The socio-economic and ecological impact of regime shifts on small-scale fisheries in northern Peru

Vidal, A.P.

Vidal, A.P. (2022) 'The socio-economic and ecological impact of regime shifts on small-scale fisheries in northern Peru', The Plymouth Student Scientist, 15(2), pp. 84-101.
http://hdl.handle.net/10026.1/20121

University of Plymouth

*The Plymouth Student Scientist, 2022, **15**, (2), 84-101*

The socio-economic and ecological impact of regime shifts on small-scale fisheries in northern Peru

Ana Paula Vidal

Project Advisor: Dr Antony Knights, School of Biological and Marine Sciences, University of Plymouth, Drake Circus, Plymouth, PL4 8AA

Abstract

Species composition is known to naturally change over time; however, these fluctuations happen frequently in shoreline ecosystems where warm and cold currents meet. This study aims to understand the social and economic impacts of changes in species composition and total catch in north-western Peru. A social perception analysis coupled with available small-scale fisheries landing data of three sites: Cabo Blanco, Los Organos, and Mancora was used to identify differences in species composition and total catch between sites from years 2010 to 2020. The results suggest that fishermen have a different perception of abundance across all sites as their responses do not match with landing data. Despite the sites being adjacent to each other, they have significantly different species composition. Therefore, each local fishery sustains itself from different target species and consequently, their presence/absence might impact fisheries differently. Furthermore, these differences might also be related to an increase of frequency of ENSO events due to climate change, fishing pressures and poor management that put fisheries at risk and are predicted to increase fisheries vulnerability.

Keywords: Small-scale fisheries, regime shifts, species composition, total catch, Peru.

Introduction

With more than 3000 kilometers of coast, Peru has one of the most productive marine ecosystems in the world (SPDA, 2019). Around 70% of Peru's marine biodiversity is found within coasts of Tumbes and Piura which also are the central zone of the ecotone of the biogeographic provinces of the Humboldt and Panamic currents (SPDA, 2019). The temperate Oriental South Pacific (Peruvian Province) associated with the Humboldt Current, and the Tropical Oriental South Pacific (Panamic Province) associated with the Tropical Ecuatorial Current flow along the coastal regions of Tumbes and Piura, known as the Tropical Sea (Cutipa-Luque, *et al*. 2020). As a result of mixing currents, the Peruvian coast presents unique characteristics with local and temporal variation, resulting in constant changes in species composition and hence its fisheries have been classified among the eight most vulnerable to climate change impacts (Morón, 2000; Nakandakari, 2013; Allison, *et al.* 2009).

In recent years, marine resources have been widely exploited in many industries (SPDA, 2019). In Peru, fishing in particular has been estimated to account between 0.6% and 1.7% of the GDP (SPDA, 2019; PRODUCE, 2017). However, fisheries development has led to frequent stock collapses and dramatic environmental shifts (Chuenpagdee, *et al*. 2006). These changes have had a strong impact on species composition and annual productivity of small-scale fisheries (SSF) in Cabo Blanco, Los Organos and Mancora (IMARPE, 2022). The causes of such changes are difficult to understand, particularly because of the geographic location of the fisheries and the complexity of the environment they rely on (Perry, *et al.* 2010; Cailloux, 2022). Physical and chemical factors, fishing techniques, overfishing and current demand might put Peruvian SSF at risk where fish abundance will not be enough to satisfy local and international markets, compromising food security and the economy of the country.

According to the Vannucini, *et al.* (2018), anthropogenic climate change is expected to have an impact on availability and circulation of aquatic food production globally, with the distribution of several species predicted to change as a result of variable environmental conditions. Particularly, these shifts in species may have a significant effect on small scale fishers and their fishing practices and techniques, and thus the nutritional habits of local communities (Kifani, *et al*. 2018). Ongoing climate change and increased fishing effort have depleted fish stocks in vulnerable coastal regions such as Southeast Atlantic, Southwest Indian Ocean and Western Central Pacific. Moreover, developing countries in south and southeast Mediterranean and Black Sea are considered to experience higher exposure to changes and to have lower adaptive capacity (Barange & Cochrane, 2018). As a multifaceted source of work and income, fishing provides economic stability to many communities (Kifani, *et al,* 2018) however, in some regions this activity might be related to culture and religion.

In Peru, fishing is an economic activity that has cultural and traditional ties to the sea, thus, it is considered a desirable employment, with relatively good profits and valuable source of food. Most of Peru's SSF landings are for direct human consumption (21.6% of animal protein), used to partially satisfy local seafood demand and international markets, employing four times more people than industrial fisheries (Chuenpagdee, *et* *al*. 2006; Béné, 2006; Alfaro-Shigueto, *et al.* 2010). Moreover, it contributes to food security, gross domestic product, and national employment. However, they are marginalized by management institutions and thus undergo the consequences of poor regulations, environmental uncertainty, social traps, and market inequity. In Peru the fisheries sector is the second most important after mining, accounting for 1124 million USD in exports in 2001 (Chuenpagdee *et al*, 2006; FAO, 2003). Artisanal fishing directly depends on the availability of resources that vary spatially and temporally, due to seasonal and interannual variations in climate and environmental conditions such as El Niño Southern Oscillation (ENSO). However, little is known about how these fisheries function under changing conditions (De la Puente, *et al*. 2020), hence forms an important factor for this study.

Fishing in this zone is considered a highly complex activity as it involves the use of various fishing units, fishing zones, extraction methods and interaction with highly diverse target species (Guevara-Carrasco & Bertrand, 2017). Consequently, it is unclear which factors are involved in the resulting abundance and diversity of the catch brought to shore. Geography, market demand, population status, gear type and other factors can play an important role on fisheries stock (Mason, *et al.* 2020). Interviewing fishers is a valuable way to fill data gaps for poorly understood fisheries. Insights from fishermen may extend scientific time series, contribute to population assessments, and provide richer social and cultural context crucial to evaluating and implementing effective conservation measures and fisheries management (Mason, *et al*. 2020). It is hypothesized that species composition and total catch across all sites has changed due to variations in environmental conditions and temporal changes which are currently having a negative economic impact on fishermen.

Based on several aspects discussed, a social perception study coupled with landing data will be used to: i) understand changes in species composition in northern Peru and the impacts (if any) it has had on human activities such as fishing within a decade; ii) identify changes in landings between sites, and iii) identify if the change in environmental conditions over time can benefit or harm the economy of fishermen.

Methods

Study area

Fish and invertebrate landing data were obtained from the Marine National Institute of Peru (IMARPE) for three sites in northern Peru: Cabo Blanco (4°15′ 05″S 81° 14′ 06″ W), Los Organos (4° 10′ 47″S 81° 7′ 43″ W) and Mancora (4° 6′ 25″ 81° 3′ 6″ W). These sites are considered three out of 13 most important landing ports in the North Tropical biogeographical zone. The social perception questionnaire was carried out at the pier of each location.

Experimental design

This study consists of two parts: (1) an analysis of social perception coupled with (2) an ecological analysis of landings in the ports of Cabo Blanco (CB), Los Organos (LO) and Mancora (MC) in northern Peru between the years 2010 and 2020. This approach was used to compare how fishermen perceive changes in the environment (questionnaire) with a decade of ecological data available.

Social perception study

Between December 18th and 21st 2021, a structured questionnaire to fishermen and local leaders in all sites was done. These sites were selected because fishers used different fishing gears, had different backgrounds and target species. Peruvian Research Institute (IMARPE) representatives acted as initial key informants to identify and select respondents. The purpose of this questionnaire was to understand the socio-economic impact of changing conditions on the marine environment in northern Peru. The number of fishermen given the questionnaire was subject their availability. Two fishermen in CB, four in LO and one in MC were able to respond.

1. <u>Landing data analysis</u>

Peruvian Research Institute (IMARPE) part of Peruvian Ministry of Production (PRODUCE) provided landing data for most of the commercially important species in CB, LO and MC from the years 2010 to 2020 (IMARPE, 2022). The Oceanic Niño Index (°C) was used to determine El Niño (2015-2017) and La Niña (2012-2013) events (NOAA, 2021). Detailed data for landings from SSF were not available / not recorded for CB and LO between the years 2010 and 2013. An MDS analysis was used to explore dissimilarities in species composition between the sites. Moreover, a PERMANOVA analysis was used to demonstrate significant differences between study sites. Dendrograms were plotted for each site excluding the biological community. Furthermore, years were clustered according to similarity and total catch in tons was estimated.

Results

Social perception study: questionnaire

Question 1: How long have you been a fisherman/fishmonger?

All fishermen interviewed had been fishing for more than 20 years.

Question 2: Do you think that the fish/shellfish species that you catch and/or sell now are different from the ones you caught 10 years ago?

According to seven fishermen interviewed, species and abundance had changed from 2010 to 2020.

Question 3: In your view and thinking about the fish stocks specifically, why have you changed the type of fish you stock? *Indicate which answers apply*

- Change in species/community composition – the species are no longer caught
- Fewer individuals of the species (more rare)
- Cost/value

- All of the above

All fishermen answered that change in species/community composition, fewer individuals of some species and cost value where the main reasons why their stock had changed. However, two out of seven added that climate change and global warming has heavily impacted their stocks.

Question 4: Do you think that the number of fish (i.e. their abundance) has changed dramatically over the past 10 years? If so, by how much?

Yes, however all fishermen had different perceptions on how much the abundance had changed (Table 1).

Table 1: For question 4, fishermen responded with estimates of reductions in fish catch between 2010 and 2020.

	Fisherman	**Reduction in abundance**
Cabo Blanco	Esgardo	40%
Cabo Blanco	Eligio	85%
Los Organos	Luis	50%
Los Organos	Luis	50%
Los Organos	Francisco	90%
Los Organos	Henry	93%
Mancora	Henry	30%
Overall Mean	62.6%	
Overall Standard deviation	26.04%	

Question 5: Do you catch the fish yourself or buy it from a local provider?

All fishermen catch their own fish.

Question 6: If you buy from a local provider, do you buy different fish/shellfish from different providers or just one?

All people interviewed were fishermen who catch fish themselves.

Question 7: If you catch the fish/shellfish yourself, how do you do it and what materials do you use?

In Cabo Blanco, hooks #11, #12 and #80 are predominantly used with nylon as well as bottom set / drifting longlines and coastal gillnets within two and five nautical miles from the coast. Fishermen in Los Organos also use longlines and coastal gillnets while in

Mancora fishermen use pelagic gillnets and harpoon within 10 and 50 nautical miles from the coast.

Question 8a: Do you think that the fishing gear other fishermen use harms the environment, and if so in what ways?

All fishermen responded that illegal and legal bottom trawling damage the sea bottom and deplete fish and other commercially important species.

Question 8b: Do the potential impacts of those approaches concern you and would you move to use another approach if it was better for the environment?

Recently, fishermen from all sites have become more aware of bycatch and ghost fishing, therefore, in some sites such as Los Organos fish nets are retrieved from the ocean safely and recycled.

Question 9: Between the years 2010 and 2020 have your sales increased or decreased?

Half the fishermen responded that their sales had increased, and the other half stated that it has decreased. Prices might vary seasonally and by species. For example, one kilogram of yellowfin tuna between November and April costs S/. 8.00 – S/. 12.00 and from May until October between S/. 30.00 – S/. 34.00 according to Henry, president of fisheries guild in Mancora.

Question 10: To what extent has the value of what you stock changed?

Overall, there are three reasons as to why the value of the stock has changed: lower abundance, size, and demand which changes depending on the daily catch. However, most fishermen highlighted that size is the main factor influencing value.

Question 11: Has an increase/decrease in cost affected how much fish people buy? The following results are shown in Figure 2.

Question 12: Has the value of certain species gone up because they are scarce? If yes, which ones and would you target them more because of their increased value?

Seven out of six fishermen agree that the more the rare species become, the higher value they get. Moreover, they would add that bigger fish can be sold at greater cost, e.g. grapeeye seabass, Chilean jack mackerel, white shark, shortfin mako and smooth hammerhead shark (most commercially important species).

Question 13: Do you think you have been impacted by the scarcity of some species?

All fishermen have been negatively impacted by changing biodiversity in the past ten years.

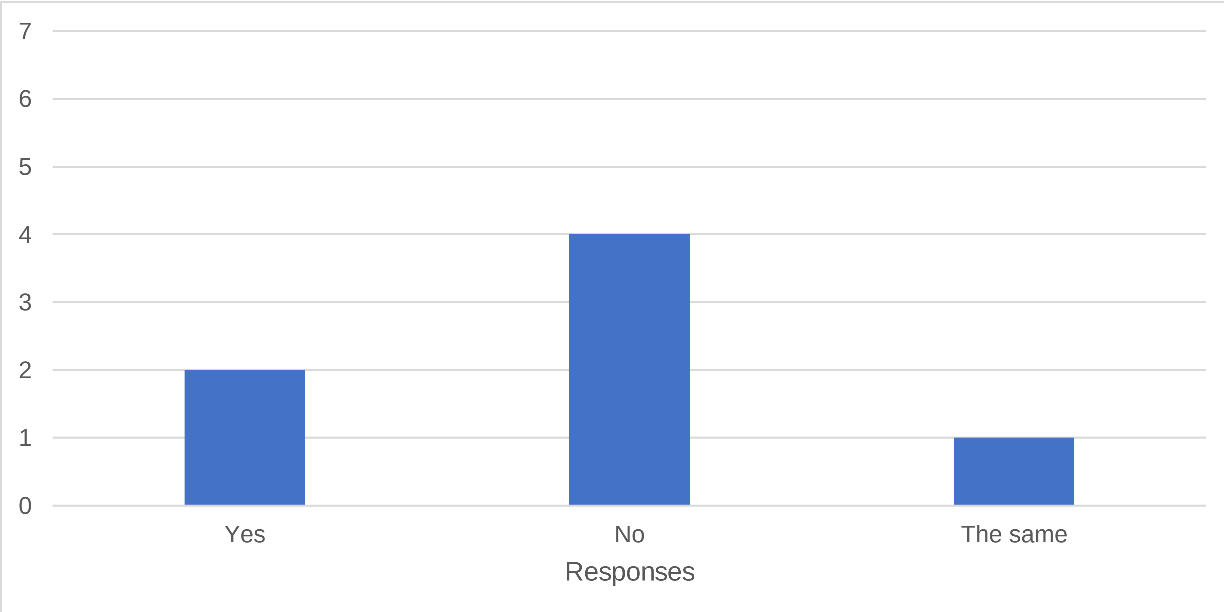

Figure 1: Fishermen perception of changes in market price for fish/molluscs and its effect on current sales in Cabo Blanco, Los Organos and Mancora.

Question 14: Which three species generate the highest demand from consumers?

Fishermen responses are shown in Table 2.

Table 2: Species on high demand in Cabo Blanco, Los Organos and Mancora

Cabo Blanco	Los Organos	Mancora
• *Epinephelus labriformis* (starry grouper) • *Paralabrax callaensis* (Southern rock bass) • *Hemilutjanus microphthalmos* (grape-eye seabass)	• *Paralabrax humeralis* (Peruvian rock seabass) • *Trachurus murphyi* (Chilean jack mackerel) • *Merluccius gayi peruanus* (Peruvian hake)	• Cartilaginous fish: *Sphyrna zygaena* (smooth hammerhead), *Alopias vulpinus* (thresher), *Isurus oxyrinchus* (shortfin mako) • *Peprilus medius* (Pacific harvestfish) • *Thunnus albacares* (yellowfin tuna)

Question 15: If you do not catch any of the species on high demand, does that represent a major economic loss?

All fishermen answered that returning without any the fish from Table 2 would represent an economic loss. However, three out of seven mentioned that when that happens, they usually try to compensate that higher value with more kilos of common species. For example: Peruvian hake or giant squid.

Question 16: Who are your major consumers? Individuals? Restaurants? Hotels?
None of the fishermen interviewed sell their catch directly to individuals hotels or restaurants. All catch is sold to a distributor who then gathers all the fish and sells it to fishmongers, restaurants, and hotels. Based on the answers for these questions, Figure 2 represents how fisheries dynamics function within these regions.

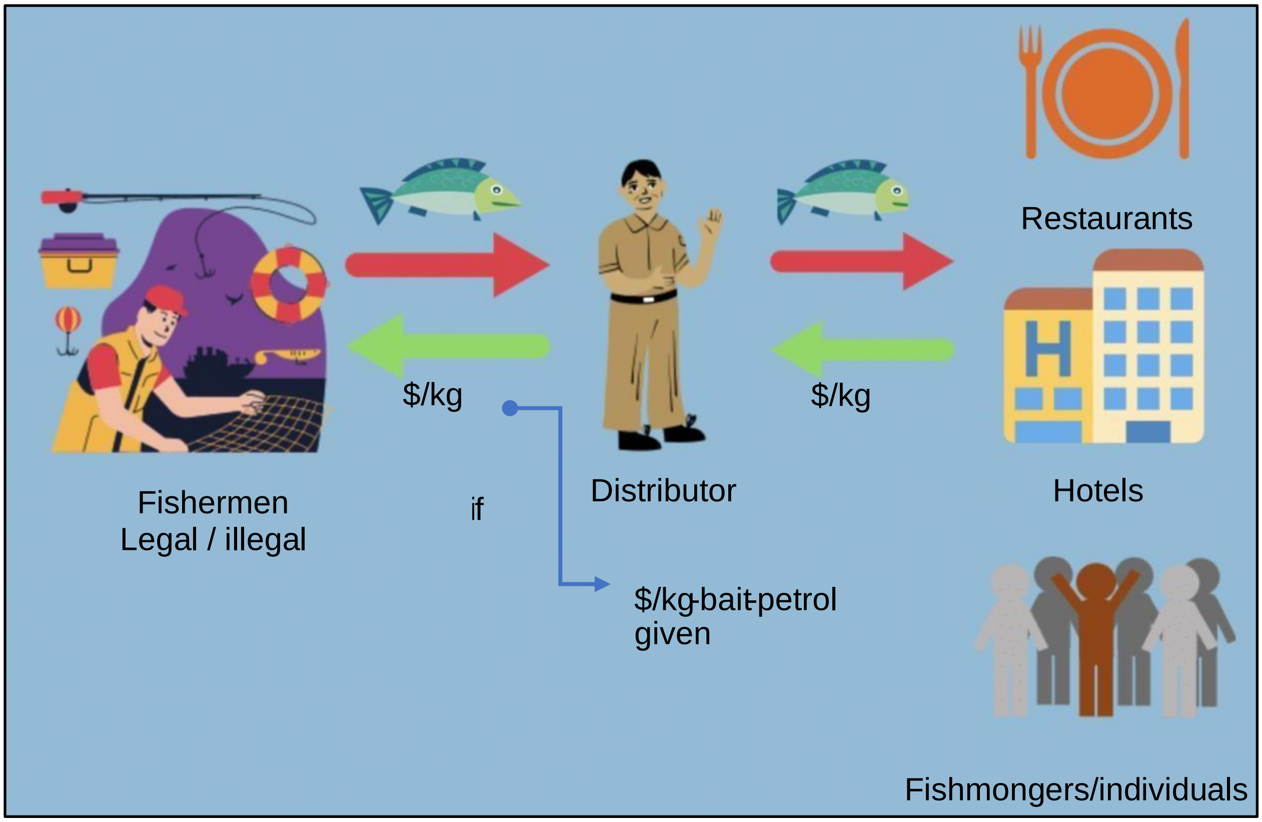

Figure 2: Fisheries dynamics in study sites CB, LO and MC. Fishermen sell whole catch to a single distributor, who offers it local restaurants, hotels or fishmongers. If the fisherman is illegal (i.e. not registered in PRODUCE), distributor provides bait, petrol or both reducing the total amount given to fisherman. This occurs in Cabo Blanco and Los Organos**.**

Question 17: How do you decide on what to charge for your stock and how frequently do you change those prices?
Across all sites, the distributor who buys the catch sets the price per kilo, but this may be more or less depending on if he/she has provided resources (e.g. petrol, boat or bait) for fishing.

Summary

Overall, all fishermen have perceived that species composition has changed over the past ten years. However, they have noticed that decreases in abundance rather than diversity, highlighting that species are still present but not in quantities that satisfy current demand. According to most respondents, these changes are a result of warming, climate change and fishing pressure. Generally, fishermen catch the fish themselves and sell it to a distributor who buys all the catch of the day and sell it to final clients i.e., restaurants, hotels, and individuals. There are mixed opinions about whether sales have decreased or increased. Prices may vary seasonally and with demand, however, not all clients can afford higher prices, reducing sales. Fisheries in CB, LO and MC have different target species of high value but most of them are present seasonally. Further, sites have different fishing techniques that target coastal or pelagic stocks. Fishermen are aware of ghost fishing, bycatch, and trawling, thus use selective fishing gear that can be retrieved from the ocean and recycled.

Landing data analysis

Species composition

The PERMANOVA analysis demonstrated significant differences in landing diversity between the three sites ($p>0.05$), see Figure 3.

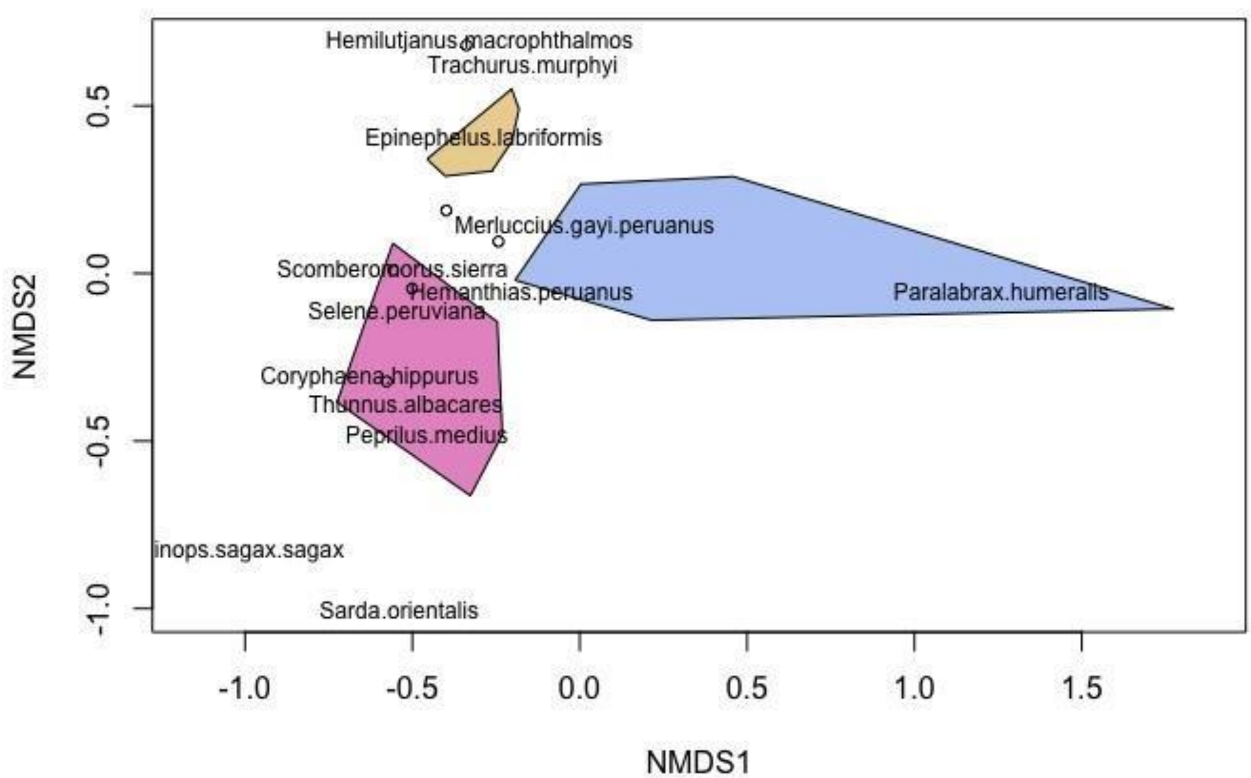

Figure 3: Multidimensional scaling (MDS) ordination based on Bray-Curtis similarities for three sites Cabo Blanco (yellow), Los Organos (blue) and Mancora (pink) between the years 2010-2020. The stress value for the MDS plot was very low, 0.076, indicating the MDS was adequate for the two-dimensional representation.

The analysis demonstrated that some species such as: *Merluccius gayi peruanus* (Peruvian hake), *Hemanthias peruanus* (splittail bass), *Scomberomorus sierra* (Pacific sierra) and *Epinephelus labriformis* (starry grouper) can be found across all sites. However, *Hemilutjanus microphthalmos* (grape-eye seabass) and *Trachurus murphyi* (Chilean jack mackerel) are restricted to Cabo Blanco, while *Paralabrax humeralis* (Peruvian rock seabass) and *Thunnus albaceres* (Yellowfin tuna) may only be present in Los Organos and Mancora, respectively.

Species composition per year

Differences in species composition based on landing data per year for each site were estimated. Between the years 2015-2017 species composition in CB remained similar however, 2018 onwards the community changed by 20% (Figure 4a). In LO, species composition in 2013 was significantly different by 20% from communities in 2014-2020 (Figure 4b). MC presented three significantly different communities through time. Species composition in 2016 differed by 25% compared to communities in 2018 and 2020 while landings from 2010 to 2017 significantly differed by 20% (Figure 4c).

Total catch

Cabo Blanco presented a general decrease in abundance between 2014 and 2020, with an increase in 2016. Landings decreased by 87% between 2016 and 2018. Los Organos showed an increasing trend in landings, reaching an 97% increase between the years 2013 and 2017, although there have been declines since 2018. Landing data for Mancora revealed highly variable catches, ranging from between 1.X tons and five tons (Figure 5).

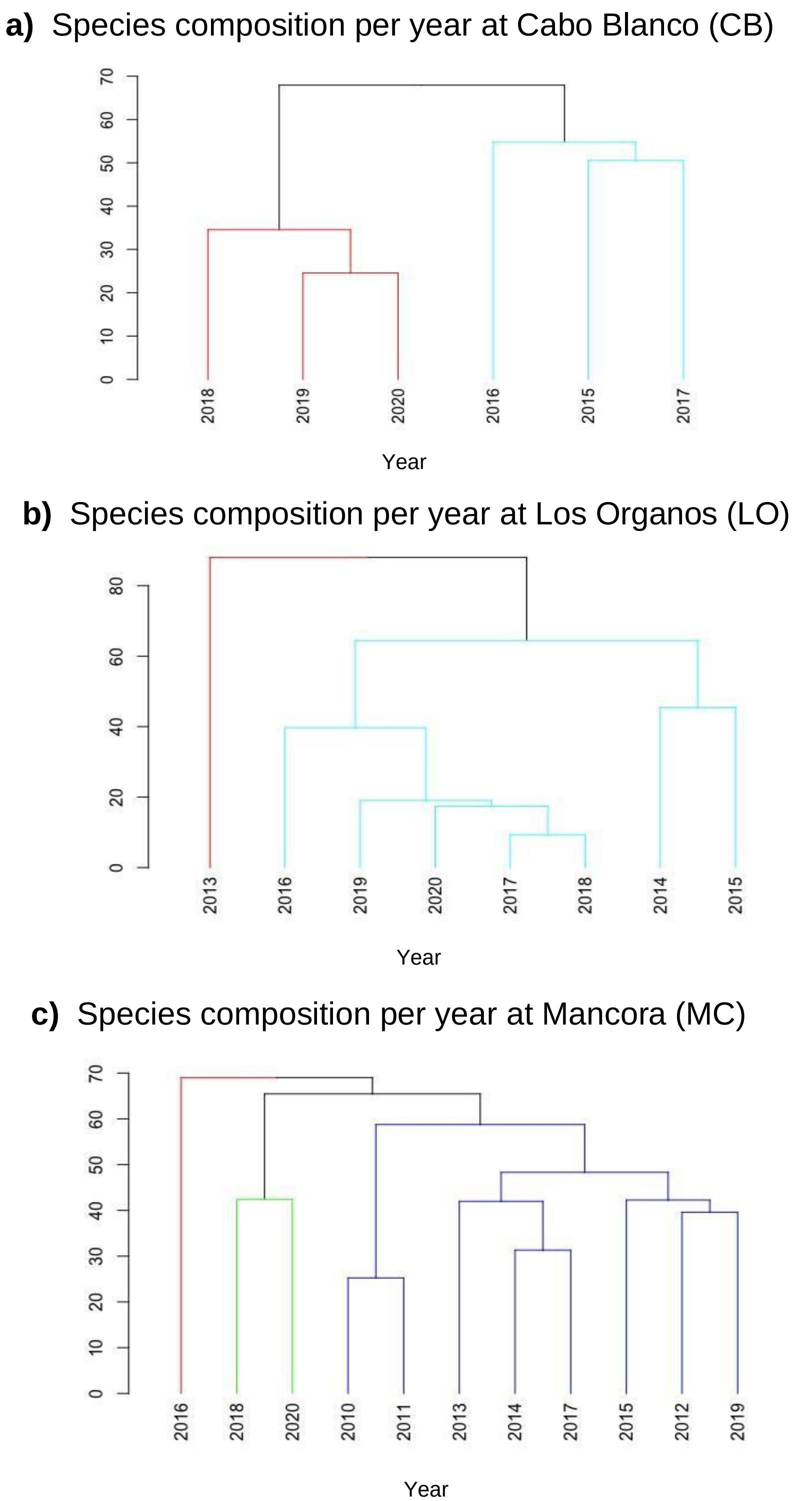

Figure 4: Dendrogram showing dissimilarities across sites through time. Figure 4a presents two significantly different communities between 2015-2020 in CB, Figure 4b also showed two. significantly different groups between 2013-2020 in LO and Figure 4c presents three significantly different groups in MC from 2010-2020.

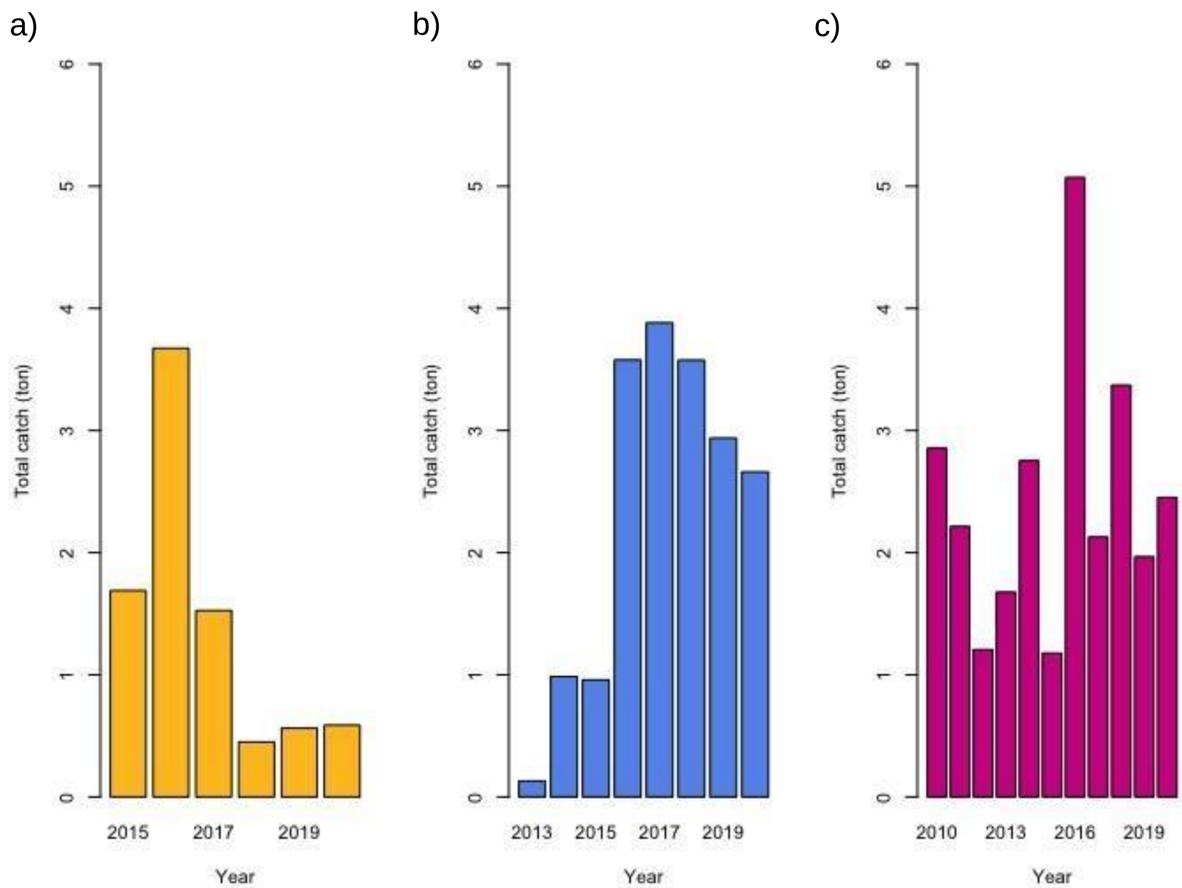

Figure 5: Total catch in tons for three sites: a) CB, showing data from 2015-2020 b) LO showing data from 2013-2020 and c) MC from 2010 to 2020.

Discussion

Ongoing anthropogenic climate change has significantly influenced physical and biological processes at global and regional scales (Allison, *et al.* 2009). The observed and predicted changes in global climate present significant opportunities and challenges for societies and economies, particularly for vulnerable Peruvian SSF that depend nutritionally and economically on fishing resources. The social perception questionnaire together with conversations and interviews to fishermen reflected this vulnerability and provided an insight of fisheries dynamics in a developing country. This method allowed comparison between people who experience change first-hand and landing data recorded by IMARPE from the same sites. Moreover, it helped to identify knowledge gaps and inconsistencies between both sources that will be discussed further.

Climate variability: ENSO and physical-chemical factors

The MDS analysis and the social perception questionnaire suggested that species composition was significantly different across all sites (Figure 4) and thus had different target species. However, some species such as the Peruvian hake and splittail bass may occur across all sites temporally, this species might be found in similar numbers as the latter is accompanying fauna to the hake together with the Peruvian rock seabass. The Peruvian coast is strongly affected by El Niño Southern Oscillation (ENSO) that originates in the equatorial Pacific (Lehodey, *et al*. 2020). This phenomenon alters the physical (e.g. upwelling efficiency, temperature, salinity, oxygen, vertical stratification) and biological (species composition, abundance, distribution) environment and thus may extend the distribution of hake eggs and larvae equatorwards to sites with higher temperatures (Ballón, *et al*. 2008) which might explain its presence in CB and MC. ENSO, has increased its frequency since 1980s as a consequence of greenhouse gases, atmospheric aerosol changes and solar and volcanic variability (Ballón, *et* al. 2008; Lehodey, *et al.* 2020; Vecchi & Wittenberg, 2010). These variations will continue to occur and influence weather and climate even away from the tropical Pacific and as demonstrated in Figure 5, can change species composition annually. The sites chosen the Northern Humboldt Current Ecosystem are in close proximity to the equator which means that Kelvin waves travelling eastward during El Niño events impacts the sites almost directly (Taylor, *et al*. 2008).

Consequently, the “basin-wide ecosystem” of the Pacific which normally maintains a slope in sea level, thermal and nutrient structure due to trade winds are reversed (Taylor, *et al*. 2008). Upwelling-favorable winds continue along the coast, but water is now upwelled from the deep thermocline and nutricline, reducing primary productivity to 1/10 that could be in normal conditions (Nixon & Thomas, 2001; Taylor, *et al.* 2008). This currently has diverse and complex impacts on commercially important species with some winners and losers (Vecchi & Wittenberg, 2010; Lehodey, *et al*. 2020). The “tropicalization” of the Humboldt Current shown in Figure 5 between 2015-2017 might explain changes in species composition varying between *Mugil cephalus*, *Thunnus albacares, Paralabrax humeralis, Selene peruviana,* and *Dosidicus gigas* on the data (Lehodey, *et al.* 2020; IMARPE, 2022). Meanwhile, landings of subtropical species such as *Sarda chiliensis chiliensis, Scomber japonicus* and *Sardinops sagax sagax* declined.

Other physical, chemical, and biological factors might also explain differences in composition between sites (Figure 4). Marine resource productivity in the HCS is mostly controlled by climate and its effect on the production of phytoplankton and higher trophic levels (Gutiérrez, *et al*. 2009). A study by Taylor, *et al.* (2008) elucidated the dynamics of the Northern Humboldt under ENSO fluctuations and suggested that such events influence the quality and quantity of primary production as nutrient-rich waters are replaced with subtropical phytoplankton, influencing ecosystem dynamics. Oxygen and temperature are key regulatory factors for fish stocks, for example, Lehodey, *et al*. (2020) suggested that higher oxygen levels increase fish populations of *Merluccius gayi peruanus* while shifting the distribution of small pelagic fish (anchovy, sardine, mackerel, jack mackerel) away from warm waters in Northern Peru. Moreover, in the northern HCS well-oxygenated water can be less than 10m deep, limiting the habitat for many species but favouring the abundance of coastal resources such as Peruvian hake, Peruvian rock seabass and Southern rock bass targeted by coastal fisheries CB and LO.

Contrary to expectation, fishermen responses did not match total catch landing data (Figure 6). For example, fishermen in LO perceived a 60% reduction in total catch in the last decade, however landing data did not reflect this result as it presented an 90% increase in total catch in tons from 2013 to 2020 (Figure 6a). Nonetheless, in CB fishermen provided a more accurate response compared to the data (Figure 6b). Only one fisherman was able to respond the questionnaire in MC and it roughly matched with the data (Figure 6c). These results might be explained by the fact that for most people who live from the fishing industry in northern Peru, daily catches represent their only source of income. When highly valued species are not found, they may tend to assume that all stocks have decreased, leading to differences between their perception and data. This case has been shown in LO, where total catch of *Hemanthias peruanus,* a non-target species, increased while a target species *Trachurus murphyi* landings declined but still fishermen perceived a significant reduction.

Non-climate factors: fishing techniques, overfishing and poor management

Although it is outside the scope of this study, fishing practices and poor management could also contribute to changes in species composition and total catch. As coastal communities rely on fish for economic and nutritional purposes, increased fishing efforts have depleted commercially important species in the last decade. From 1997 to 2012 the number of SSF vessels increased more than twofold, the number of fishers reached 67 400 in 2015, and landings increase by almost one order of magnitude to reach 1.2 million tonnes in 2012 (Guevara-Carrasco & Bertrand, 2017). This development was unregulated and mainly informal (Galarza & Kármiche, 2015), as a consequence of hierarchical governance and de facto open access regime that characterize Peruvian SSF. This, coupled with social heterogeneity, natural variability, dynamism, and intensity of these fisheries, contributes to limited governability (Nakandakari, *et al*. 2017). Fishermen in CB, LO and MC stated that landings are not always monitored by the relevant authority, PRODUCE, which led to seabed destruction due to illegal trawling and depletion of larger fish. For example, landings of the subtropical species *Hemilutjanus microphthalmos* have significantly decreased over the past ten years. Fishermen and IMARPE representatives reported that this species had been heavily overfished and hence its abundance was scarce. Indeed, researchers Zhou, Smith, and Knudsen (2015) suggested that the root of overfishing was selective fishing which is exactly the fishing technique fishermen in CB use. They use hooks and line to catch the fish, targeting specific species and desired size, which depleted grape-eye seabass stocks by 2020 (IMARPE, 2022).

Literature suggests that fisheries in Peru might be among the most vulnerable to climate change impacts (Allison, *et al.* 2009). However, SSF in North Peru have presented high adaptive capacity to increasing changes since 1980s. This was reflected on the social perception questionnaire and interviews where fishermen stated that when highly valued species are not found they compensate that loss with more kilos of low value species. In LO, fishermen perceived declines in total catch which influenced their behaviour towards the environment. They have learned about ghost fishing and now recycle their fishing gear, and are aware of how bottom trawling can damage the seabed and reject it. In some cases, some fishermen suggested that they wanted to promote ecotourism rather than fishing which could in turn reduce fishing pressures and provide a more stable income.

Limitations and recommendations

Data provided by IMARPE is a sample of total landings per site from years 2010-2020, thus might not reflect all fish and invertebrate landings. Moreover, data was not sufficient for Cabo Blanco and Los Organos due to limited budgets from PRODUCE that did not always allow complete monitoring of fisheries. Therefore, variability across all sites could not be shown to the same extent. Future studies should include a higher number of respondents for a social perception study to show a more accurate trend of overall responses across all sites. In addition, shark landings in Mancora should be included and compared to fishermen perception as they are considered commercially important.

Conclusions

This study provided an analysis of the impacts of changes in environmental conditions of some of the most productive fisheries in South America and how have these changed over the past ten years in terms of species composition and total catch. There are multiple factors that play an important role on fisheries productivity, from bottom-up processes in the water column to top-down effects of poor management. The sites chosen for this study are very similar as they are located in the same geographical zone, however they have different target species, gear and fishing zones. Cabo Blanco and Los Organos target coastal fish stocks such as the starry grouper, Peruvian rock seabass, grape-eye seabass and Peruvian hake and use set longlines and coastal gillnets, while in Mancora SSF target oceanic resources such as sharks and the yellowfin tuna using harpoon and pelagic gillnets. Therefore, the socio-economic and ecological effects of regime shifts will have through time, are expected to differ between fisheries. Changes in superficial waters might have a negative impact on Cabo Blanco and Los Organos, while pelagic fisheries like Mancora would not be impacted to the same extent. Although fisherman have presented adaptive capacity in recent years, increased frequency of events such as ENSO and shifts physical and biological patterns might negatively impact fisheries vulnerability in the future.

Acknowledgements

A special thank you to Dr. Antony Knights from the University of Plymouth for supervising this project. This work is supported by IMARPE, part of Ministerio de la Producción del Perú (PRODUCE). I am grateful to José Allemant, who granted me an interview and helped contact IMARPE representatives: Martín Salazar (Paita), Ángel Cix (Cabo Blanco), Javier Mogollón (Los Órganos) and Braulio Diaz (Mancora) who facilitated communication for the social perception questionnaire. I would also like to thank all respondents and president of fisheries guild in Mancora, Henry Navarro.

References

Alfaro-Shigueto, J., Mangel, J. C., Pajuelo, M., Dutton, P. H., Seminoff, J. A., & Godley, B. J. (2010) 'Where small can have a large impact: structure and characterization of smallscale fisheries in Peru'. *Fisheries Research*, 106(1), pp.8-17.

Allison, E. H., Perry, A. L, Badjeck, M. C., Adger, W. N., Brown, K., Conway, D., Halls, A.S, *et al***.** (2009) 'Vulnerability of national economies to the impacts of climate change on fisheries'. *Fish and Fisheries,* 10(2), pp 173 -196.

Barange, M. & Conchrane, K. (2018) 'Impacts of climate change on fisheries and aquaculture: conclusions', in Barange, M., Bahri, T., Cochrane, K., *et al*. (eds.) *Impacts of climate change on fisheries and aquaculture: conclusions' synthesis of current* knowledge, adaptation, and mitigation options. Rome, Italy: FAO, pp. 611-628.

Béné, C. (2006). Small-scale fisheries: assessing their contribution to rural livelihoods in developing countries. Rome, Italy: Food and Agriculture Organization of the United Nations.

Cailloux, M. (2022) Conversation with Matias Cailloux, 21 March.

Chuenpagdee, R., Liguori, L., Palomares, M. L., & Pauly, D. (2006) *Bottom-up, global estimates of small-scale marine fisheries catches*. Fisheries Centre: University of British Columbia.

Cutipa-Luque, L. M., Alvariño, L., & Iannacone, J. (2020) 'Current situation of Marine Protected Areas in Peru and conservation proposals'. *Paideia XXI,* 10(2), pp. 573-612.

De la Puente, S., López de la Lama, R., Benavente, S., Sueiro, J. C., & Pauly, D. (2020) 'Growing into poverty: Reconstructing peruvian small-scale fishing effort between 1950 and 2018'. *Frontiers in Marine Science*, 681.

Food and Agriculture Organization for the United Nations. (2003) *Informative Fishing Summary for the Republic of Peru.* Available at: https://www.fao.org/fi/oldsite/FCP/en/per/profile.htm (Accessed: 26 February 2022).

Galarza, E. & Kámiche, J. (2015). *Pesca artisanal: oportunidades para el desarrollo regional.* Lima: Universidad del Pacífico. Available at: https://doi.org/10.13140/RG.2.1.4696.2000 (Accessed: 18 March 2022).

Guevara-Carrasco, R. & Bertrand, A. (2017) *Atlas de la pesca artesanal del Mar del Perú.* Lima: IMARPE-IRD.

Gutiérrez, D., Sifeddine, A., Field, D.B., *et al*. (2009) 'Rapid reorganization in ocean biogeochemistry off Peru towards the end of the Little Ice Age'. *Biogeosciences,* 6, pp. 835-848.

Instituto del Mar del Peru (IMARPE). (2022) *Información (preliminar) para uso científico OFICIO N° 063 -2022-IMARPE/OGA.* IMARPE - Oficina de Pesca Artesanal.

Kifani, S., Quansah, E., Masski, H., *et al*. (2018) 'Climate change impacts, vulnerabilities and adaptations: Eastern Central Atlantic marine fisheries', in Barange, M., Bahri, T., Cochrane, K., *et al*. (eds.) *Impacts of climate change on fisheries and aquaculture:* conclusions' synthesis of current knowledge, adaptation, and mitigation options. Rome, Italy: FAO, pp. 159-183.

Lehodey, P., Bertrand, A., Hobday, A. J., *et al.* (2020). 'ENSO impact on marine fisheries and ecosystems' in McPhaden, M., Santoso, A., & Cai, W. (eds.) *Geophysical Monograph Series 253*. American Geophysical Union: Wiley & Sons, pp. 429-451.

Mason, J. G., Alfaro-Shigueto, J., Mangel, J. C., Crowder, L. B., & Ardoin, N. M. (2020) 'Fishers' solutions for hammerhead shark conservation in Peru' . *Biological Conservation*, 243, pp. 108460.

Ministerio de la Producción (PRODUCE). (2017) Anuario estadístico pesquero y acuícola, la actividad pesquera en número. Available at: https://ogeiee.produce.gob.pe/index.php/en/shortcode/oee-documentos-publicaciones/publicaciones-anuales/item/825-anuario-estadistico-pesquero-y-acuicola-2017 (Accessed: 11 March 2022).

Morón, O.A. (2000) 'Características del ambiente marino frente a la costa Peruana'. *Bol Inst Mar Perú,* 19, pp. 179-204.

Nakandakari, A. (2013) Planificación Ecoregional en el Mar Tropical del Perú: Identificando sitios prioritarios para la conservación. *Internal The Nature Conservacy report.* Unpublished.

Nakandakari, A., Cailloux, M., Zavala, J., Gelcich, S. & Ghersi, F. 'The importance of understanding self-governance efforts in coastal fisheries in Peru: insights from La Islilla and Ilo' (2017). *Bulletin of Marine Science,* 93(1), pp. 199-216.
National Oceanic and Atmospheric Administration (NOAA). (2021) Climate Variability: *Oceanic Niño Index.* Available at: https://www.climate.gov/news-features/understandingclimate/climate-variability-oceanic-niño-index (Accessed 23 March 2022).

Nixon, S & Thomas, A. (2001) 'On the size of the Peru upwelling ecosystem'. *Deep Sea Research I,* 48, pp. 2521-2528.

Perry, R. I., Ommer, R. E., Allison, E. H., *et al.* (2010) 'Interactions between changes in marine ecosystems and human communities', in Barange, M., Field, J. H., Harris, R. P, *et al.* (eds.) *Marine Ecosystems and Global Change*. Oxford University Press, pp. 221252.

Sociedad Peruana de Derecho Ambiental (SPDA). (2019) *Guía Legal para la Defensa de las Ecosistemas y Especies del Mar Peruano.* Available at: https://spda.org.pe/?wpfb_dl=4604 (Accessed: 26 February 2022).

Vannuccini, S., Kavallari, A., Bellù, *et al*. (2018) 'Understanding the impacts of climate change for fisheries and aquaculture: global and regional supply and demand trends and prospects', in Barange,M., Bahri, T., Cochrane, K., *et al*. (eds.) *Impacts of climate change on fisheries and aquaculture: conclusions' synthesis of current knowledge, adaptation, and mitigation options*. Rome, Italy: FAO, pp. 41-61.

Vecchi, G. A., & Wittenberg, A. T. (2010) 'El Niño and our future climate: where do we stand?'. *Wiley Interdisciplinary Reviews: Climate Change*, 1(2), pp. 260-270.

Zhou, S., Smith, A. D., & Knudsen, E. E. (2015) 'Ending overfishing while catching more fish'. *Fish and Fisheries*, 16(4), pp. 716-722.