Copyright Statement

The digital copy of this thesis is protected by the Copyright Act 1994 (New Zealand).

This thesis may be consulted by you, provided you comply with the provisions of the Act and the following conditions of use:

- Any use you make of these documents or images must be for research or private study purposes only, and you may not make them available to any other person.
- Authors control the copyright of their thesis. You will recognise the author’s right to be identified as the author of this thesis, and due acknowledgement will be made to the author where appropriate.
- You will obtain the author’s permission before publishing any material from their thesis.

To request permissions please use the Feedback form on our webpage. [http://researchspace.auckland.ac.nz/feedback](http://researchspace.auckland.ac.nz/feedback)

General copyright and disclaimer

In addition to the above conditions, authors give their consent for the digital copy of their work to be used subject to the conditions specified on the [Library Thesis Consent Form](http://researchspace.auckland.ac.nz) and [Deposit Licence](http://researchspace.auckland.ac.nz).

Note: Masters Theses

The digital copy of a masters thesis is as submitted for examination and contains no corrections. The print copy, usually available in the University Library, may contain corrections made by hand, which have been requested by the supervisor.
POPULATION STRUCTURE, ABUNDANCE AND REPRODUCTIVE PARAMETERS OF BOTTLENOSE DOLPHINS (*Tursiops truncatus*) IN THE BAY OF ISLANDS (NORTHLAND, NEW ZEALAND)

Gabriela Tezanos-Pinto

A thesis submitted in fulfilment of the requirements for the Degree of Doctor of Philosophy in Biological Sciences

© Gabriela Tezanos-Pinto

2009
ABSTRACT

Bottlenose dolphins (Tursiops truncatus) occupy a wide range of coastal and pelagic habitats throughout tropical and temperate waters worldwide. Around New Zealand, bottlenose dolphins inhabit three discontinuous regions in the north-eastern coast of the North Island, Marlborough Sound and Fiordland in the South Island. All these populations are subject to anthropogenic activities including dolphin-based tourism industry. Along the north-eastern coast of the North Island, the Bay of Islands presents a unique opportunity to study this population because of regular occurrence year-round and a history of long-term studies conducted in the region. This study examines the population structure and genetic diversity of the three New Zealand bottlenose dolphin populations to define their boundaries. Second, it focuses on the Bay of Islands subpopulation to investigate the dynamics of dolphin groups, pattern of habitat use, abundance and trends over time. Finally, it estimates reproductive parameters of female bottlenose dolphins to predict the long-term viability of the Bay of Islands subpopulation.

To investigate the population structure and genetic diversity of bottlenose dolphin, skin samples were collected using a remote biopsy dart from the three New Zealand populations. Analysis of the molecular variance (AMOVA) from mitochondrial DNA (mtDNA) control region sequences (n = 193) showed considerable differentiation among populations (FST = 0.17, ΦST = 0.21, P < 0.001) suggesting little or no female gene flow or interchange. All three New Zealand populations showed higher mtDNA diversity than expected given their small population sizes and apparent isolation. To explain the source of this variation, 22 control region haplotypes from New Zealand were compared to 108 haplotypes worldwide representing 586 individuals from 19 populations and including both ‘inshore’ and ‘offshore’ ecotypes as described in the Western North Atlantic. All haplotypes found in the Pacific, regardless of population habitat use (i.e., coastal or pelagic) were more divergent from populations described as ‘inshore’ ecotype in the Western North Atlantic than from a population described as ‘offshore’ ecotype. Analysis of gene flow indicated long-distance dispersal among coastal and pelagic populations worldwide, except for those haplotypes described as ‘inshore’ ecotype in the Western North Atlantic; suggesting that these populations are interconnected on an evolutionary time scale. This finding suggests that habitat specialization has occurred independently in different ocean basins, perhaps with T. aduncus filling the ecological niche of the ‘inshore’ ecotype in some coastal regions of the Indian and Western Pacific Oceans.

The dynamics of dolphin groups in the Bay of Islands and their use of the habitat were investigated using two standardised datasets of consistent effort (1997-99 and 2003-05). The 1997-99 dataset contained a total of 1,711 sighting records of 258 individual dolphins, of which 39% were newly added to the photo-identification catalogue (n = 101) and the rest (n = 157), were re-sightings of previously catalogued dolphins. The 2003-05 dataset included a total of 1,889 sightings records of 159 individual dolphins. Overall, 98 dolphins sighted during 1997-99 were resighted during 2003-05. Encounters with dolphins increased significantly (P < 0.001) from 69.5% during 1997-99 to 87.1% encounters during 2003-05. There were more individually identified dolphins using the Bay of Islands during 1997-99 when compared to 2003-05; despite a lower number of sightings and groups encountered. There were annual variations in the number of groups encountered including a lower number of dolphins sighted during winter. Analysis of resighting rates suggested a very dynamic pattern of habitat use with fewer individuals sighted in the area more often than expected (i.e., frequent users; ~20%) while most dolphins were occasional or infrequent visitors. Additionally, a change in use of the area was detected, with 40 frequent users out of 67 using the Bay of Islands differentially. Changes in habitat use over time may be attributed to foraging (changes in prey distribution or abundance), reproductive strategy, competition for resources, a consequence of anthropogenic impacts or a combination
of all or some of the above. During 2003-05 there were relatively few frequent users (n=37) found in the Bay of Islands regularly. Therefore, the exposure of frequent users to tour-boat operators should be closely monitored to avoid cumulative impact and potential detrimental effects on survival or reproductive fitness.

The composition of maternal lineages of biopsy sampled frequent users (n=23) was not significantly different from other dolphins in the Bay (n=108) suggesting that social affiliations, as opposed to direct kinship, play a more important role in the maintenance of long-term relationships between individuals. The sex ratio of the population was estimated at 1.3:1 males: females with no significant differences between sexes. Sex information was available for 37 frequent users and no differences (P = 0.099) between sexes were detected, indicating no sex-segregation within frequent users in the Bay of Islands.

Four Cormack-Jolly-Seber models were used to estimate survival and capture probabilities over different temporal scales. An open population model that allows for variation in capture probabilities and survival over time best describes this subpopulation with the pooled annual dataset. This is because the effects of migration, heterogeneity and higher capture probabilities observed in the Bay of Islands dataset. Results suggested a 38% decline from 204 (CV=0.03) individually identified adult dolphins using the Bay of Islands in 1998 to 126 (CV=0.02) in 2004. The abundance of the larger north-eastern North Island population was estimated at 428 adult dolphins. A decline in apparent adult survival was observed in the Bay of Islands, with lower values than those reported for other regions (0.907 in 1999 and 0.717 in 2004). Several documented deaths among the frequent users of the Bay of Islands have contributed to this lower survival rate. Despite the decline in estimated abundance, dolphins continue to be found regularly in the Bay of Islands, suggesting a change from more individuals using the area irregularly, to fewer individuals using the Bay of Islands more regularly. Consequently, it seems that a shift in habitat use as well as some combination of emigration, mortality and low recruitment could underlie the estimated decline. Although the cause of these changes requires further investigation, a precautionary approach to manage all anthropogenic disturbances is recommended throughout the range of the north-eastern North Island population.

A total of 53 dolphins were observed to be reproductive females over ≥ 2 consecutive and independent encounters. Additionally, 11 females were sexed using molecular methods and direct observation but were never sighted with a calf. Since 1994, 52 young of the year were successfully assigned to individually identified mothers; the fates of 41 of these were documented over differing periods of time. Similarly to studies conducted in other regions, and consistent with the estimated calving rate (0.25 calf (reproductive female)⁻¹ yr⁻¹; CI = 0.16-0.35), average calving interval was estimated at 4.25 years (range 2.20-6.78; SD = 1.54). Conversely, mortality rates to age 1+ (0.42; CI = 0.27-0.57) and 2+ (0.22; CI = 0.08-0.58) were higher than reported elsewhere. The high calf mortality observed here in conjunction with a decline in abundance highlight the vulnerability of this utilised subpopulation.

The present study provided substantial evidence to suggest that dolphins using the Bay of Islands are genetically differentiated from the other populations in New Zealand. Further analyses suggested a decline in abundance, high calf mortality and a decline in adult survival. Long-term monitoring in the Bay of Islands is needed to examine the causes of decline; which could threaten the persistence of this population and the sustainability of dolphin-related tourism activities. Different management conservancies throughout the bottlenose dolphin range along the coast of the north-eastern North Island need to coordinate their conservation efforts in a consistent manner and implement a precautionary approach to manage all sources of anthropogenic disturbances.
DEDICATION

Dedico esta tesis:

A quienes me dieron el ser
A quien unió a mi ser su destino
A quien ha continuado mi ser

Celina y Pablo de Tezanos Pinto
Daniel Mario Pouwels
Rawiri Luciano Pouwels
I am very grateful with my supervisor, Dr Charles Scott Baker, who took me onboard on this project and supported me until the end. Thank you Scott for your patience and for the time you have spent teaching me things...from backing up a trailer, interpret a PCR, shot a biopsy gun or write a scientific paper (to name a few). I am honestly surprised you did not go bold while reading this thesis! It has been an incredible journey and I was very fortunate to have you as my supervisor. I have great respect for your knowledge, integrity and humanity.

This project involved the collaboration of many people to whom I am very grateful to. In this regard, I thank Dr Rochelle Constantine who gave me access to her data and catalogue and provided valuable advice to improve the quality of this work. I received support from the Department of Conservation (DoC) in particular Tony Beauchamp, thank you Tony for your patience and friendship. Thanks to Adrian Walker, Tony Beachman, Alan Fleming, Lon Peters, Elke Reufels (Bay of Islands); Karl Macleod, Bill Trusewich, Dan Breen, Hamelia Jamieson (Auckland and Great Barrier Island); Ross Kemper, Beth Masser, Helen Kettles, Rosalyn Colin (Te Anau). Thanks to Clinton Duffy for all the shark info and Anton Van Helden (DoC and New Zealand Museum Te Papa Tongarewa) for access to the Tursiops stranding database. Thanks to Uniservices for advice and support, especially Gary Putt. Thanks to the tour operators in the Bay of Islands, who generously provided a platform for field surveys; particularly, Fullers Bay of Islands, Dolphin Discoveries, Kings and Carino. Thanks to the Tutunui crew: Floppy, Tammy, Phil, Bronwyn, Natasha and Ross; Carino’s crew: Vanessa Mackay. Thanks to the crew of Discovery III and IV, Orca II and Dolphin Seeker for assistance in locating the dolphins. This thesis was generously funded by the Department of Conservation (Bay of Islands); the Northland Marine Mammal Trust; J. Watson Conservation Trust from the Royal Forest and Bird Society; Postgraduate Tuition Fee Bursary (University of Auckland) and the Whale and Dolphin Adoption Project.

This thesis has been a long and life-changing journey. I came to New Zealand in December 2001 to assist with Maui’s dolphin research and ended up staying permanently. I started this PhD research in February 2003, later down the track I got married to an Invercargillian and had a beautiful son. During this long journey, I met Scott’s ‘older’ students: Natalie Patenaude, Franz Pichler, Rochelle Constantine, Merel Dalebout and Tony Hickey. And the ‘newbies’ with whom I shared some wonderful times: Carlos Olavarría, Susana Caballero, Marc Oremus, Nicky Wiseman, Doro Heimeier, Alana Alexander, Colm Carragher, Fabi Mourão, Murdoch Vant, Emma Caroll, Rebecca Hamner and Renee Albertson. Thanks to Kirsty Russell for teaching me how to drive a boat and use a biopsy sampling gun. Debbie Steel, Murdoch Vant and Hamish McInnes trained me on labwork and helped me with most lab-related issues. Debbie also corrected manuscripts and improved my espanglish. Thanks to Shane Lavery and Tony Hickey (and his great sense of humour!) for all the population genetic discussions and general advice. Thanks to Jen Jackson for her friendship and support. I am very grateful to my friend Carlos Olavarria for always been there for me... Gracias Carlitos! I had the pleasure to share the PhD and motherhood journey with my very good friend Susana Caballero, que hubiera sido de mi sin vos Susu! Nicky Wiseman and Dorothea Heimeier started their PhD’s at about the same time I did mine and we shared some good times in the water and late nights in the lab. Merci to Marc Oremus for coming along my fieldtrips, always answer my annoying questions and for his friendship. Thanks to Jess Hayward, Andrew Veale, Josh Guilbert, Bjørn Heijistras and Emma Carroll (and Simon Waugh too) for their great sense of humour.

I am very grateful to Jennifer Jackson who took the time to review all the chapters in this thesis and provided valuable comments to improve the quality of this work. Thank you Jen for being
such a nice person; I think the world is a better place because of you! I am grateful with those who took the time to review independent chapters: Emma Carroll and Doro Heimeier (Chapter 1); Carlos Olavarria and Emma Newcombe (Chapter 3); Simon Childerhouse, Andrew Gormley and Karen Stockin (Chapter 4); Marc Oremus (Chapter 5 and Appendix 8.5); Manue Martinez and Danny Pouwels (Chapter 6). Thanks to Jenny Wilcox and Dr Rachel Fuster for the support with statistics.

Thanks to Dr Lyndon Brooks (Southern Cross University) for helping me with mark-recapture and particularly, the transience models. Thanks to Jennifer Fan from the student learning centre for her support with English grammar. I am grateful with John Wang, Rochelle Constantine, Fabiana Mourão, Michael Ritchlen, Marc Oremus and Monika Merriman for allowing me to use their photos. Thanks to Neve Baker for providing me with the beautiful drawing that illustrates the cover of chapter 6.

I am very grateful with the people that came along my fieldtrips volunteering their time (and patience) in the water. Especially Sarah J. Wells (Poochie-poohs!) who worked long hours, helped matching so many photos and reviewed the photo-ID catalogue. Thanks to Alyson Fleming, Jillian Brueggeman, Catherine Clark, Emma Caroll, Jennifer Jackson, Daniel Pouwels, Fabiana Mourão, Marc Oremus, Kirsty Russell, Karl McLeod, Murdoch Vant, Emma Newcombe, Dorothea Heimeier, Neve Baker, Susana Caballero, Jacky Guerts, Ruma Gosh, Bevan Woodward and Michael Ritchlen. Thanks to Arthur Cozens, Brady Doak and Bill Murray (Leigh Marine Laboratory) who organised the R. V. Hawere surveys; thanks also to Arthur and Brady for looking after the Lancer and providing support and advice when needed. Thanks to all the people who provided photographs for matching; these are very valuable resources and help in our understanding of the dolphin’s biology.

Thanks to my friends outside Uni that kept me sane: Andy Strachan, Carla Grosman, Tania Mallow, Kim Mazur and the Fowler family. My friends at Massey have supported me during the final stages of this PhD: Karen Stockin (just keep swimming, keep swimming…), Manue Martinez and Mónica Merriman. Thanks to my good friend Gabriel Machovsky Capuscha and his family (Karen and Sabrina), for always been there for me. Sos un amigazo y te queremos mucho! Thanks to my New Zealand in-laws, particularly my sis Chrissy Frizzle Pouwels Thanks to my dear friends in Argentina: que están siempre y gracias a quienes, soy hoy: Beti Froute, Marisa Cerra, Edgar Lacombe, Ale Maiolo, Adri Rosales, Adri Bertol, Pablo Garcia, Lala y Moi, Poli Marrónkle y flia., Tin Felix, Silvina Kindgard y flia., Matias Nille, Tania Rogel y flia., Agus Goya y flia…y a todos los que han compartido conmigo parte de este largo viaje.

I have no words to properly acknowledge the support my family provided me along the years. My parents Celina Snopek and Pablo de Tezanos Pinto have generously supported (both financially and emotionally) all my journeys and I am very grateful for your kind love and generosity. Gracias por estar siempre conmigo y por el apoyo para terminar esta tesis. My grandparents Guillermo Snopek and María Ángela Valente were my inspiration and one of the reasons I pursued academic studies with marine mammals. I have great respect for their hard work, generosity and integrity. Leaving Argentina meant being away of my dear nephews and nieces: Victoria, Gerónimo, Itiaki, Alejo y Agustina; pero saben que los quiero con todo mi corazón! Thanks to my sisters Celina and Verónica (and her husband Gustavo Tulu Zurueta) and my brother Pablo Martín for their support. I am very grateful to Romina Ortiz, who looked after my son with so much love and dedication while I was writing this thesis.

My dear husband and sexy marido, ‘el motivador’ Daniel Mario Pouwels provided me with so much love and support throughout the different stages of this thesis. It has been a long journey and I could not have done it without you. You are a great companion and I am very lucky for
having you in my life. I love you honey-bunny... con todo mi corazón! My gorgeous son Rawiri Luciano was born while I was writing this thesis and had to share his mami with a computer and big piles of paper!
# TABLE OF CONTENTS

Abstract..................................................................................................................................................i  
Dedication...........................................................................................................................................iii  
Acknowledgements..............................................................................................................................iv  
Table of Contents....................................................................................................................................vii  
List of Figures.........................................................................................................................................xix  
List of Tables..........................................................................................................................................xx  
1 Chapter: General Introduction...........................................................................................................1  
  1 Introduction ................................................................. 2  
    1.1 Taxonomy of bottlenose dolphins ........................................ 3  
    1.1.1 Difficulties in the *Tursiops* taxonomy ......................... 5  
    1.1.2 The *Stenella, Tursiops* and *Delphinus* complex ............ 6  
    1.1.3 How many *Tursiops* species or subspecies are there? ... 7  
    1.2 Distribution and habitat specialization of *T. truncatus* ....... 11  
    1.2.1 *T. truncatus* ecotypes ............................................. 13  
    1.3 Molecular ecology of *T. truncatus* ................................. 14  
    1.4 *Tursiops* life history parameters, demography and ecology 16  
        1.4.1 Residency patterns, habitat and site fidelity ............... 21  
        1.4.2 Movements ....................................................... 21  
        1.4.3 Group size ....................................................... 22  
        1.4.4 Cognition ....................................................... 26  
        1.4.5 Social organization ............................................ 26  
        1.4.6 Threats ........................................................ 27  
    1.5 Bottlenose dolphins in New Zealand ............................... 31  
        1.5.1 Distribution ..................................................... 31  
        1.5.2 The North Island population ................................. 33  
        1.5.3 The Marlborough Sound population ....................... 36  
        1.5.4 The Fiordland population ..................................... 37  
    1.6 Why investigate the molecular ecology and demography of the New Zealand bottlenose dolphin? 38  
    1.7 Methods employed in this thesis ..................................... 40  
        1.7.1 Molecular ecology ............................................. 40  
        1.7.2 Individual cetacean identification: the photo-identification technique 45  
    1.8 Thesis structure ....................................................... 53  
        1.8.1 Format and collaborative arrangements ...................... 53  
        1.8.2 Permits ........................................................ 56  
2 Chapter: A worldwide perspective on the population structure and genetic diversity of bottlenose dolphins (*Tursiops truncatus*) in New Zealand................................................................. 57
2.1 Abstract  
2.2 Introduction  
2.3 Materials and Methods  
2.3.1 mtDNA datasets used  
2.3.2 DNA extraction, PCR amplification and sequencing  
2.3.3 Taxonomy, ecotype and habitat classification  
2.3.4 Sequences analysis and phylogenetic reconstruction  
2.3.5 Population structure and genetic diversity  
2.3.6 New Zealand compared to worldwide populations  
2.3.7 Migration rates among New Zealand populations  
2.3.8 Worldwide phylogeography  
2.4 Results  
2.4.1 Phylogeography, genetic diversity and female migration rates among New Zealand populations  
2.4.2 Worldwide *T. truncatus* genetic diversity and population structure  
2.4.3 Population structure by ecotype and ocean basin  
2.4.4 New Zealand compared to worldwide populations  
2.4.5 Worldwide phylogeography  
2.5 Discussion  
2.5.1 Coastal New Zealand populations are isolated but retain surprisingly high diversity  
2.5.2 Bottlenose dolphins experience long-distance gene flow  
2.5.3 Habitat specialization and ‘ecotopes’ occur independently between oceans  
2.5.4 *T. truncatus* ‘offshore’ and ‘unknown’ ecotypes are evolutionary interconnected  
2.6 Conclusion  

3 Chapter: Analysis of group dynamics, pattern of habitat use and composition of maternal lineages of bottlenose dolphins in the Bay of Islands  
3.1 Abstract  
3.2 Introduction  
3.3 Materials and Methods  
3.3.1 Study area  
3.3.2 Photo-identification surveys  
3.3.3 Photo-identification analysis  
3.3.4 Catalogue description  
3.3.5 Group size, age class composition and reproductive status  
3.3.6 Frequent and infrequent users  
3.4 Results  
3.4.1 Survey effort and datasets
3.4.2 Comparison of encounters, sightings and identified dolphins per period 95
3.4.3 Analysis of group size 96
3.4.4 Proportion of individuals in each age class 101
3.4.5 Pattern of habitat use: frequent users in the Bay of Islands 102
3.4.6 Maternal lineages 106
3.4.7 Sex ratio 107

3.5 Discussion 108
3.5.1 Group dynamics in the Bay of Islands 109
3.5.2 Age class composition 111
3.5.3 Pattern of habitat use 111
3.5.4 Maternal lineages 112
3.5.5 Sex ratio 113

3.6 Conclusion 113

4 Chapter: Apparent decline in abundance of bottlenose dolphins (*Tursiops truncatus*) in the Bay of Islands ................................. 114

4.1 Abstract 115
4.2 Introduction 115

4.3 Materials and Methods 118
4.3.1 Study area 118
4.3.2 Photo-identification surveys 118
4.3.3 Analysis of photo-identification data 119
4.3.4 Datasets used for population abundance estimates 119
4.3.5 Mark ratio: proportion of identifiable dolphins 120
4.3.6 Assessing mark-recapture assumptions 121
4.3.7 Population abundance methods 123
4.3.8 Model selection and goodness of fit 125

4.4 Results 128
4.4.1 Photo-identification effort and datasets 128
4.4.2 Rate of discovery 129
4.4.3 Mark ratio: proportion of identifiable dolphins 130
4.4.4 Assessing mark-recapture assumptions 130
4.4.5 Best model selected and abundance estimates for the Bay of Islands 132
4.4.6 Estimates of apparent adult survival 134
4.4.7 Trends in abundance 134
4.4.8 Estimate of abundance of the north-eastern North Island population 135

4.5 Discussion 136
4.5.1 Assessing MRC assumptions: Are estimates of abundance biased? 136
4.5.2 Abundance estimates 139
4.5.3 Apparent adult survival 140
4.5.4 Trend of decline in apparent abundance 140
4.5.5 Causes of decline in apparent abundance 140
4.6 Conclusion 143

5 Chapter: Reproductive parameters of bottlenose dolphins (Tursiops truncatus) in the Bay of Islands (Northland, New Zealand)………………………………………………………………………145
5.1 Abstract 146
5.2 Introduction 146
5.3 Materials and Methods
  5.3.1 Study area and photo-identification surveys 147
  5.3.2 Data collection 147
  5.3.3 Group composition 148
  5.3.4 Sex identification, reproductive and non-reproductive females 148
  5.3.5 Datasets used 149
  5.3.6 Estimation of reproductive parameters 149
  5.3.7 Calf survival/mortality and definition of mother-calf identification 150
  5.3.8 Sex ratio of stranded specimens 152
5.4 Results 152
  5.4.1 Reproductive and non-reproductive females 152
  5.4.2 Female reproductive rate and calving interval 154
  5.4.3 Calving seasonality 155
  5.4.4 Calf mortality 156
  5.4.5 Sex ratio of stranded specimens 158
5.5 Discussion 158
  5.5.1 Female reproductive rates 158
  5.5.2 Calving seasonality 159
  5.5.3 Bottlenose dolphins in the Bay of Islands have high calf mortality 161
  5.5.4 Sex ratio of stranded specimens 162
5.6 Conclusion 162

6 Chapter: Summary of results, future research and management recommendations……….164
6.1 Overview 165
6.2 Population structure, genetic diversity and connectivity of the New Zealand bottlenose dolphin
  6.2.1 Bottlenose dolphins in the Pacific Ocean may have only recently adapted to coastal habitats 165
  6.2.2 T. aduncus in the Indo-Pacific Ocean may fill the ecological niche occupied by the ‘inshore’ ecotype in the Western North Atlantic 167
  6.2.3 The New Zealand bottlenose dolphin seems to be interconnected to other populations through long-distance gene flow 167
6.2.4 Pelagic bottlenose dolphins are sporadically sighted in New Zealand coastal waters and may represent a source of gene-flow

6.3 Groups of bottlenose dolphins in the Bay of Islands present a dynamic pattern of habitat use over time

6.3.1 The number of frequent users has declined and some of them have changed their pattern of habitat use over time

6.4 The abundance of bottlenose dolphins in the Bay of Islands has declined at 38% from 1997 to 2005

6.4.1 Bottlenose dolphins along the north-eastern coast of the North Island and around New Zealand have relatively low abundance

6.5 Bottlenose dolphins in the Bay of Islands have low abundance but high calf mortality

6.6 Risk of living in coastal/estuarine environments

6.7 Research and management recommendations

6.7.1 Pelagic bottlenose dolphins in New Zealand waters

6.7.2 Fine-scale population structure and sex-biased dispersal

6.7.3 Foraging strategies and feeding ecology of the bottlenose dolphin

6.7.4 Impact of tourism activities in the Bay of Islands and along the north-eastern coast of the North Island

6.7.5 Monitoring population abundance and trends over time

6.7.6 Reproductive parameters and calf mortality

6.8 Conclusion

7 References

8 Appendices

8.1 Northland Sea Surface Temperature (Electronic appendix)

8.2 Table of unique mtDNA control region sequences of worldwide bottlenose dolphins (Electronic appendix)

8.3 New Zealand bottlenose dolphins mtDNA control region sequences (Electronic appendix)

8.4 New Zealand bottlenose dolphins are T. truncatus

8.5 Individual and group behavioural reactions to remote biopsy sampling in two bottlenose dolphins populations of New Zealand

8.6 Evaluation of photo quality and nick distinctiveness in the Bay of Islands photo-identification catalogue

8.7 Exclusions from the photo-identification catalogue (Electronic appendix)

8.8 False negatives and loss of marks in the photo-identification catalogue

8.9 The Bay of Islands photo-identification catalogue (Electronic appendix)

8.10 Potential bias in group size estimation during 2003-05

8.11 Frequent users during 1997-99 that were not re-sighted during 2002-06 (Electronic appendix)
8.12 Time between resightings of bottlenose dolphins photographed in the Bay of Islands
238
8.13 Dolphins resighted in the Bay of Islands after 9-10 years of their last sighting
239
8.14 Summary of photo-identification data employed for the estimation of mark ratio
240
8.15 Additional models explored to estimate the abundance of bottlenose dolphins in the Bay of Islands
241
8.16 Stranding database of bottlenose dolphins found in the North Island of New Zealand during 1996-2008 (Electronic appendix)
243
8.17 Bottlenose dolphins sighting database in the Bay of Islands 2002-06
243
LIST OF FIGURES

Figure 1-1. Photographs of *T. truncatus* and *T. aduncus* (Indo-Pacific Ocean)…………………………10
Figure 1-2. Reported or assumed worldwide distribution range of *T. truncatus* and *Tursiops* spp.
(Shark Bay) including study sites referred to in the text…………………………………………………………12
Figure 1-3. Summary of population structure studies conducted in regional populations of *T. truncatus* mentioned in the text………………………………………………………………………………16
Figure 1-4. Presumed distribution and range of the three New Zealand bottlenose dolphins’
populations based on live sightings…………………………………………………………………………………………32
Figure 1-5. Bay of Islands including inner and outer bay, four inlets and major towns………36
Figure 2-1. Locations represented by genetic samples of bottlenose dolphins (*T. truncatus*)
including New Zealand populations………………………………………………………………………………………63
Figure 2-2. Phylogenetic reconstruction (Neighbor-joining with HKY + I distance correction) of
bottlenose dolphin mtDNA control region sequences……………………………………………………………………68
Figure 2-3. Dendrogram showing mtDNA control region sequence divergence (da) among
worldwide regional populations of bottlenose dolphins based on a mid-point rooting
neighbor-joining reconstruction……………………………………………………………………………………74
Figure 2-4. Worldwide parsimony network of mtDNA control region sequences of *T. truncatus*
from 19 regional populations including ‘inshore’, ‘offshore’ and ‘unknown’
ecotypes……………………………………………………………………………………………………………………………77
Figure 3-1. Map of New Zealand including the three bottlenose dolphin populations………85
Figure 3-2. Average number of individually identified dolphins per encounter and effort by
years in the Bay of Islands during two time periods………………………………………………………………………96
Figure 3-3. Annual variation in group size of bottlenose dolphins in the Bay of Islands………97
Figure 3-4. Frequency of group size by season for 1997-99 and 2003-05……………………………100
Figure 3-5. Frequency of group size for bottlenose dolphins groups with calves and without for
data collected during 2003-06…………………………………………………………………………………………101
Figure 3-6. Pattern of habitat use of bottlenose dolphins in the Bay of Islands during 1997-99
and 2002-06……………………………………………………………………………………………………………………103
Figure 3-7. Individual dolphins found to be frequent users (≥ 9 sightings per lunar month) from
the Bay of Islands in either 1997-99, 2002-06 or both including sex
identification………………………………………………………………………………………………………………………105
Figure 3-8. Proportion of maternal lineages in the Bay of Islands subpopulation and those of
frequent users biopsy sampled……………………………………………………………………………………………107
Figure 3-9. Proportion of maternal lineages by sex biopsy sampled bottlenose dolphins in the
Bay of Islands…………………………………………………………………………………………………………………108
Figure 4-1. Rate of discovery of newly identified bottlenose dolphins in the Bay of Islands
between December 1993 and May 2006……………………………………………………………………………………129
Figure 4-2. Percentage of bottlenose dolphins with different levels of nick distinctiveness by sex
in the Bay of Islands…………………………………………………………………………………………………………131
Figure 4-3. Pooled annual estimates of abundance (ln) of individually identifiable adult
bottlenose dolphins in the Bay of Islands……………………………………………………………………………………135
Figure 5-1. Calving seasonality inferred from the frequency of the first sighting of a neonate
assigned to an identified mother including average SST (°C; line)……………………………………………………156
LIST OF TABLES

Table 1-1. Presumed taxonomy of bottlenose dolphins, species designation employed in this thesis, examples of study locations, methods used for characterisation of taxonomic units and references.........................................................9
Table 1-2. Summary of population structure studies mentioned in the text conducted in regional populations of T. truncatus.................................................................15
Table 1-3. Demographic parameters of bottlenose dolphins referred to in the text........20
Table 1-4. Summary of studies conducted on T. truncatus that are discussed in this thesis including group size, characteristics of the habitat, photo-ID catalogue size, residency pattern and site fidelity.................................................................24
Table 2-1. Summary of mtDNA control region sequences available for T. truncatus populations worldwide, showing the total number of samples, number of haplotypes, sequences length, published ecotype origin and genetic diversity values.............................65
Table 2-2. Pairwise FST and ΦST with their respective p values for the three New Zealand T. truncatus populations.............................................................69
Table 2-3. Most probable estimates (MPE) of female migration rates per generation (Nmf) using Bayesian analysis between the three T. truncatus populations in New Zealand.................................................................70
Table 2-4. Pairwise FST and ΦST for 14 regional bottlenose dolphin populations worldwide.............................72
Table 2-5. Pairwise FST and ΦST of T. truncatus ecotypes: ‘inshore’ (I), ‘offshore’ (O) and ‘unknown’ (U).................................................................73
Table 2-6. Average net (da), gross (dxy) sequence divergence between populations and within population diversity (dx and dy) among New Zealand (NZ), published ‘inshore’, ‘offshore’ and ‘unknown’ ecotypes.................................................................73
Table 2-7. Pairwise FST and ΦST of T. truncatus by ocean basins.................................74
Table 3-1. Age class criteria to classify bottlenose dolphins in the Bay of Islands........91
Table 3-2. Summary of surveys and photo-identification effort from December 1993 until May 2006 including information on the Bay of Islands’ sighting database, photo-identification catalogue and biopsy sample collection.................................................................94
Table 3-3. Number of sightings, individually identified dolphins (ID), groups encountered, total number of individuals photographed and surveys conducted during 1997-99 and 2003-05.................................................................95
Table 3-4. Summary of group size statistics by seasons for data collected during 1997-99, 2003-05 and for both periods combined.........................................................99
Table 3-5. Proportion of individuals in each age-class as judged by body size for data collected during 1997-99 (from Constantine 2002) and 2003-05..............................102
Table 4-1. Contingency 2 x 2 table for test 3.SR based on the number of individuals encountered (i.e., photo-identified) at capture occasion i..........................126
Table 4-2. Contingency 2 x 2 table for test 3.SR based on the expected number of individuals encountered at capture occasion i..........................127
Table 4-3. Summary of photo-ID effort conducted in the Bay of Islands using similar methodologies during 1997-99 and 2003-05.........................................................129
Table 4-4. Across-year re-sightings of bottlenose dolphins in the Bay of Islands during periods of consistent effort (1997-99 and 2003-05)..............................132
Table 4-5. AIC estimates from different CJS open models when pooling data annually and by 2-seasons/year.................................................................133
Table 4-6. Annual estimates of abundance (CJS) and survival of identifiable adult bottlenose dolphins in the Bay of Islands.................................................................133
Table 4-7. Estimates of abundance of individually identifiable adult bottlenose dolphins using the Bay of Islands when pooling the data by 2 seasons/year using CJS model \( \Phi(t)p(t) \) .............................................................................................................. 134

Table 4-8. AIC estimates from different POPAN open models when pooling data annually................................................................. 135

Table 5-1. Reproductive history of females resighted in the Bay of Islands since 1994 to 2006 with one or more calves............................................................................................................. 152

Table 5-2. Dolphins assumed to be non-reproductive females, including the frequency of sightings from 1994-2006............................................................................................................. 154

Table 5-3. Calving rates of bottlenose dolphins in the Bay of Islands for 2003-05................................................................................ 154

Table 5-4. Calving interval for reproductive females with >1 calf for which the time of birth could be inferred................................................................. 155

Table 5-5. Calf mortality during their 1st and 2nd year of life................................................................. 157

Table 5-6. Summary of \textit{Tursiops}’ calf mortality estimates mentioned in the text......................... 161

Table 6-1. Demographic parameters of bottlenose dolphins referred to in the text including results from this thesis............................................................................................................. 180