departure data directly from vessel owners when they apply for a sailing permit. In their application for a permit, vessel owners should indicate if they will be active during a specific month and how many days approximately they will be active. As we inferred this is a mere approximation of the boats' fishing activity and could be contaminated by measurement error, more in the information related to the frequency of participation than in the information about the decision of participation. Since we do not know exactly how many days and which days vessel owners will be active it would be more difficult to determine accurately the total effort applied in the fishery; and

3) There is not complete, detailed and updated information about the characteristics of each boat that participates in the Pomada shrimp fishery in Posorja. This problem did not allow us to standardize the fishing effort, but instead we had to assume that the fleet is homogenous to reduce measurement error and bias in this component of the data (i.e. characteristics of each boat).

The way to solve the first two problems is simple, especially for the next years and would depend on only one institution, the SRP (Sub-secretaría de recursos pesqueros). The SRP has been collecting landing information from 2013 through a continuous survey process to fishermen from whom they gathered different type of data such as, date and time of departure and return, total catch for a trip, crew during a trip among other information. This survey could provide more accurate information about the total catch of the fleet and the catch level during different days along the month as well as it will permit to relate individual catch with individual effort. In addition, the same SRP is applying a VMS system for the Pomada fleet. With that information is possible, first to confirm the information of the landing survey (specifically about date and time of departure and return of vessels) and second to provide spatial information related to the movement of the fleet. Both information collection initiatives are very recent (i.e. 2013 the landing survey and 2011 the VMS), which suggests that there would be enough information to replicate this analysis more accurately in the future. This will depend on the capacity of the SRP to provide real time information from the dockside and satellite monitoring systems for fishery science purposes.

To solve the third information problem mentioned above, we recommend conducting a thorough census of the characteristics of each boat that belongs to the fleet that participate in the Pomada shrimp fishery in Posorja. This census should be done each year to keep an updated record of the capabilities of the fleet. We consider that this initiative should not be expensive mainly because of the small size of the fleet (i.e. 38 boats). After that census process we will consider possible to standardize the effort for the different type of boats that participated in the fishery. Specifically, the method that could be applied is as follows: first, determine a standard boat as well as the effort related to that boat. Afterwards the individual effort of each of the participating boats will be transformed using the standard measure obtained through the characteristics of the standard boat. The final step will be to add the standardized individual effort of each vessel to obtain what is known as the total standardized effort.

Finally, we obtained the price series for the Pomada shrimp from private databases of a group of vessel owners. We recommend that this type of information should be gathered officially by the fishing cooperative (i.e. Primero de Mayo) to systematize and formalize the recollection of this information as well as to have it available for the entire fleet as a planning tool.

All these recommendations are directed to improve the quality and availability of data to replicate our analysis. However, we consider that sooner rather than later the analysis should transition to more sophisticated techniques that incorporate a very detailed biological component into the structure of the models. Not only that, we consider that it is necessary to understand what the effect of the climatic and oceanographic conditions are on the abundance and the profitability of this fishery, especially because of the threat of climate change. This is even more important to consider for the future research in the light of our preliminary results shown in Appendix A in which we found a possible relationship between climatic/oceanographic conditions and those variables that are fundamental for the profitability of the fishery (i.e. price and abundance). For this purpose, we recommend for future (more complete) models to get the support of the INOCAR (Instituto Oceanográfico de la Armada) which is a public institution that has access to an extensive collection of climate and oceanographic databases and climatic models as well as an important expertise that can be used to formulate adaptation and/or mitigation policies for this fishery.

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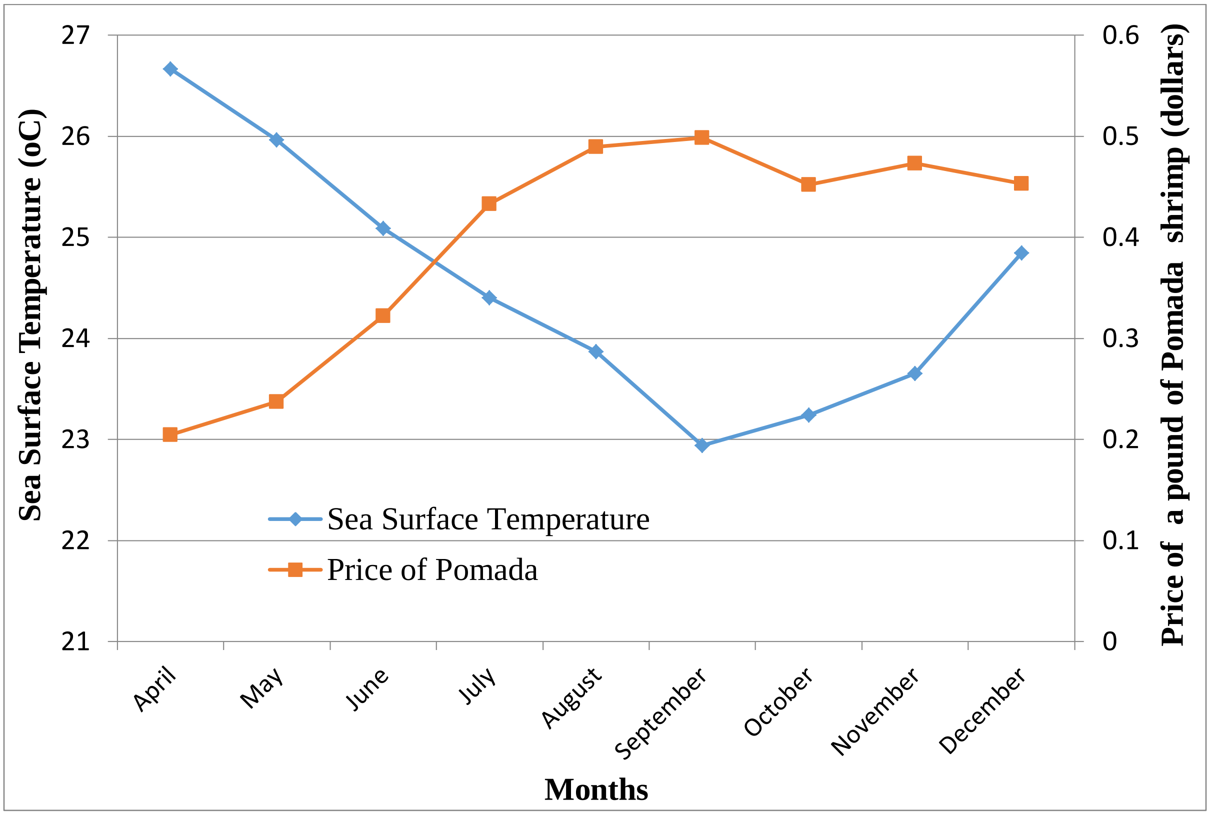
Appendix A

We conduct a preliminary analysis on the relation between climatic/oceanographic conditions and those variables that are fundamental for the profitability of the fishery (i.e. price and abundance).

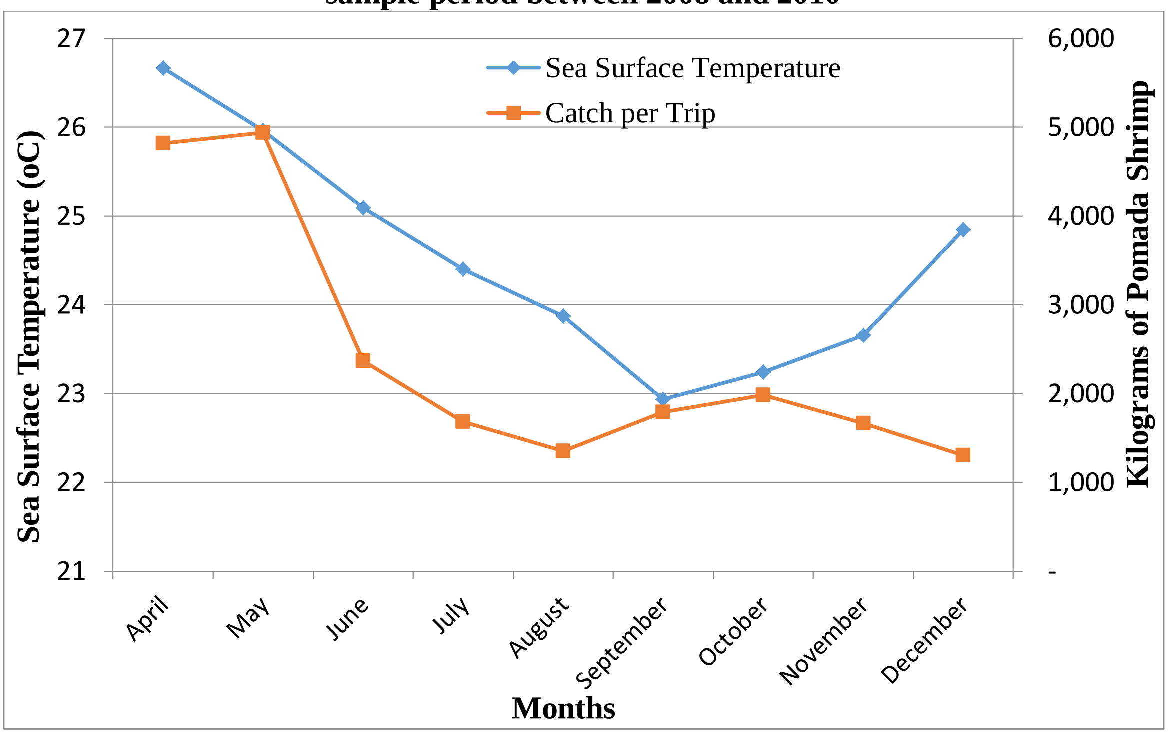
Figure A.1 Average sea surface temperature and for each month in a year using a sample period between 2008 and 2010



For instance in Figure A.1 we have two series; the first one is the average temperature for each month during the period 2008 – 2012 gathered from the Physical Oceanographic Distributed Archive Center (PO.DAAC) that belongs to the NASA and the Jet Propulsion Laboratory (JPL) of the California Institute of Technology. The other series is the average price of a pound Pomada shrimp in US dollars during the same period obtained from a personal database of a group of vessel owners. It is important to note that 3 months have been excluded from the analysis (i.e. January, February and March) because they have been months in which a fishing closure has been in placed at least once. Thus, we can observe in Figure A.1 that the price of Pomada shrimp during any year has a behavior that is inversely related to the behavior of the sea surface temperature. We calculated a negative correlation of -0.92 (which is very high) which indicates that there is a strong negative relation (not causality) between these two series. The reason of this negative relationship could be related to an indirect relationship between temperature and abundance. We hypothesized that a higher temperature would favor a high abundance which in consequence would affect negatively the price of the product.

For this purpose, to test preliminarily this hypothesis, we show in Figure A.2 two series; they are the sea surface temperature (showed in Figure A.1 as well) and a series that was constructed from a sample of 3 boats which contains their average catch per trip per month during the period 2008-2012. Therefore, in Figure A.2 we observed, as we expected, a positive relationship between catch per trip (which could be a proxy of abundance) and the sea surface temperature. We should warn that this is an incomplete and not statistically significant analysis because for constructing the catch per trip variable we use catch from a sample of 3 boats (i.e. 7% of all the participant boats) only. However, the relation that we found in Figure A.2 provides a notion that there could be a mechanism that operates in this fishery that works as follows: an increase in temperature favors the spawning and consequently increases the abundance of the product; the latter consequently reduces the price. Then as months pass by the sea temperature falls which inhibit the reproduction of the Pomada and then there is no new stock in the system; this along with the effort applied by the fleet produce that the abundance reduces continuously and the price start to increase. In other words, it is very likely based on this very preliminary evidence that climate and oceanographic factors play an important role in the relationship between abundance and price for this fishery.

Figure A.2 Average sea surface temperature and for each month in a year using a sample period between 2008 and 2010



If the previous hypothesis is correct we consider that it is important that future studies include climate and oceanographic variables in their models. In addition, it is important to start developing this type of model because of the threat of climate change which imposes an additional urgency to understand the influence of the climate and oceanographic factors on the profitability of this fishery to be able to develop adaptation and mitigation measures against this threat.