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Spatial ecology of delphinids in Queen Charlotte Sound, New Zealand: Implications for conservation management

A thesis submitted in partial fulfilment of the requirements
for the degree of
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Cheryl Lynne Cross
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This thesis is dedicated to my parents. Without you, I would not exist. You have supported me during every major decision I have made without judgement. I am eternally grateful for you, your love and your support. I could not have done this without you.

I also dedicate this to the memory of my Grandma Cross. I have felt your strength along this challenging path. I miss you.

"It is not the mountain ahead of you that wears you down, it's the pebble in your shoe"

–Muhammad Ali (and Robert W. Service)

Frontispiece

–Robert Frost

Abstract

Understanding species' ecological interactions and area usage depends on clear insight into their temporal and spatial patterns. Such information combined with recognition of regional human-invested interests, is crucial for developing conservation management efforts. Queen Charlotte Sound (QCS), South Island, New Zealand is a unique environment inhabited by diverse marine life, including several cetacean species. The area is subject to rising levels of anthropogenic activity inclusive of marine farming, tourism and vessel traffic. With conservation management in mind, this thesis focused on three key delphinid species: Hector's (*Cephalorhynchus hectori*), bottlenose (*Tursiops truncatus*) and dusky dolphins (*Lagenorhynchus obscurus*). Specifically, this study sought to: 1) explore long-term historical temporal and spatial trends in delphinid occurrence 2) identify recent patterns in delphinid distribution, density and range 3) investigate delphinid species' habitat use 4) initiate research of regional swim-with-dolphin tourism.

Dolphin sighting data were: 1) collated from tour vessel logbooks spanning 1995–2011 and 2) collected during dedicated surveys aboard opportunistic platforms from 2011–2014. Dynamic and static environmental variables were sourced from local government agency databases to use in analyses with both datasets. Historical delphinid presence (from logbook data) was correlated with dynamic environmental variables during two separate time frames (1995–2002; 2003–2011), using Generalized Additive Models (GAMs) and Generalized Linear Models (GLMs). Spatial patterns of these sightings were explored across temporal periods (*i.e.,* seasons; blocks of year). Dedicated survey data were used to generate kernel density estimates and to determine species' range and central range. These dolphin density estimates were correlated with static and dynamic habitat parameters using (GAMs). Spatial predictions were then generated from the resultant significant variables. Bottlenose dolphin engagement in swim-with-dolphin encounters was assessed according to several proxies using Linear Models (LMs) and GLMs.

A total of 5,295 historical records consisting of 6,055 delphinid sightings were compiled, demonstrating a long-term presence of the focal species. Of these, Hector's dolphins consistently had the highest trip encounter rate. Seasonal patterns indicated peaks in occurrence for Hector's during summer/autumn, bottlenose during autumn/winter and dusky dolphins during winter/spring. Further investigation with GAMs suggested that each

species' presence was associated with a unique set or range of dynamic variables. Annual variation occurred amongst all species. During both historical time frames (1995–2002 and 2003–2011), Hector's dolphin occurrence was associated with higher SST values. Bottlenose dolphins displayed an association with mid-low SST (during 1995–2002) and with high turbidity (during 2003–2011). Dusky dolphins were influenced by low SST (during both time frames) and from 2003–2011 were also influenced by low turbidity and mid-value tidal range. Spatial patterns illustrated that Hector's and dusky dolphins have become more restricted in their use of QCS over time. Finally, logbook data indicated an increased prevalence of swim-with-dolphin encounters, suggesting an expansion of local tourism from 2004–2011.

A total of 677 dedicated opportunistic surveys were completed. These equalled 1,613 hrs of search effort spanning 263 km^2. Sighting rate calculations indicated that Hector's and bottlenose dolphins occurred more frequently than dusky dolphins. Seasonality was particularly notable amongst Hector's dolphins, whereas the sighting and encounter rates were higher during summer and autumn. The collective range of all species suggests that delphinids utilized most of QCS. However, both the range and central range of Hector's dolphins were more limited. Notable spatial patterns included peaks in Hector's dolphin density mid-Sound, during summer/autumn and peaks in bottlenose dolphin density toward the outer Sound during summer/autumn. Temporal overlap was relatively high for bottlenose and Hector's dolphins (0.67) and low for Hector's and dusky dolphins (0.22), while spatial overlap was quite low for all species combinations. The patterns explored here offer evidence of temporal and spatial multi-species habitat partitioning within QCS. This may be due to the broader ecological trends within New Zealand and is likely attributed to the availability and movement of prey.

Habitat models (GAMs) indicated a unique set of significant drivers associated with dolphin density for each species. Hector's dolphins displayed an association with dynamic and static variables (SST, fluorescence, depth, slope and distance to the closest marine farm). Dusky dolphins were influenced by the same variables, as well as year. Consistency with the earlier models in the association with SST for Hector's (higher values) and dusky dolphins (lower values) was detected. Bottlenose dolphins were only influenced by static variables (depth, slope and distance to the closest marine farm) and year. The habitat differences suggested by these models offer further insight to the ecological meaning of dolphin spatial patterns in QCS. In particular, these findings offer additional evidence of delphinid resource partitioning, specifically on a trophic scale. This likely occurred because all three species exhibit both dietary

and foraging plasticity. While similarities were observed between comparable studies in other areas, the presence of some variation is likely due to unique physical and hydrographic regional characteristics. Spatial predictions that were generated from significant model variables were valuable in estimating potential locations of dolphin density beyond sighting locations, including areas that they previously occupied.

Data representing animal area usage, like those presented here, are integral to conservation management, especially amidst growing anthropogenic influences, like tourism. This first ever tourism-based study in QCS indicated bottlenose dolphins as the main target species for swim-with-dolphin activity. A total of 190 bottlenose dolphin swim encounters were assessed according to several proxies. Interactions were very short ($\bar{x}$=4.2 min), with most dolphin reactions neutral (82.9 %), suggesting animal disinterest. Swim encounters occurred regularly, irrespective of group composition or behavioural state. Furthermore, tour operators travelled great distances ($\bar{x}$=11.7 km) amongst dolphin groups to complete swim encounters, demonstrating pursuit of interaction. Collectively, these proxies suggest a lack of dolphin engagement in swim activity.

This thesis encompassed the first multi-species comprehensive assessment of delphinid density, range, habitat use and swim-with-dolphin tourism in QCS. It established a baseline of data, contributing to regional ecological knowledge. Detailed evidence of when and where three sympatric dolphin species utilized QCS was provided. Moreover, this work established an understanding of delphinid inter-specific interactions and associations with habitat variables. Applications of the findings presented here include contributions to developing comprehensive conservation management and further research. Periods and regions of high density and predicted density may be considered in regional management decisions regarding anthropogenic use of the Sound and during the design of future surveys.

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Along the way that you discover that, a PhD is much more than a research project and a written document. It is an opportunity for intellectual, emotional and personal growth that will test your limits. It is a journey; the road less travelled. The assistance and insight of supportive and generous people lend to its fruition. As such, I gratefully acknowledge those people in my life that have supported me throughout my journey, without whom, this project would not have been a reality.

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"They always say that time changes things, but you actually have to change them yourself."

–Andy Warhol

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List of Abbreviations

AIC	Akaike information criteria
ANOVA	Analysis of variance
BSS	Beaufort sea state
CI	Confidence interval
CTD	Conductivity temperature depth
df	Degrees of freedom
DOC	Department of Conservation
e.g.	*exampli gratia,* for example
ER	Encounter rate
et al.	*et alii,* and others
GAM	Generalized additive model
GIS	Geographic information system
GLM	Generalized linear model
GME	Geospatial modelling environment
GPS	Global positioning system
hp	horsepower
i.e.	*id est*, in other words
IDW	Inverse distance weighted
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
KDE	Kernel density estimate
km	Kilometres
LM	Linear model
LINZ	Land Information New Zealand
m	Metre
MDC	Marlborough District Council
min	Minute
mm	Millimetres
MPAs	Marine protected areas
MSIMT	Marlborough Sounds Integrated Management Trust
MSRMP	Marlborough Sounds Resource Management Plan
MODIS	Moderate resolution imaging spectroradiometer

NIWA	National Institute of Water and Atmospheric Research
NOAA	National Oceanographic and Atmospheric Administration
NZ	New Zealand
NZTM	New Zealand transverse mercator
OISST	Optimum interpolation sea surface temperature
pers. comm.	Personal communication
pers. obs.	Personal observation
PoPs	Platform of opportunity
QCS	Queen Charlotte Sound, New Zealand
SCUFA	Self-contained underwater fluorescence apparatus
SD	Standard deviation
SE	Standard error
sp.	Unspecified species within a certain genus
SR	Sighting rate
SST	Sea surface temperature
subsp.	Subspecies
TER	Trip encounter rate
VIFs	Variation inflation factors
°	Degrees
°C	Degrees Celsius

Publications and presentations

The following presentations and report were produced during this PhD, based on the findings presented in this thesis.

Conferences

Cross, C.L., Clement, D., and K. A. Stockin. 2013. Queen Charlotte Sound, NZ: A region of high species diversity and significance for nationally endangered cetacea. *20th Biennial conference of the Society for Marine Mammalogy, Dunedin, NZ* (poster).

Cross, C.L., M. D. M. Pawley, R. Summers and K. A. Stockin. 2017. Characterizing the distribution and habitat of Hector's dolphins using GIS. *20th Annual conference of the Society for Conservation GIS, Monterey, CA, USA* (oral).

Cross, C.L., M. D. M. Pawley, D. Clement and K. A. Stockin. 2017. The first quantitative investigation of Hector's dolphin density and habitat use in Queen Charlotte Sound, New Zealand. *22nd Biennial conference of the Society of Marine Mammalogy, Halifax, Nova Scotia, Canada* (oral).

Administrative report to the Department of Conservation

Cross, C.L. 2013. Queen Charlotte Sound: A habitat for marine mammals. *Interim report to the Department of Conservation, Picton, New Zealand*. 36 p.