Spatial Ecology and Conservation of Cetaceans using the Hauraki Gulf, New Zealand

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ABSTRACT

Understanding species' distributions and habitat use, and how they change spatially and temporally, is crucial for conservation management. The Hauraki Gulf, North Island, New Zealand is a highly productive marine ecosystem that is important for a range of marine megafauna, including cetaceans. This study investigated the spatial and temporal distribution and habitat use of three focal species: common dolphin (*Delphinus* sp.), Bryde's whale (*Balaenoptera edeni*) and bottlenose dolphin (*Tursiops truncatus*) in the Hauraki Gulf, with the overarching goal of providing scientific information for conservation and management. A dedicated research vessel was used for data collection and surveys were focused in the inner Hauraki Gulf (IHG) and off the west coast of Great Barrier Island (GBI; outer Hauraki Gulf). The likely spatial use of the Hauraki Gulf by cetaceans, and how that likelihood changes seasonally, was investigated using species distribution modelling (SDM). A novel approach to SDM for cetaceans that incorporates detection probability was investigated with occupancy models and compared with generalised linear model (GLM) outputs. Additionally, photo-identification was used to assess the population ecology of bottlenose dolphins using GBI waters for the first time in light of the reported decline in abundance in what has formerly been recognised as the core region (i.e. Bay of Islands) for the North Island population.

Survey effort totalled 20,803 km in IHG and GBI waters during 279 survey days between January 2010 and November 2012. Central northern IHG regions were important for common dolphins year-round, with increased probabilities of encounter during winter and spring compared with summer and autumn at GBI. The inshore movement of common dolphins in Hauraki Gulf waters during winter may represent an overall offshore to inshore shift in distribution, combined with an influx of dolphins into the Gulf from the wider surrounding areas of the northeast coast. This is likely to be related to prey distribution. Estimates of the functional habitat models suggested that the use of more southerly waters in the IHG during summer and autumn reflects habitat use by nursery rather than by feeding dolphin groups. However, the overall predictive maps were more temporally and spatially similar to the feeding than the nursery group predictions, indicating that prey availability likely has important implications for the general distribution and habitat use patterns of common dolphins in the Hauraki Gulf. Furthermore, occupancy model outputs showed similar spatial and temporal trends in distribution and habitat use of common dolphins in the IHG as the GLMs. While incorporating detection probability reduced the bias in parameter estimates, the depth covariate was still identified as the most important predictor of seasonal occurrence using both model types.

Overall, the spatial and temporal distribution patterns of Bryde's whales were the most unpredictable of the focal species, particularly inter-annually off GBI. Notably, habitat use by Bryde's whales and common dolphins in GBI waters was considerably different, unlike in IHG waters. This may be indicative of whales foraging more frequently on krill in outer Hauraki Gulf waters than in the IHG, albeit dependent on inter-annual variation in prey availability. It is important to note that the results of this study occurred under predominantly La Niña conditions. Given the strong

effects of winds on ocean circulation in the Hauraki Gulf, variations in patterns described here may vary under more neutral and El Niño conditions.

The high encounter rates of bottlenose dolphins at GBI compared with the IHG support the hypothesis that GBI is a hotspot for the North Island population. Groups using GBI waters were larger than previously reported for the North Island population and predominantly contained neonates and calves. In particular, the southwest coast of GBI appeared important for bottlenose dolphins, possibly due to a combination of factors including food availability, its suitability for breeding or calving, and the likely decreased levels of anthropogenic pressures associated with other regions of the population's home range. Photo-identification analyses confirmed overall site fidelity (MSR = 0.33) to the GBI region was high, albeit with variable re-sighting patterns among individuals. A total of 171 dolphins (CI = 162–180) used the area during the study period, representative of a significant proportion of the North Island population. Seasonal abundance estimates peaked in summer and autumn and were lower during winter months, with individuals leaving the study area for multiple seasons but subsequently returning. Thus, individuals of the North Island population clearly spend extended periods of time outside of what has formerly been recognised as their core home range. It is apparent that the GBI region is not simply being used as a corridor to reach other destinations but instead is a key location for at least a part of the North Island population.

A number of important baselines have been identified via this study and the future challenge will lie in securing enough resources to ensure continuity in research and monitoring for further conservation purposes. The fact that the use of GBI waters by bottlenose dolphins has been overlooked until now highlights the need for researchers, managers and funding agencies to maintain an open outlook on their population of interest as a whole when conducting or funding research. For management of North Island bottlenose dolphins to be effective, a comprehensive approach including the entire home range of this population along the northeast coast is required.

This research also demonstrated for the first time that occupancy models can be successfully applied to cetacean sighting data to assess habitat use while simultaneously accounting for imperfect detection. There was strong agreement between predicted areas of high use for common dolphins identified by the GLMs and occupancy models. This congruency between different model types suggests that the predictive maps presented here provide reliable seasonal distributional information that will be useful to support current and future conservation initiatives. An improved understanding of the processes driving the differences in habitat use will enable refined predictions of spatial and temporal distribution, which is required for effective management and conservation of cetaceans using the Hauraki Gulf.

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LIST OF ABBREVIATIONS

AIC	Akaike's Information Criterion
ANOVA	Analysis of Variance
BIC	Bayesian Information Criterion
BOI	Bay of Islands
BOP	Bay of Plenty
BPMMS	Banks Peninsula Marine Mammal Sanctuary
CI	Confidence interval
CJS	Cormack-Jolly-Seber
Contd.	Continued
CSV	Comma separated values
CV	Coefficient of variation
df	Degrees of freedom
DOC	Department of Conservation
EAUC	East Auckland Current
ECBOP	East Coast Bay of Plenty
e.g.	For example
ENSO	El Niño Southern Oscillation
ER	Encounter rate
ESRI	Environmental Systems Research Institute
Fig.	Figure
GAM	Generalised additive model
GBI	Great Barrier Island
GIS	Geographic Information System
GLM	Generalised linear model
GME	Geospatial Modelling Environment
GPS	Global Positioning System
HGBDC	Hauraki Gulf Bottlenose Dolphin Catalogue
HGMPA	Hauraki Gulf Marine Park Act
h	Hours
hp	Horse power
i.e.	That is
IHG	Inner Hauraki Gulf
IQR	Interquartile range
IUCN	International Union for Conservation of Nature
km	Kilometre
LME	Large marine ecosystem
m	Metre
ML	Maximum likelihood
MMAP	Marine Mammal Action Plan
MMPR	Marine Mammals Protection Regulations
MPA	Marine protected area
MPI	Ministry for Primary Industries
MSP	Marine spatial planning
MSR	Monthly sighting rate

NIWA	National Institute of Water and Atmospheric Research
NA	Not applicable
NE	Not estimated
NP	Number of parameters
NPP	Net primary production
OHG	Outer Hauraki Gulf
PAU	Proportion of area used
PDU	Probability of common dolphin use
Pr	Probability
SAC	Special Area of Conservation
SD	Standard deviation
SDM	Species distribution modelling
SE	Standard error
SPUE	Sightings per unit effort
SR	Sighting rate
SSM	Safe Ship Management
SSR	Seasonal sighting rate
SST	Sea surface temperature
USA	United States of America
VGPM	Vertically Generalised Production Model
VIF	Variance inflation factor