AN ABSTRACT OF THE DISSERTATION OF

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Abstract approved:

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Selina Heppell

Small-scale fisheries (SSF) around the world face many challenges. They are a highly dynamic, important sector for coastal communities in developing nations, playing a critical role in poverty alleviation and food security. SSFs generally have few resources to ensure their long-term sustainability. They are often fished and managed locally and may have limited commercial value, primarily providing subsistence for the community. As such, they may be a low priority for national fisheries management. SSFs are about 50% of the world's fisheries by harvested volume, but in most cases, they are data-poor. To meet these challenges for sustainability, SSFs need access to tools that can help them assess the status of the resource and monitor the specific characteristics of the fishery to evaluate the health and sustainability of local fish stocks.

In this research, I integrate the biological and ecological dimensions of small-scale fisheries assessments with the local knowledge of the communities that use the resources. This dissertation is an effort to assess different aspects of data-poor fisheries: the quantity and quality of knowledge of the life-history parameters of the stock, the importance of spatial scale in the stock risk assessments, and the potential for a synergy of scientific data and local knowledge to improve the assessment of coastal fisheries.

My first data chapter explores the incorporation of local stock condition information into a risk assessment technique: Productivity and Susceptibility Analysis (PSA), an

expert opinion-based model that combines information about the productivity of a stock with its susceptibility to fishing activities using a semi-quantitative scoring system. My goal was to assess how spatial scale and incorporation of fishermen's knowledge affects the vulnerability assessment of data-poor fisheries in Oregon, USA. I gathered local information on nearshore fishes in Oregon and combined biological data for ten nearshore species with information obtained from fishermen. I found some key differences between coastwide vulnerability ratings and those obtained for the same species but in different parts of the Oregon coast, reflecting the influence that local information can have on the results of the model. I found that our results generally matched those generated for a previously published coastwide PSA, but with somewhat lower vulnerability scores provided by the local productivity and susceptibility estimates. PSA can be useful to identify important local differences in stock susceptibility to fishing or other impacts that may be lost when stocks are monitored at the coastwide level.

The remainder of my dissertation focuses on SSFs in Colombia. In chapter 3, I present a gap analysis of the life-history parameters of commercially important stocks in the Colombian Pacific. I conducted a literature review of 23 biological and ecological parameters of 37 marine species and found a lack of basic life-history characteristics for the species fished. I found that the species information is scattered throughout the country, only a small amount of information is published in peer-reviewed journals, and a high amount of the research and knowledge available exists in "grey literature". To offer recommendations for future assessments, we provide a review of data-poor fisheries assessment tools that could be employed with the country data-availability and data-needs for each species.

In chapter 4, I introduce a modified Productivity and Susceptibility Analysis (PSA) that integrates scientific knowledge with information from local fishermen to address the lack of data for Colombian Pacific coastal fisheries. I assessed the vulnerability to overfishing of 15 local stocks and used participatory surveys in 12 fishing communities to elicit local fishermen's knowledge of susceptibility parameters. My results revealed a general lack of life history data for the species that are necessary to assess the productivity of the stocks. I collected information from 113 fishermen, and increased the number of susceptibility parameters to reflect the local conditions of the study area and scored those based on the information provided. All the species assessed received high susceptibility values, and the PSA prioritized three species as vulnerable to overfishing. Our adaptation of the PSA provides a first attempt to assess and prioritize the data-poor fisheries in the Colombian Pacific, integrating local fishermen knowledge into the risk assessment and making it specific to the conditions of the study area. Our approach allows a comparative evaluation of stocks in a local area when little or no susceptibility information is available, especially in cases in which scientific expertise is difficult or impossible to get.

Integration of Scientific and Local Knowledge in Data-Poor Fisheries Assessments

by
Andrea Carolina Jara Baquero

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Major Professor, representing Fisheries Science

Head of the Department of Fisheries and Wildlife

Dean of the Graduate School

I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Andrea Carolina Jara Baquero, Author

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Five years into this adventure, five years that have been full of knowledge, patience, perseverance, growth, and discoveries. These years have been shaping me into a better scientist, a better person and have been pushing me to keep fighting for the ocean, to keep trying to do my part to save the world. It has been an adventure full of amazing people who have been sharing the road with me, guiding me or helping me to remove some of the road obstacles. The first person I would love to thank is Selina Heppell, she not only allowed me to come to her lab but taught me to be a better scientist, to always take a step back and look to the "big picture". Her support, guidance, creative ideas, and critical thinking made this thesis possible. I would also like to thank my committee members. Michael Harte always showed me how important is to think "out of the box" and to look things from another perspective. Bryan Tilt and Kelly Biedenweg guided me in my exploration of a new scientific discipline, I would have been lost in the social sciences without their patience, help, and guidance. David Kling not only filled his position as graduate representative but was always open to provide me with good advice and ideas. I will be eternally grateful for their time and support.

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CONTRIBUTION OF AUTHORS

Dr. Selina Heppell was my advisor in the Fisheries Science graduate program and contributed to all aspects of this research. She contributed to the research design, implementation, data interpretation and editing of all chapters. Matt Damiano contributed to the data-gathering, gap analysis, and editing of Chapter 2. Luis Zapata assisted with the Colombian field design, field logistics, data-gathering, and editing of Chapter 4.

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Chapter 1—Introduction

Fisheries are a prosperous sector within the commercial and recreational economies, with a high and growing demand. In the last five decades, the global fish production has grown steadily at an average annual rate of 3.2 percent including the aquaculture production (FAO, 2014). However, the world population is also growing at an accelerated pace, increasing the fish consumption from an estimate of 9.9 kg per person on average in the 1960s to 19.2 kg in 2012 (FAO, 2018). The demand for fish protein is high in many developing countries where marine fisheries provide the most affordable animal protein for rural communities but also in developed or rapidly developing economies where fish demand is higher than local production, creating a dependency on fish imported from developing countries (Pauly & Zeller, 2016). Management of the fisheries resources need to address these challenges and fisheries biologists have moved away from goals of maximum exploitation rates to focus more on methods to ensure long-term sustainability and ecosystem health (Wallace et al., 2001).

Stock assessments help managers to track fisheries status and trends. Typically, assessments incorporate species biology, catch information, local and regional management concerns, and jurisdictional boundaries. Biological and ecological information of the species is analyzed in stock assessment as well as the specific characteristics of the fishery in order to evaluate the health and sustainability of populations (Cooper, 2006). Stock assessments typically focus on industrial or commercial fisheries with high economic value and detailed historical catch and landings records. Large datasets allow for development and model testing of different management plans, supported by sophisticated predictive models (Berkes, Mahon, McConney, Pollnac, & Pomeroy, 2001; Prince, 2010). However, most of the fisheries worldwide are small-scale, locally developed, relatively unmanaged, with a low monetary value or often for subsistence, and as a consequence, are data-poor (Andrew et al., 2007; Costello et al., 2012; Hobday et al., 2011; Prince, 2010).

Worldwide, small-scale fisheries (SSF) contribute to the livelihoods of over five hundred million people and employ over 90% of the people related with fishing activities (Béné, Macfayden, & Allison, 2007; WorldBank, 2012). These fisheries are found predominantly in countries with low financial support for research and in communities that rely on fishing for income and food security (Fujita, Karr, Battista, & Rader, 2013; Honey, Moxley, & Fujita, 2010). It is unlikely these fisheries will ever have funds, scientific knowledge or datasets to develop a complete quantitative stock assessment (Prince, 2010). However, to achieve sustainable livelihoods and maintain ecosystem services, it is a priority to assess and manage SSF in both developed and developing countries (Berkson & Thorson, 2015; Jacquet & Pauly, 2008).

Recently, modeling methods have been developed to assess fisheries with little or no data, that require less data than a traditional stock assessment, and often utilize the best fisheries information available. These methods allow managers to prioritize fisheries for research or management action, establish fishing/catch limits, and estimate biomass levels for fisheries where full stock assessments are infeasible (Honey et al., 2010). A number of data-poor models exist, both quantitative and qualitative. For example, basic risk assessments can determine the susceptibility of the target species to overfishing due to its biological and catchability characteristics, even without solid information of population status (Hobday et al., 2011). One technique that incorporates biology and direct and indirect effects of fishing is the Productivity and Susceptibility Analysis (PSA), which aims to provide a biological basis for the vulnerability of a stock to fisheries impacts (Milton 2001).

The PSA relies on expert opinion and combines information about the productivity of a stock (biological information) and its susceptibility to fishing and other environmental and human factors. PSA prioritizes the species that require additional research and status evaluation by comparing vulnerability scores for some species that are fished commercially, recreationally, or both (Patrick et al., 2010). This method not only establishes warning signs for specific stocks but also allows integration of scientific and local or traditional knowledge as the basis of the model. This attribute is essential in data-poor fisheries, especially for developing countries where the knowledge of local fishermen might be the only reliable source of information available on the history and status of a fishery (Barnes-Mauthe, Oleson, & Zafindrasilivonona, 2013; Fujita et al., 2013; Mackinson, Wilson, Galiay, & Deas, 2011).

In addition to the vulnerabilities of the fish population, it is also important to consider human dimensions. SSF are embedded in complex socio-ecological systems with critical ecosystem services supporting food security and poverty reduction (Defeo et al., 2013). Effective management decisions and regulations should account for vulnerabilities and risks to the stability of fishing communities, (Tuler, Agyeman, Da Silva, LoRusso, & Kay, 2008). The integration of different dimensions in the assessment and management process is especially essential in developing countries where multiple pressing priorities exist, fisheries are data-poor, and resources are lacking (Beaudreau & Levin, 2014; McClanahan, Castilla, White, & Defeo, 2009). There is an urgent need to recognize that the social and cultural reality of each place is specific and the integration of local knowledge, local communities, and scientific expertise is required (Huntington, Callaghan, Fox, & Krupnik, 2004; McClanahan et al., 2009).

In the last decade there has been new evidence that local knowledge can be complementary to the scientific knowledge and that the integration of social and natural science methodologies can identify temporal changes in population structure and historical abundance trends, and can help in monitoring programs and management decisions (Ames, 2006; Beaudreau & Levin, 2014; Huntington, 2000; Huntington et al., 2004). By recognizing the importance of including local and traditional knowledge in the assessment and management of fisheries, we can improve the quantity and quality of the data and the management of the fishery. The fishermen will be actively participating in the process and more willing to implement the required changes, being part of the assessments and monitoring processes (Mackinson et al., 2011).

In this research, we integrate biological and ecological dimensions of the fisheries assessments with the local knowledge of the communities that use and depend on the resource. We will use as input both scientific and local fishermen knowledge in the assessment of data-poor fisheries. This research is explored in three main Chapters (sections): The first illustrates the synergy of local and scientific information with a Productivity and Susceptibility Analysis, to assess if fishermen's knowledge, can improve the knowledge baseline of data-poor fisheries at a local scale. It also highlights the differences in the vulnerability of species when they are assessed at a local, regional and coast-wide scale and with different types of knowledge (Chapter 2).

The following chapter identifies the knowledge gaps in the life-history characteristics of the small-scale commercial fisheries in the Colombian Pacific. It also analyzes the most and least studied parameters and species in the region, to prioritize future research efforts. To offer some recommendations for future research, this chapter provides a set of assessment tools, with the data-availability and data-needs for each species, which could be implemented in the country for better and more robust assessments (Chapter 3). The next chapter proposes a modification of the Productivity and Susceptibility Analysis, integrating scientific and local fishermen knowledge in the vulnerability assessment. The method links biological information on the productivity of 15 nearshore stocks with local expertise on susceptibility to fishing and other stressors. It is an exploratory analysis for small-scale fisheries on the Pacific coast of Colombia and illustrates the value of tailoring the general PSA approach to local conditions (Chapter 4). The final chapter summarizes this work, presents the general conclusions and explore the future research efforts that will help to keep improving the assessment of small-scale fisheries.

Chapter 2—Integration of scientific and local expertise to develop risk assessments for nearshore species at different spatial scales

Abstract

The Oregon Department of Fish and Wildlife (ODFW) currently sets harvest caps to manage fishery stocks in state waters based on federal stock assessments. However, the data for full stock assessments are combined for all three western states, and many nearshore species have not been assessed. Additionally, local catch and stock condition information are not incorporated into models in a way that reflects smaller-scale processes important to local fisheries. We gathered local information on nearshore fishes in Oregon to contribute to a Productivity and Susceptibility Analysis (PSA), an expert opinion-based model that combines information about the productivity of a stock with its susceptibility to fishing activities, pollution, habitat degradation, or other factors. The Pacific Fisheries Management Council (PFMC) has developed PSAs for federally managed stocks on a west coastwide scale. This research sought local expertise to develop a PSA for nearshore species at a smaller spatial scale, so we can better understand the characteristics of Oregon fish. We applied this technique by combining biological data for ten nearshore species with information obtained from fishermen during a series of outreach meetings and an online survey. We found some key differences between the coastwide vulnerability ratings and smaller spatial scale ratings, reflecting the influence that local information can have on the results of the model. Although some of the evaluation questions differed, we found that our PSA results generally matched those generated for West Coast stocks, but with somewhat lower vulnerability scores provided by the local data. While PSA provides only general information on vulnerability and stock status, it can be useful to identify important local differences in stock susceptibility to fishing or other impacts that may be lost when stocks are monitored at the coastwide level.

Introduction

Effective local management of fisheries resources requires focused assessments and local information (Ayers & Kittinger, 2014; R. S. Pomeroy, Cinner, & Raakjær, 2011). Oregon nearshore fisheries resources are managed through harvest caps (HC), based on catch limits defined by federal stock assessments. Oregon contributes data on catch history and fisheries dependent monitoring to the federal stock assessment process, and sets HCs based on catch history, with the total allowable catch set by the Pacific Fishery Management Council (PFMC) as the upper limit not to be exceeded (NMFS & NOAA, 2016).

However, local catch and stock condition information are not incorporated into models that reflect smaller-scale processes important to fisheries at local/small scales. Further, many nearshore species that are found predominantly in Oregon state waters are not included in the federal assessment process and thus have no federally-recommended catch limit. For species that are assessed, most are evaluated on a coast-wide spatial scale on a two to five-year cycle (NMFS & NOAA, 2016), a process that may not reflect smaller-scale spatial population dynamics.

Recent advances in assessment techniques for data-poor species could allow HCs to be based on a more local assessment process by working with available data, and therefore within budget constraints (Berkson & Thorson, 2015; Carruthers et al., 2014; Dick & MacCall, 2011; Newman, Berkson, & Suatoni, 2015). Local, small-scale fisheries can be neglected or overlooked by regional or national assessments, and as the scale of the assessments increase, the opportunity to capture the local and regional characteristics of the stock decrease (Moreno-Báez, Orr, Cudney-Bueno, & Shaw, 2010). Assessing stocks at a smaller spatial scale can be problematic, however, because most small-scale fisheries lack basic local information about the life history of the species or population, its spatial distribution, migration patterns, landings, fishing effort, and other traits (Moreno-Báez et al., 2010). It is unlikely that these fisheries will have funds or data sets to develop a detailed stock assessment that is specific to the local area (Prince, 2010). However, data-poor fisheries assessments can be employed and may benefit from the incorporation of local knowledge from fishermen. The information provided by resource users reflects the local conditions, increases the scientific spatial and temporal assessment window, and decreases assessment data-gaps (Mackinson, 2001; Saavedra-Díaz, Rosenberg, & Martín-López, 2015). Fishermen's knowledge can be collectively accumulated and assimilated with information from traditional science into assessments, providing an invaluable source of local information (Lima, Oliveira, de Nóbrega, & Lopes, 2017; Mackinson, 2001).

A tool that allows assessing data-poor fisheries at a smaller spatial scale and integrates local knowledge is the Productivity and Susceptibility Analysis (PSA). PSA was originally developed to assess the sustainability of the bycatch species in the Australian prawn trawl fishery. This method identified the species at risk for scientific research and management action (Milton, 2001; Stobutzki, Miller, & Brewer, 2001; Stobutzki, Miller, Heales, & Brewer, 2002; Stobutzki, Miller, Jones, & Salini, 2001). In the U.S., following the reauthorization of the Magnuson-Steven Act, the method was modified and implemented to conduct vulnerability analyses of U.S stocks and develop sustainable management measures (Jason Cope et al., 2011; Cortés et al., 2010; Field, Cope, & Key, 2010; Patrick et al., 2010).

The PSA tool relies primarily on expert opinion and combines information about the productivity of a stock (biological information) with its susceptibility to fishing and other environmental and human factors. PSA prioritizes the species that require additional research and status evaluation, establishes warning signs for specific stocks, and allows integration of scientific and local or traditional knowledge as the basis of the model. This attribute is essential in data-poor fisheries, especially for developing countries where the knowledge of local fishermen might be the only reliable source of information available on the history and status of a fishery (Barnes-Mauthe et al., 2013; Fujita et al., 2013; Mackinson et al., 2011).

In this paper, we illustrate the synergy of local and scientific information with a Productivity and Susceptibility Analysis to assess if fishermen's knowledge can improve the knowledge baseline for the assessments of data-poor fisheries at a local scale. We also highlight the differences in the vulnerability of species when they are assessed at a local, regional and coast-wide scale and with different types of knowledge.

Methods

Using the method described by Patrick et al. (2010), we developed a Productivity and Susceptibility Analysis (PSA) to assess the vulnerability of ten nearshore fishes that are encountered in Oregon's recreational fisheries. The subject species were Black Rockfish (BRF, *Sebastes melanops*), Buffalo Sculpin (BS, *Enophrys bison*), Cabezon (CAB, *Scorpaenichthys marmoratus*), China rockfish (CHRF, *Sebastes nebulosus*), Copper Rockfish (CRF, *Sebastes caurinus*), Kelp Greenling (KG, *Hexagrammos decagrammus*), Lingcod (LING, *Ophiodon elongatus*), Quillback Rockfish (QRF, *Sebastes maliger*), Red Irish Lord (RIL, *Hemilepidotus hemilepidotus*), and Redtail Surfperch (RSP, *Amphistichus rhodoterus*). For species that have been evaluated coastwide, the Oregon PSA was compared with Cope et al.'s (2011) PSA of the US west coast groundfishes to assess if vulnerability values change according to the scale and the information used, and how this might modify local management.

Vulnerability (V) to overfishing is defined by two components: the productivity (P), or life history characteristics of each stock, and the susceptibility (S), or ways that the stock is affected by the fishery. Each of the two components is explained by ten attributes (Table 1) that were scored following a simple 1 to 3 ranking system. Once each attribute is scored, the values are averaged, and the result was a single score for productivity and one for susceptibility for each of the species assessed per area (coast-wide or smaller spatial scales, described below). The PSA includes a weighting system (from 0 to 4), that upgrades or downgrades each one of the attributes depending on their importance for the species being analyzed, multiplying each attribute by the assigned weight. For our group of fishes, we kept the recommended default weight of 2 for all the attributes, except for maximum size and measured fecundity, which were kept at 1 following Cope et al.'s (2011) scoring system.

After weighting, the attributes were averaged, obtaining one score for productivity and one for susceptibility for each species. These scores were graphically displayed in an XY plot and the vulnerability calculated as the Euclidean distance from the origin of the plot (Patrick et al., 2009).

Productivity

We performed a gap analysis for the ten nearshore fish stocks in Oregon to qualitatively assess the data richness of ten life history parameters used in the PSA. Parameter values were obtained from peer-reviewed journals, state management or gray literature, and stock assessments and STAR panel reports provided by NOAA Fisheries and the Pacific Fisheries Management Council (PFMC) (Appendix A). We worked collaboratively with the Oregon Department of Fish and Wildlife (ODFW) Nearshore Management staff to develop two 10 x 10 data richness scorecard (ten stocks, ten parameters, 100 values total) to create a richness score based on two criteria: spatial relevance, the location of the study used to derive the parameter (no data available, fish from an area outside of Oregon, or fish from Oregon waters, Table 2a) and temporal relevance, the age of the parameter estimate (<10 years, 10-20 years, or >20 years ago, Table 2b). For the spatial relevance criterion (Table 2a), we assumed that a parameter was "local" to Oregon if it was estimated using catch data from Oregon within the stock assessment. Mean trophic level (MTL) values were obtained from FishBase (Froese & Pauly, 2017), and we assumed that values were obtained or updated within the last ten years, but that they were not estimated using local data. For the temporal relevance criterion (Table 2b), we assumed that the date of the publication corresponded to the date of measurement of the parameter unless a prior source was explicitly cited.

The content of the scorecard was used to assign a productivity data-richness score to each stock which can be used to prioritize future research (Table 3). For the spatial relevance scorecard (Table 2a), we awarded one point if the parameter was available, and a second one if the parameter was "local" to the Oregon stock. For temporal relevance scorecard (Table 2b), we awarded one point if the parameter was measured within the last 10 years, 0.5 points if measured within the last 20, and no points if measured over 20 years ago. We assigned a data-richness rank out of the 30 possible points. For stocks with 20 points or greater, we assigned a “good” score; for stocks that scored 10 - 19 points, we assigned a “fair” score; for stocks with less than 10 points, we assigned a “poor” score. We modeled our approach after the “scorecard method” outlined in Honey et al., (2010) because it is an established framework that provides fisheries managers with an itemized synthesis of data quality and quantity that can be used to inform analysis and management strategy as well as future research needs.

The values obtained for each one of the productivity attributes were scored between High (3) and Low (1), following the scoring ranking system (Table 1) (Patrick et al. 2009). Once each attribute was scored, the attributes were multiplied by the assigned weight and the average per species recorded as the productivity scores of the species (Table 4).

Data quality of the productivity attributes

The PSA methodology includes a data quality index to acknowledge the uncertainty associated with the data-poor stocks. The vulnerability of the species is not affected by this index, and instead assess the quality of the information used to score it (Patrick et al., 2010). We followed the five tiers data-quality index from Patrick et al. (2009) ranging from best data, or high belief in the score (score of 1), to no data or low belief in the score (score of 5). In the present study, the productivity quality scores (PQS) were calculated modifying the five tiers to match it with our 30 points data-richness score, and assign a data-quality score. Stocks with a data-richness score between 30 to 24 points, got a data-quality score of 1; between 23 and 16, got a data-quality score of 2; between 15 and 8 , a data-quality score of 3; between 7 and 0, a data-quality of 4; and no data a quality of 5 (Table 3).

Susceptibility

The PSA method relies on expert opinion, and previous research used expert knowledge of the Vulnerability Evaluation Group or the Groundfish Management Team of the PFMC to assess the susceptibility attributes (Jason Cope et al., 2011; Patrick et al., 2010). For our study, we introduce local knowledge of resource users as the primary source of information to assess the susceptibility attributes of species in each of the four areas shown in Figure 1. We developed a questionnaire (Appendix B) to collect the necessary information to score the susceptibility attributes of the ten species at a local level (Table 1). We did not include the susceptibility attributes of fishing mortality rate (relative to M), and relative spawning biomass due to a lack of data at the local level.

Our survey consisted of 22 questions per species, with at least two questions defining each susceptibility attribute. We sent paper surveys to commercial fishermen and companies (N = 108) registered in the Oregon Department of Fisheries and Wildlife (ODFW) databases and advertised an online survey through posters and postcards left in port offices, fishing supplies stores along the Oregon coast and in the ODFW offices (Appendix C). We also solicited responses from fishermen and other stakeholders who attended one of two "Stock Assessment 101" workshops hosted in Newport and Port Orford, Oregon. After reviewing the survey protocol and data use agreement, participants were invited to respond to questions for any of the ten species with which they were familiar. Survey answers were scored between Low (1) and High (3), following the scoring ranking system (Table 1) (Patrick et al. 2009). Once each attribute was scored, the attributes were multiplied by the assigned weight and the average per species recorded as the susceptibility scores of the species (Table 3).

Data quality of the susceptibility attributes

The data quality information of the susceptibility attributes was scored following the Patrick et al. (2009) five tiers scale. Data quality scores range from 1 to 5 as follows:

> Best data: Information is based on collected data for the stock and area of interest that is established and substantial.
>
> Adequate Data: Information with limited coverage and corroboration
>
> Limited Data: Estimates with high variation and limited confidence and may be based on similar taxa or life history strategy

Very Limited Data: Expert opinion or based on general literature review from a wide range of species, or outside of the region

No Data: No information on which to base the score

Each susceptibility attribute was scored individually, and a single susceptibility data quality value per species was calculated by the average of the scores.

Vulnerability Calculation

To perform the PSA at a smaller spatial scale, we divided the Oregon coast into four regions (Figure 1) following the Pacific Fisheries Management Council Areas and the natural geographic breaks (Cape-to-Cape). These regions were shown in a map to participants of our local knowledge survey and participants were asked to specify where their expert knowledge was based. The PSA was conducted for each geographic region, using local information, and as a grouped PSA for the Oregon coast, which combined information from all four regions.

For the Oregon coast and each one of the four areas (Figure 1), the mean productivity and susceptibility scores for each species were graphically displayed in an XY plot and the vulnerability calculated as the Euclidean distance from the origin of the plot (Patrick et al., 2009). The state-wide species' vulnerability, was calculated with the productivity values used at the local scale, and the averaged susceptibility scores from the four areas.

Scale comparison

To determine if the scale and the sources of the information used in the PSA can change the vulnerability assessment of the species, we compared our results by region, against the combined Oregon-wide PSA, and against the vulnerabilities from the coast-wide assessment of the U.S West Coast groundfishes (Cope et al., 2011). We interchanged Cope's productivity and susceptibility values with our own and ran two more PSA for seven species analyzed in both studies.

Results

Productivity

The gap analysis provided most of the information to score each one of the productivity attributes (Table 4). Most of the information was measured or estimated within the last ten years, but only a few parameters were based on life history information measured in Oregon waters (Table 2a and 2b).

There were some emerging patterns in the gap analysis. The breeding strategy was the most common missing parameter; this information was only available for 5 of the 10 species (Table 2a and 2b). Maximum length was the only information available for all ten stocks. Maximum age, age at maturity, and mean trophic level were available for 9 out of 10 stocks. Breeding strategy and age at maturity were the most common parameters measured more than ten years ago. Excluding cabezon, the two-least data-rich stocks were cottid fishes: Red Irish lord and buffalo sculpin. The productivity values for Red Irish Lord and Redtail Surfperch were calculated with only seven attributes, while the rest of the species used ten attributes (Table 4).

The species with the largest amount of data receiving a “good” data-richness rank for the local productivity attributes were Black rockfish (scored 23 out of 30 possible points), copper rockfish (21.5/30), kelp greenling (21/30), and lingcod (22/30). The species with a “fair” data-richness rank were cabezon (19.5/30) china rockfish (18.5/30), quillback rockfish (18/30), redtail surfperch (15/30), and red irish lord (13.5/30). Buffalo sculpin was removed from the analysis because of a score of 6.5/30.

Data quality of the productivity attributes

The productivity data quality scores (Table 4) were in general well informed, and redtail surfperch and red irish lord had the lowest quality scores. This low data quality for the two species is a reflection of the low amount of local information or no information at all for the two species (Table 2a and b).

Susceptibility

A total of 60 surveys from fishermen and stakeholders (Table 5), most of them with information of at least two different species, provided all the information to score the susceptibility attributes of 9 of the 10 species (Table 4). Most of the respondents provided information for more than one species. The highest number of surveys corresponded to Area 2, located between Cape Falcon and Cape Perpetua (Figure 1). Black Rockfish received the most information (N=32), followed by Lingcod (N=26), Cabezon (N=22), Kelp Greenling (N=17), China Rockfish (N=16), Copper Rockfish (N=9), Quillback rockfish (N=8), Redtail surfperch (N=7), and Red Irish Lord had the fewest number of surveys (6 out of 60 surveys). Most of the fishermen surveyed live or work in the area, and on average have 14 years of experience working in the region.

Data quality of the susceptibility attributes

Susceptibility attributes had low data quality scores (Table 4) because most of our susceptibility information came from the local fishermen knowledge and the scale used, following Patrick et al. (2009), scores expert opinion as very limited data (data-quality score of 4). The management strategy score was the only attribute taken from the literature and not from expert knowledge.

The productivity and susceptibility quality scores (Table 4) were averaged to assess the general quality of the analysis and to provide an estimate of uncertainty for the vulnerability of each species. All the species, on the Oregon coast and each one of the areas, obtained a moderate quality of data score.

Vulnerability

The Oregon coast PSA results showed that Quillback Rockfish, Copper Rockfish, and China Rockfish displayed the highest assessed vulnerabilities among the nine species. The remaining six species showed low assessed vulnerabilities, with Red Irish Lord the species having the lowest score (1.06) (Figure 2, Table 6).

When analyzed at the local scale, the vulnerability of the species in Areas 1, 2 and 3, was in general lower than calculated for the Oregon coast scale, while in area 4 all the species vulnerabilities were higher (Table 6). The PSA on Area 1 was only done for five species because the information obtained to assess the other species was insufficient. Results in Area 2 were similar to the Oregon coast, but all the vulnerabilities were lower; Area 3 showed the greatest variation in results, with low susceptibility values for Cabezon and China Rockfish; and Area 4 the highest vulnerabilities (Table 6). In the last three areas, Quillback Rockfish, Copper Rockfish, and China Rockfish continued to be the species with the greatest vulnerabilities (Table 6).

Scale comparison

We compared our state-wide PSA results for 7 of the 10 species with published values for the US West Coast (Cope et al. 2011) (Figure 3). In their research, Cope et al. (2011) described their scoring process as an informed, scientific consensus among all the co-authors. The susceptibility values that they presented used expert knowledge as the source of information to score the attributes. The susceptibility scores used in our study used local knowledge as the primary source of information about susceptibility and updated scientific information for productivity scores.

We compared these differences in a 2 x 2 framework (Figure 3). The scale and origin of the information, whether scientific or local knowledge, influence the distribution of the species in the PSA, but some patterns are consistent. The susceptibility of all species is higher for all species in Cope et al.'s analysis, but Copper Rockfish, China Rockfish, and Quillback Rockfish are displayed in the highest relative vulnerability area for both studies. When we combined our results with Cope's susceptibility or productivity, the graphic changes in the vulnerability of the species is evident. Using Cope's susceptibility, the species are driven towards the areas of higher vulnerability on the plot, but when we used our susceptibility values, all the species tended to go to the area of low productivity and low susceptibility. The biggest inconsistency is in Black Rockfish, which was ranked with much higher vulnerability in Cope et al. (2011) due to lower estimates of productivity. It is important to note that the results of Cope et al. (2011) are given for the entire US West Coast, while this study focused only on the state of Oregon. These results illustrate the importance of the type of knowledge used to inform the PSA and the spatial scale at which it is performed.

Discussion

In this research, we were able to integrate scientific and local fishermen knowledge in the assessment of local data-poor fisheries. Our approach can contribute to local fisheries that do not have enough information to be assessed with more traditional methods. In our analysis, we found a lack of basic life-history information of the species at the local and regional level and a low amount of information specifically for the Oregon coast. Our PSA approach can be an excellent tool for local assessments, but it will require more and better-quality information to continue an updated assessment and monitoring of the Oregon nearshore species.

The PSA is used in data-poor fisheries assessments because it requires minimal information that can be obtained through expert opinion and it is simple to update when more data become available. However, the life-history information required to populate the PSA tool can be difficult or impossible to obtain in very data-poor fisheries (Duffy & Griffiths, 2017; Micheli, De Leo, Butner, Martone, & Shester, 2014). In this study, a lack of information led to the removal of Buffalo sculpin from the analysis, because the productivity and susceptibility parameters did not have enough information to be scored. Cope et al. (2011) discussed that, even in situations with limited information on the life-history attributes of the species, it is only necessary to get a general understanding of these attributes because the PSA uses bins and not precise estimates for them. However, for our study, 1 out of 10 species did not have enough information to be properly evaluated with a PSA, and this may be true for other species that are rarely harvested. Gap analyses can identify critical data needs for species that are exploited but poorly known.

Some studies have tried to use fewer productivity parameters, without altering the vulnerability results. Duffy and Griffiths (2017) found significant redundancy among some of the attributes of the PSA and recommended the use of fewer parameters. They suggested that for data-poor fisheries lacking the required data, it is possible to use just one attribute per pair, out of the following parameters: the intrinsic rate of growth (r) or the von Bertallanfy growth (k); the maximum length or maximum age; and length at maturity or age at maturity. Our gap analysis, highlighted how difficult it is to find reliable and complete information of the life-history parameters in data-poor fisheries. Future PSA applications assessing data-poor fisheries could explore the possibility to reduce the number of parameters or include other life-history parameters that could be explaining the productivity of the species. Another possibility will be to return to previous versions of the PSA (Stobutzki, Miller, & Brewer, 2001; Stobutzki et al., 2002; Stobutzki, Miller, Jones, et al., 2001), and include a higher and more diverse selection of attributes that could help to explain the productivity of the species. The PSA used in this research, following the methodology of Patrick et al. (2009), proved to be quite restrictive and the parameters are difficult to obtain, especially at the local scale, even though the PSA is designed for data-poor species.

Local fishermen’s knowledge was a valuable source of information for local susceptibility scores in our PSA. The information provided by fishermen showed that, even for species with limited data, such as Red Irish lord or Redtail surfperch, local knowledge could help to fill the biological and ecological knowledge gaps needed for a local PSA. We found that the questionnaire was an excellent tool to elicit the local knowledge about the interaction of the fishers with each one of the stocks. Cope et al. (2011) discussed that the susceptibility attributes, assessed with scientific experts, have a high level of subjectivity and that it is difficult, although important, to maintain a consistency in the scoring of these attributes, especially with multiple scorers. In our research, we tried to decrease that subjectivity with the local knowledge, assuming that the local assessment will be better informed with multiple local independent responses, rather than with a consensus.

Although some of the species received a low number of survey responses (Table 4), and we acknowledge that this can increase the uncertainty of the analysis, the case of Black Rockfish shows how different the assessment of a species can be, according to the type of knowledge used. Future research could be benefited with a sampling design comprising the same amount of surveys per region. We believe the diversity of the "connection to the area and to the Oregon fisheries" interviewees (Table 5), was an advantage for our local assessment. The combined knowledge of residents, visitors, commercial and recreational fisheries, researchers, and shoreside support, among others, might be reducing the subjectivity of the susceptibility attributes that Cope et al. (2011) described.

The differences between Cope et al. (2011) analysis and our research could have been impacted by updated life-history information in this research and by a different perception of the scorers. Cope's analysis, focused on a coast-wide perception of the interaction of the fisheries with the stocks, integrating information from different States. This research focused on the analysis on the local fishermen knowledge, whose perception is local, and it is reflecting the local susceptibility of the stocks. Future PSA research could combine both types of knowledge to increase the accuracy of the assessments.

The differences we observed in the susceptibility and vulnerability of the species for each area of the Oregon coast showed that local knowledge reflects local fisheries conditions and could improve assessments at smaller spatial scales. Local fishermen knowledge is often excluded from assessment or management processes, despite being extremely valuable, because it is less quantitative than data collected by scientists. Local conditions are often better known and understood by local resource users. For example, the knowledge of the distribution and behavior of fishes is a prerequisite for the daily job of catching them (Mackinson, 2001). Fishermen have detailed local information about environmental and temporal changes, and local behavior patterns of the species, that scientific knowledge can be lacking or missing some of the detail because of the assessments scale (Mackinson, 2001; Saavedra-Díaz et al., 2015). As a semi-quantitative risk assessment tool that does not require precise estimates of its parameters, the PSA is an excellent way to combine the knowledge of local fishermen with scientific knowledge.

Our results illustrate the importance that the scale might have in the vulnerability assessment of the species, and this can have direct effects on the local management strategies and regulations, established following coast-wide assessments (Moreno-Báez et al., 2010). Not only because the local characteristics of the stocks might be different from the coast-wide ones, but because fishermen knowing the local stocks, might see scientific-based management strategies established for the whole coast, inaccurate for their local fishing areas (Bevilacqua, Carvalho, Angelini, & Christensen, 2016).

We found that the spatial attributes of the PSA (vertical overlap and spatial overlap) were the most difficult attributes to evaluate because the methodology requires scoring the horizontal and vertical overlapping of the gear with the distribution of the species. This proportion is a problematic concept to assess, especially when fishermen know where they are fishing, but do not necessarily know the complete distribution of the stock. Previous research (Close & Hall, 2006) has shown successful examples of the articulation of local knowledge and scientific research to assess these kinds of attributes, through processes of local knowledge mapping. GIS-based protocols for the collection of local fishermen knowledge are an excellent tool when scientific research and knowledge only have a narrow temporal window of the stocks (Aswani & Lauer, 2006; Close & Hall, 2006). In contrast to limited scientific sampling, fishermen have a continuous "sampling" process, not only of the stocks but of the places the species are living, movement of the stocks, temporal movements or migrations, among others (Bevilacqua et al., 2016; Hill, Michael, Frazer, & Leslie, 2010; Lima et al., 2017).

This study showed the importance of continued monitoring of the essential life-history characteristics of fished species. Assessment and management of some of the stocks will depend entirely on data-poor assessment tools that require, at minimum, high quality biological and ecological characteristics of each species from the local area. Future research could include fewer productivity parameters but should be updated and regionally or locally measured to reduce uncertainty and improve risk assessment of the species. Our results suggest that integration of scientific and local knowledge in a PSA can be a reliable and successful tool to develop local risk assessments and improve local and regional management. Information elicited from resource users with well-structured surveys can accurately inform local processes, complement scientific assessments, and highlight local and regional peculiarities.

Figure 1. Areas in which the coast was divided following natural oceanographic breaks (cape to cape) to evaluate appropriate spatial scale to apply the PSA.

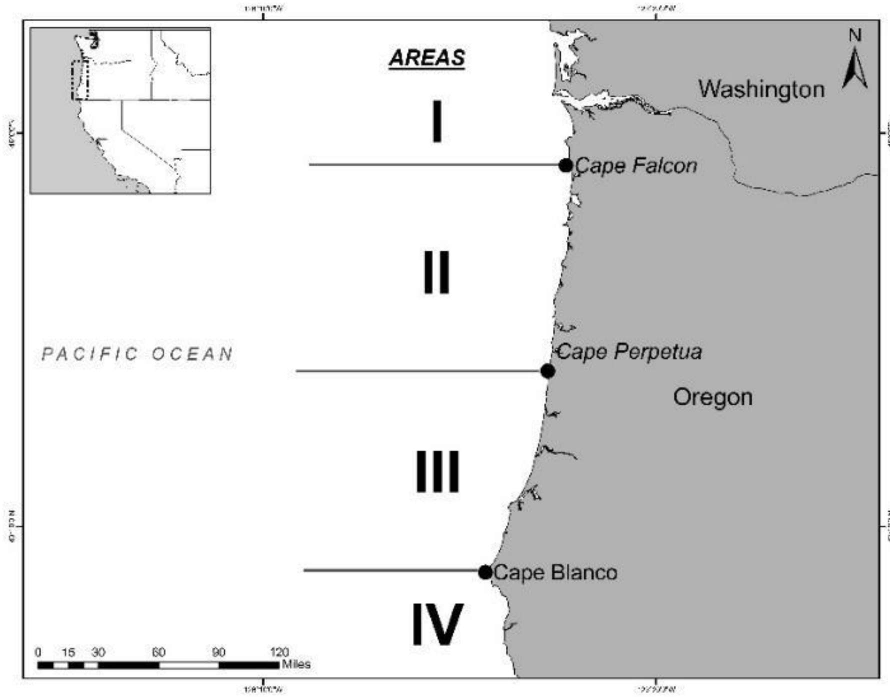

Figure 2 Productivity and susceptibility analysis plot of the nine groundfish species assessed in the Oregon coast. Change in color shows the vulnerability of the species, from green (Low vulnerability) to red (High vulnerability). The assessed species are Black Rockfish (BRF), Cabezon (CAB), China Rockfish (CHRF), Copper Rockfish (CRF), Kelp Greenling (KG), Lingcod (LING), Quillback Rockfish (QRF), Redtail surfperch (RSP) and Red Irish Lord (RIL).

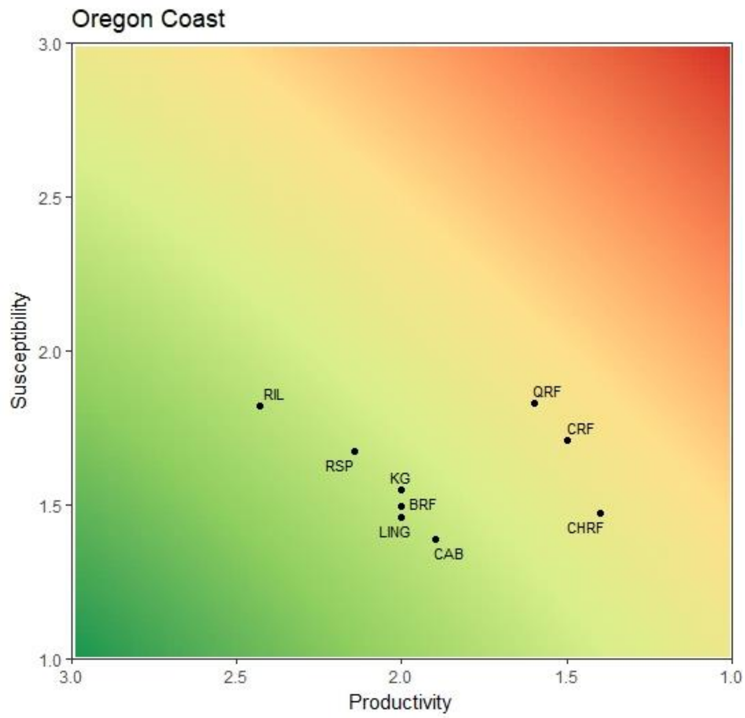

Figure 3 Graphic comparison of the Productivity and Susceptibility Analysis (PSA) results of this research and the results of Cope et al. (2011), along with plots combining the productivity and the susceptibility values of the two studies. (A) PSA plot of seven groundfish species assessed in the Oregon coast. B) PSA from the Pacific coast showing the seven species that match the present study (modified from Cope et al. 2011). C) PSA for the Oregon coast that takes the productivity values from the present study and the susceptibility values from Cope et al. (2011). D) PSA for the Oregon coast that takes the productivity values from Cope et al. (2011) and the susceptibility values from this study. The assessed species are Kelp Greenling (KG), Black Rockfish (BRF), Cabezon (CAB), Copper Rockfish (CRF), China Rockfish (CHRF), Lingcod (LING) and Quillback Rockfish (QRF).

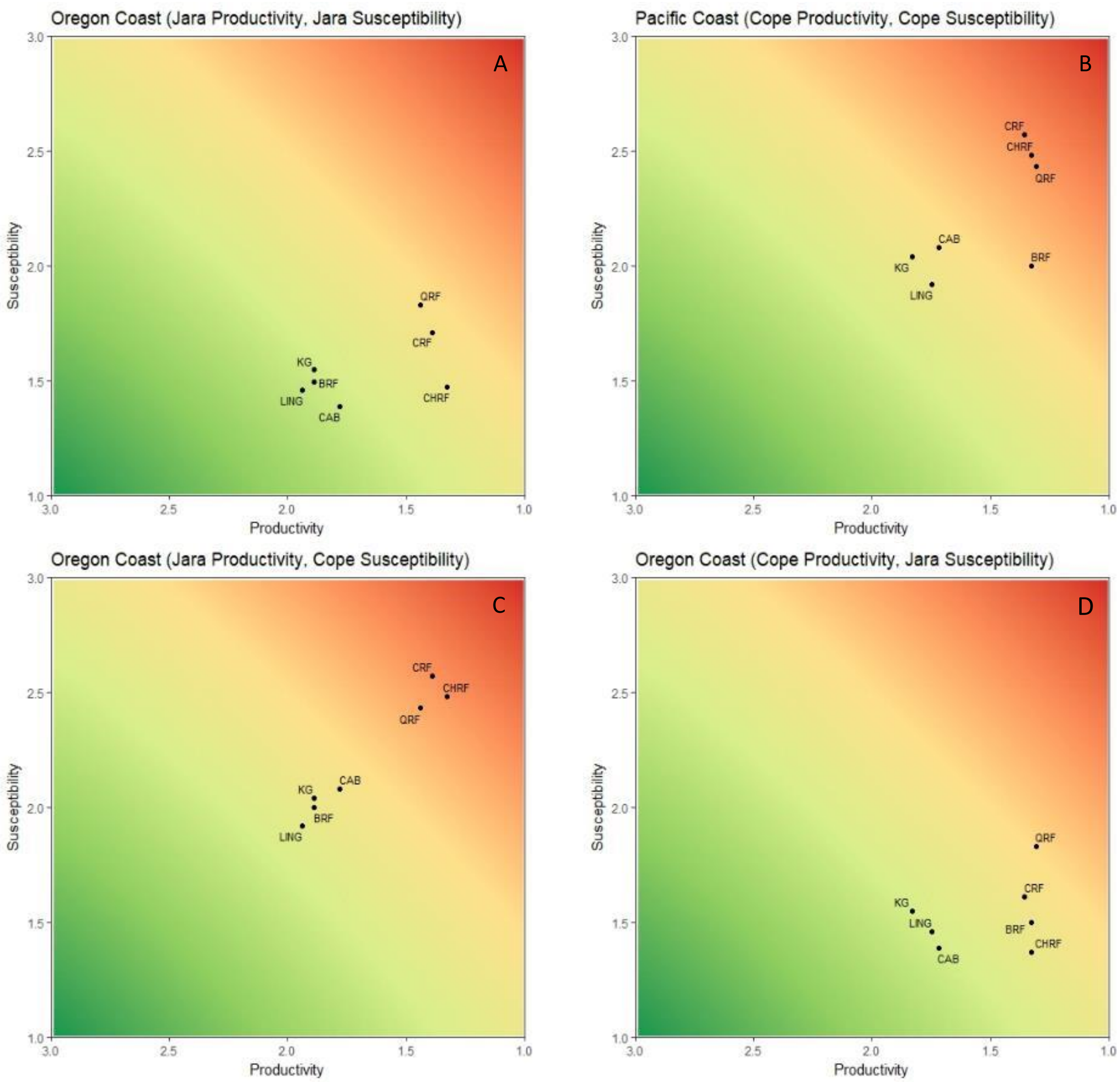

Table 1. Productivity and Susceptibility attributes and scoring thresholds used in the PSA. The description of each one of the attributes and the ranking determination can be found in Patrick et al. (2009). Note that the scale of the productivity attributes goes from High (low vulnerability) to Low (high vulnerability). Meanwhile, the scale for the susceptibility attributes goes in the opposite direction from Low (low vulnerability) to High (high vulnerability).

	Ranking		
Productivity attributes	High (3)	Moderate (2)	Low (1)
Population growth (r)	>0.5	0.5 to 0.16	<0.16
Maximum age	10 years	10 - 30 years	> 30 years
Maximum length	< 60 cm	60 - 150 cm	> 150 cm
von Bertalanffy Growth coefficient (k)	0.25	0.15-0.25	< 0.15
Natural mortality (M)	> 0.40	0.20 - 0.40	< 0.20
Fecundity	$\geq 10^4$	10^2 to 10^3	$\leq 10^2$
Breeding strategy[1]	0	Between 1 and 3	≥4
Recruitment pattern	Highly frequent recruitment success (> 75% of year classes are successful)	Moderately frequent recruitment success (between 10% and 75% of year classes are successful)	Infrequent recruitment success (<10% of year classes are successful)
Age at maturity	< 2 years	2-4 years	> 4 years
Mean trophic level	<2.5	Between 2.5 and 3.5	>3.5

	Ranking		
Susceptibility attributes	Low (1)	Moderate (2)	High (3)
Management strategy	Targeted stocks have catch limits and proactive accountability measures; non-target stocks are closely monitored	Targeted stocks have catch limits and reactive accountability measures	Targeted stocks do not have catch limits or accountability measures; non-target stocks are not closely monitored
Areal overlap	Fishery overlaps with less than half of the area or habitat where this fish species lives	Fishery overlaps with more than half of the area or habitat where this fish species lives, but not all of it	Fishery overlaps with all of the area or habitat where this fish species lives
Geographic concentration	Stock is distributed in > 50% of its total range	Stock is distributed in 25% to 50% of its total range	Stock is distributed in < 25% of its total range

[1] Breeding strategy of a stock provides an indication of the level of mortality that might be expected for the offspring in the first stages of life and it is estimated with an index of parental investment. The index is composed by the placement of larvae, the length of time of parental protection and the length of gestation period or nutritional contribution (Patrick et al., 2009).

Seasonal migration	Seasonal migrations decrease overlap with the fishery	Seasonal migrations do not substantially affect the overlap with the fishery	Seasonal migrations increase overlap with the fishery
Catchability	Fish is caught incidentally, usually discarded/Fish is caught incidentally, usually kept and sold (1.5)	Fish is part of a targeted complex (2)/Fish is targeted when the catch of other species is down (2.5)	Fish is usually targeted
Morphology affecting capture	The catch is more difficult because of fish shape or behavior	The catch is not affected by fish shape or behavior	The catch is easier because of fish shape or behavior
Survival after capture and release	Good chance of surviving, more than 67% (at least 2 out of 3 fish released will survive)	Medium chance of surviving, 33% to 67% (1 or 2 out of 3 fish released will survive)	Low chance of surviving, less than 33% (no more than 1 out of 3 fish released will survive)
Desirability/value of the fishery	Not highly valued less than $1/lb.	Moderately valued: $1-$2.25/lb.	Highly valued: more than $2.25/lb.
Fishery impact on habitat	No habitat impacts	Limited habitat impacts	High habitat impacts
Vertical overlap	Fishing gear overlaps with less than half of the range of the stock in the water column	Fishing gear overlaps with more than half of the range of the stock in the water column, but not all of it	Fishing gear overlaps with all the range of the stock in the water column

Table 1 (Continued)

Table 2a. Scorecard 1 detailing the availability of each life history parameter (light grey), and whether that parameter was local to Oregon (dark grey) or was not available (white). Stocks are arranged vertically in columns with the number of points awarded out of 20 presented at the bottom of each column. The assessed species are Black Rockfish (BRF), Buffalo Sculpin (BS), Cabezon (CAB), China Rockfish (CHRF), Copper Rockfish (CRF), Kelp Greenling (KG), Lingcod (LING), Quillback Rockfish (QRF), Redtail surfperch (RSP) and Red Irish Lord (RIL).

	BRF	BS	CAB	CHRF	CRF	KG	LING	QRF	RSP	RIL
Population Growth Rate (r)										
Maximum age										
Maximum length										
von Bertalanffy growth coefficient (k)										
Natural mortality										
Fecundity										
Breeding strategy										
Recruitment pattern										
Age at maturity										
Mean trophic level										
Score	15	3	11	11	12	13	15	11	8	8

Table 2b. Scorecard 2 detailing the relative timing of parameter measurement. Parameters measured within the last ten years are light grey, within the last 20 are dark grey, over 20 years in black, and no data in white. Stocks are arranged vertically in columns with the number of points awarded out of 10 provided at the bottom of each column. The assessed species are Black Rockfish (BRF), Buffalo Sculpin (BS), Cabezon (CAB), China Rockfish (CHRF), Copper Rockfish (CRF), Kelp Greenling (KG), Lingcod (LING), Quillback Rockfish (QRF), Redtail surfperch (RSP) and Red Irish Lord (RIL).

	BRF	BS	CAB	CHRF	CRF	KG	LING	QRF	RSP	RIL
Population Growth (r)										
Maximum age										
Maximum length										
von Bertalanffy growth coefficient (k)										
Natural mortality (M)										
Fecundity										
Breeding strategy										
Recruitment pattern										
Age at maturity										
Mean trophic level										
Score	8	3.5	8.5	7.5	9.5	8	7	7	7	5.5

Table 3. Gap analysis scorecard containing the stock name, data-richness score, and data-quality score. The quality score was modified from the five tiers data-quality index from Patrick et al. (2009). The data-quality is scored following five tiers, ranging from best data (score of 1.), or high belief in the score, to no data or low belief in the score (score of 5).

Species name	Data- richness score	Data-quality score
Black rockfish	23/30	2
Buffalo sculpin	6.5/30	4
Cabezon	19.5/30	2
China rockfish	18.5/30	2
Copper rockfish	21.5/30	2
Kelp greenling	21/30	2
Lingcod	22/30	2
Quillback rockfish	18/30	2
Redtail surfperch	15/30	3
Red Irish lord	13.5/30	3

Table 4. Overall scores of the Productivity and Susceptibility Analysis for the ten species at the Oregon Coast and on each of the four designated Areas (Figure 1). P = Productivity score, PQS = Productivity quality score, S = Susceptibility score, SQS = Susceptibility Quality Score, V = Vulnerability score. The assessed species are Black Rockfish (BRF), Cabezon (CAB), China Rockfish (CHRF), Copper Rockfish (CRF), Kelp Greenling (KG), Lingcod (LING), Quillback Rockfish (QRF), Redtail surfperch (RSP) and Red Irish Lord (RIL).

	Stock	P	PQS	S	SQS	N	V
Oregon Coast	BRF	1.89	2	1.50	3.70	28	1.22
	CAB	1.78	2	1.39	3.70	22	1.28
	CHRF	1.33	2	1.37	3.70	14	1.71
	CRF	1.39	2	1.61	3.70	9	1.72
	KG	1.89	2	1.55	3.70	16	1.24
	LING	1.94	2	1.46	3.70	26	1.15
	QRF	1.44	2	1.83	3.70	8	1.76
	RIL	2.33	3	1.82	3.70	6	1.06
	RSP	2.17	3	1.68	3.70	9	1.07
Area I	BRF	1.89	2	1.35	3.70	3	1.17
	CAB	1.78	2	1.48	3.70	2	1.31
	KG	1.89	2	1.38	3.90	2	1.17
	LING	1.94	2	1.44	3.70	2	1.14
	RSP	2.17	3	1.65	3.70	1	1.06
Area II	BRF	1.89	2	1.48	3.70	13	1.21
	CAB	1.78	2	1.30	3.70	10	1.26
	CHRF	1.33	2	1.12	3.70	6	1.67
	CRF	1.39	2	1.47	3.80	3	1.68
	KG	1.89	2	1.38	3.70	4	1.17
	LING	1.94	2	1.38	3.50	12	1.12
	QRF	1.44	2	1.54	3.70	2	1.65
	RIL	2.33	3	1.58	3.70	2	0.88
	RSP	2.17	3	1.62	3.70	3	1.04
Area III	BRF	1.89	2	1.17	3.90	2	1.12
	CAB	1.83	2	1.00	3.90	2	1.17
	CHRF	1.33	2	0.90	3.70	2	1.67
	CRF	1.39	2	1.50	4.20	1	1.69
	KG	1.89	2	1.60	4.00	2	1.26
	LING	1.94	2	1.20	4.00	2	1.07
	QRF	1.44	2	1.70	4.20	1	1.71
	RIL	2.40	3	1.89	3.80	1	1.07
Area IV	BRF	1.89	2	1.60	3.70	10	1.26
	CAB	1.78	2	1.62	3.70	8	1.37
	CHRF	1.33	2	1.86	3.70	6	1.88
	CRF	1.39	2	1.79	3.70	5	1.79
	KG	1.89	2	1.83	3.70	8	1.39
	LING	1.94	2	1.58	3.70	9	1.20
	QRF	1.44	2	2.02	3.70	5	1.86
	RIL	2.33	3	2.04	3.70	4	1.24
	RSP	2.17	3	1.82	3.80	4	1.17

Table 5. Demographic information from fishermen collected with the surveys (N=60) developed in the Oregon coast. The regions numbers correspond to the areas of Figure 1

		Total # of surveys	Percentage
Region	I	8	13%
	II	31	52%
	III	7	12%
	IV	14	23%
Connection to the area	Live in the area	33	28%
	Work in the area	28	24%
	Lived in the area in the past	4	3%
	Worked in the area in the past	2	2%
	Heard about fish in the area from others	10	8%
	Spend recreational time in the area	41	35%
Connection to Oregon fisheries	Commercial Fishing	22	22%
	Recreational Fishing	52	51%
	Diving	8	8%
	Shoreside support (gear, processing)	3	3%
	Research	10	10%
	Other	6	6%

Table 6. Vulnerability scores of the groundfish species assessed at the Oregon coast and each one of the regions. The arrows indicate if the vulnerability of the species in that area increased or decreased when compared with the Oregon coast vulnerability.

Stock Name	Oregon Coast	Area 1		Area 2		Area 3		Area 4	
Black Rockfish	1.22	1.17	↓	1.21	↓	1.12	↓	1.26	↑
Cabezon	1.28	1.31	↑	1.26	↓	1.17	↓	1.37	↑
China Rockfish	1.71			1.67	↓	1.67	↓	1.88	↑
Copper Rockfish	1.72			1.68	↓	1.69	↓	1.79	↑
Kelp greenling	1.24	1.17	↓	1.17	↓	1.26	↑	1.39	↑
Lingcod	1.15	1.14	↓	1.12	↓	1.07	↓	1.20	↑
Quillback Rockfish	1.76			1.65	↓	1.71	↓	1.86	↑
Red Irish Lord	1.06			0.88	↓			1.24	↑
Redtail surfperch	1.07	1.06	↓	1.04	↓	1.07	↓	1.17	↑

Chapter 3—Gap analysis of the life-history parameters of Colombian Pacific stocks needed to improve fisheries assessments

Abstract

Fisheries management addresses the challenges of meeting human protein needs and the requirement to ensure the long-term sustainability of stocks and the health of coastal ecosystems. Although some research suggests that well-assessed fisheries are sustainably managed, most of the unassessed fisheries, especially from developing countries, do not have enough information to assess the stocks and their level of exploitation. Colombian small-scale fisheries (SSF), despite their critical contribution to the livelihood of the country's coastal communities, have been continually ignored, and the assessment and management of SSF have been hindered by the instability of the fisheries governmental agencies in charge. This project aims to identify the information gaps in the available biological and ecological information of commercially important stocks in the Colombian Pacific, specifically, the life-history parameters of species commonly captured in SSF. We examined the amount of information available in the country for 23 biological and ecological parameters of 37 marine species from the Colombian Pacific coast and found an alarming lack of basic life-history characteristics of the populations fished. We found fisheries information scattered throughout the country, low amount of information published in peer-reviewed journals, and research and knowledge buried in "grey literature". To offer some recommendations for future assessments, we provide a review of data-poor fisheries assessment tools and determine the data needs for future assessments. We hope that this analysis will provide a roadmap for future research and monitoring to support better and more robust assessments in Colombia and can also be a model to be duplicated for small-scale fisheries elsewhere in data-poor countries.

Introduction

Fisheries are a prosperous sector within the commercial and recreational economies, with a high and growing demand. In the last five decades, global fish production has grown steadily at an average annual rate of 3.2 percent, but most of that growth has been through aquaculture production (FAO, 2018). Fisheries management has needed to address the challenges of a growing demand for protein and the necessity to ensure long-term sustainability and ecosystems health (Wallace et al., 2001). However, the percentage of wild stocks fished at a biologically unsustainable level has increased from 10 to 30% in the last four decades, making evident that more work is needed to achieve sustainable fisheries (FAO, 2018). Although some research suggests that well-assessed fisheries are sustainably managing their resources (Costello et al., 2012), the majority of the unassessed fisheries, especially from developing countries, do not have enough information to assess the stocks and its level of exploitation, less to sustainably manage them (Rosenberg et al., 2018). Approximately 80% of the fisheries around the world are unassessed and can be already overexploiting the resources (Costello et al., 2012). Developing regions of the world, are less likely to have the human resources, funds, scientific knowledge or data sets to obtain detailed knowledge of the biological and ecological characteristics necessary to assess their stocks (Dimarchopoulou, Stergiou, & Tsikliras, 2017; Prince, 2010). And as a result, they are prone to have a deficient data collection and analysis, an inadequate evaluation of the stock status and in general a weak institutional capacity to assess and manage the resources (Rosenberg et al., 2018)

Colombia is an example of a developing country, highly biodiverse, but with inadequate resources to assess and manage their fisheries, and limited by the relatively small size of the commercially important stocks (Wielgus *et al.*, 2010). Colombian SSF employ approximately 15,000 fishers in the Pacific coast and benefit thousands of families associated with the activity (Díaz *et al.*, 2011). Despite the critical contribution of SSF to the livelihood of the country's coastal communities, assessment and management of SSF has been hindered by the instability of the fisheries governmental agencies in charge. In the last 50 years Colombia has had five different fishing authorities (Rueda, Blanco, Narváez, Viloria, & Beltrán, 2011; Zapata et al., 2013). This instability has generated decentralized sources of fisheries information, knowledge gaps, inconsistencies, lack of governance, control measures, oversight and monitoring, and decline of fisheries research in the country

(Rueda et al., 2011; Saavedra-Díaz et al., 2015; Wielgus et al., 2010). In Colombia, much of the technical and scientific information of the fishery status and future potential is outdated, limiting the accuracy of the assessment strategies. Likewise, there are information gaps to establish areas and dates to create closed seasons; and imprecise knowledge of detailed biological and ecological characteristics of the species. All this information is essential for the assessment, management, expansion, and delimitation of the artisanal and industrial fisheries (IICA, 2011), and to continue to sustain the livelihoods of thousands. When SSF are poorly assessed and managed, their benefits to people and communities are severely compromised (Costello et al., 2012).

One approach toward the sustainable assessment and management of marine species is to keep an updated status of the species and establish a baseline about their biology and ecology. Such an approach would help to predict general parameters and establish reference points, useful to respond to population changes due to environmental changes or fishing pressure (Rochet, 1998). The analysis of the species' life-history characteristics specific to a region, is increasingly important to assess and conserve biodiversity, face the consequences of a rapid global change, and sustainably manage local resources. Assembling local and regional biological and ecological characteristics of the species from a diverse array of literature into a single data set, is a fundamental exercise that will avoid the duplication of efforts, will help to expose knowledge gaps, and will centralize the species' information to reliably monitor the status of the species (Jones et al., 2009).

Our objective in this paper is to record the available biological and ecological information of commercially important stocks in the Colombian Pacific, aiming to identify the information gaps in the life-history parameters of the small-scale fisheries. Also, to analyze the most and least studied parameters and species to prioritize future research efforts. Finally, to offer some recommendations for future research or monitoring, we provide a set of assessment tools, with the data-availability and data-needs for each species, which could be implemented in the country for better and more robust assessments.

Methods

We developed a literature review to collect all the available data and information and conducted a gap analysis to analyze and quantify the amount of biological and ecological information for commercial species in the Colombian Pacific. Within the gap analysis, we developed a data-richness rank to assess, not only the information available but to score the age of the data and the information's source. In a separate analysis, we proposed a set of data-poor assessment tools that could be potentially used in Colombia, and we present the data-availability and data requirements for each one of the models.

Gap Analysis

We carried out a gap analysis of some of the commercially important marine species (based on landings) of the Colombian Pacific. To perform the gap analysis, we based our study on the scorecard methodology of Honey *et al.* (2010), an established framework that provides an itemized synthesis of data quantity and quality that can be used to inform analysis and future research needs. We investigated the amount of information available in the country about 23 different biological and ecological parameters of 37 species (Table 7). The biological and ecological characteristics assessed were selected based on the parameters used in different data-poor assessment models, particularly the Productivity and Susceptibility Analysis (Patrick et al., 2009). We also used Patrick's et al. (2009) definitions or calculations of the attributes breeding strategy, recruitment pattern, morphology affecting capture, and schooling, aggregation, and other behaviors.

To develop the gap analysis, we did an extensive literature review of published papers, technical documents, and thesis documents to complete a baseline database (Appendix D). We did an online database search with keywords in Spanish and English in Google Scholar, Web of Science, and the libraries and documentation centers of Colombian Universities, research institutes, NGOs, and from the National Authority for Fisheries and Aquaculture (AUNAP), and the Colombian Fisheries Statistical System (SEPEC). We also visited the libraries of the Jorge Tadeo Lozano and del Valle Universities, and the documentation center of the Marine and Coastal Research Institute “Jose Benito Vives de Andreis” INVEMAR, in Colombia, to obtain the documents not available online.

Once our database was populated, we determined the proportion of species that had information for each one of the parameters to analyze the most or least studied parameters and species, as well as to prioritize the biological characteristics that need future research efforts.

Data-richness scorecards

As part of the gap analysis, we developed a data-richness rank to help us assess data-availability of each one of the species. We developed three data-richness scorecards based on three different criteria: Presence – absence of information, age of the information, and source of the information. For the presence-absence criterion, we assigned one point if the parameter was available, and no points if it was not available. For the age of information criterion, we assigned one point if the parameter was measured within the last 10 years, half a point (0.5) if measured between 10 and 20 years ago, and no points if measured more than 20 years ago. Finally, for the source of information criterion, we assigned one point if the source was a peer-reviewed paper and no points if it was from any other non-peer-reviewed source. All the points were added by species, and we assigned each species a data-richness rank out of the 69 possible points. Species with less than 23 points available were scored as “data-poor,” species that obtained between 23.5 and 46 were scored as “data-moderate”, and species with 46.5 points or more were score as “data-rich.”

Assessment tools

According to the amount of available information, and as a contribution to the fisheries assessments in Colombia, we propose a possible roadmap that could improve future research and monitor efforts and create more robust assessments in the country. As a first step, we analyzed the tools Colombia is currently using to assess the small-scale fisheries stocks. Second, we selected two data-poor assessments tools that could be potentially be implemented in the country to assess the fisheries. The tools were selected assessing the data-needs, advantages, and disadvantages of the models, and the data-availability of the Colombian stocks (Appendix F).

As a final step, with the information provided by the gap analysis, we determined the amount of information required to complete each one of the proposed assessment tools. We present a detailed description of the availability of each parameter for the 37 species

Results

Gap Analysis

We completed the literature review with a total of 214 documents, including peer-reviewed papers, technical documents, books and undergraduate and master thesis. We found that none of the species had any Colombia-specific information for five parameters: maximum age, population growth rate, geographic range, morphology affecting capture, and fishery impact in habitat. Most of the species (89%) had biological information about maximum length, habitat, and depth range, as well as information about the desirability of the species or its economic value (Figure 4). Important biological parameters that are normally used in fisheries assessments, such as age at maturity, fecundity, the von Bertalanffy growth coefficient or natural mortality, have been estimated for less than half of the species. Only six parameters, out of the 23, have been estimated in more than 50% of the species (Figure 4).

Data-richness scorecards

From our gap analysis scorecard methodology, we obtained a data-richness rank for all our species (Table 8). We classified 70% (N=26) of the species as “data-poor,” because of the extremely low amount of biological and ecological information, with a high number of knowledge gaps. We found extreme cases as *Thunnus alalunga* (Atún albacora) with a score of 2 or *Centropomus medius* (Machetajo) with a score of 5. The remaining 30% (N=11) of the species were scored as “data-moderate”, and *Coryphaena hippurus* (Dorado), *Brotula clarkae* (Merluza), and *Lutjanus guttatus* (Pargo lunarejo) were the three species with the highest rank (Table 8). However, these species are still considered as data-moderate, because they did not even reach half of the 69 possible points.

In the presence-absence scorecard only 27% of the species had information for at least half of the parameters, and on average the species only had eight parameters assessed (Table 8). On the date of the information scorecard, 61% of the parameters lost points during the ranking process due to the old age of the data. The source of the parameter scorecard had a strong influence on the rank because most of their values were extremely low. This low score is reflecting that most of the research in Colombia is published in technical documents, thesis or books, but not in scientific peer-reviewed journals. On average, each species only had two parameters with information from peer-reviewed sources (Table 8).

Assessment tools

Analyzing the assessment methods of small-scale fisheries in Colombia, we found that most of the assessment is directed towards size structure, along with length at maturity of the species to establish simple indicators of the species' status. De la Hoz *et al.* (2017) reported the maximum possible yield per recruit or optimum length (L_{opt}) of some of the species of the Colombian Pacific. The authors followed Froese and Binohlan (2000) methodology to estimate the L_{opt} of the species, with a previous estimate of length at first maturity (Narváez-Barandica et al., 2012). Although the authors assessed several species in the country, only 13 species in the Colombian Pacific had an estimate of the optimum catch length.

Our literature review of data-poor assessment models showed two possible tools that could be implemented in the country without a dramatic increase in resources (Appendix G). The first one is the Productivity and Susceptibility Analysis (PSA), a risk approach to assess a stock vulnerability to overfishing. It combines information about the productivity of a stock (biological information) with its susceptibility to fishing and other environmental and human factors (Patrick et al., 2009). This tool prioritizes the species that require additional research and status evaluation and establishes warning signs for specific stocks. However, the output of the analysis does not provide a quantitative management reference point.

Because this is a tool that requires substantial information to score the attributes, our analysis showed that only a third of our species (N=12) currently have enough or nearly enough Colombia-specific information for a PSA (Table 3). Despite this lack of information, one of the advantages of the PSA is that the information data-gaps can be filled with information from similar species. So the application of this tool in Colombia is possible, but it would require the use of life-history information from the same species, taken in other countries and fisheries (Punt, Smith, & Smith, 2011).

The second assessment is Catch-MSY (Table 9), a method to estimate the maximum sustainable yield (MSY) from catch data (Martell & Froese, 2013). This assessment provides preliminary estimates of MSY that can be potentially used in simple harvest control rules (HCR) for data-poor stocks. It uses a catch time series, the relative stock sizes at the beginning and end of the catch series, the resilience of the species analyzed and prior ranges of the maximum rate of the population (r), and the carrying capacity (k) (Martell & Froese, 2013). Catches over MSY can trigger a decision rule and the implementation of the management responses. In our analysis, we found that only 11 species have catch data and at least one of the biological parameters required for the assessment (Table 9). In the case of the chondrichthyes, this assessment is impossible to run because the official landing statistic does not report any of the sharks or rays information (AUNAP, 2017b).

Discussion

There is a lack of basic life-history characteristics of the species fished in the small-scale fisheries of the Colombian Pacific. The low amount of biological and ecological information of the species was evident in our research, and is not only creating knowledge gaps, but also preventing effective fisheries assessments and future management plans, to be based in the best available science. In our literature review, it was possible to see fisheries information scattered throughout the country, low amount of information published in peer-reviewed journals, and research and knowledge buried in “grey literature” (technical documents and undergraduate and graduate thesis) in the libraries and documentation centers of the country. The difficult and time-consuming access to this information can be increasing the disconnection between researchers, managers, scientist, and policymakers. This communication failure could be preventing the assessments and management processes to be based on solid science and updated information (Shanley & López, 2009). Given the data limitations in the country, Colombia should treasure all this information, stimulate the publication of results, and use this valuable information in the assessments of the small-scale fisheries.

The country does not have a fisheries assessments roadmap, or a set of biological characteristics that should be periodically assessed (IICA, 2011). The parameters that are normally studied are those that require low sampling costs (i.e., length and habitat), while parameters that required longer sampling periods, effort or specialized tools like fecundity, biomass, mortality or growth where less abundant and have less information. Our gap analysis also showed us that important commercial species in the country are probably being assessed and managed without knowing their basic biological and ecological characteristics. The omission of the species biology in assessments or management plans can lead to the overexploitation of important resources, as assumptions about the productivity of stocks can be overestimated (Dimarchopoulou et al., 2017). The assessment of life-history characteristics is a fundamental process that needs to be done and continually updated, to assess the risk of overfishing, provide a solid basis for management processes and prepare managers and fishermen for the challenges that climate change will bring (Chasqui et al., 2017).

To fill these knowledge gaps, collaborative processes between universities, NGOs and the National Fisheries Authority (AUNAP) are necessary. Universities and NGOs are already researching the species life-history, as we found out in our literature review, especially through undergraduate thesis and private projects. However, these processes are not normally connected to the fisheries assessment priorities (Cuello & Duarte, 2010), the results obtained are only useful for the fulfillment of the student requirements or the institutions interests, and in most cases, the information ends up as “grey literature”. Joined processes could use that information (Chasqui et al., 2017), combining the ongoing efforts of the observers that register the landings statistics, with complementary sampling process done by students or NGO's to assess the biological and ecological parameters of the species. With all the information integrated, the assessments will be science-based and will improve the data quality and quantity necessary to assess and monitor the status of the stocks.

Although Colombia is estimating some species' fishing indicators and optimum catch length (De la Hoz et al., 2017), this is not reflected in management strategies (AUNAP, 2017a). Even when some indicators are available, there are not enough monitoring, control and enforcement mechanisms to fulfill those indicators (Castellanos-Galindo & Zapata, 2019). Also, few species have the optimum catch length estimate, because the parameters necessary to calculate it are not available. De la Hoz et al. (2017) only reported the catch-length estimate of 13 species, although they were trying to monitor 67 stocks in the Colombian Pacific.

Given the limitations in the data, and the urgency to assess Colombia's fishing resources we are proposing that PSA can be an appropriate tool to be used in the country. Although the amount of information required can be high (Table 3), PSA is a flexible tool that in the absence of species-specific data, allows taking data and information from other species (Jason Cope et al., 2011). The country could start a fisheries assessment process with a PSA, to prioritize the most vulnerable species and start the collection of the life-history characteristics of this species. The prioritization will help to focus the research efforts and resources in few species at a time, allowing the collection of new information and the application of more complex data-poor assessment models.

The Catch-MSY model is also an excellent tool, and it provides a quantitative output that can be used directly in an HCR (Martell & Froese, 2013). Catch-MSY also has an online module provides easy access to the model and allows the user to pull information directly from FishBase (Froese & Pauly, 2017). The main problem with the application of this model in Colombia comes from the incomplete or non-existent species catch information. Due to the instability of the fisheries governmental agencies in the last 50 years, continuous datasets of landing statistics are rare in Colombia SSF (Cuello & Duarte, 2010). Also, SSF in the Colombia Pacific are highly used for subsistence, and most of that catch is not officially reported (Castellanos-Galindo & Zapata, 2019)**.** Therefore, we consider that this method can be used with caution and must account for the unreported and incomplete catch information.

In general, our results pointed out to a low level of assessment effort for important economic species in the SSF of the Colombian Pacific. We believe that the research of the basic life-history characteristics of the species should be encouraged, especially the parameters with low or no information, like maximum age, age at maturity or fecundity. Sharks and rays should be a priority to study because the knowledge gaps and lack of information are alarming for such susceptible species (Navia et al., 2009). Our research highlighted the usefulness of a gap analysis to assess the amount of information and knowledge status of the species, and as a first step to inform and guide the scientific community, government agencies, and stakeholders in the assessment processes. The higher the knowledge of the species, the better the biological and ecological basis in which the assessments and future management plans will be built (Dimarchopoulou et al., 2017).

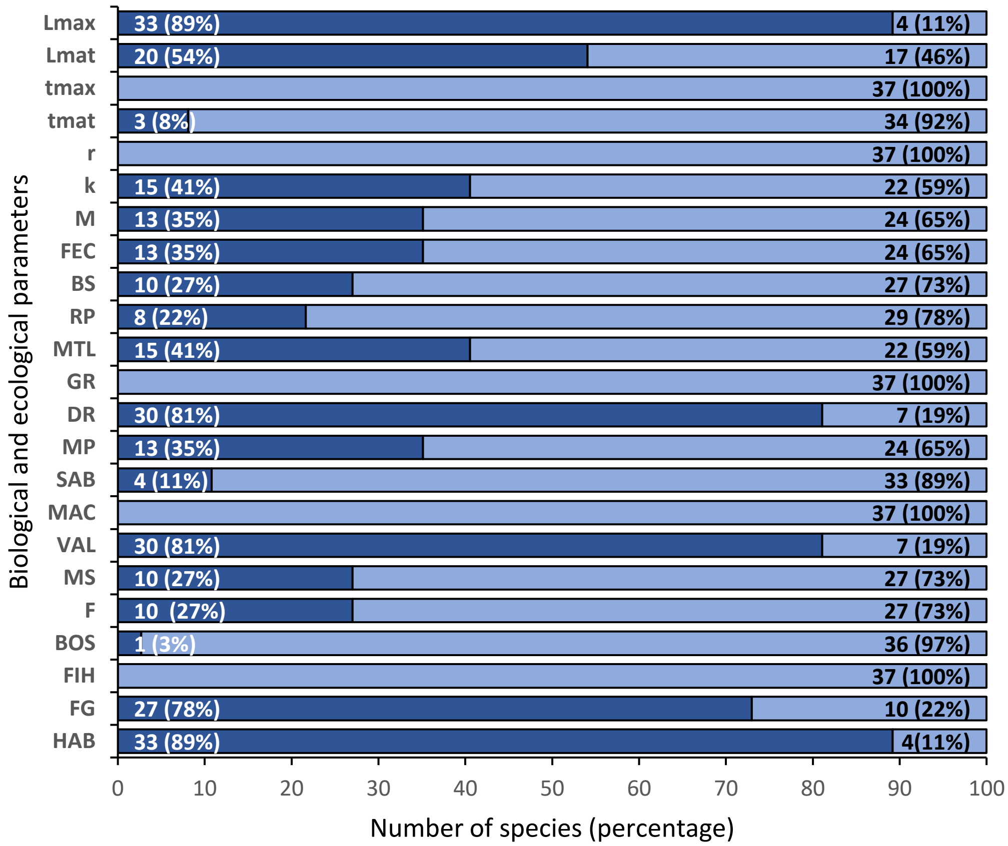

Figure 4. Percentage of fish species (N=37) with (dark blue) and without (light blue) information on each one of the biological parameters assessed. The biological parameters assessed are: Maximum length (Lmax), Length at maturity (Lmat), Maximum age (tmax), Age at Maturity (tmat), Population growth (r), von Bertalanffy growth coefficient (k), Mortality (M), Fecundity (FEC), Breeding Strategy (BS), Recruitment Pattern (RP), Mean Trophic Level (MTL), Geographic range (GR), Depth range (m) (DR), Migration Pattern (MP), Schooling, aggregation, and other behaviors (SAB), Morphology affecting capture (MAC), Desirability/Value of the fishery (VAL), Management Strategy (MS), Fishing mortality rate (F), Biomass of Spawners (BOS), Fishery impact in habitat (FIH), Fishing gear (FG), Type of association/Habitat (HAB).

Table 7. Species selected as commercially important for the small-scale fisheries of the Colombian Pacific, based on landings, economic value, and expert knowledge. The common name of the species is only displayed in Spanish.

Group	Species	Common name
Fishes	*Bagre pinnimaculatus*	Alguacil
Fishes	*Bagre panamensis*	Barbinche
Fishes	*Notarius troschelii*	Ñato
Fishes	*Caranx caninus*	Jurel
Fishes	*Caranx caballus*	Burique
Fishes	*Centropomus armatus*	Gualajo
Fishes	*Centropomus medius*	Machetajo
Fishes	*Coryphaena hippurus*	Dorado
Fishes	*Lobotes pacificus*	Berrugate
Fishes	*Lutjanus guttatus*	Pargo lunarejo
Fishes	*Lutjanus peru*	Pargo rojo
Fishes	*Lutjanus argentiventris*	Pargo coliamarillo
Fishes	*Mugil cephalus*	Lisa
Fishes	*Cynoponticus coniceps*	Zafiro
Fishes	*Brotula clarkae*	Merluza
Fishes	*Mycteroperca xenarcha*	Cherna
Fishes	*Cynoscion albus*	Corvina
Fishes	*Cynoscion phoxocephalus*	Pelada blanca
Fishes	*Macrodon mordax*	Pelada amarilla
Fishes	*Scomberomorus sierra*	Sierra
Fishes	*Thunnus albacares*	Atún aleta amarilla
Fishes	*Thunnus alalunga*	Atún albacora
Fishes	*Euthynnus lineatus*	Atún patiseca
Fishes	*Sphyraena ensis*	Picúa
Chondrichthyes	*Alopias pelagicus*	Tiburón zorro
Chondrichthyes	*Carcharhinus falciformis*	Tiburón sedoso/jaquetón
Chondrichthyes	*Carcharhinus limbatus*	Tiburón aletinegro
Chondrichthyes	*Prionace glauca*	Tiburón azul, Toyo aguado
Chondrichthyes	*Hypanus longus*	Raya látigo largo coluda
Chondrichthyes	*Hypanus dipterurus*	Raya latigo (cola corta)
Chondrichthyes	*Aetobatus narinari*	Raya pintada, Chucho
Chondrichthyes	*Rhinobatos leucorhynchus*	Raya guitarrilla (sin manchas)
Chondrichthyes	*Sphyrna lewini*	Cachuda, Tiburón martillo
Chondrichthyes	*Sphyrna media*	Cachuda gris
Chondrichthyes	*Sphyrna corona*	Cachuda amarilla
Chondrichthyes	*Mustelus lunulatus*	Toyo vieja
Chondrichthyes	*Mustelus henlei*	Toyo vieja

Table 8. Gap analysis results showing the assigned species' data-richness rank based on the cumulative scores of the three scorecard criteria for the 23 life history parameters: presence-absence, age of information, and source of the parameters. Species with a data quantity score less than 23 points were scored as "data-poor," species with scores between 23.5 and 46 were labelled "data-moderate". None of the species received a "data rich" score of 46.5 or greater (2/3 of the maximum 69 points).

Species	Common name	Presence - Absence	Age of information	Source	Total Parameter Score (out of 69)	Data-richness rank
Brotula clarkae	Merluza	14	11.5	5	30.5	Moderate
Carcharhinus falciformis	Tiburón sedoso/jaquetón	14	7.5	1	22.5	Poor
Coryphaena hippurus	Dorado	13	10.5	7	30.5	Moderate
Lutjanus guttatus	Pargo lunarejo	13	13	4	30	Moderate
Lutjanus peru	Pargo rojo	13	12.5	4	29.5	Moderate
Lobotes pacificus	Berrugate	13	12.5	1	26.5	Moderate
Cynoscion phoxocephalus	Pelada blanca	13	10.5	1	24.5	Moderate
Sphyrna lewini	Cachuda, Tiburón martillo	13	8.5	3	24.5	Moderate
Scomberomorus sierra	Sierra	12	11	3	26	Moderate
Centropomus armatus	Gualajo	12	10.5	1	23.5	Moderate
Mustelus lunulatus	Toyo vieja	11	10	5	26	Moderate
Mustelus henlei	Toyo vieja	10	8	1	19	Poor
Rhinobatos leucorhynchus	Raya guitarrilla (sin manchas)	9	8	7	24	Moderate
Hypanus longus	Raya látigo coluda	9	7.5	3	19.5	Poor
Bagre pinnimaculatus	Alguacil	9	8.5	1	18.5	Poor
Thunnus albacares	Atún aleta amarilla	8	7.5	2	17.5	Poor
Bagre panamensis	Barbinche	8	4.5	1	13.5	Poor
Cynoscion albus	Corvina	7	6.5	4	17.5	Poor
Lutjanus argentiventris	Pargo coliamarillo	7	4	5	16	Poor
Alopias pelagicus	Tiburón zorro	7	7	0	14	Poor
Mugil cephalus	Lisa	7	2.5	1	10.5	Poor
Carcharhinus limbatus	Tiburón aletinegro	6	5.5	2	13.5	Poor
Aetobatus narinari	Raya pintada, Chucho	6	5	2	13	Poor
Sphyraena ensis	Picúa	6	4	2	12	Poor
Caranx caninus	Jurel	5	4	2	11	Poor
Hypanus dipterurus	Raya latigo (cola corta)	5	4	2	11	Poor
Sphyrna corona	Cachuda amarilla	5	4	2	11	Poor
Euthynnus lineatus	Atún patiseca	5	3.5	2	10.5	Poor
Mycteroperca xenarcha	Cherna	4	3.5	2	9.5	Poor
Caranx caballus	Burique	4	3	2	9	Poor
Cynoponticus coniceps	Zafiro	4	2	3	9	Poor
Notarius troschelii	Ñato	4	2.5	2	8.5	Poor
Macrodon mordax	Pelada amarilla	4	3.5	1	8.5	Poor

Table 8 (Continued)

Sphyrna media	Cachuda gris	4	4	0	8	Poor
Prionace glauca	Tiburón azul, Toyo aguado	4	3	0	7	Poor
Centropomus medius	Machetajo	3	2	0	5	Poor
Thunnus alalunga	Atún albacora	1	1	0	2	Poor

Table 9.Amount of information required to complete the current (L_{opt}) and proposed (PSA and CATCH-MSY) assessment tools for Colombia Pacific species. L_{opt}: optimum length, PSA: Productivity and susceptibility Analysis, CATCH-MSY: maximum sustainable yield from catch data. Grey shades indicate the relative amount of required information: Darkest grey: High amount of information needed, dark grey: High-moderate amount of information needed, light grey: Moderate amount of information needed, lightest grey: Low amount of information needed, Blank spaces indicate that the indicator already exists for the species

Species	Common name	L_{opt} indicator	PSA	CATCH-MSY
Bagre pinnimaculatus	Alguacil			
Bagre panamensis	Barbinche			
Notarius troschelii	Ñato			
Caranx caninus	Jurel			
Caranx caballus	Burique			
Centropomus armatus	Gualajo			
Centropomus medius	Machetajo			
Coryphaena hippurus	Dorado			
Lobotes pacificus	Berrugate			
Lutjanus guttatus	Pargo lunarejo			
Lutjanus peru	Pargo rojo			
Lutjanus argentiventris	Pargo coliamarillo			
Mugil cephalus	Lisa			
Cynoponticus coniceps	Zafiro			
Brotula clarkae	Merluza			
Mycteroperca xenarcha	Cherna			
Cynoscion albus	Corvina			
Cynoscion phoxocephalus	Pelada blanca			
Macrodon mordax	Pelada amarilla			
Scomberomorus sierra	Sierra			
Thunnus albacares	Atún aleta amarilla			
Thunnus alalunga	Atún albacora			
Euthynnus lineatus	Atún patiseca			
Sphyraena ensis	Picúa			
Alopias pelagicus	Tiburón zorro			
Carcharhinus falciformis	Tiburón sedoso/jaquetón			
Carcharhinus limbatus	Tiburón aletinegro			
Prionace glauca	Tiburón azul, Toyo aguado			
Hypanus longus	Raya látigo largo coluda			
Hypanus dipterurus	Raya latigo (cola corta)			
Aetobatus narinari	Raya pintada, Chucho			
Rhinobatos leucorhynchus	Raya guitarrilla (sin manchas)			

Table 9 (Continued)

Sphyrna lewini	Cachuda, Tiburón martillo			
Sphyrna media	Cachuda gris			
Sphyrna corona	Cachuda amarilla			
Mustelus lunulatus	Toyo vieja			
Mustelus henlei	Toyo vieja			

Chapter 4— Combining scientific and local knowledge to estimate vulnerability of data-poor stocks in the southern Colombian Pacific

Abstract

Developing countries are often limited in their capacity to assess small-scale fisheries, and it is unlikely these fisheries will ever have the resources to develop complete stock assessments for these fisheries. Researchers have developed a number of models that require fewer data and that utilize the information available. However, for data-poor fisheries, even those models can require an excessive amount of information. We introduce a modified Productivity and Susceptibility Analysis (PSA) that integrates scientific knowledge with information from local fishermen to overcome the lack of data. We assessed the vulnerability to overfishing of 15 local stocks in the southern Colombian Pacific and used surveys to elicit local fishermen knowledge in 12 communities. We found a general lack of life history information for the species, necessary to assess the productivity of the stocks. We increased the number of susceptibility parameters to reflect the local conditions of the study area and scored those through the knowledge provided by the fishermen. All the species assessed got high susceptibility values and we prioritized Ambulú (*Hyporthodus acanthistius*), Alguacil (*Bagre pinnimaculatus*) and Cubo (*Caulolatilus affinis*) as vulnerable to overfishing. Our modified approach to the PSA, allowed us to tailor the PSA to local conditions, integrate local fishermen knowledge, apply it to the specific conditions of the study area, and prioritize vulnerable species in a previously unassessed fishery.

Introduction

Worldwide, small-scale fisheries (SSF) contribute to the livelihoods of over five hundred million people and employ over 90% of the people that gain their livelihood through fishing activities (Béné et al., 2007; WorldBank, 2012). These fisheries are found predominantly in countries with low economic support for research and in communities that strongly rely on fishing for income and food security (Fujita et al., 2013; Honey et al., 2010). It is unlikely these fisheries will ever have funds, scientific knowledge or data to develop a complete quantitative stock assessment (Prince, 2010). However, to achieve sustainable livelihoods and maintain ecosystem services, it is a priority to assess and manage SSF in both developed and developing countries (Berkson & Thorson, 2015; Jacquet & Pauly, 2008).

Data-poor models

Recently, a number of modeling methods have been developed to assess fisheries with little data, that require less data than a traditional stock assessment, and often utilize the most basic fisheries information available. These methods allow managers to prioritize fisheries for research or management action, establish fishing limits, and estimate biomass levels for fisheries where complete stock assessments are infeasible (Honey et al., 2010). One technique for prioritizing that incorporates biology, and direct and indirect effects of fishing is the Productivity and Susceptibility Analysis, which aims to provide a biological basis for the vulnerability of a stock to fisheries impacts (Milton 2001).

The PSA prioritizes the species that require additional research and status evaluation by comparing vulnerability scores for a number of species that are fished commercially, recreationally, or both (Patrick et al., 2010). This method not only establishes warning signs for specific stocks but also allows integration of scientific and local knowledge as the basis of the model. This attribute is essential in data-poor fisheries, especially for developing countries where the knowledge of local fishermen might be the only reliable source of information available on the history and status of a fishery (Barnes-Mauthe et al., 2013; Fujita et al., 2013; Mackinson et al., 2011).

Local knowledge

We define local knowledge as the type of knowledge that is location specific. It is based in the interaction between humans and the environment, can contain historic information, but it is also dynamic in time, and can reflect the modern changes occurring in culture and environment (Berkes, 1999; Drew, 2005). The inclusion of local knowledge in ecological sciences has been a long and difficult process because it requires the integration of two different disciplines. Disciplines with different languages, origins, approaches to science and objectives (Drew & Henne, 2006; Strang, 2009). This has created the challenge of create bridges between the social and natural sciences and translate the methods and tools to make those accessible and understandable to both sides (Strang, 2009).

In the context of fisheries, for more than a decade, marine researchers and resource managers have known that local knowledge can provide critical information in the assessment and management of the local resources (Johannes, 2000). Fishermen, because of their daily activity, have a deep knowledge of the ecological, biological and environmental processes that surround the fishing activity. This accumulated knowledge is an invaluable source of information, especially in small-scale and in data-poor fisheries, it can be the only source of information on the history of the stocks, the fishery, and the changes in the local ecosystems (Haggan, Neis, & Baird, 2007; Johannes, 2000). Local knowledge has been integrated into different studies as a baseline of the ecology, biology, and behavior of local species or location-specific knowledge. In remote areas, or data-poor fisheries communities, fishermen have been able to help with local characteristics of the fisheries or the stocks, information about the presence of species, habitats preferences, spawning aggregations, migration patterns, and, in general, biology and ecology of the species (Drew, 2005; Fischer et al., 2015).

Local fishermen knowledge can be complementary to the scientific knowledge, and the integration of social and natural science methodologies can identify temporal changes in population structure and historical abundance trends (Ames, 2006; Beaudreau & Levin, 2014; Bevilacqua et al., 2016; Close & Hall, 2006; Mackinson, 2001).

Colombia

Colombia is a country where local knowledge has been undervalued in management plans and scientific studies in general, and where the management strategies have been focused on command and control approaches, ignoring local fishermen knowledge to develop medium and long-term analyses (Cuello & Duarte, 2010). Saavedra-Díaz et al. (2015)

explored the differences of social perceptions of problems and conflicts in SSF in Colombia among different stakeholders (fishermen, local leaders, and fishing experts), and offered some insights for the management of SSF on both the Caribbean and Pacific coasts in Colombia. The study highlighted the need to incorporate knowledge from different fishing stakeholders because their perceptions of the problems differ in scale: fisheries experts or scientists detected problems at a national scale, while local leaders and fishermen detected problems at a local scale. Combining sources of information will create a powerful tool for fisheries management with an integrative understanding of the different fisheries stakeholders, with knowledge of the circumstances at different scales, as well as an involvement of the fisheries communities in the assessment process (Cuello & Duarte, 2010; Saavedra-Díaz et al., 2015).

By recognizing the importance of including local knowledge in the assessment and management of fisheries, we can improve the quantity and quality of the data, and ultimately the management of the fishery (Hill et al., 2010; Mackinson et al., 2011). The fishermen will be immersed in the process and may be more willing to implement any required changes, being part of the assessments and monitoring processes and contributing to the long-term success of management plans (Hill et al., 2010; Mackinson et al., 2011).

In this paper, we elicit and integrate scientific and local fishermen knowledge in a vulnerability assessment through a proposed modification of a Productivity and Susceptibility Analysis. Our method links biological information on the productivity of 15 nearshore stocks with local expertise on susceptibility to fishing and other stressors. We aim to provide a first-cut analysis for small-scale fisheries on the Pacific coast of Colombia and to illustrate the value of tailoring the general PSA approach to local conditions.

Methods

We modified the PSA as described by Patrick et al. (2009) by integrating local fishermen knowledge into the vulnerability assessment. We also changed the amount of productivity and susceptibility attributes to reflect the local conditions of the study area. We assessed the vulnerability of overfishing of 15 species (Table 10) captured in the southern region of the Colombian Pacific (Figure 5) and prioritized the species with the highest vulnerabilities to overfishing. With the collaboration of the Community Council Bajo Mira y Frontera, we visited 12 communities covered by the Council structure and collected some of the information necessary to complete the PSA (Figure 5).

The PSA helps to prioritize species by assessing their vulnerability (V) to overfishing. That vulnerability is explained by two components, the Productivity (P) of the stocks, or life history of the species, and the Susceptibility (S), or the interaction between the fishery and the stocks. The productivity and the susceptibility are composed of a certain number of attributes, which are scored individually and then averaged to obtain a unique value for the productivity and one for the susceptibility. Below we explain in detail each one of the attributes, where the information came from and how they were scored.

Productivity attributes

The PSA method developed in this research contains modifications from the one described by Patrick et al. (2009). We reduced the productivity attributes from 10 to 9 (Table 11), to adapt the PSA to the available information. First, we removed two attributes, intrinsic growth rate (r) and maximum age, due to a lack of information, following the conclusions of Duffy and Griffiths (2017). They analyzed the redundancy of some of the productivity attributes and recommended, that the removal of those did not have an impact on the overall vulnerability due to the correlation between some of the variables. Next, we included length at maturity as one of the attributes defining the productivity of the species (Micheli et al. 2014) considering that in extreme data-poor situations, any available information is valuable.

The productivity attributes information was collected entirely from the scientific literature. We reviewed peer-review journals, technical reports, and grey literature, looking for the life-history information of the selected 15 species in the Colombian Pacific. Because these are data-poor species, much of the information was absent, so we extended our search to include data for the same species or genus in other countries.

After we collected all the information for the productivity attributes, we followed the PSA methodology and scored the information according to the scoring bins (1 to 3 scale) developed by Patrick et al. (2009) (Table 11). The maximum length ranking bins were modified to reflect the biological characteristics of tropical fishes following the ranks of Micheli et al. (2014). After we obtained the scores, all the productivity attributes were averaged to obtain one productivity attribute value per species.

Productivity quality index

The PSA uses a data quality index to acknowledge for uncertainty. This analysis was done separately from the PSA to keep the quality of the data out of the vulnerability analysis of the species. In our approach, we used two different scales to assess the quality of the productivity and the susceptibility attributes. For the productivity attributes we followed a scale of five tiers, ranging from the best available information to no-data or low-quality information as follows:

1. Information about the species collected in the Colombian Pacific
2. Information about the species collected in close countries
3. Information about the same genus of the original species, collected in the Colombian Pacific
4. Information about the same genus of the original species, collected in other countries
5. No data

The quality scores were averaged per species to obtain a single value per species and combined it with the susceptibility data quality.

Susceptibility attributes

Previous applications of the PSA have relied on scientific expert knowledge to score the susceptibility attributes of the analysis (Jason Cope et al., 2011; Patrick et al., 2010). In this paper, we introduced local fishermen knowledge as the exclusive source of information to assess these attributes. To elicit the necessary information, we developed a questionnaire and conducted surveys in the 12 communities visited in the Colombian Pacific (Figure 5). The surveys contained 22 questions and aimed to collect the necessary information to score the susceptibility attributes of the PSA (Appendix H). For our visits to the communities we always had the company of a Community Council member, and on each place, we were received by the local leader on that community. According to the dynamics of each place, our approach to the fishermen was different. In some of the places (i.e., the community Milagros), we waited by the shore and interviewed each fisher as they were arriving, and while they were processing the capture of the day. In other communities as Bajito Vaquería or Teherán, the fishers were already at home and it was possible to go from home to home interviewing them.

Because we were aiming to adapt the PSA to the local conditions, we removed some of the susceptibility attributes, due to a lack of information or because the attributes were impossible to estimate from fishermen knowledge alone. We included some new ones to improve the detail of the local susceptibility attributes (Table 12) (Patrick et al. 2009). The removed attributes were areal and vertical overlap, fishing mortality, the biomass of spawners and survival after capture and release. The new attributes were maximum catch depth, other impacts on habitats and other fisheries impacts on small-scale fisheries (Table 12).

Most of the questions in the survey had a three options answer, corresponding to the scoring bins of the PSA (Table 12). These bins allowed us to transform the fishermen information into a 1 to 3 scale (Table 12,Appendix I), to later combined it with the productivity information. All the susceptibility attributes were averaged to obtain a single productivity attribute per species (Patrick et al., 2010).

Susceptibility quality index

The data-quality for the susceptibility attributes was assessed based on the number of surveys per species and the years of experience of the fishermen that provided information for that particular species. This also followed a five-tier scale, from the best information to no-data with ranges for each tier binned according to the range of data collected, as follows:

Years of fishing experience:

1. More than 20 years of experience
2. Between 10 to 20 years of experience
3. Between 5 to 10 years of experience
4. Less than 5 years of experience
5. No data

Number of surveys

1. Between 55 and 69 surveys
2. Between 40 and 54 surveys
3. Between 25 and 39 surveys
4. Between 12 and 26 surveys
5. No data

The scores obtained from the years of fishing experience and the number of surveys were averaged, and a single value of data-quality was obtained for each species.

The quality scores for productivity and susceptibility were averaged and plotted with the PSA results in a bubble plot. The size of the bubbles indicates the quality of the information and the change in the results' reliability, with larger bubbles indicating less reliability.

Consistency of the fishermen information.

To analyze the variability of the information provided by the fishermen, we assessed the consistency of the fishermen answers to our questionnaire. We calculated the percentage of fishermen who used the same answer per attribute and species and created a color-coded table to analyze the variability of their answers. The attributes in which more than 75% of fishermen answered the same, were considered highly consistent.

Vulnerability analysis

The vulnerability of the species was calculated with the final mean value of productivity and susceptibility of each one of the species. These values were displayed in an XY plot, and the vulnerability was calculated as the Euclidean distance from the origin of the plot (Patrick et al., 2009). None of the attributes were weighted, as described in the original methodology because the definition of an individual attribute weight might be increasing the subjectivity of the tool (Duffy and Griffiths 2017).

Results

Productivity, susceptibility, and vulnerability

Local information of the life history characteristics of the 15 species that inhabit the Colombian Pacific was lacking and the search for the information was extended to other countries, and other species from the same genus in Colombia and other countries. The absence of data influenced the data quality index, but not the vulnerability assessment. Even with the extended search some of the attributes were left blank because it was not possible to find information to score them.

We collected information from 113 fishermen in the 12 communities of the Colombian Pacific. 80% of the fishermen were between 25 and 64 years old, 71% have lived in the same area for most of their lives, and 72% of them have more than 20 years of experience. When we asked them to assess their expertise, 60% considered to have very high expertise and 24% high expertise.

The survey design allowed fishermen to give us the information from the species they chose. From the 113 surveys, we collected susceptibility information for 69 species. Of those, 23 species got more than ten surveys and were the selected ones for the PSA. After the review done to collect the productivity information, only 15 species had enough data to be included in the final analysis.

Alguacil, Ambulú, and Cubo were the species with the lowest productivities (<2), and Gualajo, Machetajo, Pelada, and Pelada Blanca had the highest productivities (>2.5) among all the species. All the species got a medium-high susceptibility between 2.2 and 2.4 (Figure 6). The highest vulnerability was for Ambulú, followed by the Alguacil and Cubo (Table 13). Even though these three species are prioritized as the most vulnerable, it is important to acknowledge the high susceptibility of all the species (Figure 6).

Data quality index

Most of the productivity and susceptibility parameters obtained a moderate data-quality index (2.0–3.5). On the productivity parameters, only the Sierra (*Scomberomorus sierra*) obtained a high-quality index value (<2), while Pelada (*Macrodon mordax*) scored the lowest quality of information among all the species (>3.5) (Table 13). On the susceptibility parameters, none of the species obtained a low-quality index, due to our tailored approach that includes the number of surveys and the experience of the survey respondents. Lisa (*Mugil cephalus*) and Pargo (*Lutjanus spp.*) scored a high-quality value (Table 13, Figure 7).

When plotted, the size of the bubbles reflects the uncertainty of the information, according to the quality of the data used to score the parameters (Figure 7). In our case, Pargo (*Lutjanus spp.*) obtained the highest quality of information because we did not assess a species but the genus. This was a particular case because how the fishermen provided the information. For them, it is more important the size of the snappers (pargos) captured than the species. Snappers, the size of a plate (pargo platero), are more valuable than the biggest ones, so they do not differentiate between the species. The information used to assess the productivity of this group was taken from different species of snappers commonly fished in the study area. Although most of the species showed a moderate-quality value, it is important to collect more information about the species to reduce the uncertainty of the scores.

Consistency of the fishermen information

We found that in 60% of the attributes, at least 75% of the fishermen answered the same. Most of the attributes had a high consistency in the fishermen answers and only in 4 attributes we found a low consistency of the answers (Table 14). Geographic concentration was the attribute with the lowest consistency for most of the species. In several cases, the fishermen were divided between the three ranks of the attributes assessments (Table 12) or were divided into the two extremes of the ranking.

Discussion

Our adaptation of the PSA provides the first attempt to assess and prioritize the data-poor fisheries in the Colombian Pacific, integrating local fishermen knowledge into the risk assessment and making it specific to the conditions of the study area. Our approach allows the assessment of stocks with little or none-susceptibility information, especially in cases in which scientific expertise is difficult or impossible to get. Like any other risk assessment, this approach only shows the potential vulnerability of the species, but it leaves an open the door to include more accurate and better-quality information when it becomes available.

The productivity analysis highlighted the lack of life-history information and basic biology and ecology data in the country, and it should be an urgent priority that needs to be managed to obtain better estimates of the species' status. In the last 20 years, the instability of the fisheries governmental agencies in charge has hindered fisheries management efforts in Colombia. The country has had five different fishing authorities in that time frame (Rueda et al., 2011; Wielgus et al., 2010; Zapata et al., 2013), generating a dispersion of the fishery information, knowledge gaps, inconsistencies, and reduction of the fisheries research in the country (Rueda et al., 2011; Saavedra-Díaz et al., 2015; Wielgus et al., 2010). These challenges prevented rigorous consistency in sampling, monitoring, and analysis of fishing information and made continuous datasets of landing statistics or complete stock assessments, rare in Colombia SSF (Cuello & Duarte, 2010).

The PSA is designed to score fisheries with a limited amount of information, and the lack of a fine resolution is compensated by the scoring process that uses bins and not specific estimates (Jason Cope et al., 2011). The general moderate quality of the information, despite the lack of detailed productivity information confirms that the PSA approach could be applied in a broad spectrum of data-poor fisheries, due to the inherent flexibility of the method and relatively inexpensive costs, especially those with similar conditions, in developing countries and with a general lack of information.

The integration of local knowledge also opens a new window of spatial and temporal information, that in many cases can be impossible for scientists to assess. Saavedra-Díaz et al. 2015 discussed that in the Colombian Pacific, perceptions between fishermen, stakeholders and managers changed in scale. Fishermen think on a local scale, while managers and scientist think in a more national or broader scale. Our Productivity and Susceptibility Analysis results, integrating local knowledge, highlighted the species' vulnerability at a local scale. These values could change if scientists or managers conducted the analysis without the knowledge and the specifics of the study area. As an example, the new attribute we included in the susceptibility assessment, impacts on the habitat of the species, revealed the dramatic impacts produced by the 2015 oil spill in the Tumaco area. Of 113 fishermen surveyed, 85 stated that the oil is affecting the fisheries in a daily-basis, decreasing the number of fishes, displacing the fishes from the area or damaging their gear. Without that new attribute or with just a scientific expert knowledge assessment, it would have been difficult to obtain that level of specificity in the assessment, and the susceptibility estimations would not have included that important impact.

Previous research (Close & Hall, 2006; O'Donnell, Pajaro, & Vincent, 2010) has shown successful examples of the integration of local knowledge and scientific research, in GIS knowledge mapping or historical declines in CPUE of the species. Local fishermen knowledge is an excellent tool since they have a regular and mostly uninterrupted relation with the local stocks, and the processes that are influencing it (Bevilacqua et al., 2016; Hill et al., 2010; Lima et al., 2017). While scientific research only has a limited temporal and spatial window of information, and the local characteristics of the stocks can be missed or overseen.

The design of the questionnaire also allowed us to have a structured method to elicit local information and reduce the subjectivity of the PSA. Cope et al. (2011) discussed the high subjectivity of the PSA method, especially the scoring of the susceptibility attributes. Having a questionnaire with closed questions, that match the 1 to 3 scale of the attributes, allowed us to decrease part of that subjectivity and quantified and scored the fishermen knowledge. The modification of the data-quality index, to separately assess the productivity and the susceptibility parameters, also reflected a high quality of the susceptibility parameters. This higher data-quality helped to raise the average of the productivity parameters and in general increase the reliability of the results.

Our questionnaire also offered a glimpse of the future local management strategies that could be established to improve the fisheries. Within the survey (Appendix H), although it was not included in the PSA, we asked the fishermen if there were any fishery regulations they would like to see, or they think they fishery needs. Some of the recommended actions or management needs included the control of certain gear types, delimitation of an exclusive artisanal fisheries area, such as the ZEPA (Artisanal fisheries exclusive zone, in Spanish) system used along the Northern Colombian Pacific coast, control of international boats illegally fishing in the area, closed seasons, local fishing collection centers with fair prices, among others.

The benefits of integrating local knowledge into assessment and management processes have been evident for some years. As well as the devastating consequences that occur when local knowledge of fishermen is ignored in those processes (Johannes, 2000). We integrated locally-relevant information in a data-poor situation, and prioritized species that required an urgent assessment or management. Although extremely valuable, local knowledge must be managed with care. On the one hand, elicitation of local knowledge cannot be an extractive activity, in which the only benefits go to science, but it requires a long-term collaboration and the empowerment of the communities (Drew, 2005; Stephenson et al., 2016). Increased participation, increases transparency of the cooperation and of the results.

The use of local knowledge has traditionally been perceived as biased or as a low-quality source of information, and therefore less reliable, because fishermen do not sample their environments in ways that conform to scientific methods (Stephenson et al., 2016). However, local knowledge can be used as any other source of information if it has been collected and processed with a systematic approach that aims to reduce the sources of bias and errors. These potential problems can be controlled and reduced, and the benefits of the integration of local knowledge will outweigh the possible problems (Stephenson et al., 2016). In this research, our estimation of consistency allowed us to have an idea of how reliable was the information provided by the fishermen. However, future research could use validation tools to increase the reliability of the information and objectively screen the data for quality. We reduced participant bias and errors, with personalized surveys with the company of a local leader with interest in the project and knowledge of the community. And to reduce the researcher bias, most of the questions we used in the questionnaire were closed, and we pre-tested it with local fishermen leaders and fisheries scientists (Trochim & Donnelly, 2008).

Direct comparisons with previous PSAs from other parts of the world are not possible because the changes we made to the methodology to tailor the analysis for Colombian small-scale fisheries. The use of the PSA in the Colombian small-scale fisheries could be an excellent strategy to assess the vulnerability of the species and prioritize stocks for research and management at a local scale. The prioritization of species can help to focus funds and research in few species at a time and improve the use of the resources in the local assessment and management processes. Future research using our approach could combine local and scientific knowledge to obtain a more robust analysis. More and better life history information of the species is needed for a more accurate assessment. The local knowledge of fishermen, acquired by fishers during their fishing trips or life experience, verified and complemented with scientific data, can be an excellent alternative to assess local Colombian SSF (Cuello & Duarte, 2010; Saavedra-Díaz et al., 2015).

Figure 5. Southern region of the Colombian Pacific with the location of the 12 communities visited to elicit local fishermen information (N=113).

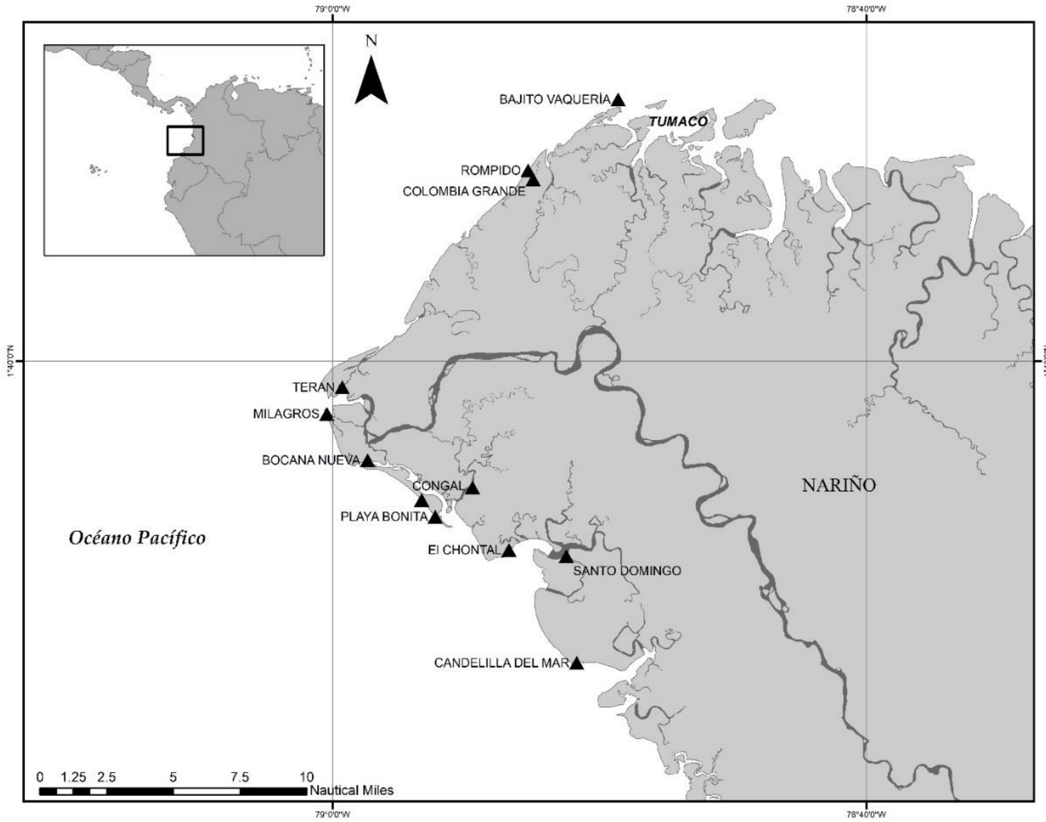

Figure 6. Productivity and susceptibility analysis plot of the 15-fish species assessed in the Colombian Pacific. Change in color shows the vulnerability of the species, from green (Low vulnerability) to red (High vulnerability). Note that the productivity axis is reversed to show a descending productivity. Refer to Table 10 for the ID of the species.

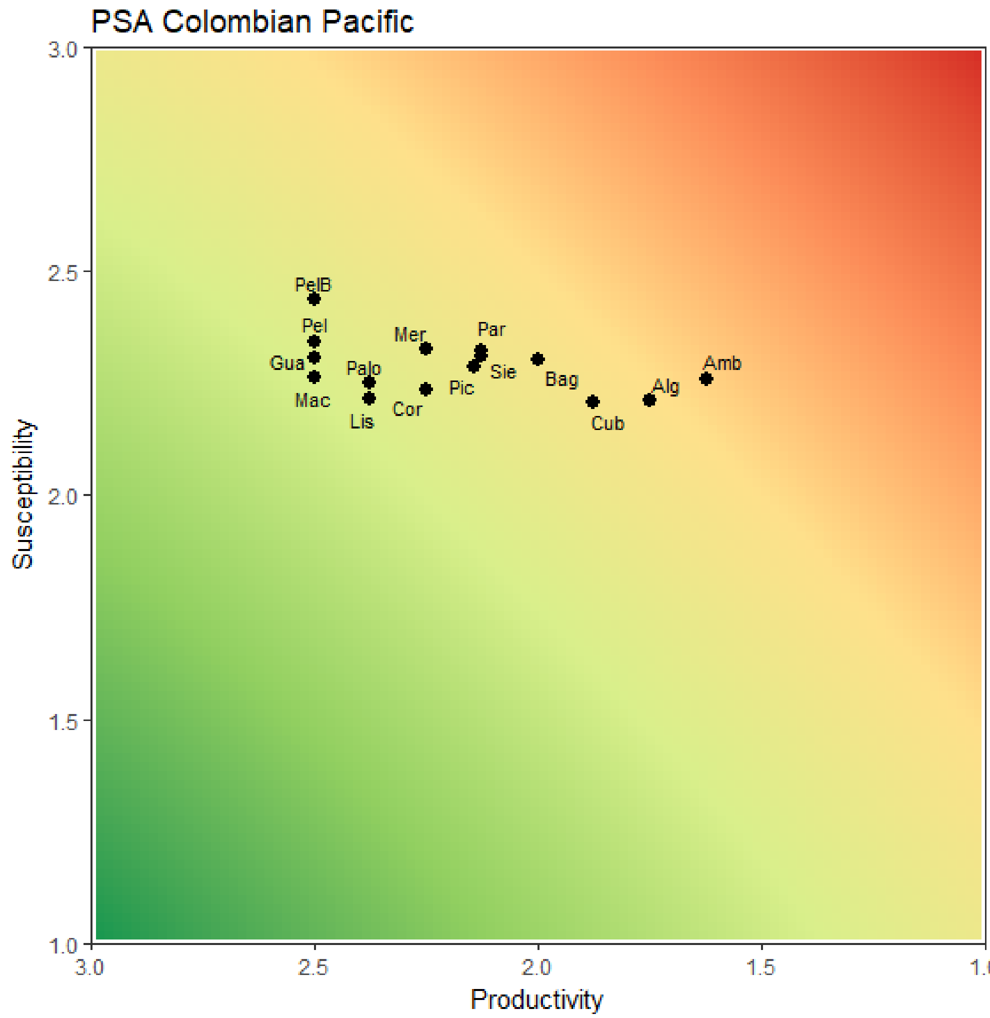

Figure 7. Data-quality index plot for the 15-species assessed in the Colombian Pacific. The size of the bubbles indicates the average quality of the data used to assess the species. The larger the bubble, the lowest the quality of the information. Refer to Table 10 for the ID of the species.

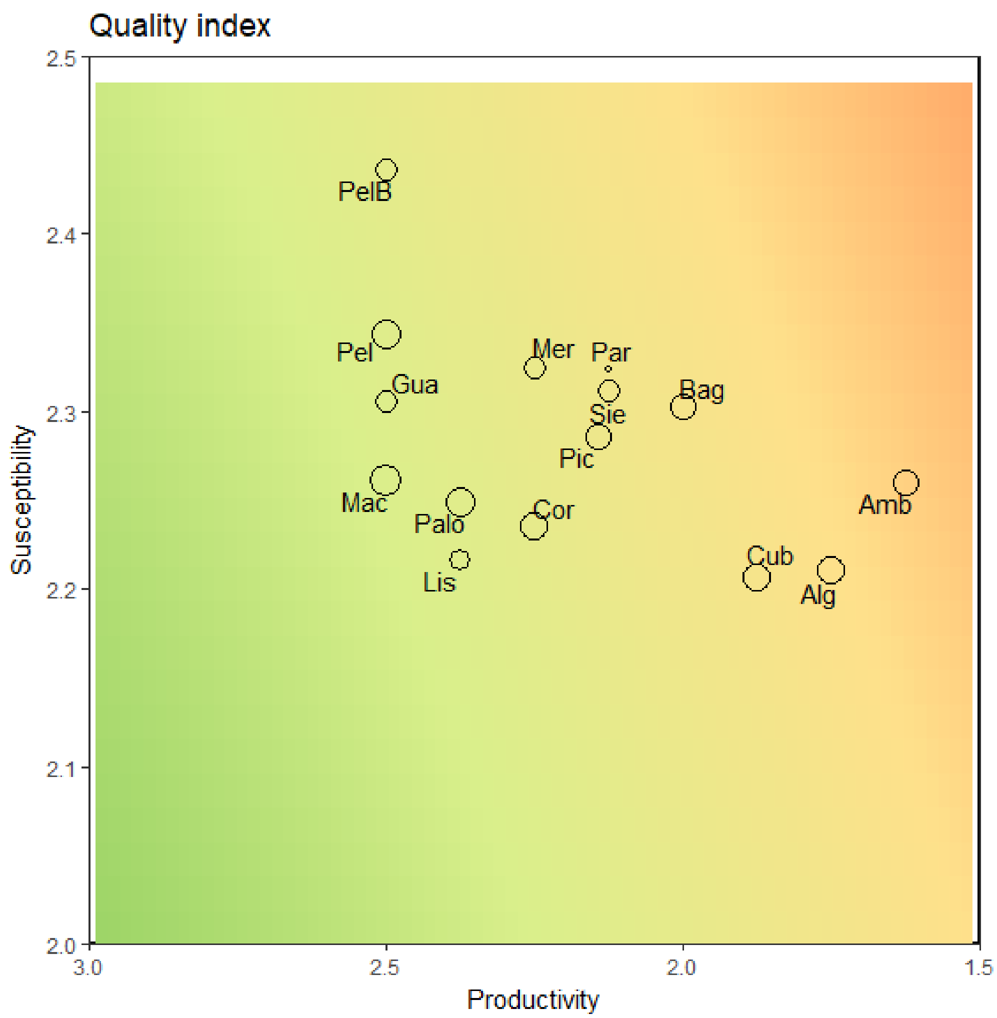

Table 10. Species captured in the southern region of the Colombian Pacific and analyzed with the Productivity and Susceptibility Analysis (PSA). The common names in Spanish will be used through the document, and the IDs are the short names used to display the results.

SPANISH COMMON NAME	ENGLISH COMMON NAME	ID	FAMILY	SPECIES
Alguacil	Red sea catfish	Alg	Ariidae	*Bagre pinnimaculatus*
Ambulú / cherna roja	Rooster hind	Amb	Serranidae	*Hyporthodus acanthistius*
Bagre	Chilhuil sea catfish	Bag	Ariidae	*Bagre panamensis*
Corvina de altura	Whitefin weakfish	Cor	Sciaenidae	*Cynoscion albus*
Pelada blanca	Cachema weakfish	PelB	Sciaenidae	*Cynoscion phoxocephalus*
Cubo	Bighead tilefish	Cub	Malacanthidae	Caulolatilus affinis
Gualajo	Armed snook	Gua	Centropomidae	*Centropomus armatus*
Lisa	Flathead grey mullet	Lis	Mugilidae	*Mugil cephalus*
Machetajo	Blackfin snook	Mac	Centropomidae	*Centropomus medius*
Merluza	Pacific bearded brotula	Mer	Ophidiidae	*Brotula clarkae*
Palometa	Peruvian mojarra	Palo	Gerreidae	*Diapterus peruvianus*
Pargo	Snapper	Par	Lutjanidae	*Lutjanus spp.*
Pelada	Dogteeth weakfish	Pel	Sciaenidae	*Macrodon mordax*
Picuda	Mexican barracuda	Pic	Sphyraenidae	*Sphyraena ensis*
Sierra	Pacific sierra	Sie	Scombridae	*Scomberomorus sierra*

Table 11. Productivity attributes and scoring thresholds used in the PSA. The maximum length thresholds changed following Micheli et al. (2014) to reflect the biological characteristics of tropical fishes. Note that the ranking goes from a high productivity =3 (meaning less risk) to low productivity =1 (meaning high risk). The description of each one of the attributes and the ranking determination can be found in Patrick et al. (2009). Breeding strategy is defined as an indication of the level of mortality that may be expected for the offspring in the first stages of life. It is estimated with the index of parental investment that scores the placement of larvae or zygotes, the length of time of parental protection of zygotes or larvae, and the length of gestation period or nutritional contribution (score ranges from 0 to 8).

	Ranking		
Productivity attributes	High (3)	Moderate (2)	Low (1)
Maximum length	< 40 cm	40 - 80 cm	> 80 cm
von Bertalanffy Growth coefficient (k)	>0.25	0.15-0.25	< 0.15
Natural Mortality (M)	> 0.40	0.20 - 0.40	< 0.20
Fecundity	$\geq 10^4$	10^2 to 10^4	$\leq 10^2$
Breeding Strategy	0	Between 1 and 3	≥4
Recruitment Pattern	Highly frequent recruitment success (> 75% of year classes are successful)	Moderately frequent recruitment success (between 10% and 75% of year classes are successful)	Infrequent recruitment success (<10% of year classes are successful)
Age at Maturity	< 2 years	2-4 years	> 4 years
Length at Maturity	>100 cm	40-100 cm	<40 cm
Mean Trophic Level	<2.5	Between 2.5 and 3.5	>3.5

Table 12. Susceptibility attributes and scoring thresholds used in the PSA. The number of attributes was increased to reflect local impacts of the stocks and interactions between the fisheries and the species. The value of the fishery is expressed in the local currency, Colombian pesos (COP), approximately US$1 equals COP$2800. Note that the scale goes from a low susceptibility =1 (meaning less risk) to a high susceptibility =3 (meaning high risk).

Susceptibility attributes	Ranking		
	Low (1)	Moderate (2)	High (3)
Local Management Strategy	Targeted stocks have catch limits and proactive accountability measures; non-target stocks closely monitored	Targeted stocks have local and self-imposed management strategies	Targeted stocks do not have catch limits or accountability measures; non-target stocks are not closely monitored
Geographic concentration	Widely spread across the area	Found in half of the area	Concentrated in small parts of the area
Temporal concentration	Can rarely be found throughout the year	Can be found a few months of the year	Can be found throughout the year
Maximum catch depth	More than 60 fathoms	Within 31 and 60 fathoms	Less than 30 fathoms
Catchability	Caught incidentally	Caught incidentally, usually kept and/or sold.	Fish is usually targeted
Morphology or behavior affecting capture	The catch is more difficult because of fish shape or behavior	The catch is not affected by fish shape or behavior	The catch is easier because of fish shape or behavior
Desirability/value of the fishery	Not highly valued less than COP$5000/kg	Moderately valued: COP $5001-10000/kg.	Highly valued: more than COP $10000/kg
Fishery impact on habitat	No habitat impacts	Limited habitat impacts	High habitat impacts
Other impacts on habitat	No habitat impacts	Limited habitat impacts	High habitat impacts
Other fisheries impact on small-scale fisheries	No impacts from other fisheries	Yes, limited impacts from other fisheries	Yes, high negative impacts from other fisheries

Table 13. Overall scores of the Productivity and Susceptibility Analysis for the 15-species assessed in the Colombian Pacific. P = Productivity score, PQS = Productivity quality score, S = Susceptibility score, SQS = Susceptibility Quality Score, V = Vulnerability score. The assessed species are Alguacil (Alg), Ambulú (Amb), Bagre (Bag), Corvina de altura (Cor), Cubo (Cub), Gualajo (Gua), Lisa (Lis), Machetajo (Mac), Merluza (Mer), Palometa (Palo), Pargo (Par), Pelada (Pel), Pelada Blanca (PelB), Picuda (Pic), Sierra (Sie).

STOCK	SCIENTIFIC NAME	P	PQS	S	SQS	V
Alg	*Bagre pinnimaculatus*	1.8	2.2	2.2	2.9	1.7
Amb	*Hyporthodus acanthistius*	1.6	2.8	2.3	2.2	1.9
Bag	*Bagre panamensis*	2.0	2.7	2.3	2.3	1.6
Cor	*Cynoscion albus*	2.3	2.4	2.2	2.7	1.4
PelB	*Cynoscion phoxocephalus*	2.6	2.2	2.4	2.3	1.5
Cub	Caulolatilus affinis	1.8	3.0	2.2	2.3	1.7
Gua	*Centropomus armatus*	2.5	2.3	2.3	2.3	1.4
Lis	*Mugil cephalus*	2.3	2.3	2.2	1.9	1.4
Mac	*Centropomus medius*	2.5	3.1	2.3	2.9	1.4
Mer	*Brotula clarkae*	2.3	2.0	2.3	2.7	1.5
Palo	*Diapterus peruvianus*	2.4	2.9	2.2	3.0	1.4
Par	*Lutjanus spp.*	2.1	2.0	2.3	1.3	1.6
Pel	*Macrodon mordax*	2.5	3.8	2.3	1.8	1.4
Pic	*Sphyraena ensis*	2.0	2.7	2.3	2.4	1.6
Sie	*Scomberomorus sierra*	2.1	1.7	2.3	2.8	1.6

Table 14. Analysis of the fishermen answers consistency. Green shows the attributes in which more than 75% of the fishermen had the same answer for the species. Yellow the attributes with an agreement between 75% and 50%. Red shows the attributes in which less of 50% of fishermen provided the same answer.

SPECIES	Geographic concentration	Temporal distribution	Maximum catch depth	Catchability	Morphology affecting capture	Desirability/value of the fishery	Local management Strategy	Fishery impact on habitat	Other impacts on habitats	Other fisheries impacts
Alguacil	Yellow	Yellow	Green	Green	Red	Yellow	Yellow	Green	Green	Green
Ambulú	Red	Yellow	Red	Green	Yellow	Yellow	Green	Green	Green	Green
Bagre	Yellow	Yellow	Green	Green	Yellow	Yellow	Yellow	Green	Green	Green
Corvina de altura	Yellow	Green	Green	Green	Yellow	Green	Green	Green	Green	Green
Pelada blanca	Red	Yellow	Green	Green	Red	Yellow	Yellow	Green	Green	Green
Cubo	Red	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Green
Gualajo	Yellow	Yellow	Green	Green	Green	Yellow	Yellow	Green	Green	Green
Lisa	Yellow	Yellow	Green	Green	Yellow	Green	Yellow	Green	Green	Green
Machetajo	Yellow	Yellow	Green	Green	Yellow	Yellow	Yellow	Green	Green	Yellow
Merluza	Yellow	Yellow	Green	Green	Yellow	Green	Green	Green	Green	Green
Palometa	Green	Green	Green	Green	Yellow	Green	Yellow	Green	Green	Green
Pargo	Red	Yellow	Green	Green	Green	Red	Yellow	Green	Green	Green
Pelada	Yellow	Yellow	Green	Green	Yellow	Yellow	Yellow	Green	Green	Green
Picuda	Red	Yellow	Green	Green	Yellow	Yellow	Green	Green	Green	Green
Sierra	Red	Yellow	Green	Green	Yellow	Yellow	Green	Green	Green	Yellow

Chapter 5—Conclusions

Fisheries around the world are facing the challenges of providing food security and livelihoods for millions of people, while at the same time suffering from declining or overfished stocks. To reverse adverse trends, it is necessary to reduce the percentage of stocks that are being overfished, rebuild declined stocks, keep updated status assessments of the species and manage fishing activity sustainably. However, many of these activities might be extremely difficult or almost impossible for nations that do not have the technical expertise, the support, or the resources to assess and manage their fisheries, or for fisheries that are focused on non-commercial species. These data-poor countries and fisheries, despite their lack of information, need to assess their resources, acknowledge their limitations and develop the best tools to assess and sustainably manage fisheries resources.

This dissertation was an effort to explore different aspects of data-poor fisheries, including the basic knowledge of the life-history parameters and the productivity of the species, the interaction between the stocks and the fisheries, the importance of the scale in the data-poor stock assessments, and the integration of scientific and local fishermen knowledge to improve the local assessment of the species. We focused this research in data-poor fisheries in developed and developing countries, using as study cases the Oregon coast and the Colombian Pacific. Moreover, we expect that our methodologies and results can be useful to other data-poor fisheries and can help to support research and assessment efforts. With this dissertation, we also aimed to contribute to fisheries assessment processes at local and regional scales, since most of the data-poor fisheries are also small-scale and tend not to be commercially important. Lastly, as the title of this dissertation suggests, we integrated two types of knowledge in the assessment of the data-poor fisheries. The first one was the scientific knowledge, which we defined in this research as the cumulative body of information coming from the scientific literature, assumed to be collected with standardized methods, and acquired through the scientific method. The second one is the local knowledge, a type of information that is experienced based, held by individuals or communities, and shaped by culture, custom, and traditions.

In the second chapter, we assessed how the vulnerability of the species to overfishing could be perceived differently when the species are assessed at different scales. We took the case of 10 groundfish species of the Oregon coast, which are normally managed with catch limits established following federal stock assessments. These assessments normally do not include state-wide and local information of the species, so smaller-scale processes, critical to local fisheries, are not included in the management strategies. Our approach included the risk assessment of the ten species at different scales and the comparison of their vulnerability with a previous risk assessment conducted for the species at a coast-wide scale.

Most of the species analyzed are also considered data-poor, so the assessment of their local conditions is even more relevant to know the possible status of the stocks. To overcome the lack of information and use the available local knowledge to the assessment of local fisheries, we integrated local fishermen knowledge into the risk assessment of the species. This participation of commercial and recreational fishermen provided us with an important amount of information, helped us to fill some of the knowledge gaps and showed that our method could help to complement data-baselines to assess data-poor fisheries. The local participation of fishermen also allowed to recognize local peculiarities of the areas. Our results highlighted changes in the perception of the susceptibility of the species when analyzed at different scales, influencing the vulnerability of the species in each one of the areas. We concluded that those changes in perception are a result of the local differences of the stocks and the fisheries characteristics of the study area.

Our vulnerability results generally matched those generated from a previously published coastwide risk analysis, but with somewhat lower vulnerability scores. We conclude that the assessment scale is important in the vulnerability assessment of the species. Local assessments can highlight peculiarities of the study area and the local fisheries, that otherwise could be lost due to the lack of detail in larger assessments. This can have direct effects on the local management strategies and regulations, established coast-wide, not only because the local characteristics of the stocks might be different from the coast-wide ones, but because fishermen knowing the local stocks, might see scientific-based management strategies established for the whole coast as inaccurate for their local fishing areas. Our approach can also be useful to identify important local differences in stock susceptibility to fishing or other impacts that may be lost when stocks are monitored at the coastwide level.

The PSA, as mentioned through this document, is a tool that helps to prioritize species and focus attention in some of the species. Our approach not only prioritized the species, but helped to highlight those local differences that might be fundamental in a regional or local management strategy. Future fisheries assessments should include these types of local characteristics when assessing the stocks or when establishing the harvest quotas for the State. Ideally, we would suggest a stronger integration between fishermen and scientist in the data-poor fisheries assessments, through participatory activities and a two-way interaction in the assessment and decision-making processes.

In our third chapter, we focused on an important aspect of data-poor fisheries, the assessment of basic life-history and fishery information of the species. Our objective was to record all the available information on the biological and ecological attributes of commercially important species and described the information gaps in the life-history information. We focused our efforts on the stocks capture in the small-scale fisheries of the Colombian Pacific. We chose this region, because of the importance that small-scale fisheries have on the Pacific coast of Colombia, the 15000 fishermen that depend on fisheries for their livelihoods, and the urgency we have, as a country to monitor the local stocks. We chose 37 species of fishes, sharks, and rays, caught in the small-scale fisheries of the Colombian Pacific and selected 23 different attributes, normally used or needed in data-poor assessment models. Despite our efforts to compile 214 documents and try to compile the attributes information for the 37 species, we found a lack of basic life history information. We found that important biological parameters that are normally used in fisheries assessments have been estimated for less than half of the species. Our analysis showed that 26 out of the 37 species could be considered data-poor. Our literature search also allowed us to analyze the age and source of information, and while most of the information has been measured or estimated within the last 15 years, the sources of information highlighted a lack of peer-reviewed information in the country. It seems that the scientific culture of the country has been directed towards publications of technical documents or grey literature and not to information assessed and scrutinized by peers. Future efforts must be directed to the publication of results, to the improvement to the accessibility of information and the periodical updates of the stocks and species information.

Based on the lack of information we found, but considering the country's economic and logistical capabilities, we provided some recommendations for future research, with a set of assessment tools, which could be implemented in the country for better and more robust assessments. We performed an analysis of the existing data-poor assessment models and determined which ones could be potentially be used in the country, based in the amount of available information. We also analyzed the current stocks assessment method that Colombia is using and compare and described the benefits to use any of the other tools. The first tool is a Productivity and Susceptibility Analysis (PSA), a risk assessment that prioritizes species that are vulnerable to be overfished. Based on the information available for the country, this is a tool that might complement the current assessment and can also help to focus the research efforts to the most vulnerable species in the country that might need urgent management. The other tool, Catch-MSY, provides a preliminary estimate of the maximum sustainable yield of the species and it might help in the development of harvest control rules. This is a tool that correctly used, can have immense benefits for the small-scale fisheries in the country. This method, along the current efforts that Colombia is doing to improve the fisheries data collection, can help not only to assess the stocks, but to improve the monitoring processes, and establish management strategies through harvest control rules.

Our last chapter is directly linked to the results of chapter 3. Following the results that lead to the necessity to apply new assessments tools in the country, we decided to use one of the recommended assessment tools, the Productivity and Susceptibility Analysis (PSA). However, we wanted to make this tool useful for local conditions in extremely data-poor fisheries. For that, we elicited and integrated scientific and local fishermen knowledge in a vulnerability assessment through a proposed modification of the PSA. Our method linked biological information on the productivity of 15 nearshore stocks with local expertise on the species' susceptibility to fishing and other stressors. We provided a first-cut analysis for small-scale fisheries on the Pacific coast of Colombia and illustrated the value of tailoring the general PSA approach to local conditions.

Our approach also allowed the assessment of stocks with little or non-susceptibility information, especially in cases in which scientific expertise is difficult or impossible to get. Like any other risk assessment, this approach only showed us the potential vulnerability of the species, but it leaves an open the door to include more accurate and better-quality information when it becomes available. Our tailored PSA was designed to the particular conditions of the study area, so we do not expect that our results can be extrapolated to any other region. However, the tailoring process of the PSA was designed with the idea that eventually could be used in other small-scale fisheries assessment processes, to help in the prioritization of local stocks.

But probably the most important result we got, was the successful integration of the fishermen information in the analysis. The benefits of integrating local knowledge into assessment and management processes have been evident for some years, as well as the consequences that occur when local knowledge of fishermen is ignored in those processes. We integrated locally-relevant information in a data-poor scenario, and prioritized species that required an urgent assessment or management, all with the help and participation of fishermen. We took the necessary steps to assess the quality of the data collected via local knowledge to control and reduce bias and errors. These potential problems can be managed, and the benefits of the integration of local knowledge, especially in data-poor scenarios outweigh these problems.

For the case of Colombia, our results are extremely relevant because it is the first time that a risk assessment has been developed in the southern Colombian small-scale fisheries. Due to the lack of data, previous assessments kept Colombian data-poor fisheries unassessed. However, lack of information should not be enough reason to not assess the status of the Colombian fisheries. Our approach tried to use the information available in Colombia, but also relied in information from other countries, relevant to the assessed species. We also overcame this lack of information with the extensive literature search that we did to collect the species information. As described in chapter 2, the amount of information in the country is scarce and most of the species lack the basic life-history information required to populate the data-poor assessment tools. However, without that data-search, the amount of information would have been less, because most of the data is in grey literature and is not available online. These characteristics of the data are an important problem in Colombia, because some of the species information exist, but it is in documents that are not accessible to fisheries managers, not even to the fisheries authority (AUNAP). Future research, could benefit of this type of data-search, and will help increase the amount of data-poor species assessed. The lack of data also highlighted the low amount of research focused in small-scale fisheries in the Colombian Pacific. It is important to acknowledge the contribution of small-scale fisheries to the local livelihoods of the communities that depend on the fisheries resources. The lack of research, assessment, and management of the species could be having a direct effect in the sustainability of the stocks and the fisheries.

The Productivity and Susceptibility analysis was a useful and flexible tool that allowed me to address my research question. However, due to that flexibility, the PSA has big assumptions that should be managed carefully. Previous applications of the PSA have modified the number of attributes that define the productivity and susceptibility parameters, the rank of the scoring system, or the weight of each one of the parameters. But that same flexibility can be bringing subjectivity to the analysis, since each researcher is defining the importance of the weights, number of attributes or quality of the information. In chapter 2 we followed the methods of Cope et al. (2011), to compare our results with their previously published coast-wide PSA. Although we scored and used the same number of attributes and weighted them the same way, it is not clear in the Cope's paper why two of the attributes, maximum size and measured fecundity were downweighted. These type of modifications to the PSA can increase the uncertainty of the final result. In chapter 4 we decided to remove that weight, following previous research, that has showed that the final vulnerability does not change when the weight is removed and it does reduce the subjectibity of the tool. The number of attributes defining the productivity and the susceptibility of the species has also been a topic of discussion in previous research (Hordyk & Carruthers, 2018), because of the diverging views in the appropiate way to do it. Different applications of the PSA had use different number of attributes either for the productivity or the susceptibility parameters, changing the original method. However, considering that this is a data-poor method, that it is often use in data-escarcity situations, these changes are often neccesary to be able to provide a first assessment of species that otherwise will probably never be evaluated. It is fundamental then to aknowledge the changes and assumptions of these applications and justify the PSA structure differences.

In this dissertation, we also found some challenges and limitations that can be improved or changed in future assessments of data-poor fisheries. Fishermen participation is excellent, but it can be challenging to get if there is not a previous relationship with the fishing communities being studied. In chapter 2 and chapter 4, the processes were completely different in how we approached the communities and obtained the information. The approach to the communities in Oregon was a little more complicated, the online and mailed surveys made the process impersonal. On the other hand, our approach in the Colombian communities was done with the help of an NGO that has worked with the communities for a long time. All the interviews were done personally, and we had the company of a local leader the whole time.

In the fourth chapter of the dissertation, we had to exclude some of the parameters. Although we collected the information from the fishermen, we perceived fishermen did not completely understand the questions related with the migration of the species, or survival after capture and release, results that were also reflected in the consistency of the answers. Future research might benefit from more in-deep participation of fishermen in the development of the questionnaire. It seems that particularly the attributes related with the spatial distribution of the species or the movements through space as the migrations can be perceived in a differently by the fishermen and the researchers. Personal conversations with the fishermen led us to think that as researchers we visualized the space features as we usually do with maps. Instead, fishermen practically visualize the space, according to the requirements of their activity.

Finally, we expect that the presented results showed the urgency to assess and improve the collection of life-history information of the species, not only in the Colombian Pacific but in the whole country. And, that the lack of data or knowledge is not an excuse to not keep assessing and managing the species in these data-poor scenarios. The presented approaches could be used under the current conditions, but it should be a priority the development and construction of new data-collection strategies and continuous update of the assessment tools when more and better data become available.

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Appendices

Appendix A. Productivity scores used in the PSA with the respective reference from which we took the parameter value. For some of the parameters for which we did not find information (see tables 2a and 2b) we used the parameters scores directly from the PSA developed by Cope et al. (2011).

	r	Maximum age	Maximum size	von Bertalanffy Growth Coefficient (k)	Estimated Natural Mortality	Measured fecundity	Breeding strategy	Recruitment Pattern	Age at maturity	Mean trophic level
BRF	1	2	3	3	2	3	2	2	1	1
Source	(Jason Cope et al., 2011)	(Sampson, 2007)	(Jason Cope et al., 2016)	(Jason Cope et al., 2016)	(Jason Cope et al., 2016)	(Jason Cope et al., 2016)	(Love, Yoklavich, & Thorsteinson, 2002)	(Love et al., 2002)	(Jason Cope et al., 2016)	(Froese & Pauly, 2017)
BS	---	---	3	---	---	2	---	---	---	---
Source	---	---	(Love, 2011)	---	---	(Love, 2011)	---	---	---	---
CAB	1.5	2	2	2	2	3	1	2	2	1
Source	(Jason Cope et al., 2011)	(Love, 2011)	(Eschmeyer & Herald, 1983)	(PFMC, 2014)	(J. Cope & Key, 2009)	(Love, 2011)	(Jason Cope et al., 2011)	(J. Cope & Key, 2009)	(Cailliet, 2000)	(Froese & Pauly, 2017)
CHRF	1	1	3	2	1	1	1	2	1	1
Source	(Jason Cope et al., 2011)	(Dick & MacCall, 2010)	(Dick et al., 2016)	(Dick et al., 2016)	(Dick et al., 2016)	(Jason Cope et al., 2011)	(Jason Cope et al., 2011)	(Jason Cope et al., 2011)	(Love et al., 2002)	(Froese & Pauly, 2017)
CRF	1	1	2	2	1	3	1	1.5	1	1
Source	(Jason Cope et al., 2011)	(Jason Cope et al., 2015)	(Love, 2011)	(Jason Cope et al., 2015)	(Jason Cope et al., 2015)	(Love, 2011)	(King & McFarlane, 2003)	(Jason Cope et al., 2011)	(Jason Cope et al., 2015)	(Froese & Pauly, 2017)
KG	2	2	3	3	2	3	1	1	2	1
Source	(Jason Cope et al., 2011)	(Rodomsky, Kautzi, Hannah, & Good, 2015)	(Rodomsky et al., 2015)	(Rodomsky et al., 2015)	(Berger, Arnold, & Rodomsky, 2015)	(Love, 2011)	(Jason Cope et al., 2011)	(Jason Cope et al., 2011)	(J. Cope & MacCall, 2005)	(Froese & Pauly, 2017)
LING	2	2	2	2	2	3	2	2	2	1
Source	(Jason Cope et al., 2011)	(Haltuch et al., 2017)	(Haltuch et al., 2017)	(Haltuch et al., 2017)	(Haltuch et al., 2017)	(Shaw, Hassler, & Moran, 1989)	(King & McFarlane, 2003)	(Hamel, Sethi, & Wadsworth, 2009)	(Haltuch et al., 2017)	(Froese & Pauly, 2017)
QRF	1	1	3	1	1	3	1	2	1	2
Source	(DFO, 2012)	(DFO, 2012)	(Hannah & Blume, 2011)	(Cailliet, 2000)	(Dick & MacCall, 2010)	(Love et al., 2002)	(King & McFarlane, 2003)	(Jason Cope et al., 2011)	(Hannah & Blume, 2011)	(Froese & Pauly, 2017)
RIL	---	3	3	---	3	3	1	---	2	2
Source	---	(ODFW, 2002)	(Love, 2011)	---	(Reuter & Tenbrink, 2006)	(Love, 2011)	(King & McFarlane, 2003)	---	(Love, 2011)	(Froese & Pauly, 2017)
RSP	---	2	3	3	3	1	---	---	2	2
Source	---	(Love, 2011)	(Baltz, 1984)	(Love, 2011)	(Bennett & Wydoski, 1977)	(Love, 2011)	---	---	(Love, 2011)	(Froese & Pauly, 2017)

Appendix B. Sample of the questionnaire used to collect information about the 10 groundfish species. Here we only show the questions for one of the species, but in the online survey (developed in the software Qualtrics) and in the paper survey they had the option to select the species for which they wanted to provide information

Nearshore Fish Susceptibility Questionnaire

Project Title:	Improving regional fisheries assessments with local knowledge
Principal Investigator:	Dr. Selina Heppell
Student Researcher:	Andrea Jara Baquero
Sponsor:	Oregon Sea Grant

Purpose: You are being asked to take part in a research study. The purpose of this research study is to include local knowledge in our research of the status and strategies for monitoring Oregon's nearshore fish resources. You will be asked a series of multiple choice questions about the "Productivity" and "Susceptibility" of a common nearshore fish species found in your area. The information will be used in an index to classify different species and see if they differ across regions of the coast. Activities: The study activities include a survey for coastal residents, particularly fishermen, about the habits and relative abundance of eight different nearshore fish species, as well as fisheries for those species in the local area. The survey is available on-line, by paper copy that can be mailed, and on tablets that will be available during local workshops about fisheries monitoring and evaluation.

Time: Your participation in this study will last about 10 minutes per species that you choose. The questions are simple multiple choice. There is space for notes or comments if you have additional information to share.

Payment: You will not be paid for being in this research study.

Confidentiality: Your participation in this study is voluntary and your responses will remain confidential. All responses will be compiled by fish species and region, and anything that may identify you will be removed from the data. It is possible that others could learn that you participated in this study but the information you provide will be kept confidential to the extent permitted by law. The security and confidentiality of information collected from you online cannot be guaranteed. Confidentiality will be kept to the extent permitted by the technology being used. Information collected online can be intercepted, corrupted, lost, destroyed, arrive late or incomplete, or contain viruses.

Voluntary: Participation in this study is voluntary. You can skip any questions that you prefer not to answer, and you can provide information on multiple species or regions as you wish.

Study contacts: If you have any questions about this research project, please contact: Selina Heppell in the Department of Fisheries and Wildlife at Oregon State University, selina.heppell@oregonstate.edu, (541) 737-9039. If you have questions about your rights or welfare as a participant, please contact the Oregon State University Institutional Review Board (IRB) Office, at (541) 737-8008 or by email at IRB@oregonstate.edu

Which region would you like to tell us about?

❍ I
❍ II
❍ III
❍ IV

How do you know this area? (You can choose more than 1)

❑ I live here. How many years? ____________________
❑ I work here. How many years? ____________________
❑ I lived here in the past. When? ____________________
❑ I worked here in the past. When? ____________________
❑ I spend recreational time in this area
❑ I have heard about fish in this area from others.

NOTES

How are you connected to Oregon fisheries? You can choose more than 1

- ❑ Commercial Fishing
- ❑ Recreational Fishing
- ❑ Diving
- ❑ Shoreside support (gear, processing)
- ❑ Research
- ❑ Non-fishing coastal resident
- ❑ Other: ____________________

NOTES

Select ALL the species you want to provide information for: (NOTE: Each species questionnaire takes 5 - 8 min)

- ❑ Black rockfish
- ❑ Buffalo sculpin
- ❑ Cabezon
- ❑ China rockfish
- ❑ Kelp greenling
- ❑ Lingcod
- ❑ Red Irish Lord
- ❑ Redtail Surfperch
- ❑ Copper rockfish
- ❑ Quillback rockfish

NOTES

BLACK ROCKFISH

Image:Steve Lonhart (SIMoN/MBNMS)

Select the gear(s) type(s) that you have used to catch this species

- ❑ Trawl
- ❑ Longline
- ❑ Pot/trap
- ❑ Hook and Line
- ❑ Other ____________________
- ❑ Not fishing

NOTES

How often do you target this species (last 5 years)? Choose one:

- ❍ Target regularly
- ❍ Target occasionally
- ❍ Discard
- ❍ Rare or No Catch
- ❍ Not a Fisherman

NOTES

<u>SUSCEPTIBILITY QUESTIONS</u>

The following questions are about how this species of fish is susceptible to fishing, based on where the fish live and where people fish for them. In some cases, there may be depths or habitats where the fish can't be caught, or areas that are too far offshore for a particular fishery to catch them.

Is this species common in your area?

- ❍ Species is common
- ❍ Species is common but only at certain times of year
- ❍ Species is of moderate abundance
- ❍ Species is rare
- ❍ Don't know

NOTES

How concentrated is the species in your area?

- ❍ Species is widely spread across the area
- ❍ Species is found in 25%-50% of the area
- ❍ Species is concentrated in small parts of the area
- ❍ Don´t know

NOTES:

Do any fisheries catch small juveniles of this species in your area?

- ❍ Frequent bycatch of juveniles
- ❍ Some bycatch of juveniles
- ❍ Limited or no bycatch of juveniles
- ❍ Don't know
- ❍ NOTES:

How much does the fishery that uses this gear type overlap with where the fish live in your area? Please select only one option for each gear type

	Trawl	Longline	Pot/trap	Hook and Line	Other	Not fishing
Fishery overlaps with less than half of the area or habitat where this fish species lives	❑	❑	❑	❑	❑	❑
Fishery overlaps with more than half of the area or habitat where this fish species lives, but not all of it	❑	❑	❑	❑	❑	❑
Fishery overlaps with all of the area or habitat where this fish species lives	❑	❑	❑	❑	❑	❑
Don't know	❑	❑	❑	❑	❑	❑

23 NOTES:

How much does the fishing gear vertically overlap the range of the stock in the water column? Please select only one option for each gear type

	Trawl	Longline	Pot/trap	Hook and Line	Other	Not fishing
Fishing gear overlaps with less than half of the range of the stock in the water column	❑	❑	❑	❑	❑	❑
Fishing gear overlaps with more than half of the range of the stock in the water column, but not all of it	❑	❑	❑	❑	❑	❑
Fishing gear overlaps with all the range of the stock in the water column	❑	❑	❑	❑	❑	❑
Don't know	❑	❑	❑	❑	❑	❑

NOTES:

Does this species migrate seasonally?

- ❍ Yes, species migrates across depths between deeper and shallower water
- ❍ Species migrates along the coast
- ❍ No, species is in this area year-round
- ❍ Don´t know

NOTES:

Do migrations of the species affect the fishery overlap? Please select only one option for each gear type

	Trawl	Longline	Pot/trap	Hook and Line	Other	Not fishing
Migrations decrease overlap with the fishery	❑	❑	❑	❑	❑	❑
Migrations do not affect the overlap with the fishery	❑	❑	❑	❑	❑	❑
Migrations increase overlap with the fishery	❑	❑	❑	❑	❑	❑
No migrations	❑	❑	❑	❑	❑	❑
Don’t know	❑	❑	❑	❑	❑	❑

NOTES:

Is this species regularly targeted by the fishery or is it caught in a complex of other species? Please select only one option for each gear type

	Trawl	Longline	Pot/trap	Hook and Line	Other	Not fishing
Fish is caught incidentally, usually discarded	❑	❑	❑	❑	❑	❑
Fish is caught incidentally, usually kept and/or sold	❑	❑	❑	❑	❑	❑
Fish is part of a targeted complex	❑	❑	❑	❑	❑	❑
Fish is targeted when catch of other species is down	❑	❑	❑	❑	❑	❑
Fish is usually targeted	❑	❑	❑	❑	❑	❑
Don't know	❑	❑	❑	❑	❑	❑

NOTES:

Is there anything about the shape of this fish or its behavior that make it easier or more difficult to catch with this gear (e.g., body shape flat or round, spiny versus soft rayed fins, avoids the gear, etc.)? Please select only one option for each gear type

	Trawl	Longline	Pot/trap	Hook and Line	Other	Not fishing
The catch is easier because of fish shape or behavior	❑	❑	❑	❑	❑	❑
The catch is not affected by fish shape or behavior	❑	❑	❑	❑	❑	❑
The catch is more difficult because fish shape or behavior	❑	❑	❑	❑	❑	❑
Don´t know	❑	❑	❑	❑	❑	❑

NOTES:

What is the probability of survival after release from each gear type? Please select only one option for each gear type

	Trawl	Longline	Pot/trap	Hook and Line	Other	Not fishing
Good chance of surviving, more than 67% (at least 2 out of 3 fish released will survive)	❍	❍	❍	❍	❍	❍
Medium chance of surviving, 33% to 67% (1 or 2 out of 3 fish released will survive)	❍	❍	❍	❍	❍	❍
Low chance of surviving, less than 33% (no more than 1 out of 3 fish released will survive)	❍	❍	❍	❍	❍	❍
Don't know	❍	❍	❍	❍	❍	❍

NOTES:

How is this species valued by the fishery that uses this gear type? Please select only one option for each gear type

	Trawl	Longline	Pot/trap	Hook and Line	Other	Not fishing
Highly valued: more than $2.25/lb	❑	❑	❑	❑	❑	❑
Moderately valued: $1-$2.25/lb	❑	❑	❑	❑	❑	❑
Species is not highly valued less than $1/lb	❑	❑	❑	❑	❑	❑
Don't know	❑	❑	❑	❑	❑	❑

NOTES:
Are there impacts of this gear on the habitat of this species in your area? Please select only one option for each gear type

	Trawl	Longline	Pot/trap	Hook and Line	Other	Not fishing
No habitat impacts	❑	❑	❑	❑	❑	❑
Limited habitat impacts	❑	❑	❑	❑	❑	❑
High habitat impacts	❑	❑	❑	❑	❑	❑
Don´t know	❑	❑	❑	❑	❑	❑

NOTES:
Are there other things impacting the habitat of this species in your area (pollution, development)?
❍ Impacts absent, minimal or temporary
❍ Impacts more than minimal but getting better
❍ Impacts are increasing
❍ Don't know

41 NOTES (Tell us what impacts you are concerned about):

PRODUCTIVITY QUESTIONS
Do you know where the fish spawn? (Depth, habitat, specific areas)

Do you know when the fish spawn (season or month)?

Do you think that fish move here from other areas or live here full time once they have settled as juveniles?
❍ Low movement rates, very sedentary
❍ Highly variable movement rates
❍ High movement rates
❍ Don't know
NOTES:
Have you seen a change in the size of fish caught in this area over the past 10 years?
❍ Fish have gotten smaller
❍ No observable change
❍ Fish have gotten larger
❍ Don't know
NOTES:

How has the fish abundance of this fish changed over the last ten years?

- ❍ Fish are more common here now than in the past
- ❍ Fish are about the same abundance
- ❍ Fish are less abundant here than they were
- ❍ Don’t know

NOTES:

How quickly do fish move back into an area that has been fished heavily for a while?

- ❍ Fish take a long time to recover
- ❍ Fish recolonize over several months
- ❍ Fish recolonize quickly (days to weeks)
- ❍ Don't know
- ❍ NOTES:

Do you think that this species should be monitored at a smaller spatial scale? (for example, area I, II, III, IV in the map or by smaller areas along the coast)

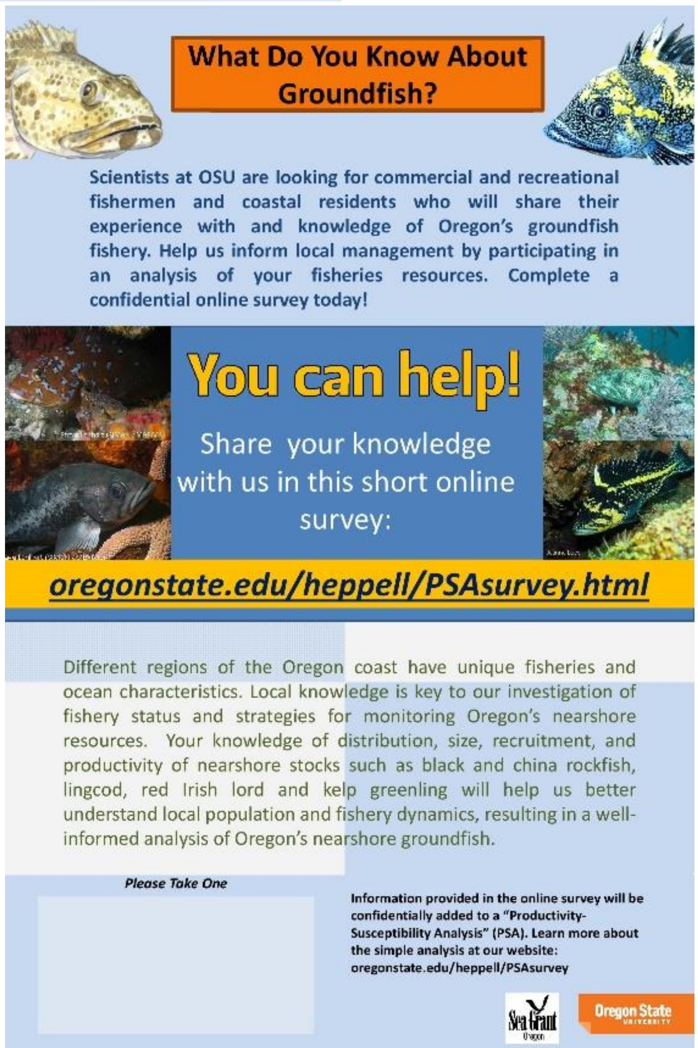
- ❍ No, federal coastwide assessment (WA+OR+CA) is sufficient
- ❍ Species should be monitored at a state level (OR)
- ❍ Species should be monitored for local changes in abundance (e.g., area scale)
- ❍ Don’t know

NOTES:

Would you like to provide information on some of the other species you choose?

- ❍ Yes, I would like to continue with the other species
- ❍ No, I would like to end the survey

Appendix C. Postcard and poster distributed through the fishing community of the Oregon coast to advertise the online survey



Appendix D. Detail of the availability of each life-history parameter, dark grey is showing the parameters with available information, light grey unavailable parameters. The parameters assessed are: Maximum length (Lmax), Length at maturity (Lmat), Maximum age (tmax), Age at Maturity (tmat), Population growth (r), von Bertalanffy growth coefficient (k), Mortality (M), Fecundity (FEC), Breeding Strategy (BS), Recruitment Pattern (RP), Mean Trophic Level (MTL), Geographic range (GR), Depth range (m) (DR), Migration Pattern (MP), Schooling, aggregation, and other behaviors (SAB), Morphology affecting capture (MAC), Desirability/Value of the fishery (VAL), Management Strategy (MS), Fishing mortality rate (F), Biomass of spawners (BOS), Fishery impact in habitat (FIH), Fishing gear (FG), Type of association/Habitat (HAB).

Species	Common name	L_{max}	L_{mat}	t_{max}	t_{mat}	r	k	M	F	BS	RP	MTL	GR	DR	MP	SAB	MAC	VAL	MS	FM	BS	FIH	FG	HAB
Bagre pinnimaculatus	Alguacil	■	■				■	■						■				■		■			■	■
Bagre panamensis	Barbinche	■							■	■		■		■				■					■	■
Notarius troschelii	Ñato	■																■					■	■
Caranx caninus	Jurel	■												■	■	■								■
Caranx caballus	Burique	■	■											■										■
Centropomus armatus	Gualajo	■	■				■	■	■			■		■		■		■		■			■	■
Centropomus medius	Machetajo																	■					■	
Coryphaena hippurus	Dorado	■	■				■	■			■	■		■	■			■	■		■		■	■
Lobotes pacificus	Berrugate	■	■		■		■	■			■	■		■				■	■	■			■	■
Lutjanus guttatus	Pargo lunarejo	■	■				■	■	■	■	■			■				■	■	■			■	■
Lutjanus peru	Pargo rojo	■	■				■	■			■	■		■	■			■	■	■			■	■
Lutjanus argentiventris	Pargo coliamarillo	■					■	■		■		■		■										■
Mugil cephalus	Lisa	■			■		■		■	■	■													■
Cynoponticus coniceps	Zafiro	■												■				■						■
Brotula clarkae	Merluza	■	■				■	■	■	■	■	■		■				■	■	■			■	■
Mycteroperca xenarcha	Cherna													■	■	■								■
Cynoscion albus	Corvina	■	■									■		■				■					■	■
Cynoscion phoxocephalus	Pelada blanca	■	■				■	■			■	■		■		■		■	■	■			■	■
Macrodon mordax	Pelada amarilla	■																■					■	■
Scomberomorus sierra	Sierra	■	■		■		■	■	■		■			■				■		■			■	■
Thunnus albacares	Atún aleta amarilla	■	■						■					■	■			■					■	■
Thunnus alalunga	Atún albacora														■									
Euthynnus lineatus	Atún patiseca									■				■	■									■
Sphyraena ensis	Picúa	■	■											■				■						■
Alopias pelagicus	Tiburón zorro	■	■											■	■			■					■	■
Carcharhinus falciformis	Tiburón sedoso/jaquetón	■	■				■	■	■	■		■		■	■			■	■	■			■	■
Carcharhinus limbatus	Tiburón aletinegro	■												■	■			■					■	■
Prionace glauca	Tiburón azul, Toyo aguado	■													■			■						
Hypanus longus	Raya látigo largo coluda	■	■						■	■		■		■				■					■	■
Hypanus dipterurus	Raya latigo (cola corta)	■												■				■					■	■
Aetobatus narinari	Raya pintada, Chucho	■												■	■			■					■	■
Rhinobatos leucorhynchus	Raya guitarrilla (sin manchas)	■	■						■	■		■		■				■					■	■
Sphyrna lewini	Cachuda, Tiburón martillo	■	■				■	■	■			■		■	■			■	■	■			■	■
Sphyrna media	Cachuda gris	■												■				■					■	
Sphyrna corona	Cachuda amarilla	■												■				■					■	■
Mustelus lunulatus	Toyo vieja	■	■				■		■	■		■		■				■	■				■	■
Mustelus henlei	Toyo vieja	■	■				■	■	■			■						■	■				■	■

Appendix E. Detail of the availability of the Productivity and Susceptibility Analysis data-requirements. Dark grey is showing the available parameters, light grey the unavailable parameters. The parameters assessed are: Population growth (r), Maximum length (Lmax), von Bertalanffy growth coefficient (k), Mortality (M), Fecundity (FEC), Breeding Strategy (BS), Recruitment Pattern (RP), Maximum age (tmax), Mean Trophic Level (MTL), Length at maturity (Lmat), Areal overlap (AO), Geographic range (GR), Depth range (m) (DR), Migration Pattern (MP), Schooling, aggregation, and other behaviors (SAB), Morphology affecting capture (MAC), Desirability/Value of the fishery (VAL), Management Strategy (MS), Fishing mortality rate (F), Biomass of Spawners (BOS), Survival after capture and release (SAC), Fishery impact in habitat (FIH).

Species	Common name	r	L_{max}	k	M	FEC	BS	RP	t_{max}	MTL	L_{mat}	AO	GR	DR	MP	SAB	MAC	VAL	MS	F	BOS	SAC	FIH
Bagre pinnimaculatus	Alguacil																						
Bagre panamensis	Barbinche																						
Notarius troschelii	Ñato																						
Caranx caninus	Jurel																						
Caranx caballus	Burique																						
Centropomus armatus	Gualajo																						
Centropomus medius	Machetajo																						
Coryphaena hippurus	Dorado																						
Lobotes pacificus	Berrugate																						
Lutjanus guttatus	Pargo lunarejo																						
Lutjanus peru	Pargo rojo																						
Lutjanus argentiventris	Pargo coliamarillo																						
Mugil cephalus	Lisa																						
Cynoponticus coniceps	Zafiro																						
Brotula clarkae	Merluza																						
Mycteroperca xenarcha	Cherna																						
Cynoscion albus	Corvina																						
Cynoscion phoxocephalus	Pelada blanca																						
Macrodon mordax	Pelada amarilla																						
Scomberomorus sierra	Sierra																						
Thunnus albacares	Atún aleta amarilla																						
Thunnus alalunga	Atún albacora																						
Euthynnus lineatus	Atún patiseca																						
Sphyraena ensis	Picúa																						
Alopias pelagicus	Tiburón zorro																						
Carcharhinus falciformis	Tiburón sedoso/jaquetón																						
Carcharhinus limbatus	Tiburón aletinegro																						
Prionace glauca	Tiburón azul, Toyo aguado																						
Hypanus longus	Raya látigo largo coluda																						
Hypanus dipterurus	Raya latigo (cola corta)																						
Aetobatus narinari	Raya pintada, Chucho																						
Rhinobatos leucorhynchus	Raya guitarrilla (sin manchas)																						
Sphyrna lewini	Cachuda, Tiburón martillo																						
Sphyrna media	Cachuda gris																						
Sphyrna corona	Cachuda amarilla																						
Mustelus lunulatus	Toyo vieja																						
Mustelus henlei	Toyo vieja																						

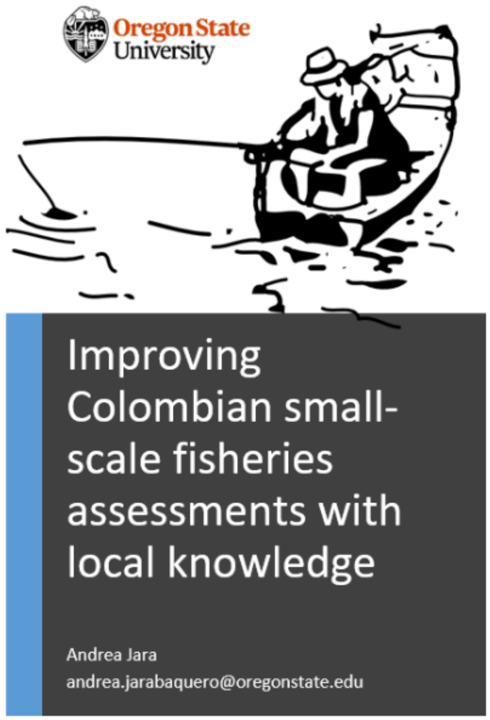
Appendix F. Detail of the availability of the Catch-MSY data-requirements. Dark grey is showing the available parameters, light grey the unavailable parameters. The parameters assessed are: Population growth (r), von Bertalanffy growth coefficient (k), Mortality (M), catches (measured as landings).

Species	Common name	r	k	M	CATCHES
Bagre pinnimaculatus	Alguacil				
Bagre panamensis	Barbinche				
Notarius troschelii	Ñato				
Caranx caninus	Jurel				
Caranx caballus	Burique				
Centropomus armatus	Gualajo				
Centropomus medius	Machetajo				
Coryphaena hippurus	Dorado				
Lobotes pacificus	Berrugate				
Lutjanus guttatus	Pargo lunarejo				
Lutjanus peru	Pargo rojo				
Lutjanus argentiventris	Pargo coliamarillo				
Mugil cephalus	Lisa				
Cynoponticus coniceps	Zafiro				
Brotula clarkae	Merluza				
Mycteroperca xenarcha	Cherna				
Cynoscion albus	Corvina				
Cynoscion phoxocephalus	Pelada blanca				
Macrodon mordax	Pelada amarilla				
Scomberomorus sierra	Sierra				
Thunnus albacares	Atún aleta amarilla				
Thunnus alalunga	Atún albacora				
Euthynnus lineatus	Atún patiseca				
Sphyraena ensis	Picúa				
Alopias pelagicus	Tiburón zorro				
Carcharhinus falciformis	Tiburón sedoso/jaquetón				
Carcharhinus limbatus	Tiburón aletinegro				
Prionace glauca	Tiburón azul, Toyo aguado				
Hypanus longus	Raya látigo largo coluda				
Hypanus dipterurus	Raya latigo (cola corta)				
Aetobatus narinari	Raya pintada, Chucho				
Rhinobatos leucorhynchus	Raya guitarrilla (sin manchas)				
Sphyrna lewini	Cachuda, Tiburón martillo				
Sphyrna media	Cachuda gris				
Sphyrna corona	Cachuda amarilla				
Mustelus lunulatus	Toyo vieja				
Mustelus henlei	Toyo vieja				

Appendix G. Description of the characteristics of the data-poor models proposed as possible assessment methods of the Colombian Pacific small-scale fisheries

Method	Overview	Advantages	Disadvantages	Input Data		References
				Productivity attributes	**Susceptibility attributes**	
Productivity and Susceptibility Analysis (PSA)	Risk approach to assess a stock vulnerability to overfishing. It combines information about the productivity of a stock (biological information) with its susceptibility to fishing and other environmental and human factors.	Prioritizes the species that require additional research and status evaluation and establishes warning signs for specific stocks. Information data-gaps can be filled with information from similar species, and the quality of the information reduced in the data-quality index of the analysis	The high amount of information required to score the attributes. The output of the analysis does not provide a quantitative management reference point. The rankings used to score the attributes are subjective, and the attributes are not always independent of each other.	Population Growth Rate (r) Maximum length von Bertalanffy growth coefficient (k) Natural mortality (M) Fecundity Breeding strategy Recruitment pattern Age at maturity Mean trophic level	Areal overlap Geographic concentration Vertical overlap Seasonal migration Schooling, Aggregations, behavior Morphology affecting capture Desirability/value of the fishery Management Strategy Fishing mortality rate Biomass of Spawners Survival after capture and release Fishery impact on habitat	Patrick et al., 2009
Catch -MSY	Estimates the maximum sustainable yield (MSY) from catch data, the resilience of the respective species, and simple assumptions about relative stock sizes at the first and final year of the catch data time series. The calculation of the catch-MSY	Provides preliminary estimates of MSY The MSY distributions can potentially be used in simple harvest control rules for data-poor stocks. Catches over MSY can trigger a decision rule and the implementation of the management responses	Data-poor fisheries are often associated with lack or limited monitoring of catch data. Not recommended for a developing fishery because of the difficulty to estimate the upper bound of k. Assumes stationary parameters over time	It uses a catch time series, the relative stock sizes at the beginning and end of the catch series, the resilience of the species analyzed and prior ranges of the maximum rate of the population (r), and the carrying capacity (k).		Martell and Froese., 2013

Appendix H. Sample of the questionnaire used to collect information about the small-scale fisheries in the Colombian Pacific. The survey administered to the fishermen was in Spanish.



1. Could you please list the species you regularly fish and have information about their life characteristics? These will be the species you will use for the rest of the interview.

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____
7. ____

2. How concentrated is the species in the area you regularly fish?

	Widely spread across the area	Found in more or less half of the area.	Concentrated in small parts of the area	Not in the area	Don't know
Species 1					
Species 2					
Species 3					
Species 4					
Species 5					
Species 6					
Species 7					

Notes:____

3. How common is this species in your area?

	Can be found throughout the year	Can be found a few months of the year	Can be rarely found throughout the year	Don't know
Species 1				
Species 2				
Species 3				
Species 4				
Species 5				
Species 6				
Species 7				

Notes:____

4. Based on your knowledge, what is the maximum depth these species can reach?

	Less than 10 meters	Within 11- and 30 meters	Within 31 and 60 meters	More than 60 meters	Don't know
Species 1					
Species 2					
Species 3					
Species 4					
Species 5					
Species 6					
Species 7					

Notes:____

5. How deep do you usually fish these species?

	Less than 10 meters	Within 11- and 30 meters	Within 31 and 60 meters	More than 60 meters	Don't know
Species 1					
Species 2					
Species 3					
Species 4					
Species 5					
Species 6					
Species 7					

Notes:____

6. Does this species migrate?

	Yes, species migrate across depths between deeper and shallower water	Yes, species migrate along the coast	No, species is in this area year-round	Don't know
Species 1				
Species 2				
Species 3				
Species 4				
Species 5				
Species 6				
Species 7				

Notes:____

7. How do migrations affect your interaction with the species?

	Migrations increase my overlap with the fishery	Migrations decrease my overlap with the fishery.	Migrations do not affect my overlap with the fishery.	Don't know
Species 1				
Species 2				
Species 3				
Species 4				
Species 5				
Species 6				
Species 7				

Notes:____

8. What kind of gear do you use to catch these species?

Species 1 Gear: _________________ ___________________
Species 2 Gear: _________________ ___________________
Species 3 Gear: _________________ ___________________
Species 4 Gear: _________________ ___________________
Species 5 Gear: _________________ ___________________
Species 6 Gear: _________________ ___________________
Species 7 Gear: _________________ ___________________

Notes:____

9. How long (meters) is the gear you use to fish each one of the species?

Species 1 Gear: _________________ Length: _________________
Species 2 Gear: _________________ Length: _________________
Species 3 Gear: _________________ Length: _________________
Species 4 Gear: _________________ Length: _________________
Species 5 Gear: _________________ Length: _________________
Species 6 Gear: _________________ Length: _________________
Species 7 Gear: _________________ Length: _________________

Notes:____

10. Is this species regularly targeted by the fishery or is it caught incidentally?

	Usually targeted	Caught incidentally, usually discarded	Caught incidentally, usually kept and/or sold.	Targeted when other species are down.	Don't know
Species 1					
Species 2					
Species 3					
Species 4					
Species 5					
Species 6					
Species 7					

Notes:____

11. Is there anything about the shape of this fish or its behavior that make it easier or more difficult to catch?

Species 1	❑ Yes; What: _____________	❑ No	❑ Don't know
Species 2	❑ Yes; What: _____________	❑ No	❑ Don't know
Species 3	❑ Yes; What: _____________	❑ No	❑ Don't know
Species 4	❑ Yes; What: _____________	❑ No	❑ Don't know
Species 5	❑ Yes; What: _____________	❑ No	❑ Don't know
Species 6	❑ Yes; What: _____________	❑ No	❑ Don't know
Species 7	❑ Yes; What: _____________	❑ No	❑ Don't know

Notes:____

12. For how much do you sell this species?

Species 1	________________	❑ Don't know
Species 2	________________	❑ Don't know
Species 3	________________	❑ Don't know
Species 4	________________	❑ Don't know
Species 5	________________	❑ Don't know
Species 6	________________	❑ Don't know
Species 7	________________	❑ Don't know

Notes:____

13. Is there a local management strategy for this species that you follow?

Species 1	❑ Yes; Which one: _____________	❑ No	❑ Don't know
Species 2	❑ Yes; Which one: _____________	❑ No	❑ Don't know
Species 3	❑ Yes; Which one: _____________	❑ No	❑ Don't know
Species 4	❑ Yes; Which one: _____________	❑ No	❑ Don't know
Species 5	❑ Yes; Which one: _____________	❑ No	❑ Don't know
Species 6	❑ Yes; Which one: _____________	❑ No	❑ Don't know
Species 7	❑ Yes; Which one: _____________	❑ No	❑ Don't know

Notes:____

14. Is there any fishery regulation you would like to see or you think the fishery needs?

Species 1	❑ Yes; Which one: _____________	❑ No	❑ Don't know
Species 2	❑ Yes; Which one: _____________	❑ No	❑ Don't know
Species 3	❑ Yes; Which one: _____________	❑ No	❑ Don't know
Species 4	❑ Yes; Which one: _____________	❑ No	❑ Don't know
Species 5	❑ Yes; Which one: _____________	❑ No	❑ Don't know
Species 6	❑ Yes; Which one: _____________	❑ No	❑ Don't know
Species 7	❑ Yes; Which one: _____________	❑ No	❑ Don't know

Notes:____

15. How is the impact of this fishery on the habitat of this species?

	High habitat impacts	Limited habitat impacts	Low habitat impacts	No habitat impacts	Don't know
Species 1					
Species 2					
Species 3					
Species 4					
Species 5					
Species 6					
Species 7					

Notes:____

16. Are there other things impacting the habitat of this species in your area (pollution, development, etc.)?

Species 1 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know
Species 2 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know
Species 3 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know
Species 4 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know
Species 5 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know
Species 6 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know
Species 7 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know

Notes:____

17. Any other fishery impact this species fishery?

Species 1 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know
Species 2 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know
Species 3 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know
Species 4 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know
Species 5 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know
Species 6 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know
Species 7 ❑ Yes; Which one: _____________ ❑ No ❑ Don't know

Notes:____

18. What is the probability of survival after release?

	Good chance of surviving, (at least 2 out of 3 fish released will survive).	Medium chance of surviving, (1 or 2 out of 3 fish released will survive).	Low chance of surviving (no more than 1 out of 3 fish released will survive).	Don't know.
Species 1				
Species 2				
Species 3				
Species 4				
Species 5				
Species 6				
Species 7				

Notes:____

DEMOGRAPHIC QUESTIONS

19. How do you know this area? You can choose more than 1.
- ❑ I live here. How many years? ___________________________
- ❑ I work here. How many years? ________________________
- ❑ I lived here in the past. When? __________________________
- ❑ I worked here in the past. When? _______________________
- ❑ I spend recreational time in this area.
- ❑ I have heard about fish in this area from others.

Notes: ____

20. What is your age?______years

21. How are you connected to the Pacific Colombian fishes? You can choose more than 1
- ❑ Artisanal Fishing
- ❑ Industrial Fishing
- ❑ Shoreside support (gear, processing)
- ❑ Research
- ❑ Non-fishing coastal resident
- ❑ Other: ____________________

Notes:____

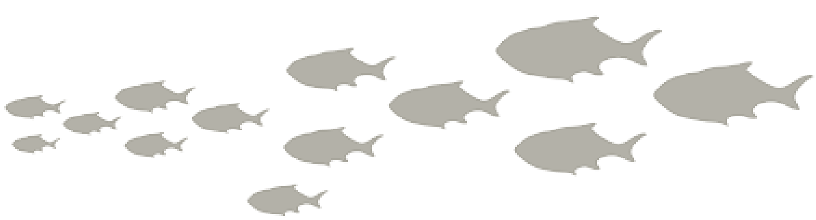
22. How many years of fishing experience do you have in this area of Colombia?
- ❑ More than20 years
- ❑ 10 - 20 years
- ❑ 5 - 10 years
- ❑ Less than 5 years
- ❑ 0 years

Notes:____

23. How would you rate your expertise about the small-scale fisheries in the Colombian Pacific?

Very Low Low Medium High Very High

Thanks for your participation



Appendix I. Susceptibility scores used in the PSA and estimated from the information provided by the fishermen of the 12 communities of the Southern Colombian Pacific.

	SUSCEPTIBILITY ATTRIBUTES									
SPECIES	Geographic concentration	Temporal distribution	Maximum catch depth	Catchability	Morphology affecting capture	Desirability/value of the fishery	Local management Strategy	Fishery impact on habitat	Other impacts on habitats	Other fisheries impacts
Alguacil	1.8	2.4	3.0	3.0	1.6	1.3	2.6	0.9	2.9	2.7
Ambulú	1.9	2.6	2.1	3.0	1.8	2.3	2.8	1.0	2.7	2.6
Bagre	1.9	2.4	3.0	2.9	1.8	1.7	2.5	1.2	2.8	2.8
Corvina de altura	2.2	2.2	1.2	3.0	1.7	2.8	2.9	1.0	2.8	2.7
Pelada blanca	2.0	2.5	3.0	2.9	2.1	2.3	2.6	1.1	2.9	2.9
Cubo	1.9	2.7	1.7	2.8	2.0	1.1	3.0	1.0	2.9	3.0
Gualajo	1.6	2.5	3.0	2.9	2.1	1.4	2.6	1.3	3.0	2.7
Lisa	1.6	2.5	3.0	3.0	2.0	1.1	2.5	1.1	2.7	2.6
Machetajo	1.6	2.4	3.0	3.0	2.1	1.4	2.7	1.1	3.0	2.5
Merluza	2.3	2.4	1.2	2.8	1.7	3.0	2.9	1.0	3.0	3.0
Palometa	1.3	2.9	3.0	2.9	2.3	1.2	2.5	0.9	2.8	2.8
Pargo	2.0	2.3	2.7	2.9	1.9	2.3	2.7	1.0	2.8	2.7
Pelada	1.8	2.4	3.0	2.9	2.2	1.6	2.7	1.1	2.9	2.9
Picuda	1.9	2.3	2.9	3.0	1.8	1.5	2.8	1.1	2.9	2.7
Sierra	1.9	2.4	2.9	3.0	1.8	1.8	2.9	1.2	2.9	2.5