The Effects of El Niño on Fishing Efforts and Corresponding Bycatch Rates

**Introduction:** Bycatch has been a crucial issue in the fishing industry since the dawn of industrialization. The act of bycatch or the incidental catch of a non-targeted marine organism has severely crippled or endangered populations all over the world. Animals threatened by unsafe fishing practices encompass marine mammals, sea birds, sea turtles, and larger fish species such as sharks. However, most people do not understand that bycatch also encompasses any non-targeted species caught; including other economically viable species other than the intended catch. Though many safe guards have been put into effect to reduce bycatch, or even prevent harm to the animals caught incidentally (Turtle Exclusion Devices, MPAs, catch quotas, etc...), bycatch quantities are continuing to climb. My research aims at understanding how the South American fishing industry, particularly in the area of the Peruvian upwelling zone, including the Galapagos Islands, alters its fishing strategies to accommodate El Niño events.

**Question 1:** What affect does El Niño have on the types of gear and overall fishing effort fisheries supply in comparison to La Niña or neutral years?—Then from these results, support predictions for how these changes alter the bycatch composition and size in that particular fishing zone.
**Question 2:** How do by-catch rates relate to the intensity and duration of El Niño events off the western shores of South America?

**Question 3:** Does a change in fishing effort and gear type diminish or increase rates of bycatch during ENSO?

**Question 4:** Are these changes in fishing effort and bycatch rates different between the Galapagos and the mainland? Why?

**Background:** El Niño Southern Oscillation has spurred the collapse of the Peruvian anchovy fishery and adjacent fisheries around the coastal upwelling zone between Galapagos and the mainland. During a typical La Niña year, the Trade Winds blow westward and push warm, surface water toward the western pacific. This establishes a temperature and climatic gradient throughout the equatorial pacific called the Walker Cell. Our eastern side is kept dry while the western side receives high precipitation from warm, low pressure atmospheric conditions. This leads to a defined thermocline that rapidly ascends in depth around western South America. The up-welling zone forms and brings up cold, nutrient rich water that supports abundant marine life and the South American fisheries. However, El Niño is the pronounced destruction of this cycle and causes the reversal of the climatic conditions on either side. The Trade Winds weaken and the thermocline flattens out; reducing upwelling events significantly in the eastern pacific. This causes reduced nutrient circulation and a decline in marine populations. This reduction in biomass threatens the fishing industries and alters their catch practices for the duration of the ENSO.
**Hypothesis 1**: As El Niño progresses or intensifies, fishing efforts will increase along with gear usage to maintain profits. Each trip will likely yield less stock so the industries will compensate by using more gear such as longer long lines, more gill nets, and overall more trips to compensate.

**Hypothesis 2 and 3**: I believe bycatch rates will increase during an El Niño event. The higher fishing efforts and more drastic catch methods will bring in more incidental catches of non-targeted species. Because El Niño events last on the lower end of 1-3 years (Read graph below), the nutrient deprivation will mostly effect the lower levels of the trophic pyramid. The higher taxa will still have fairly high populations during the pinnacle of the El Niño year, leading to far higher incidental catches.

**Hypothesis 4**: Galapagos fisheries will have very little or random fishing effort and bycatch rate alterations throughout the El Niño season as compared to Peru. The reason being that fishery and conservation policy over the last few years have been taking more effect. In a small scale fishery size such as Galapagos, policy will trump any noticeable change in fishing effort brought on by El Niño.

**Methodology**: I will be using fishing data and research papers over the last few years to find an overlapping, mathematical correlations between El Niño years, bycatch rates, and fishing efforts. These papers or assessments come from organizations such as; NOAA, BP, or individuals with published works about the zone. From these papers, I will demonstrate whether or not my hypothesis are supported.

**Galapagos Handline Fishery:**
Until recently, very little research has been conducted on the local, handline fisheries of Galapagos. Handline includes any line or baited tether operated by a user to bring in a targeted fish species. This is the most traditional form of fishing around the islands and has defined Galapagos hunting culture. However, the practice has been predicted to yield significant quantities of incidental catch. These can include illegally marketed organisms such as turtles and sharks, or unintended, marketable species. Based on their catch, fishers make decisions on the ultimate fate of these caught creatures. If the non-targeted species is profitable, it is sold in the market. If not, it is either released or used as bait for further catches.

In one particular research expedition, Zimmerhackel and her crew interviewed and followed dozens of handline fishers to understand the bycatch ramifications. Ninety-four hours of fishing, over 22 trips, across 297 sites led to a biomass yield of 2.1 tonnes. The composition of these 1,279 fish turned out to show a \textbf{40.3\%} rate of bycatch. This amount is staggering compared to industrialized fishing practices (long lining in Peru being 18\%). However, 40.3\% is almost exactly the world average on artisanal, handline bycatch; 40.1\%. Given that these rates of bycatch occurred during the end of one of the
larger La Niña events in 2012, these results would suggest that the handline fishery bycatch rates remained stagnant. This data supports my fourth hypothesis of the Galapgos not having a substantial change in fishing effort or bycatch quantity during either a La Niña or El Niño events. However, I will be analyzing a few other fisheries in order to establish a more supported hypothesis.

**Marine Management: Evaluation of the Spiny Lobster Fishery in the Galapagos Marine Reserve:**

Jorge Ramirez, Harry Reyes and Anna Schuhbauer

The size and yield of the spiny lobster fishery has fluctuated substantially over the last 15 years. What used to be a thriving industry that employed almost 1,200 boats has been reduced by nearly a third. For my research, I will be looking at the bycatch data accumulated over the past few years by means of lobster traps. These traps are wooden or metal grated boxes that are built for the targeted capture of spiny lobsters. However, a recent survey has shown that spiny lobsters only make up 2.8% of the total catch. The two most captured, non-targeted organisms are the slipper lobster and the yellow tailed grunt; both economically viable, but statistically fall under bycatch. Therefore, these traps have a bycatch rate of 97.2%; far above any reasonable fishery. This bycatch rate has been determined to be a fair average for any lobster trap used over the past few years. If the catch capabilities of the gear have not increased substantially, then another factor has been causing the fluctuations in lobster yield and success of the fishery.
My research also indicated fishing efforts in this fishery do not fluctuate with mild to weak ENSO events. El Niño is not a significant, limiting factor in the success of the spiny lobster fishery and therefore supports my hypothesis for an isolated Galapagos. However, the exceptions to this rule are of course prolonged El Niño and La Niña events. As their intensity and duration increase, we begin to see the Galapagos spiny lobster fishery react. The 1997-98 El Niño decimated the lobster yields, and its recovery immediately began in 1999-2000 until it once again almost collapsed; this time due to the substantial increase in fishing vessels. The small El Niño events on the other hand are harder to detect in the fishing patterns and success rates of the Lobster Fishery because they do not have the length or intensity to severely cripple lobster populations or alter fishery behaviors. This once again supports hypothesis 4 and transitions into the fisheries of the mainland.

**Bycatch and fishing efforts in the Port of Salaverry 2002-2005** by Paola Melly:

Salaverry is a fairly large, mainland port a few hundred miles southeast of the Galapagos. The area has had quite a few fishing studies conducted, in particular those regarding leatherback sea turtles. In this case however, I am analyzing the 2002-05 study on gillnet bycatch rates on sea birds. A gillnet is a long, weighted wall of mesh that fish and other marine creatures inadvertently swim into. Since this method is
non-target specific, it is unfortunately a great concern for bycatch. Globally, over 400,000 marine birds are caught in these nets annually (Those that escape can come out injured and mangled such as this pelican on the right).

Reasons for high seabird incidental catches

1. Surface diving to take sessile prey (mollusks) which are removed from underwater substrates at depths down to 50 m (Cramp and Simmons, 1977).

2. Surface diving to take evasive mobile prey (fish) from the water column at a range of depths down to 150 m  Hedd et al. (2009) and Williams (1995)

3. Surface diving to predominantly shallow depths  
(Carboneras, 1992 and Cramp and Simmons, 1977)

Data collected by Paola Melly and his associates was meant for the sole purpose of establishing an assessment report and action plan to reduce bycatch in the future. For my project, I have utilized their catch data to find a pattern between bycatch rates and El Niño years. As displayed by the graph below, 2002-06 experienced pretty severe and enduring El Niño conditions. However, there are noticeable intensity changes between each year. 2002 can be categorized as the beginning
and ascension of ENSO to the highest peak. 2003 would represent the full force of ENSO and its eventual decline to neutral conditions. Then in 2004 ENSO returned to plateau throughout the next 2 years with a significant spike in 2005. Now analyzing the catch rates of Melly’s trips, I found a definite correlation between fishing efforts and ENSO, but no relation to bycatch rates. The amount of fishing trips rapidly increased during 2003 and 2005 where El Niño was well defined and at its peak conditions. More trips obviously led to more sets in total, but the amount of sets per individual trip seemed to not change between years. This indicates their fishing practices and gear use had not changed per trip, but instead they simply fished more. As my hypothesis predicted, total bycatch increased during heavier El Niño years as fishing efforts grew and the chance of incidental catch rose significantly. The interesting aspect that does not support my hypothesis is that the bycatch per set does not change significantly between years. Each individual set on average had the same quantity of marine birds as a normal year. This leads me to believe that there is an equal amount of marine birds during El Niño years. The higher bycatch amount is due to the increased fishing efforts. The populations do not seem to stagger too heavily in a short (1-3 year) time period. Please read data below for further insight.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Trips</th>
<th>Number of Sets</th>
<th>Total Seabird bycatch</th>
<th>El Niño Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>411</td>
<td>3425</td>
<td>606.7</td>
<td>Just started and rose to peak</td>
</tr>
<tr>
<td>2003</td>
<td>620</td>
<td>5166.7</td>
<td>915.2</td>
<td>Peak El Niño, lowered, rose</td>
</tr>
<tr>
<td>2004</td>
<td>421</td>
<td>3508.3</td>
<td>621.5</td>
<td>Medium intensity all year</td>
</tr>
<tr>
<td>2005</td>
<td>572</td>
<td>4766.7</td>
<td>844.4</td>
<td>Relatively high, then stable</td>
</tr>
</tbody>
</table>
Small-scale fisheries of Peru: a major sink for marine turtles in the Pacific

Joanna Alfaro-Shigueto1,2, Jeffrey C. Mangel1,2, Francisco Bernedo2, Peter H. Dutton3, Jeffrey A. Seminoff3 and Brendan J. Godley

This study, much like the Salaverry report assesses the number of incidental catches throughout certain years. However, the project here has had a much higher diversity of fishing gear and a larger time frame. As the chart depicts below, 4 types of nets were being observed for the presence of turtle bycatch. Turtle species can include green, leatherback, hawksbill, and olive ridley. I am only looking at total rates of bycatch in this case to compare to ENSO intensities. Looking specifically at the gillnet data, the amount of trips and sets rapidly declined as La Niña changed to El Niño. However, over the next three years as the El Niño persisted, trips rapidly increased as fisheries were forced to fish more to bring in profitable quantities. As for the driftnet fisheries (towed net wall), we see the opposite response as the fishers begin in a strong, ongoing El Niño year that gradually shifts to La Niña. Not mentioned in my earlier hypothesis, as

<table>
<thead>
<tr>
<th>Year</th>
<th>Bycatch per set out of 1</th>
<th>El Niño Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>0.178</td>
<td>Just started and rose to peak</td>
</tr>
<tr>
<td>2003</td>
<td>0.175</td>
<td>peak El Niño, lowered, rose</td>
</tr>
<tr>
<td>2004</td>
<td>0.174</td>
<td>medium intensity all year</td>
</tr>
<tr>
<td>2005</td>
<td>0.179</td>
<td>relatively high, then stable</td>
</tr>
</tbody>
</table>
ENSO switches to La Niña the fishers profit heavily from higher biomasses in combination with their already raised fishing efforts. Therefore we can observe that either of the two extremes; strong El Niño or strong La Niña, drives the fisheries to increase their total trips to turn a higher profit. This enhances my first hypothesis by saying El Niño or La Niña promotes higher fishing efforts.

However, a noticeable trend in long lining contradicts this prediction. As the plateaued El Niño year ends and introduces some sign of La Niña, a drop in long lined fishing trips occurs. This data both confused and worried me because of how contradictory it was to my hypothesis. However, further reading and analysis of Galapgos policy gave rise to two potential sources for the drop in longline bycatch during 2006. 2006 was the beginning of the implementation of longlinging regulation, and the year Sea Shepard started cracking down on illegal fishing operations. Both of these conservation strategies would have made the longlinging industry less profitable. The higher supervision would definitely lead to fewer trips and
less bycatch in total.

<table>
<thead>
<tr>
<th>Method: years</th>
<th>trip/set</th>
<th>year 1</th>
<th>year 2</th>
<th>year 3</th>
<th>year 4</th>
<th>El Niño Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001-04</td>
<td>set</td>
<td>360</td>
<td>224</td>
<td>326</td>
<td>648</td>
<td></td>
</tr>
<tr>
<td>Driftnet</td>
<td>trip</td>
<td>572</td>
<td>593</td>
<td>600</td>
<td></td>
<td>Strong El Niño is 05, followed by half La Niña and half El Niño in 06. Then really strong La Niña 07.</td>
</tr>
<tr>
<td>2005-07</td>
<td>set</td>
<td>3718</td>
<td>3855</td>
<td>3900</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longline (Dolphinfish)</td>
<td>trip</td>
<td>543</td>
<td>794</td>
<td>641</td>
<td></td>
<td>Plateaued El Niño from 04-05 with stronger conditions in 05. Half La Niña and half El Niño in 06.</td>
</tr>
<tr>
<td>2004-06</td>
<td>set</td>
<td>4018</td>
<td>5876</td>
<td>4743</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longline (Shark)</td>
<td>trip</td>
<td>236</td>
<td>233</td>
<td>224</td>
<td></td>
<td>Plateaued El Niño from 04-05 with stronger conditions in 05. Half La Niña and half El Niño in 06.</td>
</tr>
<tr>
<td>2004-06</td>
<td>set</td>
<td>1841</td>
<td>1817</td>
<td>1747</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusion: In summary, I have analyzed 4 specific case studies to develop a clear understanding of how El Niño affects Galapagos and coastal South America. Each report provided insight into how fishing efforts or bycatch rates were modified by ENSO. Under pronounced El Niño conditions, fishers were more inclined to increase their efforts and spend more time at sea in order to compensate for a lower yield per trip. In addition, my research also revealed that La Niña years have the same effect. Fishers take
advantage of the higher standing biomass and increase their efforts in a similar manner.

When the intensity or duration of an El Niño year is relatively low or average, the populations of higher taxa tend to not be as effected. Data came to the conclusion that fishers were catching as many sea birds per trip as they would have during a La Niña or neutral year. However, this also did not support my theory that bycatch rates are increasing during El Niño years. The rate remains relatively constant around coastal environments and the Galapagos despite ENSO.

Lastly, fisheries data regarding handlining and spiny lobster trapping would suggest that bycatch rates have not changed significantly over the past few decades. Also, fishing efforts seem more dependent on recent policy and regulation changes as opposed to ENSO. The exception would of course be very large El Niño and La Niña events that completely alter the composition of the fishing practice. Therefore, small scale ENSO changes the industry very little around the islands as opposed to the noticeable adjustments around the South American coastal zones.
Bibliography:


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