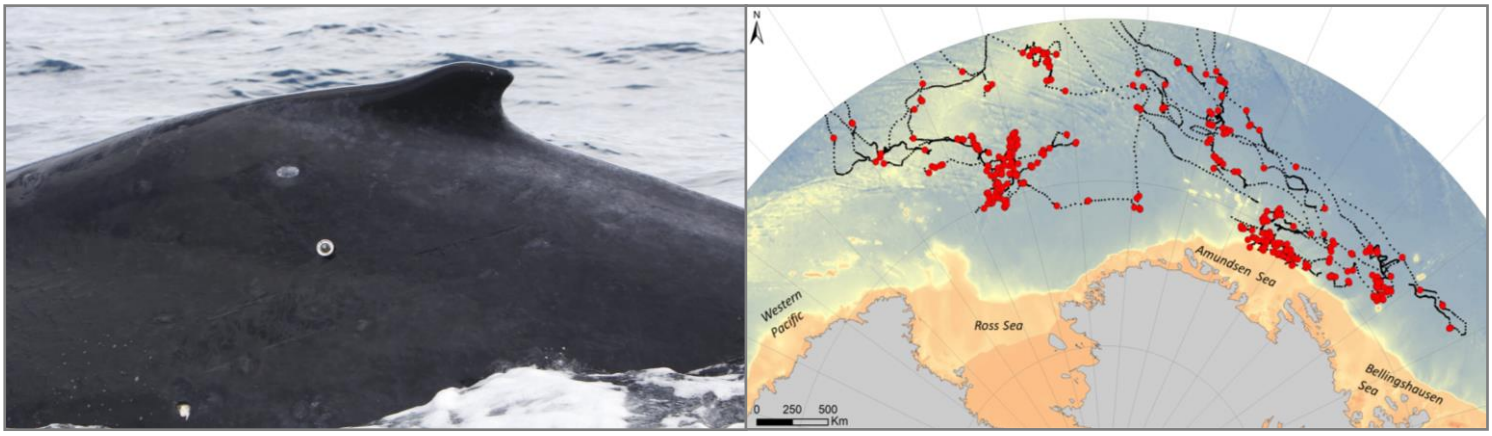
SCAR Fellowship Report

Spatial analysis of humpback whale behaviour and habitat use patterns in Antarctica



Name of Fellow: Leena Riekkola

Position: PhD Candidate
Affiliation: The University of Auckland
Country: New Zealand
Email: lrie003@aucklanduni.ac.nz

Home Institution

The University of Auckland
Home Contact: Assoc. Prof. Rochelle Constantine
Home Contact Email: r.constantine@auckland.ac.nz
Home Country: New Zealand

Host Institution

National Oceanic and Atmospheric Administration - The National Marine Mammal Laboratory (NOAA-NMML)
Host Contact: Dr Alex Zerbini
Host Contact Email: alex.zerbini@noaa.gov
Host Country: United States of America

Dates of Activity

11-21 Oct 2017 & 20 May-2 June 2018

Introduction (~ 100 words)

What motivated the application and project? Brief explanation of the background and rationale for the proposal.

Satellite telemetry and animal movement models offer a robust way to remotely monitor the behaviour of wide-ranging species, especially in remote oceanic habitats. Understanding how different behaviours (e.g. foraging) are shaped by dynamic environmental features is fundamental to understanding ecological interactions and the impact of environmental fluctuations. Our knowledge of the fine-scale behaviour and habitat use patterns of humpback whales within their Antarctic feeding grounds is still lacking. This information is critical for understanding how the physical seascape in the Southern Ocean affects the behaviour of this large predator. Furthermore, it is necessary to first understand the relationship between foraging behaviour and physical features to evaluate how future environmental changes will affect these and other krill predators in the Southern Ocean.

Project Objectives (~ 100 words)

What were the aims of the project at the outset?

By using our existing satellite tracking data and spatial modelling techniques, the aim of this project was to study the behaviour and habitat use of humpback whales with different life history stages within their Antarctic feeding grounds.
The objectives were to:

(1) Analyse the behaviour of whales throughout the feeding season, and to investigate any intra-population differences between whales feeding in the Ross Sea region *vs* the Amundsen & Bellingshausen Seas region.

(2) Build and assess the transferability of humpback whale habitat models.

Methods, Execution and Results (~200 words)

What was the nature of the research and activities undertaken? Did everything go as you and your host had hoped? What results were generated and how do they reflect expectations?

This project utilised satellite tag data collected on Oceania humpback whales in 2015 (Riekkola et al., 2018, data provided by the home institute). We used a hierarchical version of a Bayesian switching state-space model (SSM) to estimate locations and behavioural states, area-restricted search (ARS, indicative of foraging) *vs* transit, at a 6-h time-step (Jonsen et al., 2005, 2006). The distribution of locations classified as ARS within the study area indicated that there were two important resource sites for Oceania humpback whale foraging; one north of the Ross Sea and one within the Amundsen and Bellingshausen Seas (Figure 1).

Whale behaviour varied throughout the summer feeding season, with most ARS occurring in February to March. The whales' proximity to the ice edge also varied throughout the feeding season, and between animals using different feeding areas. The ARS behaviour of whales within the Ross Sea region occurred consistently

further away from the ice edge (~370km on average) than for the whales in the Amundsen and Bellingshausen Seas region (~210km on average).

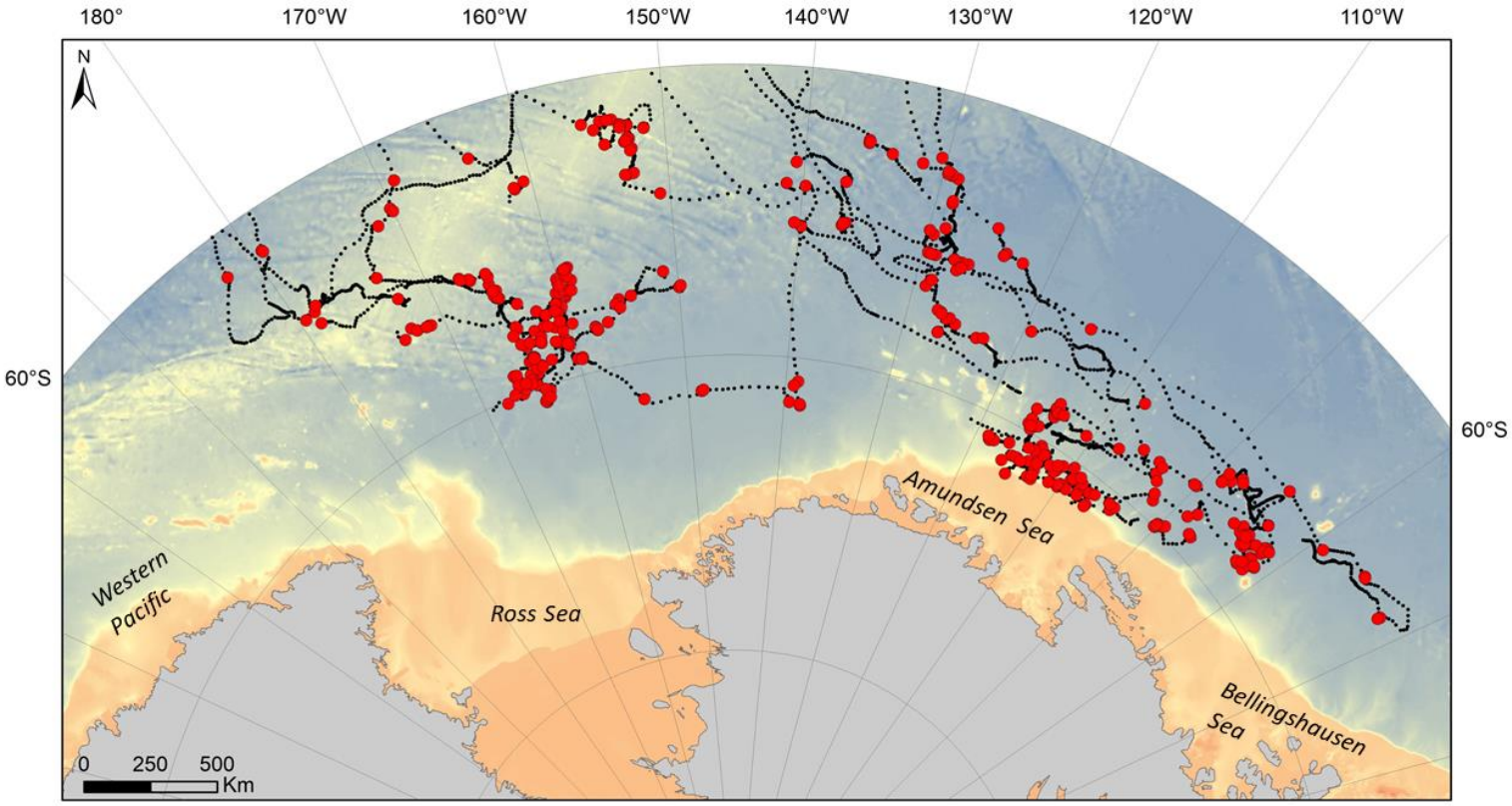


Figure 1. Tracks of 14 Oceania humpback whales on their Southern Ocean feeding grounds. Each location was assigned a state-space model estimated behavioural state: red circle = area restricted search (ARS; inferred foraging); black dot = inferred transit. The background colour scale indicates the bathymetric depth (derived from the International Bathymetric Chart of the Southern Ocean (IBCSO) digital bathymetric model of the circum-Antarctic waters).

To assess the influence of different environmental variables on the SSM estimated behavioural modes, we fitted a series of linear mixed-effect models (LMMs). Data on a comprehensive set of remotely-sensed environmental variables were obtained through our collaboration with the Australian Antarctic Division. Humpback whale foraging behaviour was strongly affected by season, sea surface height and where the ice edge was two months prior. The distance between whales and the ice edge was in general related more to the advance or retreat of the ice rather than the movement of the whales. This suggests that the whales did not actively track the ice edge itself, but instead utilised areas where productivity had previously been enhanced by melting sea ice. We detected behavioural differences between animals of the same population utilising the two near-by feeding regions (Ross Sea *vs* Amundsen and Bellingshausen Seas) but did not find differences between animals at different reproductive stages, i.e. mother-calf pairs *vs* females without calves and males. Additionally, we investigated the transferability of our humpback whale habitat model, but found that the model was not transferrable.

Project Outcomes (~ 200 words)

What do you feel were the significant outcomes in terms of the research but also in terms of personal development?

This project identified some unique habitat use patterns occurring in the Southern Ocean, including two important feeding areas for Oceania humpback whales and the behavioural differences between animals of the same population utilising two near-by feeding regions. The results of this work contribute to a better understanding of the behaviour and habitat use patterns of this large predator in the Southern Ocean and their contrasting responses to ice-edge dynamics and productivity. This work sets up further research on conducting a comprehensive assessment of the behaviour and habitat use of different humpback whale populations across the Southern Ocean. Such information could help us infer regional differences in oceanographic conditions and prey availability and could help us better understand the reasons behind different population recovery rates. The methods used in this project can also be readily applied to a range of other species.

The greatest outcome in terms of personal development was learning new statistical analysis skills and coding techniques. These skills obtained during the Fellowship not only enabled me to complete the project but are transferrable which is highly beneficial for future employment opportunities. During the remainder of my PhD I can also utilise these new skills to tutor fellow students in my lab. This Fellowship allowed me to grow as a scientist and enabled me to create new international networks and collaborations.

Publications, Presentations and Products

Are there papers or articles submitted or in preparation as a result of the Project? Have you made presentations as a result of the Fellowship? Are there significant products as a result that will have use beyond the Fellowship for yourself or others?

This work has resulted in a manuscript which will be submitted for publication in *Behavioral Ecology* shortly.

Early results of this work were presented at the Marine Ecosystem Assessment for the Southern Ocean (MEASO) conference in Hobart, Tasmania in April 2018, and the presentation received a student prize (honourable mention). More finalised results were presented at a departmental talk at the home institute (University of Auckland, June 2018), and at the New Zealand Marine Sciences Society conference in Napier, New Zealand (July 2018).

Capacity Building, Education and Outreach Activities (~ 200 words)

As a result of the Fellowship did you engage in educational and/or outreach activities before/during/after your visit? Did you meet with students to explain your work? Did you give a public lecture? Was there any publicity about your visit - either in your host country or your home country?

The project resulted in outreach in the form of three presentations given (see section above). There will be further media outreach once the paper is published as there is considerable interest in New Zealand regarding this work.

During a portion of my visit, there were two other students visiting the NOAA-NMML as well. This was an excellent opportunity to discuss our research in a peer-mentoring setting, and to share ideas, code and help each other brainstorm various issues. I especially gained a lot from the time spent with these other students by learning some valuable R coding tricks and techniques.

Future Plans and Follow ups (~ 100 words)

Do you plan to continue contact with the host institute and others you met as a result of the project? What will be the nature of the future work?

I plan to maintain active contact and collaborations with my host, as well as the students met during the Fellowship (with whom I envision working in the future).

The work conducted in this project leads onto further plans of conducting a comprehensive assessment of the behaviour and habitat use of different humpback whale populations across the Southern Ocean. We have received funding from the International Whaling Commission to undertake this work. This information could help us infer regional differences in oceanographic conditions and prey availability and could help us better understand the reasons behind different population recovery rates.

Personal Impact

How do you feel the Fellowship has and will continue to impact your research and career objectives? What was the main impact for you personally?

The most important personal impact of this Fellowship has been the huge leaps taken in understanding and mastering the use of various statistical modelling approaches with satellite telemetry data. The ups and downs experienced during the analysis process for this project have encouraged me to pursue developing these skills even further. The skills that I have obtained during the Fellowship have improved my employability immensely. Therefore, I feel that the SCAR Fellowship has had a significant positive impact on my personal development as well as on my future career prospects.

I also cannot emphasise enough the value of having had the opportunity to create new international collaborations and connections which I hope will last throughout my career.

Financial Statement

Please provide a brief breakdown how the funds were used. Example: The SCAR Fellowship was used to help cover travel to the host institute, buy supplies for the experiments and cover a month of rent at the host location.

The SCAR Fellowship was used to cover travel costs from Auckland, New Zealand to Seattle, USA, as well as accommodation and subsistence at the host location.

Acknowledgements and References:

I am grateful to SCAR for funding this research visit and therefore enabling me to complete this project. I would like to thank Dr Alex Zerbini and NOAA-NMML for hosting me during this Fellowship. I would also like to thank Assoc. Prof. Rochelle Constantine and Kevin Chang from the University of Auckland, Drs Jeremy Sterling and Charlotte Boyd from NOAA-NMLL, as well as Drs Virginia Andrews-Goff and Ben Raymond from the Australian Antarctic Division for their help and assistance with this work. Also, a big thank you to fellow students Solène Derville and Luis Bedriñana-Romano.

Jonsen, I.D., et al. 2005. Robust state–space modeling of animal movement data. *Ecology,* 86, 2874–2880.

Jonsen, I.D., et al. 2006. Robust hierarchical state–space models reveal diel variation in travel rates of migrating leatherback turtles. Journal of Animal Ecology, 75, 1046–1057.

Riekkola, L., et al. (2018). Application of a multi-disciplinary approach to reveal population structure and Southern Ocean feeding grounds of humpback whales. *Ecological Indicators*, 89, 455–465.