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Using the Bycatch Risk Assessment Tool for Small Cetaceans in a Data-Poor Fishery off Isla Grande de Chiloe, Southern Chile

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Introduction

Bycatch has been recognized as the main threat to small cetacean populations (Mitchell 1975, Perrin et al. 1994). Of the different types of fishing gear used in the world, gillnet bycatch represents an important conservation problem for small cetaceans and other non-target species (e.g. Rojas-Bracho et al. 2006, Jaramillo-Legorreta et al. 2017), causing considerable mortality of individuals each year (Perrin et al. 1994). Synthetic gillnets were widely introduced into the world's fisheries as a durable and economical fishing gear after World War II (Potter & Pawson 1991), and quickly became the main driver of population declines in many species of dolphins, porpoises and other marine mammals.

Coastal or shoreline gillnet fishing from local beaches is a historical fishery and knowledge has been transmitted from generation to generation among artisanal fishermen in Chile. Chilean fishing regulations are difficult to enforce in these remote areas, although this form of fishing from the shore has always been carried out, and is recognized by fishermen as a tradition.

Bycatch events of Chilean dolphins (*Cephalorhynchus eutropia*)and Burmeister's porpoises (*Phocoena spinipinnis*) have been reported for this fishery in central Chile (Aguayo-Lobo 1975,

Torres et al. 1979). Accidental entanglements in purse seine and longline gear have also been described in this area, for conger eel, horse mackerel and sea bass fisheries. Currently, the threats are mainly related to accidental entanglement in artisanal fisheries.

Sightings and strandings of Chilean dolphins, Peale's dolphins (*Lagenorynchus australis*) and Burmeister's porpoises have been recorded on Isla Grande de Chiloé, but there are few studies on their ranges, habitat use and population structure (Molina-Schiller et al. 2005, Ribeiro et al. 2007, Viddi et al. 2016, Heinrich et al. 2019). For the Chilean dolphin, the only endemic species of cetacean in Chile, it has been reported that they are found almost exclusively in areas very close to the coast, in shallow waters and associated with river mouths and/or estuaries (Heinrich 2006, Pérez-Alvarez et al. 2007, Viddi et al. 2015, Heinrich et al. 2019). While these three species are not considered endangered by the IUCN, current population trends for the Chilean dolphin is shown as decreasing (Heinrich & Reeves 2017), and unknown for the Peale's dolphin (Heinrich & Dellabianca 2019) and Burmeister's porpoise (Felix et al 2018).

For this research we engaged the participation of environmental authorities, local scientists and artisanal fishermen to gather existing data and characterize the spatial distribution of shore gillnets and these local cetaceans with the aim of assessing the risk of bycatch.

METHODS

Area of interest

We defined our study area as the coastal zone of south-central Chile, from 33°57'39"S, 71°52' 24"W to 43°6'49"S, 73°42'39"W (Figure 1), which includes the inland sea around Chiloe Island. Within this area, 26 caletas or villages were selected considering prior information in the literature, national and international reports and expert opinion on the use of shore gillnet, distribution, presence and strandings of small cetaceans (Pérez-Alvarez et al. 2020, Trinidad 2021). We selected a number of villages to visit that were proportional to the size of the region where they are located and that were not very close to each other, to have a more homogeneous representativeness of the study area (Figure 1). A team of three researchers visited these 26 villages between April 11 and 22, 2022. For this report we will focus on the Los Lagos region, located in southern Chile, specifically in the villages (n = 5) located on the Isla Grande de Chiloé (see inset map).

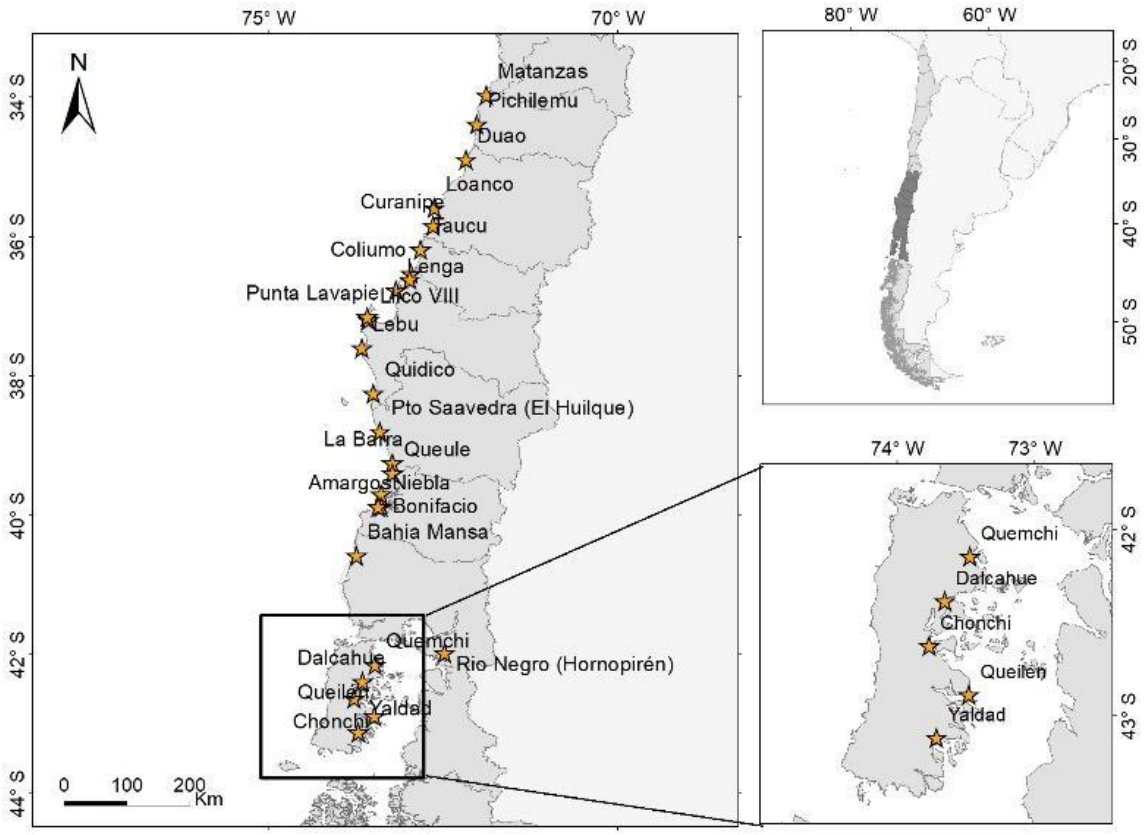

Figure 1. Villages selected and visited for interviews and information on coastal gillnet fisheries and marine mammal bycatch.

Artisanal fisheries distribution data

As these coastal gillnets are in a remote area, this fishery does not have systematic monitoring by the fisheries control authority (National Fisheries Service, SERNAPESCA), so there is no official data on the places where shore gillnets are used, fishing effort, fisheries catch or bycatch. Because of this, we did face-to-face interviews (Appendix 1), with the main objective to obtain data on fishing methods, their distribution, their temporality and bycatch of marine mammals (Costanza et al 2021). The survey was designed with the support of experts in coastal socio-ecological systems and fisheries anthropology, and a survey previously developed by another project on Chilean dolphins in Chile (Pérez-Alvarez et al. 2020) was used as an example.

In addition to the survey described above, we used additional materials to support the interviews and test the accuracy of the information collected. We created maps of the surrounding villages and coastal areas, in which fishermen could indicate and delimit the places where they use fishing gear. We also used posters with images and information of the fishing gear and different species of cetaceans (Pérez-Alvarez et al. 2020, http://www.eutropia.cl), since these can present different

common names in the different fishing villages. This way we facilitated the identification of coastal dolphins by artisanal fishermen. Once the information was collected, we digitized the results into data sheets and *polygon shapefiles* with the areas of use of the coastal gillnets using ArcMap 10.8.1 software (ESRI 2020. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute).

Species distribution data

Based on expert knowledge from our project and local scientists and local and literature review, we identified three species of small cetaceans that could interact with the shore gillnet fishery: the Chilean dolphin, the Peale's dolphin and the Burmeister's porpoise. In collaboration with one of the project scientists, we were able to incorporate species distribution models for the Chilean and Peale's dolphins on the Isla Grande de Chiloé through a *Bilinear Normal Mixing Model* (BNMM) (Bedriñana-Romano et al. 2023, not yet published). These results are not yet published so they are not included in this report. For the Burmeister's porpoise, as sightings data for this species were sparse, and literature suggests that the distribution is continuous along the coast of Chile, a coastal distribution was generated using multiple-ring buffers. We estimated this distribution considering the presence and preference of habitat found in the literature and the criteria of the experts (Reyes & Oporto 1994, Molina-Schiller et al. 2005, Clay et al. 2018). Our information suggested that porpoise distribution is continuous along the coast of Chile, so we created a multi-ring buffer of 10, 20 and 50 kilometers of the coast. A rating of 3 was assigned to areas within 10 km, indicating a high probability of presence. A rating of 2 was assigned to areas within 10 to 20 km, indicating a probability of medium presence. A rating of 1 was assigned to areas within 20 to 50 km, indicating a low probability of presence (Figure 2).

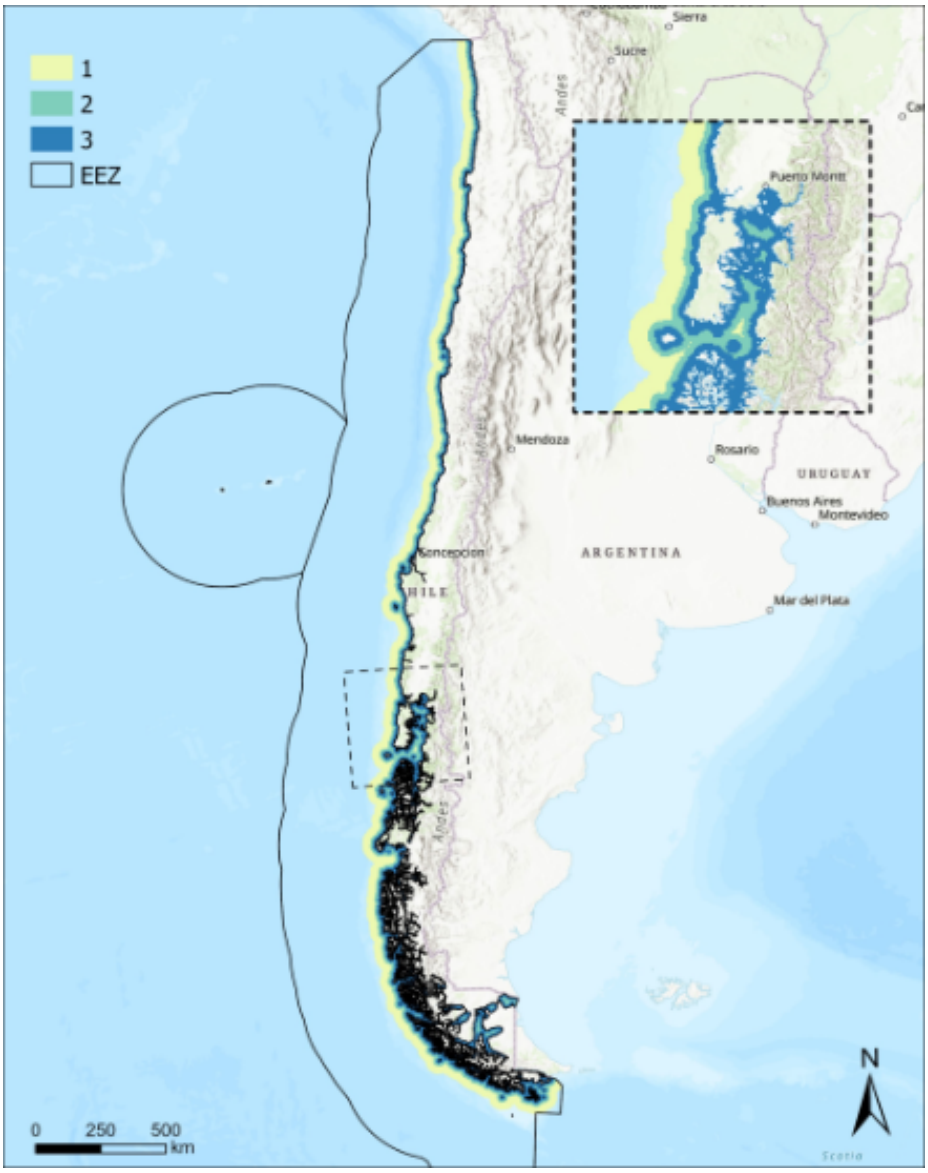

Figure 2. Distribution of Burmeister's porpoises on the southern and central coast of Chile. The inset map shows the Chiloe Island area.

Species and fisheries likelihood of interaction

As an input into the ByRA tool, to determine the probability of interaction between the fisheries gear and the species, we needed to create a map layer that showed the areas in common for the fishery and each of the dolphins. We created these maps and then reclassified them into high, medium and low spatial densities of interaction.

Preliminary ByRA models

In addition to the ByRA model inputs described above, the risk to species caused by stressors was calculated as the weighted average exposure and consequence for the species studied. Exposure quantifies the amount of stress caused to a species by a stressor, while consequence is defined as

the species' response to stressor, resilience and sensitivity, by assessing the intrinsic traits of the species. Using expert opinions from project scientists, species attributes (Table 1) and interaction properties (Table 2) were appropriately classified (Samhouri & Levin 2012, Arkema et al. 2014). The criteria below was based on Hines et al (2020) and Verutes et al. (2020). Table 3 shows the input data to specify the exposure and consequence criteria for Chilean dolphins, Burmeister's porpoises and Peale's dolphins. The ByRA model was then run using the open source Habitat Risk Assessment software tool from InVest Workbench (v.3.12.0) (http://releases.naturalcapitalproject.org/invest-userguide/latest/en/habitat_risk_assessment.html).

Table 1. Criteria for species attributes

Species Attributes	Value	Criteria
Age of maturity		
	3	> 4 years
	2	2-4 years
	1	< 2 years
Reproductive strategy		
	3	long calving interval / high parental investment
	2	medium calving interval / high parental investment
	1	short calving interval / short to medium parental investment
Population connectivity		
	3	negligible movement/exchange between the focal regional population and other populations
	2	occasional movement/exchange between the focal regional population and other populations
	1	regular movement/exchange between the focal regional population and other populations
Local species status		
	3	Endangered
	2	Threatened or of concern
	1	Low concern

Table 2. Criteria for interaction with stressors

Interaction Property	Value	Criteria
Mortality		
	3	Lethal
	2	Sublethal
	1	Negligible
Life stages affected by gear		
	3	Adults only
	2	mixed
	1	Juveniles only
Intensity		
	3	High
	2	Medium
	1	Low
Likelihood of interaction		
	3	High
	2	Medium
	1	Low
Temporal overlap		
	3	12 months
	2	4-11 months
	1	1-3 months
Catchability		
	3	High
	2	Medium
	1	Low
Current status of management		
	3	No strategy identified
	2	Management strategy identified
	1	Management strategy identified and implemented

Table 3. Spreadsheet used as an input for ByRA models to define ratings, weights, data quality, and exposure and consequence factors for the Chilean dolphin, Peale's dolphin and Burmeister's porpoise.

HABITAT NAME	Chilean_dolphin			burmeisters			peales_dolphin			CRITERIA TYPE
HABITAT RESILIENCE ATTRIBUTES										
	Rating	DQ	Weight	Rating	DQ	Weight	Rating	DQ	Weight	E/C
age of maturity	3	2	2	2	2	2	3	2	2	C
reproductive strategy	3	2	2	2	2	2	3	2	2	C
population connectivity	3	2	2	0	2	2	0	2	2	C
local species status	2	2	2	0	2	2	1	2	2	C
HABITAT STRESSOR OVERLAP PROPERTIES										
beach_gillnet	Rating	DQ	Weight	Rating	DQ	Weight	Rating	DQ	Weight	E/C
mortality	3	2	2	3	2	2	3	2	2	C
life stages affected by gear	0	2	2	0	2	2	0	2	2	C
intensity	[spatial file]	2	2	[spatial file]	2	2	[spatial file]	2	2	E
likelihood of interaction	[spatial file]	2	2	[spatial file]	2	2	[spatial file]	2	2	E
temporal overlap	3	2	2	3	2	2	3	2	2	E
catchability	2	2	2	2	2	2	2	2	2	E
current status of management	3	2	2	3	2	2	3	2	2	E

RESULTS

Artisanal fisheries distribution data

86 interviews were conducted with artisanal fishermen in the 26 villages visited, managing to do between two to five interviews per village. From the information provided by the fishermen (interview and maps), regional polygons were digitized for the areas where shore gillnets are used for the areas of Quemchi, Dalcahue, Chonchi, Queilén and Yaldad on the Isla Grande de Chiloé.

Quemchi: Three artisanal fishermen were interviewed, all of whom used the gillnet. This net is extended from the shore up to 200 m perpendicular to the coast (Figure 3). Fishermen indicated that every day there are sightings of Chilean dolphins and indicate that bycatch events of this species have occurred. The respondents did not give us specific numbers or incidents of bycatch.

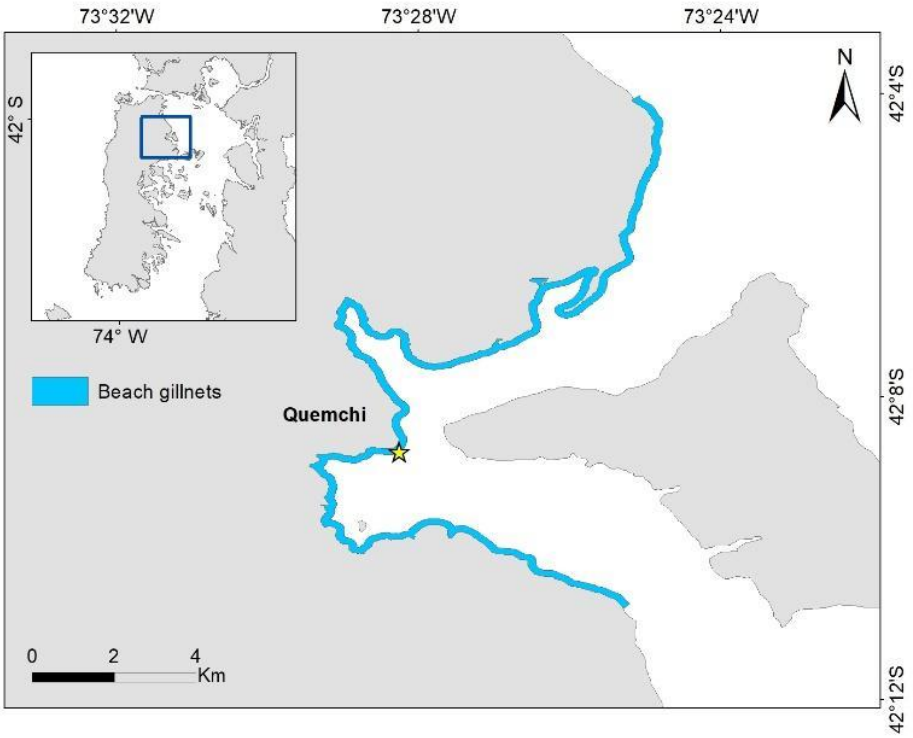

Figure 3. Area where shore gillnets are used, according to artisanal fishermen from Quemchi Cove

Dalcahue: Four artisanal fishermen were interviewed, all of whom used the gillnets throughout the year, and fished near Chonchi, mainly for sea bass fishing. These nets are placed further south, not in the village itself, from the shore to 80m perpendicular to the coast (Dalcahue is further north than the map shows)(Figure 4). Fishermen indicated that there are sightings of Chilean dolphins frequently and mentioned that Peale's dolphin bycatch events have occurred.

Chonchi: Three artisanal fishermen were interviewed, all of whom used the shore gillnet throughout the year, most often in summer, mainly for salmon and silverside fishing. These nets are deployed from the shore up to 80 m perpendicular to the coast (Figure 4). Fishermen indicated that there are sightings of Chilean dolphins but did give us specific numbers or incidents of bycatch.

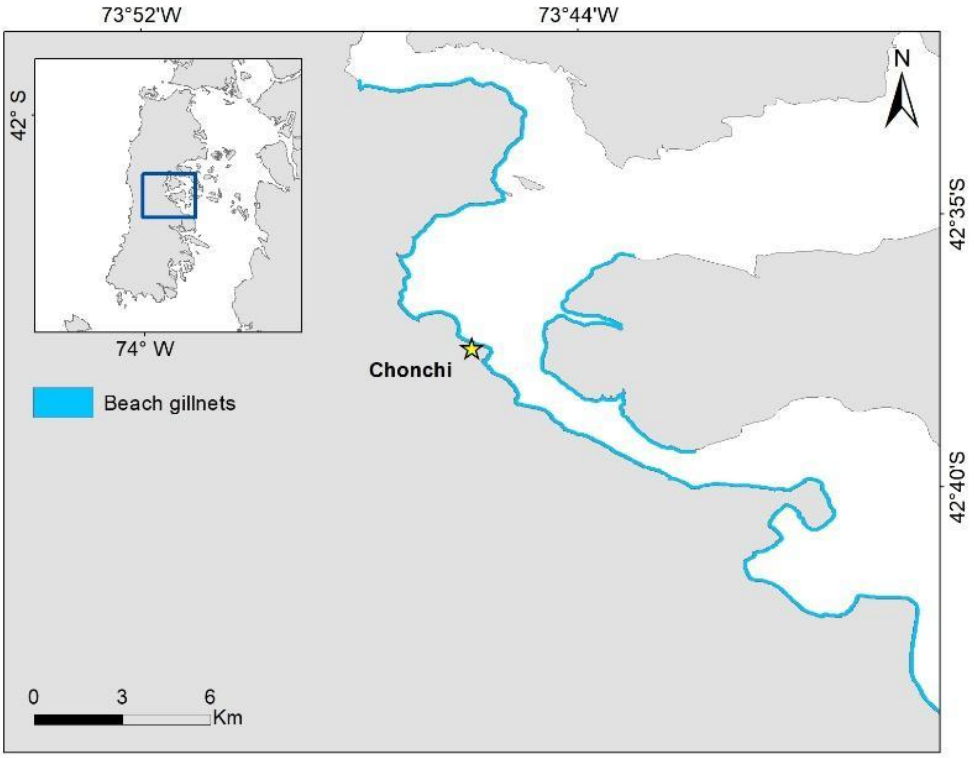

Figure 4. Areas where shore gillnets are used, according to artisanal fishermen from Dalcahue and Chonchi villages.

Queilén: Three artisanal fishermen were interviewed, all of whom used the shore gillnet throughout the year, mainly for salmon and silverside fishing. However, not many fishermen in this village use net fishing. Nets are deployed from the shore up to 80 m perpendicular to the coast (Figure 5). Fishermen indicated that everyday there are sightings of Chilean dolphins and had heard of bycatch of these dolphins in a nearby area.

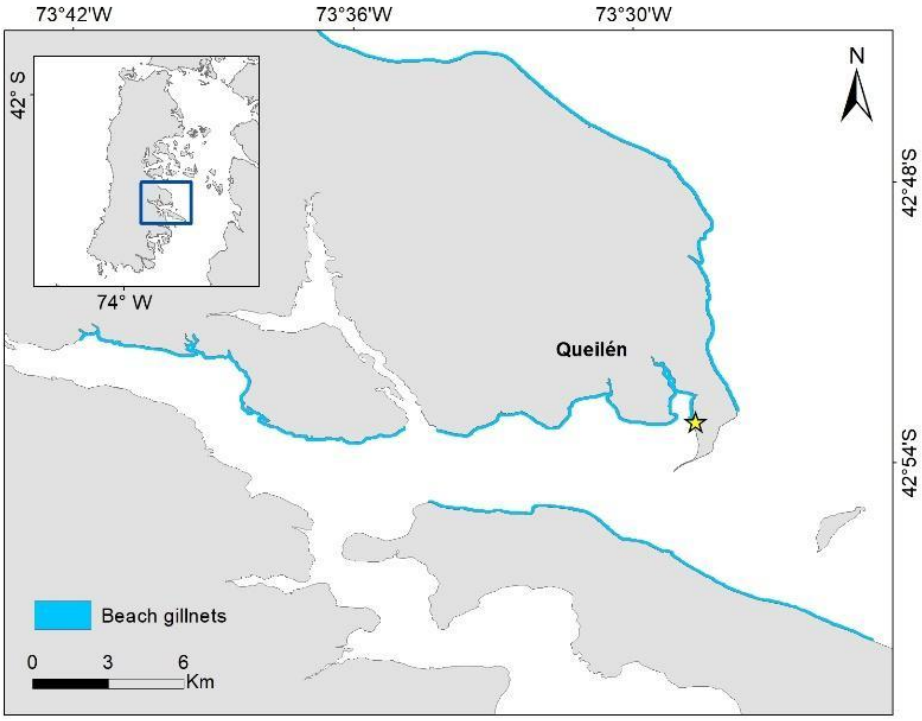

Figure 5. Areas where shore gillnets are used, according to artisanal fishermen from Queilén village

Yaldad: Three artisanal fishermen were interviewed, all of whom used the shore gillnet throughout the year. These nets are put in from the shore up to 100 m perpendicular to the coast (Figure 6). Fishermen indicated that there are frequent sightings of Chilean dolphins, however they did not tell us about specific bycatch incidents.

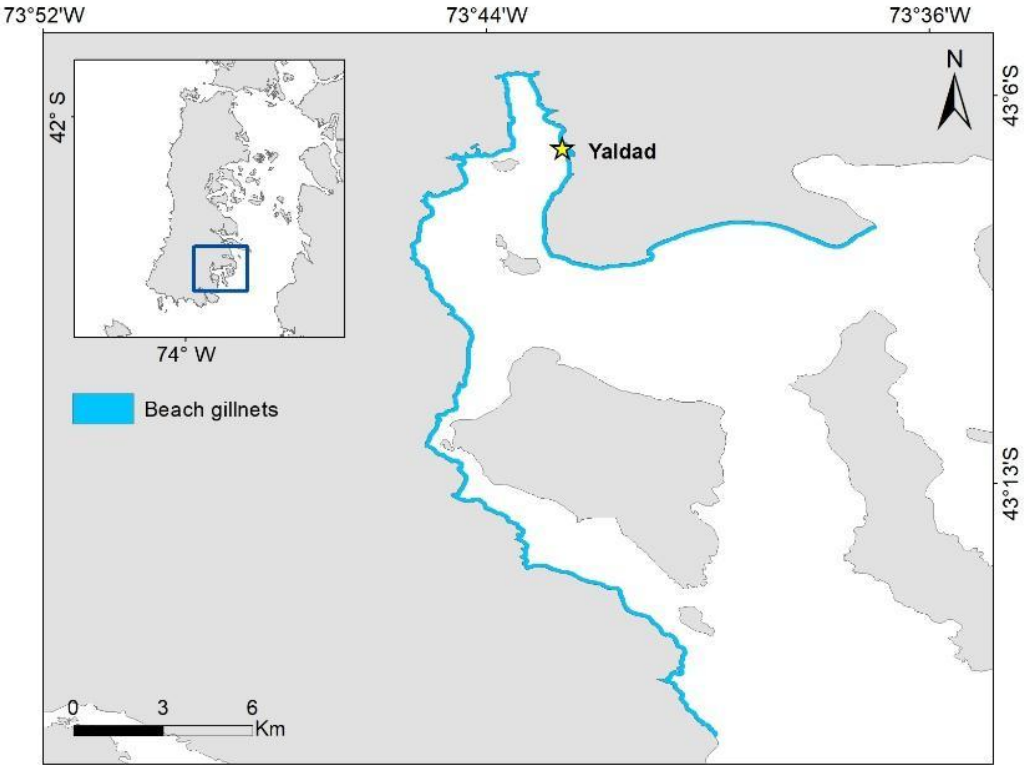

Figure 6. Areas where shore gillnets are used, according to artisanal fishermen from Yaldad Village.

Bycatch Risk maps

Running the ByRA model, we generated bycatch risk maps for each species studied, Burmeister's porpoises (Figures 7 and 8), Chilean dolphins (Figures 9 and 10) and Peale's dolphins (Figures 11 and 12). To facilitate the visualization of the risk due to the limited extent of fishing gear, separate maps are shown for northern and southern regions of Chiloé Island. For the three species studied, the model showed a high risk of bycatch in all villages.

Burmeister’s porpoises

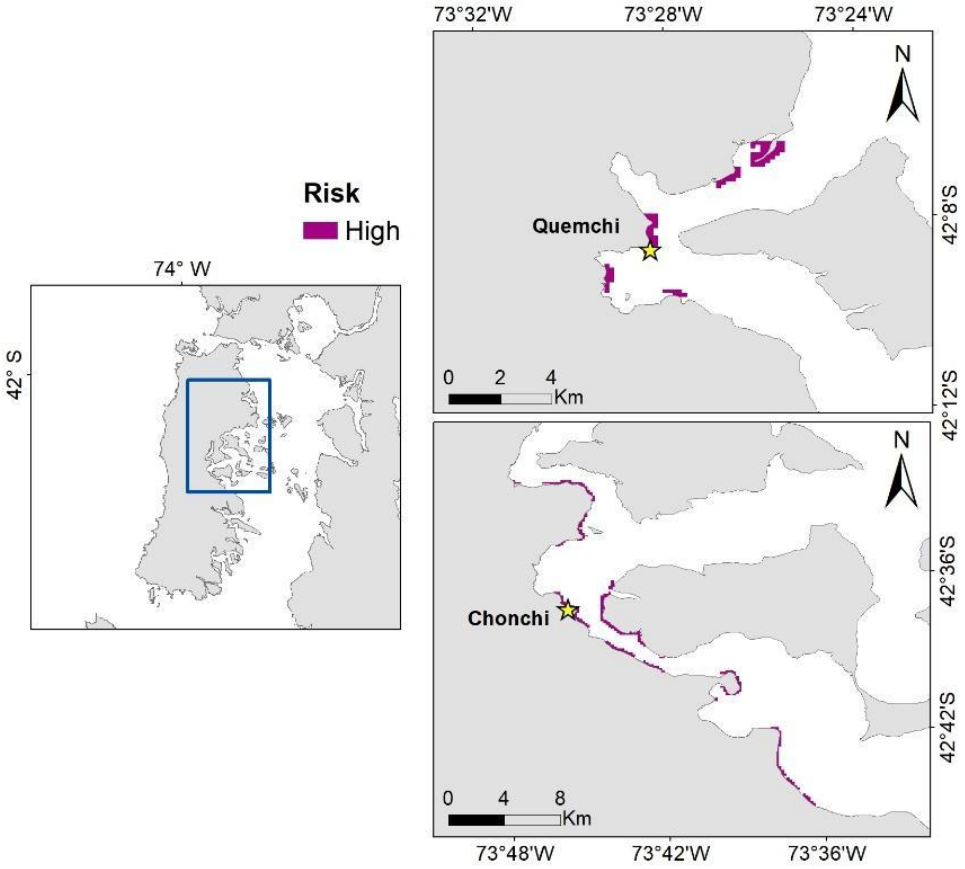

Figure 7. Bycatch risk for Burmeister's porpoises in the northern area of Chiloé.

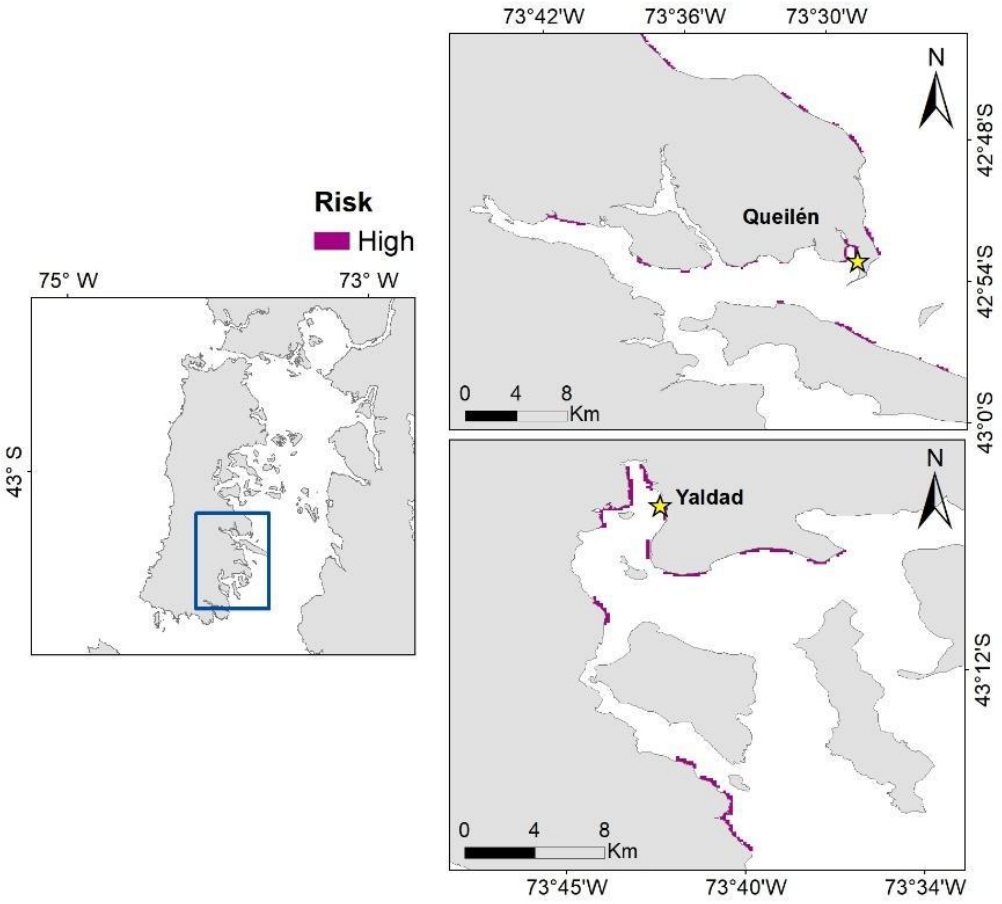

Figure 8. Bycatch risk for Burmeister's porpoises in the southern area of Chiloé.

Chilean dolphins

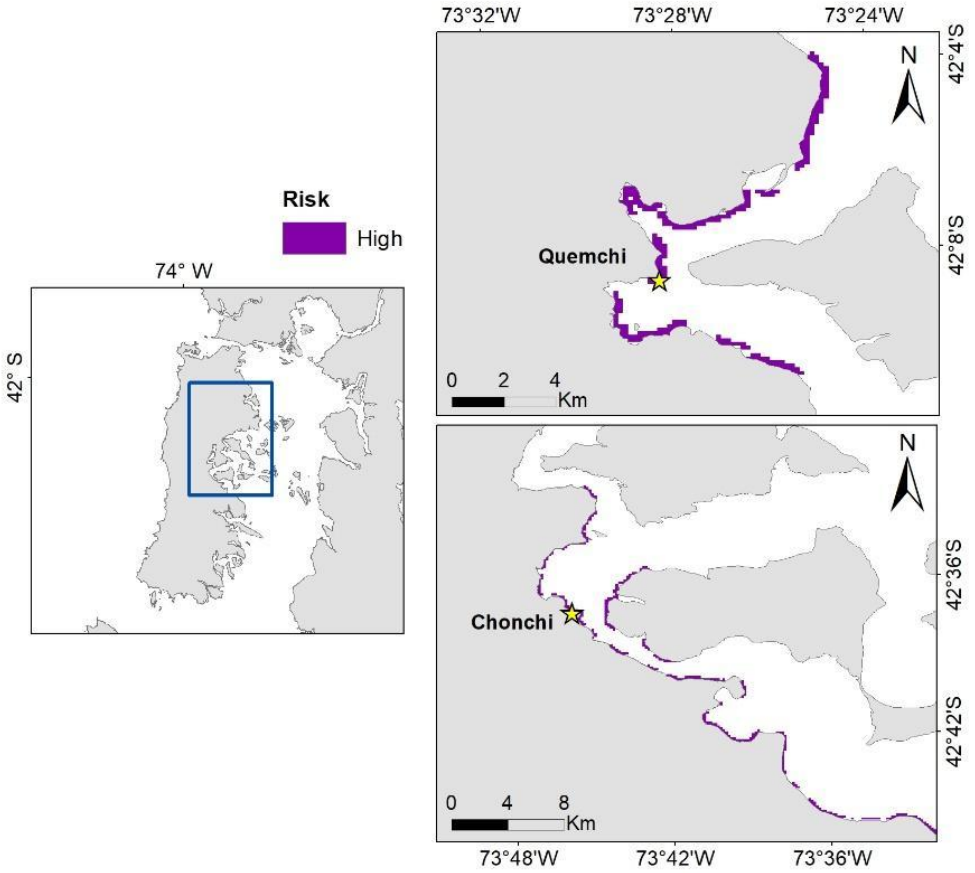

Figure 9. Bycatch risk for Chilean dolphins in the northern zone of Chiloé.

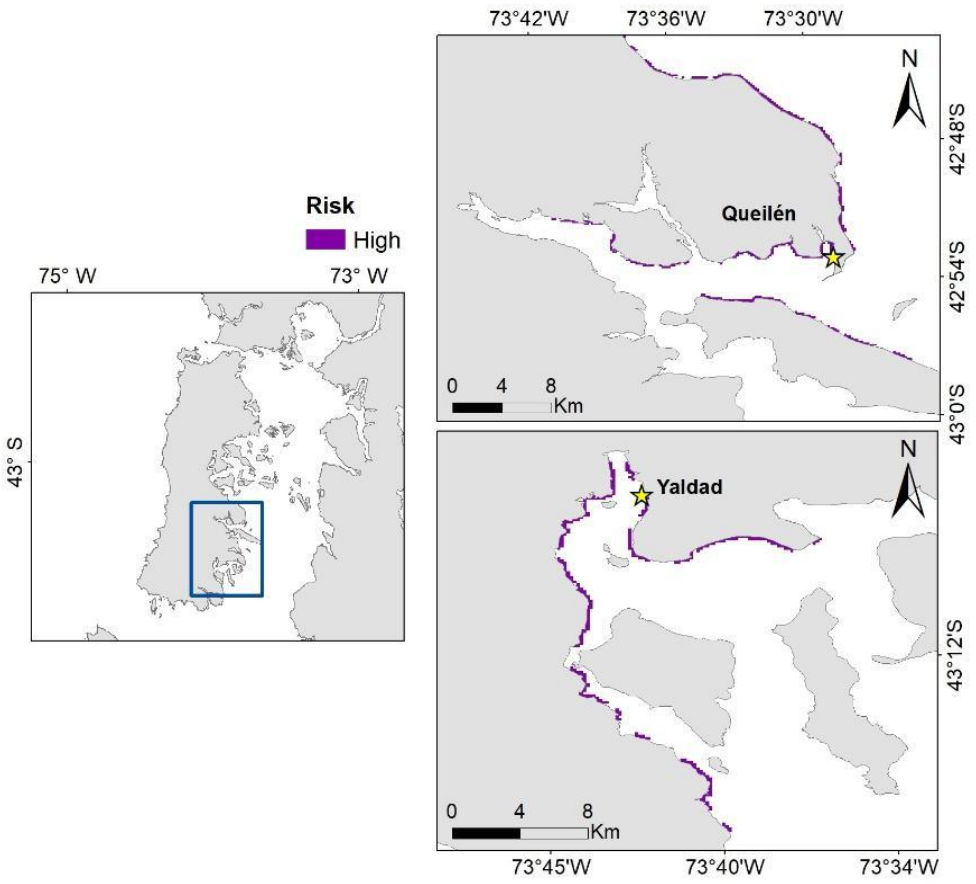

Figure 10. Bycatch risk for Chilean dolphins in the southern zone of Chiloé.

Peale’s dolphins

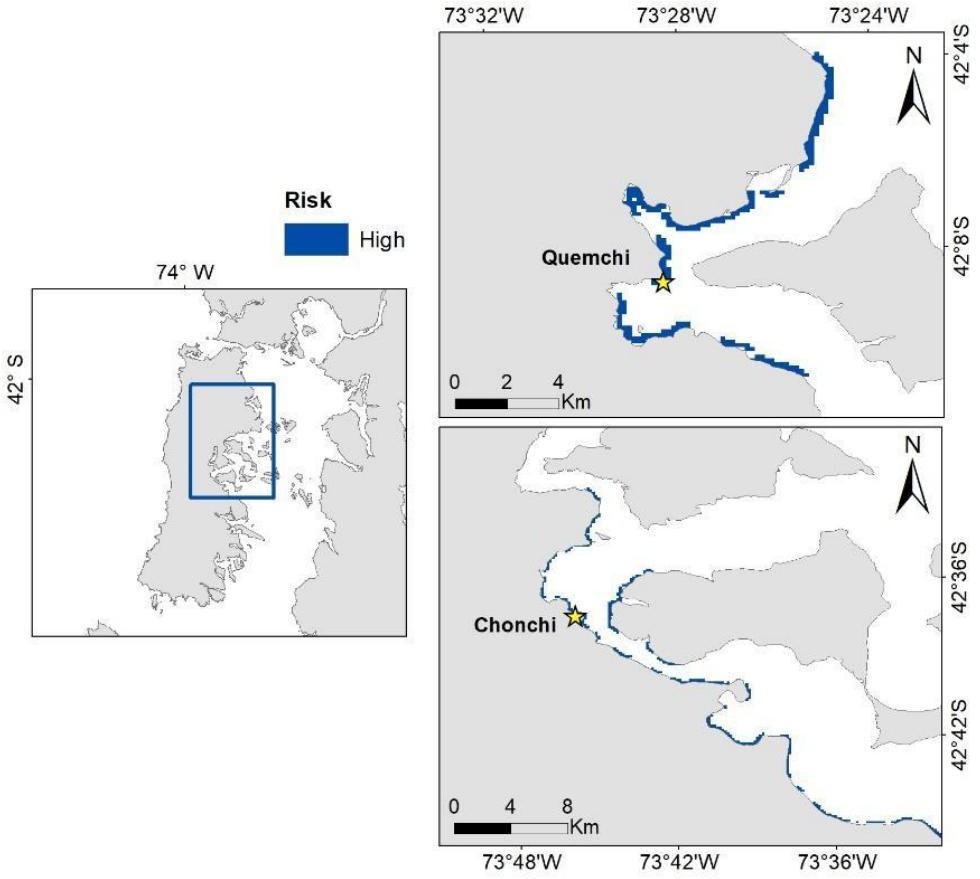

Figure 11. Bycatch risk for Peale's dolphins in northern Chiloé.

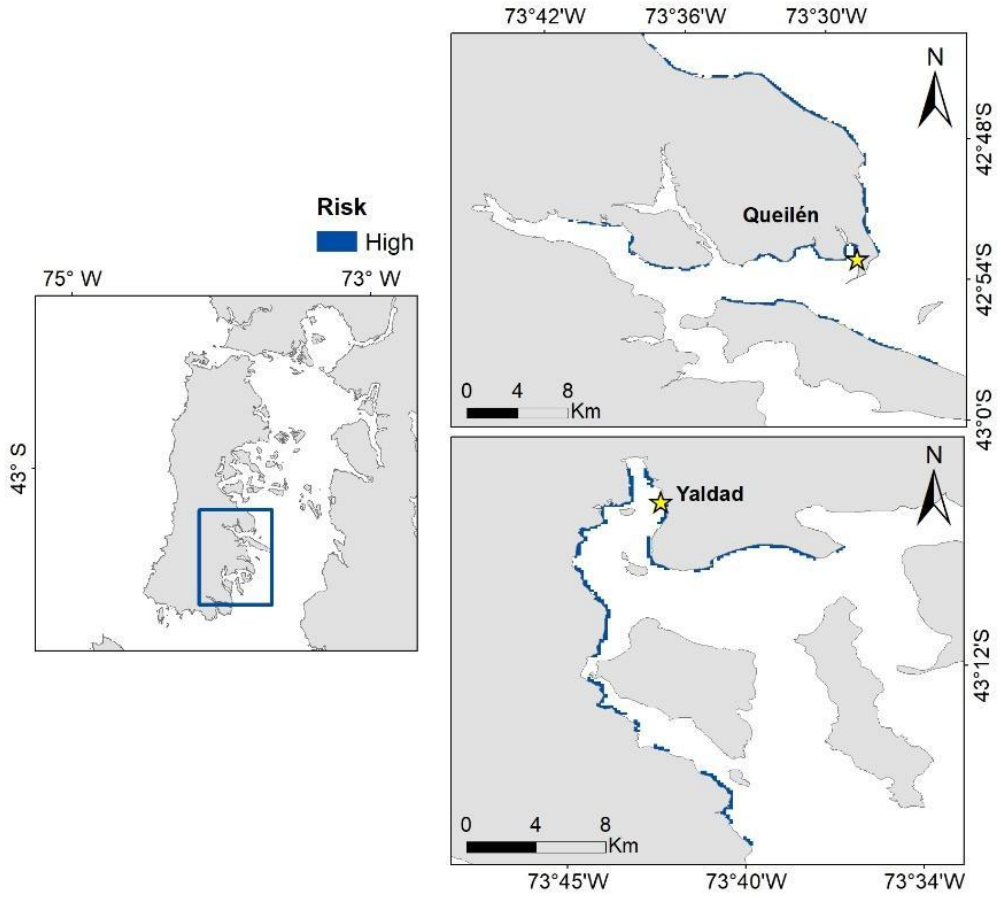

Figure 12. Bycatch risk for Peale's dolphins in the southern area of Chiloé.

Discussion

Using the Bycatch Risk Assessment (ByRA) tool, it was possible to map areas of bycatch risk for three species of small cetaceans on the island of Chiloé. Being a very coastal fishery, generally no more than 200 m from the coast, a high risk of bycatch was observed on the coast, where the fishery overlaps with the distribution of Chilean dolphins, Burmeister's porpoises and Peale's dolphins, whose distributions are strongly associated with coastal environments (Molina-Schiller et al. 2005, Ribeiro et al. 2007, Viddi et al. 2016, Heinrich et al. 2019). The ByRA model is an important tool to address risk assessment in fisheries and species with little information available, as it allows different approaches, such as the knowledge of experts and other relevant actors, to be used to obtain risk maps and contribute to fisheries management and species conservation (Costanza et al. 2021). ByRA provides opportunities to truly engage fishers in the bycatch mitigation process, encourages their conversation and representation through the exchange of information, and for fishers to influence outcomes (Costanza et al. 2021). It should be noted that questions about cetacean bycatch are delicate questions that may involve problems with the

respondent, as he could feel threatened if he answers honestly, since cetaceans have been prohibited from capture and retention since 1995 in Chile (Undersecretariat of Fisheries and Aquaculture DS No. 179-2008) and fishermen could choose not to answer truthfully. Due to this and the scarcity of systematic information on the abundance of individuals and their mortality, we still have a situation of high uncertainty in relation to the catch levels of these three species. However, through a participatory approach with artisanal fishermen, it was possible to obtain information on the distribution of the shore gillnet fishery that otherwise was not available, as it is a local and uncontrolled fishery. It is important to devote greater efforts to collect more information about this fishery, such as conducting a greater number of interviews in the villages that have already been visited, generating participatory workshops with the community for the validation of the information and visiting other villages where they could use this fishing gear, in order to assess the risk of bycatch in other coastal areas in Chile. The present results are part of a larger project that also analyzes other industrial and artisanal fisheries, with different types of quantity and quality of information related to the distribution and intensity of fishing, bycatch of marine mammals and distribution of different species of marine mammals, along the Chilean coast (https://www.lenfestocean.org/en/news-and-publications/fact-sheet/new-research-to-assess-marine-mammal-bycatch-risk-in-chile). This project has brought together a representative participation of community members, scientists and authorities, who have shared their existing databases and previous research, and their knowledge and expert opinion.

Acknowledgements

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Summary

The coastal gillnet fishery along the central and southern coast of Chile is a little-known traditional artisanal fishery. There is no regular monitoring of this fishery, but also no data collected on fishing effort, locations, catch, or marine mammal bycatch. However this fishery is of concern as local scientists and fisheries officials have heard of bycatch of Chilean dolphins, Peale's dolphins, and Burmeister's porpoises. These are species with limited ranges considered to either be in decline or with unknown population trends. As part of a larger project to assess the risk of marine mammal bycatch in Chilean fisheries, preliminary interviews were conducted in 26 villages that engage in this beach-based gillnet fishery. Based on information about the fishery from the interviews and expert-derived information about these coastal cetaceans, a bycatch risk assessment was completed using the open-source ByRA toolkit. The results of the paper show high risk of cetacean bycatch in fishery interactions and highlight areas where further research is needed. As cetacean bycatch is illegal in Chile, interview respondents did not talk about specific places, species, and numbers of cetacean bycatch. However the ByRA results show how interviews and expert input can be utilized in a data-poor area to focus management on issues of marine mammal bycatch.

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APPENDIX 1

SURVEY INFORMATION GATHERING
SHORE FISHERIES

DATE:

COVE:

NUMBER:

YEARS AS A FISHERMAN:

FUNCTION IN FISHING: Owner ___ Crew member ___
Assistant ___ Diver ___

FISHING FROM: Shore ___ Boat ___

1) Do you know if any of the following fishing gears are used in this locality?

Gillnets (midwater, trawl and/or bottom)	
Coastal gillnet (intertidal coastal edge)	
Purse seine net for small pelagics	
Three-mesh network	

2) Where are they generally/most frequently used? (mark on map)

_____

(3) Fishing gear using:

Gillnets (midwater, trawl and/or bottom)	
Coastal gillnet (intertidal coastal edge)	
Shore purse seine for small pelagics	
Three-mesh network	
Espinel	

Other: _____

4. Targeted/caught species: _____

_____

5) Fishing Zone (mark on map and / or take GPS points):

BYCATCH INFORMATION

6) In the past year, how often have you seen the following species in your fishing area:

	Never	Once	Every day	Every week	Every month	Often	Seasonal
Chilean dolphin							
Spiny porpoise							
Whales:							

7) Where have you seen/most frequently seen them? (mark on map)

8) Do you know if marine mammals have fallen into nets? _____

What animal/species? _____

Where? (mark on map) _____

How often _____

(9) Season used by fishing gear (as appropriate as follows): _____