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Lenfest Chilean Bycatch Proposal

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Full Proposal: Marine Mammal Bycatch Risk Assessment in Chile

I. PROJECT NARRATIVE

A. Project Description

Purpose

Conduct a spatial and temporal risk assessment of marine mammal bycatch in Chilean fisheries for fisheries management and endangered species conservation planning.

Background

In many developing countries, fisheries bycatch of marine mammals is poorly monitored or regulated. This poses a particular challenge for countries with economically important fisheries that export to countries with stricter bycatch regulations, like the United States and the European Union (Johnson et al. 2017). Data gaps in fishing effort, bycatch rates, and the fate of animals post-capture, as well as in abundance and trends of affected populations are key obstacles that impede the ability to characterize the risk of fisheries bycatch, including loss or damage to fishing gear and constrain management action. Helping governments like Chile that rely on fisheries exports to address these gaps, reduce bycatch, and be able to manage their fisheries sustainably, has been one of the drivers for the creation of the open-source Bycatch Risk Assessment (ByRA) toolbox (Hines et al. 2020; Verutes et al. 2020). In Chile, there is a critical information gap about the distribution and abundance for most marine mammal species (especially cetaceans), and except for sea lions, there is a lack of data on the species that are the most affected by fisheries bycatch. In the same sense, although there are some reports of direct interactions between cetaceans and industrial and artisanal fisheries (Goodall et al. 1988, Reyes y Oporto 1994, Oporto y Brieva 1994, Pérez-Alvarez et al 2007, Bravo et al 2010, González-But and Sepúlveda 2016), their impact on local populations has not been further evaluated (González-But and Sepúlveda 2016).

Despite the ever-present need for more data, there is an equally strong need to make better use of existing data to develop bycatch risk assessments for marine mammals of conservation concern, and use risk data to generate estimates of population-level impacts and inform management strategies (Stelzenmüller et al 2015). Risk assessments identify, analyze, and evaluate the likelihood or probability of an event, and the consequences of that event (Gibbs & Browman 2015). While high precision and resolution data yield assessments with low levels of uncertainty, as long as uncertainty is accurately described and accounted for, even low-resolution information can and should be used effectively to characterize bycatch risk and prioritize sites, gear types, seasons for monitoring and to guide future data collection effort (Hoffman et al 1994; Briscoe et al 2014).

Incidences of bycatch and therefore solutions are local and place-based, controlled by diverse biophysical, cultural, social, economic and political criteria. However, commonalities in many of these issues have allowed the application of a common framework, or in this case, the ByRA toolbox, to guide the creation and analysis of a spatially explicit bycatch risk analysis locally and globally (Hines et al. 2020). This geographic information systems-based toolbox allows the spatial/temporal assessment and visualization of bycatch risk using any amount or type of data, identifying areas for critical research and immediate management actions while accounting for reliability and robustness in toolbox results. For the ByRA toolbox, we adapted exposure-consequence criteria to *define bycatch risk assessment* (Arkema et al 2014; Wyatt et al 2017), where risk of fisheries bycatch is calculated as a function of the likelihood of exposure (interaction between the marine mammal and the fishery in space and time), and consequence (how a population will respond in terms of mortality or life stages affected).

This project will gather a team of experts that will consult with Chilean government fisheries agencies and local scientists to manage and analyze existing data, and generate methods for gathering new data that characterize the spatial and seasonal distribution and abundance of fishing boats, gear, and marine mammals to assess marine mammal bycatch risk. Our toolbox will introduce users to published bycatch risk assessment methods that consider abundance survey design, the spatial characterization of animal habitat and movement based on environmental modeling, bycatch spatial patterns, and statistical estimates of analysis uncertainty (Hines et al 2005; 2015; 2020; Lewison et al 2011; Komoroske and Lewison 2015; Verutes et al 2020). We will extend previous applications of the ByRA toolbox through a complementary tool for evaluating observer coverage with respect to effectiveness for documenting composition and quantity of bycatch (Curtis and Caretta 2020). The toolbox has been successfully used in four countries (five sites), with varying amounts of pre-existing data (Hines et al 2020). The site with the most data was along the eastern coast of Thailand, where several years of formal abundance surveys and environmental criteria have resulted in abundance estimates, as well as seasonal fisheries and species distribution models for Irrawaddy dolphins (*Orcaella brevirostris)* (Hines et al 2015; Jackson-Ricketts 2016; Jackson-Ricketts et al 2020). Sites with the least data included the Kien Giang Biosphere Reserve in Vietnam, and the Gulf of Mannar in Sri Lanka, with few to no formal surveys (Hines et al 2020).

For this project, we will choose areas of presumptive high bycatch risk along the coast of Chile, including examples of industrial and artisanal fisheries, that are both nearshore and pelagic. Known bycatch species in these areas range from pinnipeds (mostly sea lions) to small cetaceans to baleen whales. By selecting these diverse sites as input for our risk assessment framework, we will maximize the capacity of personnel responsible for data collection, analysis and applied management of fisheries and marine mammal bycatch in Chile and other countries.

Context

Aside from the urgency of the conservation issue for some species and populations of marine mammals, it is especially critical to address bycatch at this time, as US regulations (US Department of Commerce) from 2016 required nations exporting fish and fish products to the United States to be held to the same standards as U.S. commercial fishing operations (Federal Register 2016). Countries with relevant fisheries exporting to the United States have five years from January 2017 to document their compliance. In many of these countries there are significant data gaps on marine mammal distribution and abundance and bycatch rates, especially in developing countries, with resulting economic losses and possible overfishing as a result of non-compliance (Williams et al. 2016, Johnson et al. 2017). The MMPA rule and similar regulations from the European Union (e.g. European Union Council Regulation 2019/1241 (Official Journal of the European Union 2019) have intensified the need for better data to monitor and report marine mammal bycatch and fisheries-related population impacts.

For the government of Chile, this rule has highlighted critical gaps in knowledge of marine mammal bycatch occurrence, species involved, population-level impacts, and fishing boat distribution. While the Subsecretaría de Pesca y Acuicultura (SUBPESCA, Undersecretary of Fisheries and Aquaculture) has taken steps to address these gaps (such as the use of cameras onboard industrial vessels, new abundance estimations for some marine mammals), there is a need for further steps and capacity building. Boat distribution and bycatch occurrence information is being currently addressed with cameras and electronic logbooks recently installed on all boats above 18 meters, and with ca. 200 observers recently put on vessels for some fisheries (mostly industrial) throughout the country. In fact, scientific observers have been on fishing vessels since 2013 for trawl fisheries and since 2015 for purse-seine fisheries. In some of these fisheries, especially industrial purse seine, the coverage is poor (less than 5% of the total number of vessels) and not random, and may be inadequate to monitor catch and bycatch. According to Chilean legislation, since 2019 cameras have been being progressively installed in vessels 15 meters in length and above. Besides this, vessel-positioning systems (VMS), a satellite-based monitoring system, have been on all boats above 12 meters for the past two years. However, a major gap is the lack of a data management and analysis framework. This project proposes to address this gap by using the ByRA toolbox to develop a spatially explicit data management and analysis system as a bycatch risk assessment for Chilean fisheries.

The marine environment off Chile, identified as an Eastern Boundary Upwelling Ecosystem, is characterized by high biological productivity that supports major coastal and pelagic fisheries, both industrial and artisanal (Thiel et al. 2007). In turn, biological productivity is impacted by changes in oceanographic conditions and climate, leading to changes in the biodiversity and distribution of species that are targets for fisheries and commonly foraged on by marine mammals (Oerder et al 2015; Oyarzun & Brierley 2019). As part of our risk assessment, we will include variables that reflect changes in upwelling, sea surface temperature and primary productivity, to create preliminary scenarios of probable changes due to present and near-future climate change and how they might affect bycatch risk interactions and management planning.

Fisheries in Chile produce 12% of national exports. There are three Chilean agencies that govern fisheries: 1) SUBPESCA, responsible for fisheries policy and regulations, 2) the Instituto de Fomento Pesquero (IFOP, Fisheries Development Institute) a private/public partnership that carries out scientific and technological research, and 3) the Servicio Nacional de Pesca y Acuicultura (SERNAPESCA, National Fisheries and Aquaculture Service) executes policy and enforcement. These agencies are concerned about bycatch and fisheries management, and wish to use the ByRA toolbox to: 1) address the NOAA rule, 2) sustain marine mammal populations, and 3) integrate the human and environmental factors that cause bycatch in high-risk areas to mitigate bycatch.

The ByRA results will provide SUBPESCA and IFOP with information on areas and seasons of bycatch risk for ongoing monitoring, as well as the levels of risk for various fishing gear at those times and locations, which can support precautionary actions, policies, and inform carefully designed research and management. Once ByRA analysis has been integrated into the fisheries monitoring programs, SUBPESCA and IFOP would be able to use the resulting information for fisheries management that reduces marine mammal bycatch and addresses NOAA's bycatch monitoring and reduction rule. These mapped results can be used in marine spatial planning as mitigation measures, for instance, to plan fishing gear restrictions and seasonal closures for marine mammal protection. ByRA map visualizations will be presented to communities of fisheries stakeholders, both industrial and artisanal, to illustrate bycatch risk in fishing areas. For local scientists, ByRA results will be used to pinpoint research planning and design robust trials for mitigation measures in higher risk areas – e.g. the effectiveness of attending nets vs. leaving them unattended, fishing gear modifications, trials of pingers on nets, and time/area closures. Scientists and managers can work together to apply ByRA results to adapting observer program design as needed for bycatch management objectives with the help of the observer coverage evaluation tool. By synthesizing and organizing bycatch risk assessment methods in an accessible framework, the reach of our project extends beyond the local areas used to demonstrate the toolbox. At this writing, workshops on how to use the toolbox have been conducted by the ByRA development team in Malaysia, Thailand, India and Vietnam. Workshops in other regions around the world, in association with the International Whaling Commission's Bycatch Mitigation Initiative (IWC/BMI), are scheduled for the coming year, and are being incorporated into the BMI's capacity building program. The IWC/BMI has funded the translation of a manual for the toolbox into Spanish (Kuit et al 2020a,b).

Formulating our Research Questions

We first developed our research questions in January of 2020 at a series of meetings in Valparaiso at the offices of the SUBPESCA and IFOP. Here Dr. Hines gave a presentation on the ByRA toolkit and we started to discuss the specific issues confronting Chilean fisheries, scientists and decision-makers as relevant to marine mammal bycatch. In subsequent calls and discussions, we expanded our research team, exchanged knowledge and solidified our methods and research questions. During these interactive meetings between decision-makers and scientists, we confirmed that these research questions would meet the specific information needs of our policy-making partners for 1) MMPA Import Provisions Rule compliance, and 2) internal management of marine mammal bycatch.

1. Which sites along the coast and pelagic shelf of Chile would most accurately represent the myriad geographies, fisheries, marine mammal population structure, and bycatch situations of concern to Chilean policy-makers and scientists?
2. How can we, using varying quality and amounts of existing data, identify and quantify specific factors, gears, and fisheries that contribute to the risk of marine mammal bycatch in specific locations, scales, and seasons along the coast of Chile?
3. What environmental and biological criteria are most significant to create a spatially explicit geodatabase of fisheries occurrence, gear type and the species distribution models of the marine mammals that most accurately characterize bycatch risk in Chile?
4. How can we most accurately create data management tools and analysis systems for the analysis of marine mammal assessments, fishermen observations, VMS, and government observer data in the ByRA system adapted for Chilean fisheries?

<u>Research Methods and Analysis</u>

We have chosen the Marine Planning Concierge framework for our project. Within the Concierge framework are common themes, or steps that have been identified which emphasize stages in a science-policy process of engagement to support decision-making (Rosenthal et al 2014). We believe that a clearly defined process is needed to address the complex issues surrounding marine mammal bycatch, one that can be generally adaptable at local and regional scales. The Concierge approach has been implemented in various use-cases, and has been found effective in the generation of scientific outputs capable of informing planning and management (Rosenthal et al 2014; Ruckelshaus et al 2013). The framework consists of five steps to fit into our workshop approach for this project:

Step 1: Scoping: Within this first step, our actions will include defining roles, setting a work plan, and identifying feasible methods for analysis within each location. At this point, in addition to our country partners, we will bring in a team of scientists from international agencies and academia. Our first task as a team will be to identify specific sites of high bycatch risk with local scientists. *This step corresponds to our Research Question #1 above.* Criteria for identifying those sites will include a careful and critical review of sites with varying amounts of pre-existing data upon which to base our assessment. These sites will definitely include examples of those critical to NOAA MMPA import provisions. We would like to have a range of sites with typical gear and boat use combinations of industrial and artisanal fisheries and a range of representative marine mammal species that vary in spatial and seasonal overlap situations. Preliminarily, we have identified five different areas of concern that have these different criteria: pelagic and demersal fisheries in the north, central, central-south, south, and extreme-south of the country. As we will have a wide range of data (see below), including observer logbooks, VMS, long-term scientific datasets, and commercial fleet data, we believe it important to consider this decision as a team. We are excited, however, that within these logbooks and fleet data, there will be valuable economic data, such as fuel use, bait, ice, and landing volume that we can incorporate into a socioeconomic assessment. While these data will not be part of the ByRA toolbox per se, they will be integrated into resulting discussions and scenarios to contribute to long-term community-based spatial planning.

The spatial and seasonal scales upon which these sites will be based will be chosen to inform bycatch mitigation at the scale of management decisions at each site. These local examples will exemplify case studies that will be chosen carefully to inform national level decision-making. Each site will have spatial and seasonal AOI's (areas of interest) and management polygons carefully delineated based on reported patterns of gear use and animal distribution, changes in geography, and management criteria. In Southeast Asia for example, in Thailand and Kuching Bay, the AOI's changed seasonally based on both fishing and animal distribution patterns. In Vietnam, the AOI's were only based on fishing gear as we had so little data on animals, and in the Sibu-Tinggi Islands of Malaysia, on proposed management areas. Each site was different, and identified a range of scenarios and data gaps.

Scoping will initially take place through Internet-based conferencing towards existing data acquisition for those sites at local and regional scales. Please note that due to Covid-19 restrictions, our workshop timelines have mostly changed towards Internet-based conferencing with all participants along with corresponding local activities until our third workshop in October of 2021. We are currently discussing starting our project as soon as possible remotely during fall of 2020, as we believe we will need more time to work together during the scoping and data compilation steps of our project as we start to share skills, become familiar with our data, and make important decisions. We will plan visits by selected team members to each site, for assessing the physical environment, identifying gaps in data and training needs and gauging similarities and differences between sites. Scoping is a time to solidify our shared vision of the practical outcomes, create detailed work plans, clarify a communication plan for the length of the project, and develop a rapport between all involved (Rosenthal et al 2014; Arkema et al 2015). At our workshops, whether with local or international collaborators, in-person or remote, we will refine our scenario development goals based on data availability and governance issues specific to each site. During the project, we will work closely with our local partners to ensure that they have expertise in all methods. We will also organize manuscript and outreach assignments and goals.

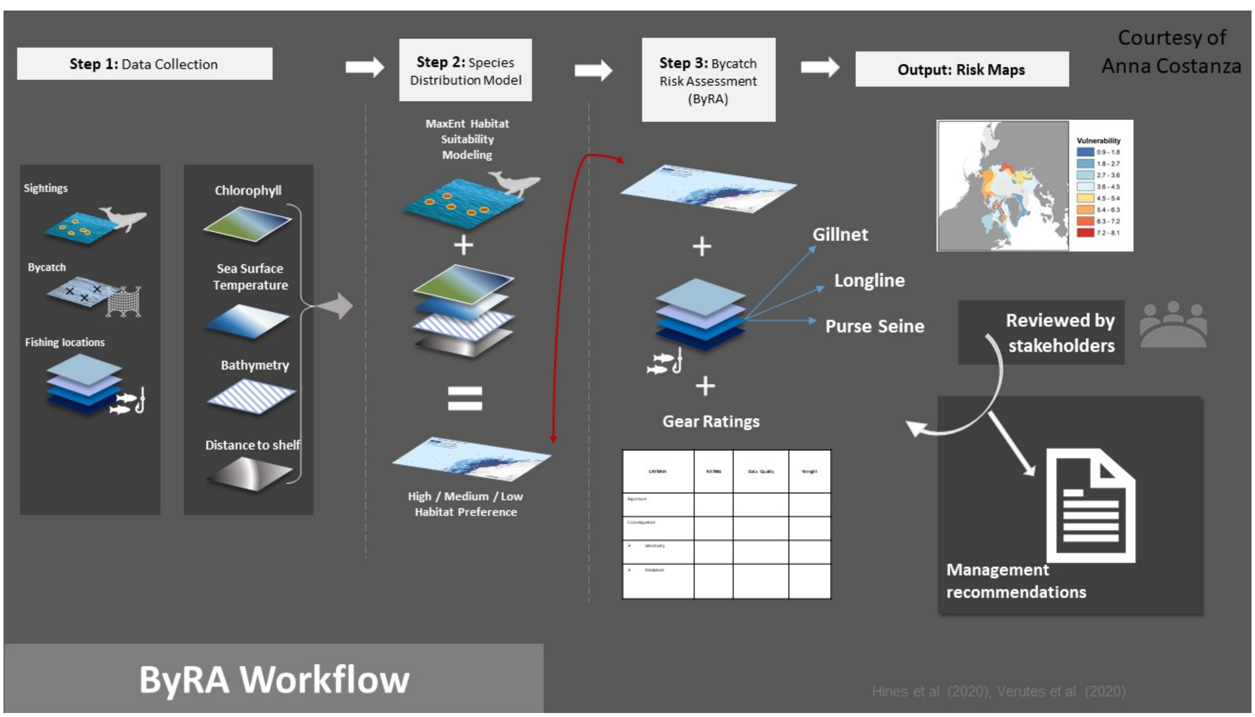

Figure 1. Bycatch Risk Assessment Toolbox (ByRA) workflow.

Step 2: Compile Data: (See Step 1 in Figure 1) *This step corresponds to our Research Question #2 above.* Within the data compilation step, we will access the most relevant and recent data and determine the appropriate resolution of analysis for risk analysis, and evaluate data needs, gaps and options (Rosenthal et al 2014). *With these data, we will be able to pinpoint the contributions of various and specific gears and fisheries to bycatch risk over time and space, and the ability of the number of observers within a certain fishery to be able to ascertain that risk.* Please see the Main Data Sources section below for a list of the main data available from SUBPESCA and our university colleagues for the Chile project. Critical data will be organized into an online geodatabase management system with a general coordinate and projection system (UTM & WGS84). Each site will have its own dataset of files with data such as species files (whether from photo-id, opportunistic sightings, transects, or expert estimates as polygons), environmental data (bathymetry, distance to land, sst), fishing occurrences, the type and amount of gear used (where and when), data from interviews, discussions with fishermen or experts, protected areas, stranding or bycatch information. *Here we are also addressing data that will help us address our Research Question #3, our geodatabase of data we need for ByRA, and contribute to Step 2 in Figure 1, our species distribution models for the marine mammal in question that helps us understand species presence in the fishing area.*

An important input layer for the ByRA incorporates the best available information on species distribution, from which we created species distribution models for each species at each location. *This is Step 2 in our Flow Chart (Figure 1), a critical layer in our GIS model, and Research Question #3.* Species distribution models are important tools for linking species observations to ecological variables and identifying critical habitat (Redfern et al 2006). If enough data on the species and environmental covariates are available, we will test for an appropriate species distribution model, if not, we will use a rule-based method based on previous literature and expert knowledge for the species (Briscoe et al. 2014).

ByRA was specifically created to include the most commonly used data formats. We have experience incorporating both quantitative and qualitative data into the GIS format. At the risk of potential bias and inexact reporting, our methods, with an assessment of uncertainty, are valuable tools that incorporate diverse data quality to evaluate areas where management can be most effective. While high-precision and high resolution data yield assessments with low levels of uncertainty (as long as uncertainty is accurately described and accounted for), even low-resolution information can be used to characterize bycatch risk and prioritize sites, gear types, and seasons for monitoring, and to guide future data collection efforts (Briscoe et al. 2014; Hines et al 2020). We will collect data on the physical and biological environment, as well as animal sightings from surveys and interviews from each field site. We will also review the literature to access the most relevant, recent local data. Data on fishing effort by season, fishing areas, and the type of gear used obtained from surveys, interviews or expert knowledge will be incorporated into layers of fisheries risk (Hines et al 2020). The most useful questions from our previous surveys were: i) What kinds of surveys and technology do you use to track marine mammals and fishing vessels? (ii) Which fisheries are present and what fishing gears are used? (iii) Which spatial data are available/exist for your field site to help understand risk of bycatch (e.g., sightings of marine mammals, bathymetric soundings from nautical charts, fisheries management guidelines) (Verutes et al 2020)?

Step 3: Build Scenarios & Analyze: *In this step, we address Research Question #4 as we start grouping and running the ByRA model, examining our results, analyzing our data, and creating new scenarios (Figure 1 Step #3)*. Once we have specified our field sites and species, decided on our spatial and seasonal scales, and compiled our data, analysis steps at this point include grouping decisions on fishing gear ratings. In Chile we will create common groupings of specific gears commonly seen in marine mammal bycatch by season for each fieldsite. This will then enable us to use expert knowledge for the measurements and analyses to assess the bycatch risk input matrices of exposure & consequence for each gear rating at each site. Bycatch risk for each species caused by any stressor is calculated as the weighted average of *exposure*, or the overlap between a species' distribution and the extent of a human activity in time and space, and *consequence*. *Consequence* can be defined by sensitivity, or an expert assessment of how a population of a given species will respond to an impact such as bycatch, or resilience, both a species-wide and local assessment of the species (see Hines et al 2020 supplemental material). Some of these criteria are calculated by the ByRA model, such as spatial overlap, intensity of fishing effort, and likelihood of species/threat interaction. Others are input into the risk model, such as status of management actions, likelihood of mortality, age of mortality, population connectivity, and global risk of extinction.

The intensity of fishing activity by gear type often vary across space and can be mapped as a surface using spatial interpolation tools available in a GIS. Likelihood of interaction between fisheries and species are calculated by the toolbox as the sum of species suitability ranking (1−3) and a combined fishing occurrence and gear-type intensity rating (1−3), then reclassified from lowest to highest (1−3). Generally, the rationale is that if both a species and gear had a high probability of being present in a given area, the likelihood of interaction or bycatch is also high.

From our final results, our Chilean team members will have:

- all rule-based or distribution models for each species in each fieldsite,
- maps of fishing gear occurrence (effort optimally) for each field site and season, ,
- maps of bycatch risk for each species/gear/fieldsite,
- a table of bycatch contribution (by %) for each gear per fieldsite per season,
- exposure/consequence diagrams for each fieldsite per season showing comparative bycatch risk by AOI
- all geodatabases and generated analysis products

While assessing the results, the team will compare and assess the validity of the synergies and tradeoffs proposed in alternative outputs. Resulting maps will be examined in comparison to observed data, similar research results and local/expert opinion to refine the model (Rosenthal et al 2014). We will also be able to characterize the limitations of the information on bycatch available from fisheries observers with respect to bycatch composition, to help identify potential uncertainty in this dimension. We then share our outputs, with a visualization of data quality, with agency scientists and fishermen to convey how existing information in data-limited sites could be used to further improve the quality of risk estimates over time. Therefore, the uncertainty of data inputs can be error checked and improved by local experts and stakeholders. Repeated scenarios can be used to predict what will happen to a population if the bycatch rate changes, observer numbers change, or if we run different mitigation strategies resulting in probable increases or decreases in bycatch rates or areas of risk, including preliminary habitat and fisheries change estimates based on changing ocean conditions.

Step 4: Synthesize: For this step we will place the results of the analysis into context, and translate outputs into clearly delineated actionable recommendations for management. Synthesis involves communicating with stakeholders to plainly demonstrate how the difference scenarios affect outcomes (Hope 2006; Rosenthal et al 2014). From the synthesize step, based on open communication and feedback from our Chilean partners, we can return to earlier steps to compile further data and modify scenarios. In our updated timeline, by our third workshop in October of 2021, we would have initial scenarios for our IFOP colleagues to present to SUBPESCA in time for them to submit as part of their mitigation planning for the NOAA MMPA regulations.

Another opportunity for synthesis for this project would be a natural collaboration with the Lenfest Expert Group that has been working with Drs Punt and Francis on distribution and size of marine mammal populations and assessment of marine mammal bycatch rates. I (Dr. Hines) have been quite interested in that group, having attended one of their meetings, and Dr. Sepulveda was a full participant. We believe, especially with Dr. Curtis' tool for evaluating observer coverage for documenting quantity of bycatch, that the ByRA could identify specific populations in Chile for PBR and bycatch assessment. If we do move forward, we would like to talk with them, in particular Dr. Siple, whose app could be particularly useful. We would like to invite collaboration between them and interested team members.

Step 5: Outreach and Socialization: We will finalize a communication plan to effectively deliver the risk assessment results to a diverse range of stakeholders. Research results can be difficult to interpret. We will create clear documentation and video tutorials in how to understand and apply the ByRA results. As we plan workshops with fishermen to present our results, they may have interpretations that we wish to reincorporate into future scenarios. During our last workshop, we will work together to finalize writing our manuscripts and plan conference presentations. The results will be presented to the IWC Scientific Committee, which could lead to global recommendations on bycatch management. The Bycatch Mitigation Committee could assist in the communication/outreach of this work at regional/international levels.

The local research team members have extensive networks and working relationships with key partners in the case study areas. Our Chilean partners have a long history of research collaboration and contacts with government agencies, research facilities, village leaders, and local environmental non-profits. Through these contacts, we will be able to multiple outputs and visualizations of this project throughout the country. Outreach materials in various forms will be distributed such as storymaps (cons.scienceontheweb.net/bycatch/viewer.html and https://arcg.is/00Liqn) through management and educational channels to artisanal and industrial fisheries, communities and schools, as well as to Indigenous communities. We can generate paper maps, poster, brochures, presentations, and bring various management scenarios to communities to show fishermen how to reduce bycatch, especially if this would allow for them to continue to export fish commercially.

Main Data Sources.

These data are all currently available through SUBPESCA, IFOP, and our other Chilean collaborators. Among the main data that will be used in the project are the following:

- Commercial Fishing Logbooks of IFOP Scientific Observers
- Cetacean warning records made by IFOP scientific observers
- Previous marine mammal research carried out in Chile
    - Opportunistic surveys
    - Acoustic surveys
    - Line transect surveys
    - Census data
- Operational data of commercial fishing fleets from SERNAPESCA
- Baseline GIS layers: bathymetry, coastline, river mouths/estuaries, major fishing piers, human population centers

Challenges.

While all current data will be made available to the team, we need to recognize that data coverage on fisheries occurrence and marine mammal abundance and distribution are uneven. For example, while there is an observer program, the density of observers for some fisheries is very low, perhaps 1-2% of the fleet in some areas. In contrast, in trawl fisheries in central and southern Chile, the coverage is much higher (>80% of the total trips). With respect to marine mammals, knowledge of distribution and abundance of pinnipeds is relatively good, as are data on pelagic baleen whales; however, there is no information about distribution and abundance of most of the cetacean species along the coast.

While the ByRA was created to work with limited data availability, we will have to assess the uncertainty of results for each fishery carefully. This is especially critical as our risk assessment results will contribute directly to management decisions and climate change assessment. Hines et al. (2020) has a reference table for uncertainty standards (Table 1), which we will adapt to be more relevant here. To meet this challenge, we will use a sensitivity analysis (or a what-if) approach where we analyze the impact of various parameters on bycatch risk scenario results. By identifying critical risk factors, we can support further research and decision-making to minimize uncertainty (Hines et al. 2005).

Given the current political and fiscal uncertainties in Chile and worldwide, the ByRA framework is uniquely well suited to scaling up and down the complexity of analyses as resources to support data acquisition and analyst time wax and wane. As mentioned previously, ByRA was especially created to leverage existing data on poorly monitored and regulated non-targeted species capture into categorized risk scenarios in the most data-scarce situations (Verutes et al 2020). However, in consultation with our colleagues in SUBPESCA and IFOP, a large part of the data that will be used in this project have already been collected in the past and current years. We see no need for specialized methods or analyses that would add to the cost of this project. It is also relevant to note that during this pandemic, IFOP scientific observers have been able to collect information onboard commercial fishing vessels, while taking the necessary safeguards to ensure their health and that of their families.

Table 1. A reference table of uncertainty standards for Bycatch Risk Assessment (ByRA) criteria classification (Hines et al. 2020).

Animal Sightings Distribution	Data collected during formal transect or photo id survey. Data can be used to estimate relative abundance	Sightings/photo id collected during opportunistic surveys.	Few sightings collected. No abundance estimation possible. Sightings only available from interviews.
Habitat Suitability	Estimated from modeling, formal collection of environmental variables.	Rule-based estimation, minimal environmental variables collected.	Criteria from other regions used to estimate animal distribution.
Fishing Occurrence/ Gear Type Densities	Surveyed fishing occurrence per unit of distance or time over seasons	Spatial a/or temporal distribution of fishing based on interviews or expert opinion.	Sparse or incomplete data. No geospatial or precise localization of fishing effort/gear
Bycatch / Stranding Data	Data available from interviews or observers on boat or stranding data. Estimation of bycatch rate possible	Relative estimation of bycatch from interviews or stranding data.	No estimation of bycatch or strandings available.

Consideration of Climate.

Oceanographic conditions determine the habitat of marine species through physiological limits or preferences and the availability of food (through the habitat preference of prey/food). Some oceanographic features, like fronts and eddies (Bost et al., 2009), and upwelling cells and fronts (Santora et al. 2020), have been identified as areas that tend to concentrate plankton and therefore are excellent feeding grounds for many species, including fish, seabirds and marine mammals. When the oceanographic conditions are suitable for both commercially exploited fish and marine mammals (or other species), interactions and by-catch can occur more frequently. Thus, identifying these areas, and in particular their oceanographic conditions, is an integral part of our *third research question* as we create scenarios that include the most significant environmental and biological criteria. Researchers have shown that consideration of these changing conditions is critical to avoid interactions, especially as these suitable areas are known to shift in response to climate variability (Benson et al. 2002, Palacios et al. 2006).

Climate change projections estimate that upwelling along the Chilean coast will intensify in the poleward regions, while it will weaken towards the equator (Rykaczewski et al. 2015), which in combination with globally increasing temperatures, will lead to local changes in biochemistry (García-Reyes et al. 2015) and therefore biological productivity (Bakun et al. 2015). Evidence of changes consistent with these projections have already been observed in Chile (Ancapichún & Garcés-Vargas 2015; Aravena et al. 2014).

With increasing temperatures, suitable habitat for forage species and marine mammals can be compressed and overlapped, bringing a higher chance of bycatch interactions. In upwelling systems, sea surface temperature (SST) has been widely used as an ecosystem-level indicator as it is readily available and is an integrator of the most important oceanographic processes in these systems: upwelling and water-column stratification; and as such, remote-sensed SST data can supply us with maps that can be used as scenarios within the ByRA. An example of such an indicator is a new habitat compression index, developed by Santora et al. (2020) based on ocean temperatures, which indicates that the area suitable for fish and marine mammals in the central California Current can expand and contract with changes in coastal upwelling and ocean temperatures. At times when upwelling is weak and/or temperatures are warm, the habitat is compressed and more frequent interactions between fisheries and marine mammals occur (Santora et al. 2020). Adding oceanographic conditions to the analysis of fisheries and marine mammal interactions provides a more complete understanding of their occurrence and a better way for managers to mitigate or anticipate them during present and future conditions. Therefore, using a similar indicator of habitat within the ByRA toolkit, we will investigate how oceanographic conditions in Chile's coastal waters might spatially and seasonally impact fisheries and mammal interactions. In particular, we will focus on the role that remote-sensed sea surface temperature (SST) and chlorophyll-a (Chl-a) play on the frequency of fisheries/marine mammal interactions in our study region.

First, we will delineate the domain of the study area. As a starting point, we will use the boundary of the Exclusive Economic Zone (EEZ) of Chile, and this area will be refined using historical and current fisheries data, as highly migratory marine mammal species and pelagic fisheries can be found outside the EEZ boundary, in areas beyond national jurisdiction. Drs. Patricia Zarate and Rodrigo Vega, senior researchers from our IFOP team, have conducted off-shore oceanographic surveys and gathered data on pelagic fisheries and migratory baleen whales off the coast of Chile, which will be available to our project.

We will obtain satellite images of SST and Chl-a and collocate the oceanographic data with fisheries and mammal interaction data points for analysis within the ByRA tool. The boundary data of the EEZ are available through the IFOP database. SST data are readily available from NASA MUR SST V4, a global dataset that provides daily values at 1km resolution by merging multiple satellites and in situ data, freely available through https://podaac.jpl.nasa.gov/. Chl-a data, as a proxy for primary productivity, are available daily from the NASA Ocean Biology Processing Group multi-mission (https://oceancolor.gsfc.nasa.gov/data/overview/).

Our team will generate habitat compression indices (similar to that created by Santora et al 2000) based on SST and Chl-a to investigate the thresholds at which the likelihood of fisheries and marine mammal interactions increases. Based on these thresholds, we will create spatial distribution maps of the results of the habitat indices as scenarios for inclusion in ByRA (see Steps 1 & 2 in Figure 1). Our ByRA results will give us a first look at how these patterns and relationships might change with climate variability. The results of these scenarios will provide a preliminary foundation for continuing research on how changing ocean conditions can be used to better inform management planning for fisheries sustainability, to avoid interactions with marine-mammals, and contribute to ongoing research.

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