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First steps for mitigating bycatch of Pink-footed Shearwaters *Ardenna creatopus*: Identifying overlap of foraging areas and fisheries in Chile

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SUMMARY

The Pink-footed Shearwater, *Ardenna creatopus*, is listed as in danger of extinction by Chile and under Annex 1 of ACAP, with an estimated global population of approximately 56,000 individuals. Incidental bycatch of this species in fisheries is thought to be an important cause in population decline (i.e. annual estimated mortality of >1000 adults).

This species is an endemic breeder in Chile, nesting only on the Juan Fernandez Archipelago (JFI; 30% of global population), and Isla Mocha (70% of global population). Using miniature GPS and satellite transmitters, we determined foraging areas of Pink-footed Shearwaters during the chick-rearing period in 2002 (JFI) and 2015-2016 (Isla Mocha). We overlaid shearwater tracking data with data from the Instituto de Fomento Pesquero (IFOP) on fishing effort in Chile (type of fishery, number sets per day, location of sets, and target species) to identify fisheries and fishing zones with the greatest potential for Pink-footed Shearwater bycatch.

During the 2002-2006 (N = 28 birds total) and 2015 (N = 18 birds) breeding periods, foraging areas were associated with the continental shelf and shelf-break, generally less than 30 km offshore. All foraging trips occurred between 31.5 and 40.0 degrees south, and birds remained in Chile territorial waters 100% of the time. We identified two primary foraging hotspots, one offshore near Talcahuano, Chile (approximately 36-37.5° south), and one offshore north of Valdivia, Chile (approximately 39-39.5° south). Birds tracked from the Juan Fernández Archipelago foraged in the Talcahuano hotspot but did not visit the

southerly hotspot near Valdivia. Birds tracked from Isla Mocha used both areas, with a greater proportion of birds using the Valdivia hotspot than the Talcahuano hotspot. Other major areas of use were around the respective breeding colonies from which the birds were tracked.

Overlay of these data with fisheries data is currently in progress. Preliminary results indicate extensive overlap of Pink-footed Shearwater foraging grounds with industrial and artisanal purse-seine fisheries within Chile, representing a significant risk of bycatch. Further work could be initiated to track Pink-footed Shearwaters during other life-stages (i.e. pre-breeding and incubation), and would enhance collaborative efforts with fisheries managers and fishers concerned with mitigating bycatch.

1. METHODS

Using miniature GPS and satellite transmitters, we determined foraging areas of Pink-footed Shearwaters during the chick-rearing period in 2002-2006 (Juan Fernández Islands [JFI]; satellite transmitters) and 2015-2016 (Isla Mocha [IM], GPS). On the JFI, birds were tagged from mid-February through early March. We captured breeding adults as they departed their burrows after they provisioned their chick and attached satellite transmitters (Microwave Telemetry, Columbia, MD and NorthStar Science and Technology, LCC, King George, VA; both 12 g solar PTTs) to each bird's back feathers using three-four strips of tape (Tesa Tape, Inc., Charlotte, NC, #4651) or surgical sutures (Adams et al. 2012). On IM, tagging studies occurred from March 17-28th in 2015 and February 18-March 5th in 2016. Birds were captured when they left their burrow after feeding their chick. We deployed a modified iGotU-120 GPS (Mobile Action Technology, Inc., New Taipei City, Taiwan) on each bird. Waterproofed within plastic heat shrink tubing, tags weighed 17 g and were programmed to acquire locations every 5 min. Tags were attached to the bird's back feathers using four strips of Tesa tape (Figure 1). In 2015, we deployed tags on 25 individuals and recaptured tags with data from 18 birds. In 2016, we deployed tags on 23 individuals and recaptured tags with data from 16. To identify fisheries and fishing zones with the greatest potential for Pink-footed Shearwater bycatch, we overlaid shearwater tracking data with data from the Instituto de Fomento Pesquero (IFOP) that quantified fishing effort of purse-seine fisheries in Chile (2005-2015; number sets per day, location and time of sets, and target species).



Figure 1. Pink-footed Shearwater with GPS tag attached to back feathers with Tesa tape.

For analysis of overlap between Pink-footed Shearwater movements and fisheries, we used ArcGIS (ESRI, Redlands, CA) to create a grid of 10 x 10-km cells (100 km²) in order to summarize both fisheries data and shearwater tracking data. For fisheries data, we quantified the number of unique sets that occurred in each grid cell separately for artisanal and industrial purse-seine fisheries and displayed results logarithmically. For Pink-footed Shearwater movements, we quantified the time spent by all tagged individuals in any grid cell and divided that value by the sum of all tracking time for all individuals, resulting in a value of % time tracked. We also quantified the number of tagged individuals that used any grid cell. This analysis was performed for 2015 data but 2002-2006 and 2016 data have yet to be incorporated.

2. RESULTS

2.1 Pink-footed Shearwater satellite and GPS tracking

Birds tracked from the JFI (n = 28 total) during the 2002-2006 chick-rearing periods foraged primarily between 31.5°S and 37.5°S, with the greatest amount of use offshore of Talcahuano and Concepción, Chile, from around 35.5 to 37°S (See Figure 2 for a representative pattern of marine habitat usage). A small number of birds (approximately 15%) also made trips to the west-southwest of the JFI in pelagic waters. In 2005, anomalous oceanographic conditions resulted in a significant decline in shearwater reproductive effort and a distinctive pattern in marine habitat usage, with the majority of tracked birds remaining in pelagic waters outside of the Humboldt Current system (P. Hodum, unpubl. data not shown).

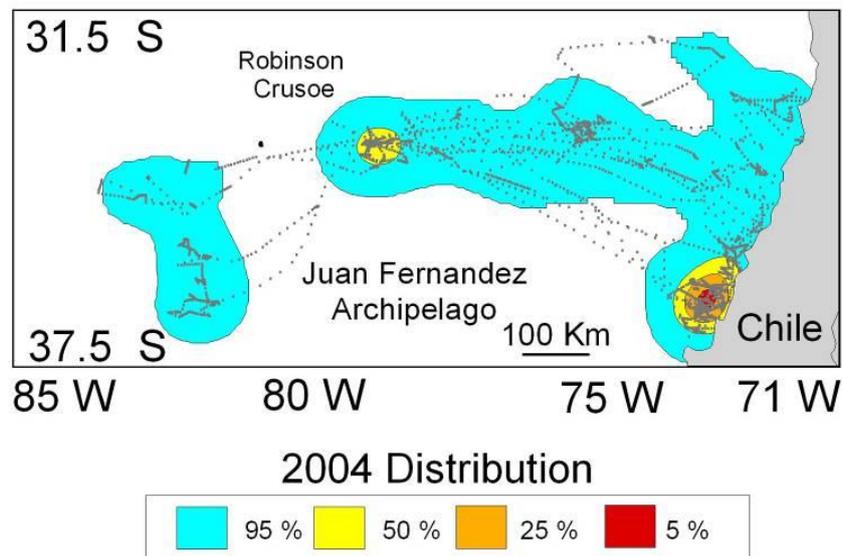


Figure 2. Kernel analysis of marine habitat usage by Pink-footed Shearwaters tracked from the JFI in 2004 (n = 10). The distribution of birds is represented by color, with the blue area representing 95% of all locations and yellow, orange, and red representing 50%, 25%, and 5%. The orange and red areas represent regions of disproportionate use by shearwaters (foraging hotspots), but it should be noted that this representation does not accommodate individual variability in space-use or overlap at sea.

During 2015, tagged Pink-footed Shearwaters from IM (n = 18) ranged from 35.5°S to 40°S and travelled up to 340 km from their breeding colony (Figure 3). Most foraging trips were 3-5 days in length. The majority of birds (83%) made at least one trip south to a distinct hot spot in coastal waters near Valdivia, whereas 39% made at least one trip north and were more dispersed between Lota/Concepción and Constitución (Figure 3). The birds that travelled to both areas did so either as two distinct trips or as one longer trip. Almost all birds stayed <20 km from the coast, but four birds travelled offshore (up to 100 km offshore) to pelagic waters (Fig. 3).

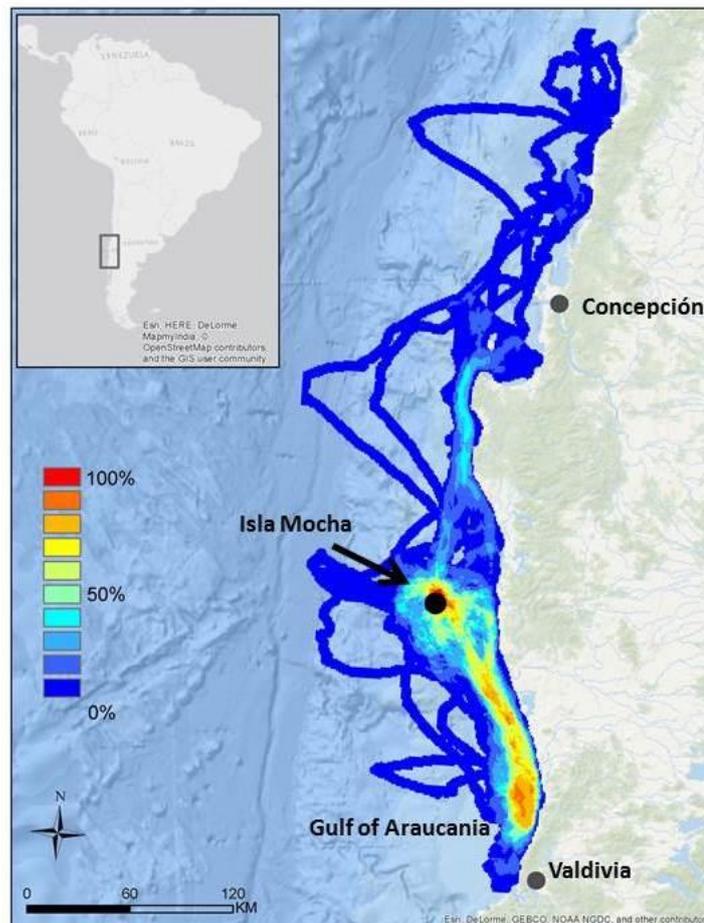


Figure 3. Percentage of individual shearwaters (n = 18) tracked from Isla Mocha, Chile, in 2015 using 1 by 1 km grid cells and a search radius of 3 km. Warmer values indicate use by more individuals and cooler values indicate use by fewer individuals.

In 2016, tagged Pink-footed Shearwaters ranged from approximately 34.0°S to 45.5°S and travelled up to 680 km from IM (Figure 4). Lengths of single trips were generally either 3-6 days or 9-15 days. The longest single trip was 15 days. The longest distance trip was to the south of IM, with the southernmost extent of the trip south of Isla Chiloé and Isla Guafo (Figure 4). All 16 tagged birds in 2016 travelled south of IM, and 44% also travelled north of IM (Figure 4), usually on a single foraging trip. All of the tagged birds used the “hotspot” area south of IM from approximately 39° to 40°S, near Valdivia (Figure 4). Other areas that appeared to be used for foraging were to the north of IM, offshore of Constitución (approximately 35.5°S) and over the subduction trench and submarine canyons to the north and south of IM (Figures 4 & 5). Forty-four percent of tagged birds used areas >100 km offshore. The farthest offshore area used by any bird was approximately 168 km offshore.

Birds travelled greater distances, made longer trips, and utilized pelagic habitat (>100 km offshore) more frequently in 2016 than in 2015 (Figure 4). There also appeared to be more use of offshore areas near the shelf break than in 2015 (Figure 4). However, most birds stayed within 100 km of the continent for the majority of their trips. Highest use areas appeared to be consistent in 2015 and 2016 (Figure 4). The area near Valdivia appeared to be the most heavily used by shearwaters from Mocha during 2015 and 2016 (Figures 3 & 4).

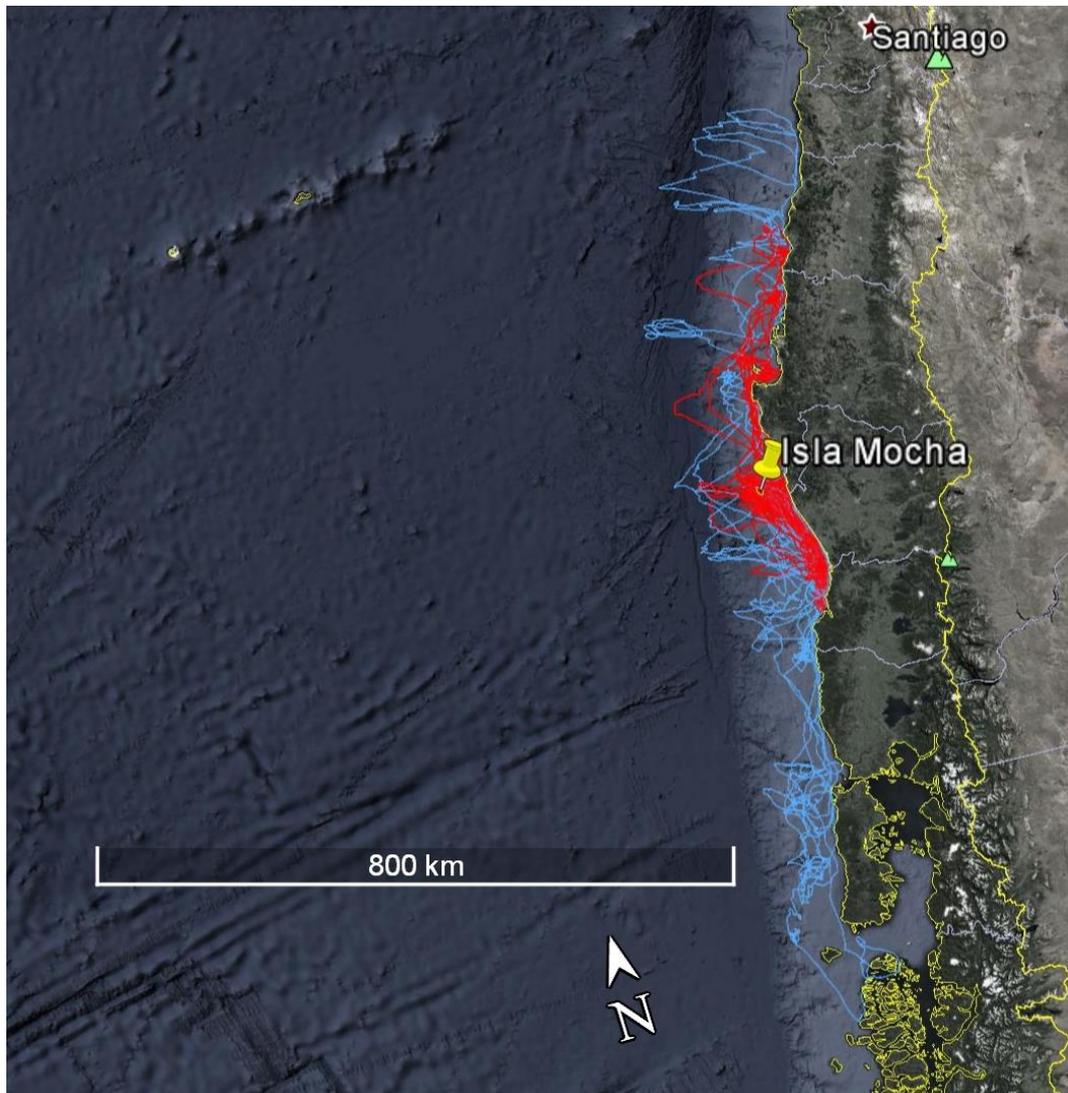


Figure 4. 2015 (red) and 2016 (blue) foraging trips of Pink-footed Shearwaters tracked from Isla Mocha, Chile. All birds from each year are shown in a single color. Shearwaters used similar coastal habitat in both years, but over a much greater north-south area during 2016.

2.2 Fisheries and Pink-footed Shearwater Overlap

Preliminary analysis of 2015 data indicated extensive overlap between Pink-footed Shearwater foraging grounds and industrial purse-seine fisheries within Chile (Figure 5). These fisheries primarily targeted Peruvian anchovy (*Engraulis ringens*), South American sardine (*Sardinops sagax*), and Chilean jack mackerel (*Trachurus murphyi*, known locally as *jurel*). Based on 2015 data, areas of greatest overlap between industrial purse-seine fisheries and shearwater habitat use occurred at the foraging “hotspot” north of Valdivia, Chile (from approximately 39-40°S, Fig. 5). Greatest overlap between shearwaters and artisanal purse-

seine fisheries occurred offshore of Talcahuano and Concepción (approximately 36-37°S, Fig. 5), as well as north of Valdivia. Pink-footed Shearwater bycatch has been directly observed in this region in both industrial (Rodrigo Vega, pers. obs.) and artisanal (Luis Cabezas, ATF, pers. comm.) purse-seine fisheries. Qualitatively, it appeared that primarily fishery target species were sardine and anchovy, rather than jack mackerel, in areas used by Pink-footed Shearwaters. Jack mackerel are typically found in more pelagic waters further offshore (Rodrigo Vega, pers. comm.) where Pink-footed Shearwater use was less. Pending analyses will focus on determining the spatial overlap of fisheries targeting each focal fish species with shearwaters, including fisheries other than purse-seine, and creating a synthesized map of all shearwater and fisheries data combined to show a metric of bycatch “risk”.

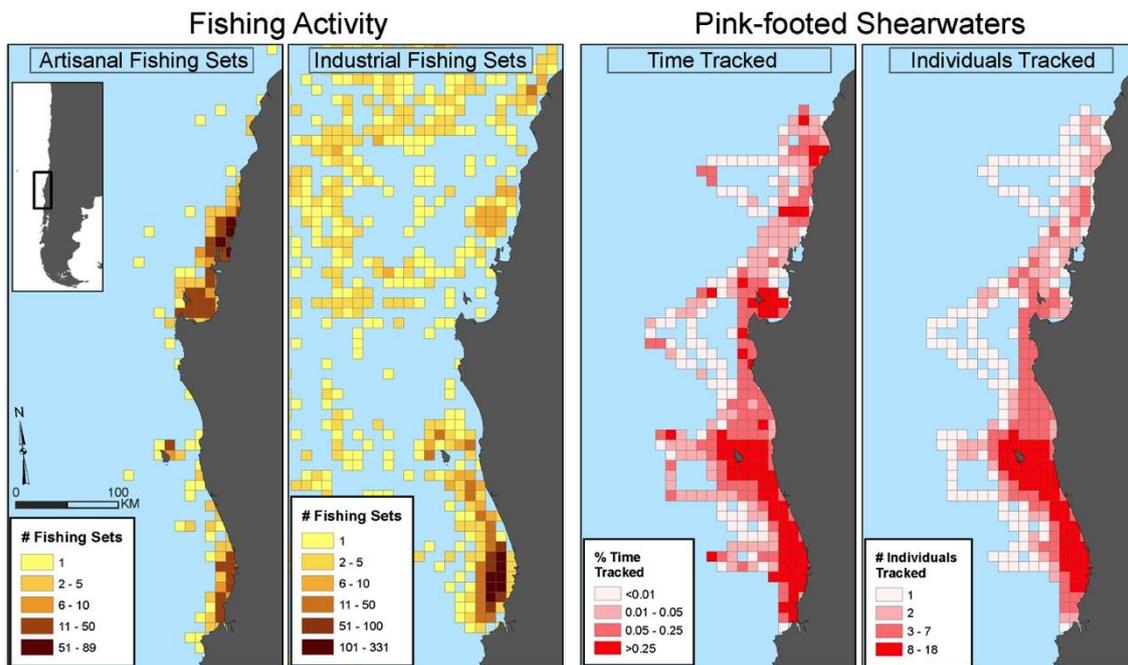


Figure 5. Number fishing sets of artisanal (far left) and industrial (second from left) purse-seine fisheries from 2005-2015, and % time tracked (third from left), and number of individuals tracked of pink-footed shearwaters tracked from Isla Mocha in 2015 (n = 18). Grid cells are 10 x 10 km (100 km²). Fisheries sets data are shown logarithmically. Pink-footed Shearwater % time tracked is the time spent by all tagged individuals in any grid cell divided by the sum of all tracking time for all individuals, multiplied by 100. Number of individuals tracked is the number of tagged individuals that used any grid cell.

3. DISCUSSION

In 2016, Pink-footed Shearwaters from IM foraged over a greater area than in 2015. We hypothesize that this was an effect of the El Niño conditions during the study period. El Niño conditions may have resulted in decreased prey availability (Barber and Chavez 1983), causing the birds to have to forage over a greater area. Observations of low occupancy and chick survival in some colonies on the JFI (Peter Hodum, pers. comm) support this hypothesis, although preliminary data from IM did not indicate abnormally poor breeding success during the tagging study (Tiare Varela & Jaime Herrera, pers. comm.).

Although birds foraged over a greater area in 2016, overall habitat use and “hotspot” areas of birds from IM were consistent between 2015 and 2016. Birds continued to spend the majority

of their foraging trips in habitat less than 100 km offshore. Likewise, the area south of IM near Valdivia continued to have the most shearwater use, consistent with results in 2015.

Results from this study indicate that to better understand Pink-footed Shearwater at-sea habitat use, further studies could be initiated to track Pink-footed Shearwaters during other life-stages (i.e., pre-breeding and incubation), and to track birds from the JFI and IM concurrently.

There was clear overlap between Pink-footed Shearwater foraging habitat and industrial and artisanal sardine and anchovy fisheries in Chile, representing a high potential of bycatch. Pink-footed Shearwater bycatch has been directly observed in both artisanal (Luis Cabezas, ATF, pers. comm.) and industrial (Rodrigo Vega, IFOP, pers. obs.) purse-seine fisheries in south-central Chile. However, there is currently no publicly available data on the rates of seabird bycatch occurring in these purse-seine fisheries. Thus, information on bycatch rates in artisanal and industrial purse-seine fisheries that overlap with shearwater use will be critical to understanding the magnitude of the threat. Likewise, new information would allow for analysis of overlap with non-purse-seine fisheries. Artisanal gill-net fishers have reported Pink-footed Shearwater bycatch, with greatest bycatch reported around the immediate vicinity of IM (Mangel et al. 2013). Finally, this research helps support collaborative efforts between scientists, fisheries managers, and fishers who desire to mitigate fisheries bycatch of Pink-footed Shearwaters within Chile.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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