Project Title: Retrospective Analysis of Antarctic Tracking data (RAATD): International Crabeater and Weddell Seal Tracking Data Sets

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The SCAR Expert Group on Birds and Marine Mammals (EGBAMM) initiated a multi-nation effort to compile and analyze all tracking data available for several species of marine top predator in the Southern Ocean. The Retrospective Analysis of Antarctic Tracking Data (RAATD) aims to undertake a predator community-wide assessment of habitat use of predatory species in the entire Southern Ocean.

As part of this initiative, Dr. Huckstadt was in charge of gathering and analyzing all data available for crabeater (*Lobodon carcinophaga*) and Weddell seals (*Leptonychotes weddelli*), two species of ice seals that inhabit the coast of the entire Antarctic continent. These two species were selected in consideration of (1) their large abundance in Antarctic waters (population sizes estimated in several hundreds of thousands individuals to tens of millions), (2) their importance as predators of the pack ice and fast ice regions in the Southern Ocean, preying upon Antarctic krill (*Euphasia superba*), Antarctic silverfish (*Pleurogramma antarcticum*) and Antarctic toothfish (*Dissostichus mawsonni*), among other prey, and (3) the availability of large datasets of tracking data available for bot species, spanning for over 30 years. Both of these species are among the most intensely studies species of marine vertebrates in the Southern Ocean.

During the first phase of this project, a considerable effort was directed towards contacting the Principal Investigators that had tracking data available for either or both species assigned to my lab. A total of 102 and 135 individual tracks were collected and analyzed for crabeater and Weddell seals, respectively (Table 1). The data analyzed for this project have been collected between the early 90s until 2013 by investigators from Australia, France, Germany, Norway, United Kingdom and United States (Table 1).

Principal Investigator	Institution	Country	Species	Area
Dr. Colin Southwell	Antarctic Australian Division	Australia	Crabeater seal	Eastern Antarctica pack ice
Drs. Mark Hindell and Clive McMahon	Institute of Marine and Antarctic Studies	Australia	Weddell seal	Princes Elizabeth Land Adélie Land
Dr. Jean-Benoit Charrassin	Muséum National d'Historie Naturelle	France		
Dr. Christophe Guinet	Centre d'Etudes Biologiques de Chizé	France		
Drs. Horst Börnemann and Joachim Plötz	Alfred Wegener Institute	Germany	Weddell seal	Eastern Weddell Sea
Drs. Erling Nørdoy and Arnoldus Blix	University of Trømso	Norway	Crabeater seal	Eastern Weddell Sea
Drs. Michael Fedak and Lars Boehme Dr. Keith Nicholls	Sea Mammal Research Unit British Antarctic Survey	United Kingdom	Weddell seal	Weddell Sea
Dr. Daniel Costa	University of California Santa Cruz	USA	Crabeater seal Weddell seal	Western Antarctica Peninsula Ross Sea
Drs. John Bengston and Peter Boveng	National Marine Mammal Laboratory, National Marine Fisheries Service	USA	Crabeater seal Weddell seal	Ross Sea
Dr. Michael Goebel	AMLR, Southwest Fisheries Service	USA	Weddell seal	South Shetland Islands

Table 1. Tracking datasets compiled and analyzed for crabeater (n = 102) and Weddell seals (n = 135).

After data were collated, Dr. Huckstadt was awarded with a SCAR fellowship to travel to Hobart, Tasmania, to work with Dr. Mark Hindell and his lab, as well as with collaborators from the Australian Antarctic Division. During the time spent at Dr. Hindell's laboratory, Dr. Huckstadt was able to analyze the data for both species, including the implementation of the filtering algorithm and posterior spatial analysis, and come up with a scientific question to be addressed in the scientific manuscript that is currently been written.

The results of this analysis showed that there are clear differences in the biology of both species: crabeater seals are highly specialized predators and feed almost exclusively on krill, perform rather shallow dives and are limited in their distribution to the pack ice. Weddell seals, on the other hand, are broad-spectrum fish eaters, deep divers and inhabit fast ice, pack ice and even ice free zones. Therefore, we expect differences between these species in their patterns of habitat utilization and movement across their ranges.

All tracking data used for this analysis corresponded to ARGOS tracks collected from the early 1990s until 2012. All tracks were filtered using a Switching State Space Model, a Bayesian approach that allows the incorporation of the uncertainty associated with the ARGOS location data, coupled with a simple model of animal movement (Correlated Random Walk). The output also provides a behavioral categorization of the location data, based on the transit speed of the animals and the turning angle, which for the purposes of our study are defined as a binary response: foraging and transit.

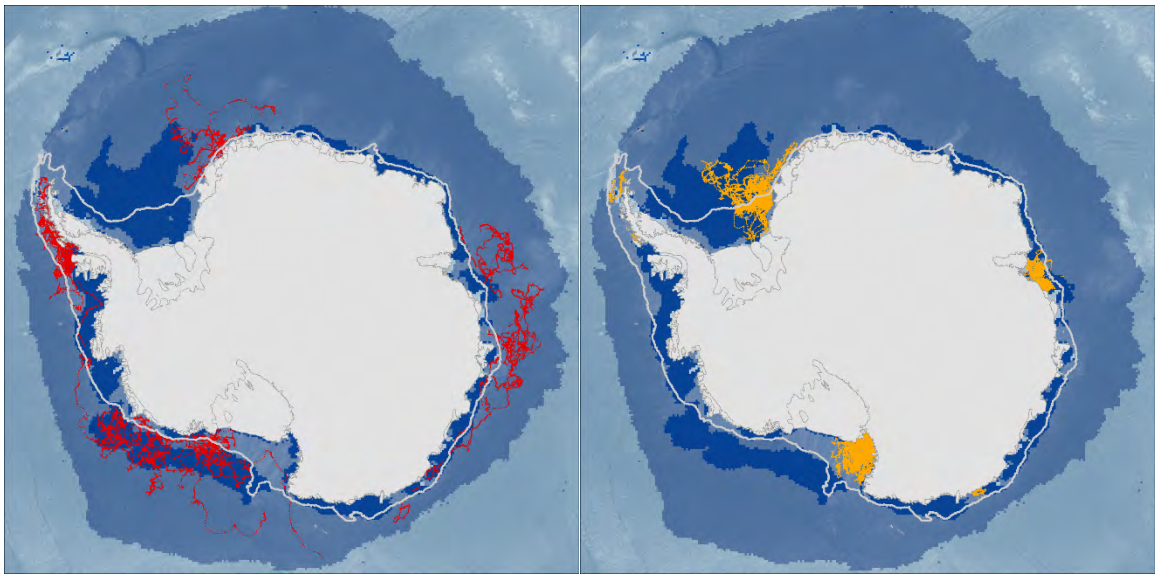

Figure 1. Tracking data of crabeater seals (red) and Weddell seals (yellow). The blue shaded area indicates the average minimum (dark blue) and maximum (light blue) sea ice coverage (1990 – 2010). The gray line indicates the break of the continental shelf (1000 m isobath)

Crabeater seals deployments (n = 102) were rather short in duration (with the exception of animals tagged in the Ross Sea), and across their distribution individuals displayed similar patterns of movement, associated to the local conditions in ice edge (Table 2). The differences found among the different locations are associated with the differences in the duration of the deployments, which explains the higher values in maximum linear excursions and total distance traveled observed for animals from the Ross Sea (Table 2).

Region	N	Maximum track duration (days)	Maximum Linear Excursion (km)	Total distance traveled (km)
Western Antarctic Peninsula	46	83	342 ± 389	1557 ± 1127
Weddell Sea	12	50	837 ± 865	1526 ± 1298
Ross Sea	17	252	569 ± 470	4849 ± 5866
East Antarctica	25	96	369 ± 198	1187 ± 462

Table 2. Crabeater seal tracking information

The tracking data for Weddell seals were not only more numerous in terms of number of individuals tagged (n = 135), but also there were more institutions and programs that have worked on the species. As a result, there are more location across the continent for which Weddell seal tracking data are available (Table 3). Weddell seal deployments also lasted longer, with a maximum length of deployment almost reaching 1 year in duration. Further, there are current deployment programs on the species whose data were not considered here due to time constrains. Weddell seal tracking data revealed a large variability across the range of the species. For instance, animals tagged at Dumont d'Urville station (Adèlie land) reached a maximum distance of only 57 km from the tagging locations, whereas Weddell seals tagged in the Weddell Sea reached over 390 km from the capture site (Table 3).

Region	N	Maximum track duration (days)	Maximum Linear Excursion (km)	Total distance traveled (km)
Queen Maud Land	6	49	11 ± 7	126 ± 73
Princess Elizabeth Land	13	155	157 ± 95	1513 ± 923
Adèlie Land	17	163	57 ± 27	966 ± 392
Western Antarctica Peninsula	2	119	93 ± 46	2334 ± 324
Weddell Sea	30	180	393 ± 245	2165 ± 1138
Ross Sea	62	202	282 ± 177	1829 ± 812
South Shetland Islands	6	334	39 ± 48	4031 ± 1261

Table 3. Weddell seal tracking information

In order to discern differences in patterns of habitat utilization between the species, we constructed weekly individual home ranges, identified as the 95% Utilization Distribution contour calculated using the kernel home range analysis (Gaussian kernel, bandwidth estimates using the PLUGIN method). By calculating the weekly variability, we avoid complications derived from comparing across individuals whose records can vary between a couple of weeks and almost a year. Crabeater seals' average weekly home range was 4441 ± 23834 km^2, and we did find differences in the weekly home ranges among the different areas of the Southern Ocean for which tracking data are available (Kruskal-Wallis, $H = 141.67, 6\ df, p < .001$). A *post-hoc* analysis of the data revealed that animals tagged in the western Antarctica Peninsula had a much more restricted distribution compared with animal from other locations. Weddell seals' average weekly home range area was 4826 ± 60030 km^2. As with crabeater seals, Weddell seals' weekly home range also varied among study sites across the Southern Ocean, (Kruskal-Wallis, $H = 252.936, 6\ df, p < .001$), but in this case all locations tested positive when testes for pairwise comparisons between study sites.

A further analysis of the patterns of habitat utilization was conducted by calculating the individual Coefficient of Variation (i.e. accounting for differences in the size of the area, Fig. 4). This analysis revealed that, when considering the scales used by both species, crabeater seals have a much lower variability in the size of their weekly home ranges between individuals and across their entire range. Contrastingly, Weddell seals have a much larger variability among study sites, likely modifying their distribution patterns in response to local conditions. These results provide new evidence on the ecology of both species, particularly with regards to the differences in their respective niche widths. I was previously known that these species vary in their feeding ecology (crabeater seals being highly specialized to feed on krill, whereas Weddell seals are more generalists, preying upon a diversity of fish species), but out analysis is providing new insights at how these species maintain given characteristics in their patters of habitat utilization. Thus, Weddell seals seem to display a relatively larger capacity to buffer and adjust to local condition, while crabeater seals might have a much more limited window to adjust their ecology, which constitutes a comparative disadvantage when considering the rate of climatic change undergoing in Antarctic waters.

These differences in patterns of habitat utilization are currently being analyzed in depth, and it is anticipated the results of such analysis will be ready for publication by the end of 2015.

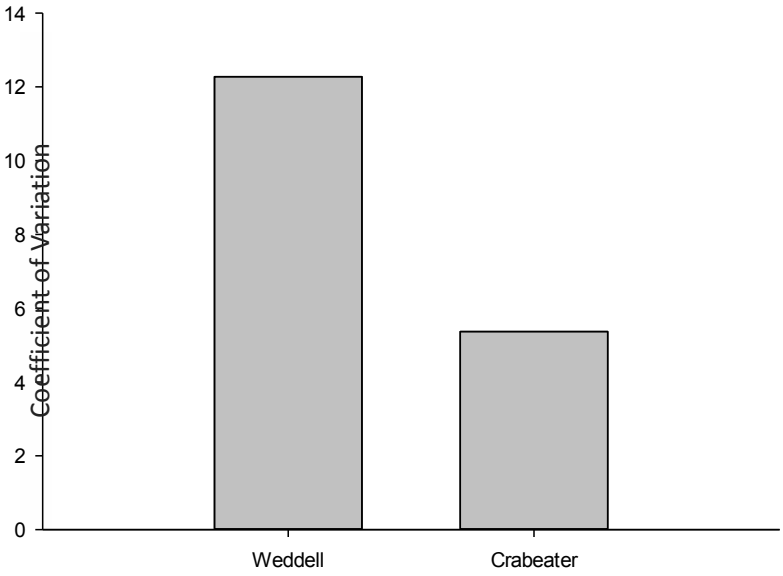

Figure 4. Variation in individual weekly home range areas for Weddell and crabeater seals. To account for the large intra-site variability, data are expressed as Coefficient of Variation (CV).

Scientific outcomes:

The results of these analyses have been presented at the following international meetings:

Costa et al. 2013. A synoptic view of the foraging behavior of crabeater and Weddell seals. XIIth SCAR Biology Symposium, Barcelona, Spain

Huckstadt et al. 2014. Habitat utilization of Weddell and crabeater seals throughout their entire distributions as obtained from satellite telemetry. XXXIII SCAR Open Science Conference, Auckland, New Zealand

Huckstadt et al. 2014. Differences in patterns of habitat utilization of Weddell and crabeater seals along their circumpolar distributions: responding to local conditions. V Biologging Symposium, Strasbourg France.

As mentioned, a scientific manuscript is being written as direct result of this grant, and we anticipate it will be ready for submission by the end of 2016.

Currently, the SCAR-RAATD program has entered its synthesis phase, and during the next month of April there will be a second workshop to discuss the final analysis with all species included in the analysis. Dr. Huckstadt will be attending the workshop and collaborating in the data analysis phase.